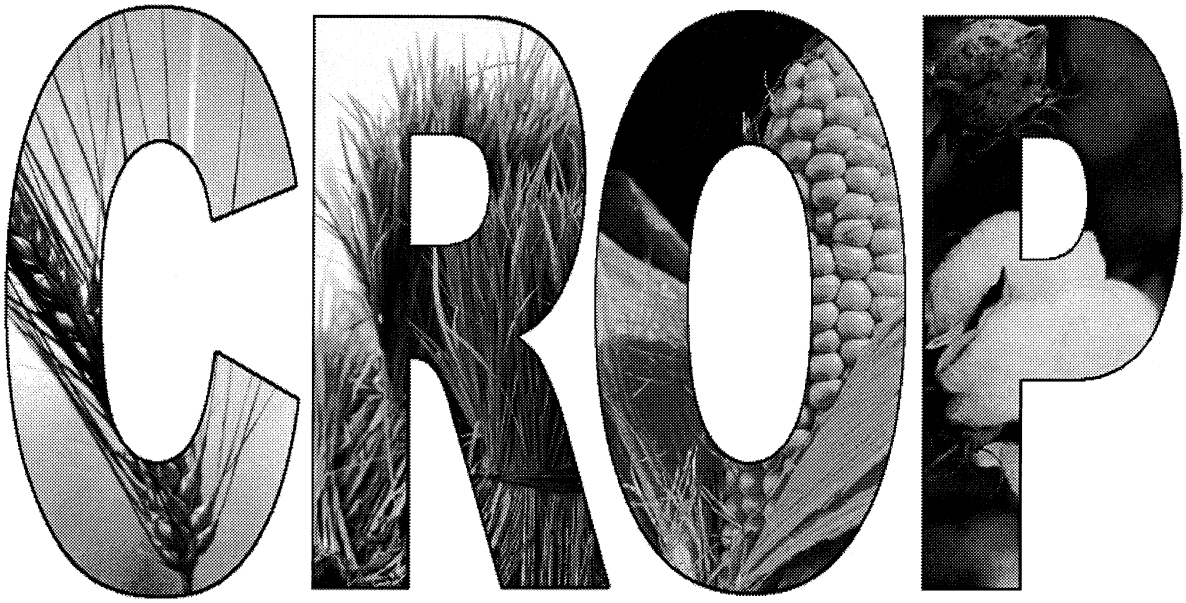
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UNIVERSITY OF MISSOURI - COLUMBIA

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ADVANCED CROP SCIENCE



STUDENT REFERENCE

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Foreword

The development of the *Advanced Crop Science* curriculum guide is the result of suggestions by the MVATA Teaching Aids Committee. The Advanced Crop Science Advisory Committee suggested the topics to be included and reviewed the materials.

This curriculum contains 11 units. Topics include an overview of crop production, plant biology, soil fertility and management, identifying and selecting crops and seeds, safety, environment, and legal issues, corn and grain sorghum production, soybean production, wheat and small grain production, forage production, cotton production, and rice production. An instructor guide can be purchased separately.

The instructor's guide to accompany this student reference incorporates the needed component parts to aid agriculture teachers in the implementation of VIMS.

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ADVANCED CROP SCIENCE

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Lesson 1: Missouri Crops and Their Uses

Most of the world's food supply comes directly or indirectly from crops. Besides food, crops contribute to the production of clothing, household and industrial products, fertile soil, and cleaner air. Americans tend to take crop production for granted due to the endless supply of food and other products that are available and affordable. This is due in part to the United States having the world's best producers who use the most up-to-date technology. However, many people in the world still go hungry, barely receiving simple food resources from crops. With this realization, and the knowledge that the world population is continually increasing, efficient crop production is as important for Missouri producers as it is for the rest of the world. This lesson provides an introduction to Missouri crop production including a discussion of the major crops produced and their many uses.

Major Agricultural Crops in Missouri

The state of Missouri is blessed with fertile soil but has broad variations in climate and topography. Due to these variable conditions, everything from grapes, grain crops, hay, and pasture land for livestock production is produced in Missouri. Rich, productive soil in Missouri's northwest, central, northeast, and southeast regions is ideal for crop production; the hilly and wooded areas of the Ozarks provide pasture and favorable weather for growing vegetables and fruits. More than 20 agricultural crops are produced in Missouri. The major crops are soybeans, corn, grain sorghum (also called milo), wheat, hay, cotton, and rice. Additional high-yielding crops produced are tobacco, vegetables, and fruits.

Soybeans are the state's largest cash crop and is grown throughout the state except in the south central region. The 107 million bushels of soybeans produced in 1998 illustrate its economic value and popularity among the state's producers.

Corn and grain sorghum, which are grown throughout Missouri, are also raised in large amounts with a combined total of nearly 311.6 million bushels of grain harvested in 1998. In addition, 1 million tons of these two crops were cut for silage, an animal feed made from immature or green corn and grain sorghum plants.

Winter wheat is also grown statewide with 50 million bushels or more produced annually since 1986. Wheat prices in recent years have led to a reduction in acres planted, but yields per acre have increased enough to compensate for this change. With its unique ability to lay dormant during cold weather, winter wheat is often double-cropped (planted in the same growing season) with soybeans to increase profits for Missouri producers.

Hay is a very large feed crop and Missouri ranks first in hay production (excluding alfalfa) in the United States. It is grown all across the state with the largest production area in the central region.

Cotton and rice production occurs in the uplands in the southeast corner of the state, or "Bootheel." Cotton is also grown in the southwest region of Missouri. Both cotton and rice add millions of dollars to the state's economy each year.

Along with the major crops, the production of tobacco, vegetables, and fruits also provide important revenue to the state. Tobacco is produced in the uplands along the Missouri River in the northwest region. Vegetables and fruits are grown mainly in the river bottoms along the Missouri and Mississippi rivers.

Table 1.1 – 1998 Top 10 Missouri Crops

1998 VALUE OF MISSOURI CROPS*			
NO.	***CROP***	***VALUE OF PRODUCTION***	***AVG. VALUE PER UNIT***
1	Soybeans	$856.8 million	$5.04 bu
2	Corn (Grain)	$550 million	$1.93 bu
3	All Hay	$532.9 million	$68.5 ton
--	*---Alfalfa*	$-----	$102.00 ton
--	*---Other Hay*	$-----	$61.50 ton
4	Winter Wheat	$137.4 million	$2.39 bu
5	Cotton	$118.6 million	$0.706 lb.
6	Rice	$64 million	$8.65 cwt.
7	Grain Sorghum	$45.6 million	$1.72 bu
8	Cottonseed	$17.6 million	$131.00 ton
9	Tobacco	$10.9 million	$1.905 lb.
10	Potatoes	$9.7 million	$5.15 cwt.

**Adapted from 1999 Missouri Farm Facts*
Updates available at <http://ext.missouri.edu/agebb/moass>

Table 1.1 lists the top 10 Missouri crops in 1998 according to their production value. The average

market price per unit that producers received for these crops is also listed. Current values may be obtained from the most recent *Missouri Farm Facts* available from the Missouri Agricultural Statistics Service or on the Internet at <http://agebb.missouri.edu/mass>.

Main Uses of Major Missouri Crops

Crops can have several uses, but most are produced for very specific needs. The following paragraphs list the main use of each of the major crops grown in Missouri.

Soybeans are the world's foremost provider of protein and oil. Whole soybeans are processed into protein-rich meal and used for livestock feed. Intensive processing of soybeans has made them just as important for industrial use. Soybean oil, which is processed from the whole bean, is used mostly for cooking purposes. Soybean oil is also used in industrial products such as diesel fuel, inks, paints, and plastics. Soybean meal, the cake left from the crushed bean, is ground and most commonly used as a high protein supplement in livestock and poultry feed.

Many products can be manufactured from corn as can be seen in Figure 1.2, but the main use of this commodity is for livestock feed. Approximately 60% of all corn growth in the United States is fed to domestic livestock as ground grain, silage, high-oil, and high-moisture corn. During the 1997-98 marketing season, the estimated feed usage of corn was more than 16.3 billion bushels and Missouri ranked 10th in the nation for grain corn production.

In 1998, 5% of all U.S. grain sorghum was grown in Missouri. Because of its similar composition to corn, grain sorghum's main use is also for livestock feed. Sorghum acreages tend to fluctuate annually but due to sorghum's resistance to drought and heat, acreages often increase if a dry, hot year is expected.

In 1998, the state ranked first in the nation in hay production, excluding alfalfa, and fourth in the nation in all types of hay production. That same year, hay acres were the second largest crop acres harvested across the state. All hay produced in the state is used as a livestock roughage feed source. The demand for hay within the state is great since Missouri also ranks second in the United States in the total number of beef cows.

Winter wheat is the primary wheat crop grown in Missouri, with spring wheat grown in some areas of the state. The seeds from both varieties are used mainly in the production of flour. Wheat production has steadily increased over the past decade due to the use of improved varieties and better fertility management by Missouri producers.

Cotton production is another important crop to the state, bringing in the fifth highest cash crop receipts in 1998. Cotton's main use throughout the world is for cotton fiber. Fiber is picked from mature cotton plants and then processed into thread that is woven into cloth and textiles. Clothing is the major use of all processed cotton fibers; however, a large amount is used in the production of textiles for home furnishings such as towels and sheets.

Rice is used almost entirely for human consumption, providing the main food source for almost half the human population of the world. Because of world population growth, the demand for rice continues to increase. The *USDA Supply and Demand Report* stated that the world use of rice in 1996 through 1997 was more than 370 million metric tons. The United States exports 40% of all rice grown in the country because U.S. technology has created the highest-quality and most sought-after rice in the world. Most of the remaining rice grown in the country is consumed as food. Although Missouri rice acres are limited (approximately 100,000 acres since 1995), yields continue at 5,000+ pounds per acre.

Main Uses of Components of Major Crops

Crop components are the parts of a plant (the seed, stem, leaves, or roots) that undergo separate or additional processing to form products for consumer use. Although Missouri's major crops are produced for one main use, most of these crops have other components that can be used in similar or very different ways.

Soybean production in the United States is growing annually due to the industrial potential of the soybean seed. Research continues to discover new uses and products from this "miracle crop" by using its main component, the seed or bean, in three ways: (1) whole beans, (2) as an oil, or (3) as

a meal or protein product. By explaining the intensive processing of the soybean seed, it is easy to see how many different uses can be made of this crop component.

Whole beans are initially hulled and rolled into full fat flakes that may be ground at this stage and used in animal feed or processed into full fat flour for commercial use. This flaking process is necessary to produce soy oil, a major use of the crop. Crude oil is extracted from the fat flakes in a three-step process. First the flakes are bathed in a solvent. Next, they are degummed, a process in which lecithin (a useable by-product) is removed. Finally, the flakes are crushed to remove the oil. This oil is further refined, or processed, into its main use as cooking oil or made into margarine and shortening. The pressed flakes that are left are recycled by removing the solvent and dried to create oil-free "defatted soy flakes." These defatted flakes are the basis of all soy protein products. The flakes are mainly ground into meal for animal feed or can be ground into soy flour that is 50% protein. Soy flour is further processed into higher protein concentrates for use in protein drinks, soup bases, or gravies. Flakes can also be chemically processed into soy isolates (90% protein), such as the chief component of many dairylike products including soy-based cheese and soy milk. Figure 1.1 lists numerous products produced from soybeans.

Components of corn include the seed or kernel, parts of the seed, the immature or green plant, and the stalks. The kernel is mainly used as a livestock energy feed source. It is generally fed in the form of cracked, rolled, or ground corn. When refined, the corn seed is divided into two groups: primary products and co-products. Primary products are the starches, syrups, and dextrose (sugar) generated from the endosperm (starch) of the corn seed. They are used in foods, industrial products, and drugs. Co-products are made from solubles (dissolved carbohydrates in water-processing solution), gluten (protein) and hulls, and from the germ (oil) of the kernel. Co-products are used in drugs, livestock feed, and foods. See Figure 1.2 for uses of primary products and co-products of corn, courtesy of The National Corn Growers Association. The green corn plant can be harvested as silage and stored in silos, pits, or bunkers. Silage is used as a forage livestock feed, particularly for dairy cows. Corn stalks remaining in harvested fields are sometimes used as a winter feed supplement for cattle.

From grain sorghum, the kernel, the green plant, and the endosperm of the seed are the main components used. The kernel is chiefly used as livestock feed. However, additional processing is required to enhance the feed efficiency of this very hard grain. Like corn, the green sorghum plant can be cut as silage for livestock feed.

Wheat is raised mainly for two components, the seed and stem. The endosperm in the wheat seed is the source for all flour manufacturing. Other parts of the seed, bran (outer coat) and germ are by-products from white flour milling and are used separately or included in whole-wheat flour. Two other by-products from flour manufacturing called middlings and shorts (the discarded waste including germ, fine bran, and some flour), are processed into livestock feed. The stem, or wheat stubble, of the wheat plant left after the grain is harvested can be cut, dried, and baled into straw for use as livestock bedding or ground cover and mulch. Wheat stubble, if not baled, is left on fields to prevent soil erosion and to add moisture and nutrients back to the soil. The immature or green plant can also be harvested as silage and used as livestock forage feed.

In hay production, the main components used are the stem, leaves, and the seed head of the grass or legume crop. The plant is cut, dried, and baled to be used as a livestock roughage feed source. All parts of the plant, except the roots, are used. However, the roots of legume hay crops play an important role in replacing nitrogen in the soil. This will be discussed in Unit II.

Fiber and seed are the components of the cotton plant used the most. The fiber, formed within the cotton boll or dried flower, is processed into thread to be woven into fabric and textiles for clothing and home furnishings such as towels and sheets. Cottonseed, also found in the boll, provides oil and meal used for food products, livestock feed, and flour. Foots, or the remains from cotton seed oil refining, are processed into fatty acids for industrial products. The hulls from the cottonseed are used separately and in combination with cottonseed meal for livestock, poultry, and fish feed or as fertilizer.

Figure 1.1 - Soybeans' Many Uses



WHOLE SOYBEAN PRODUCTS

OIL PRODUCTS

REFINED SOYOIL

Edible Uses
Coffee creamers
Cooking Oils
Filled Milks
Margarine
Mayonnaise
Pharmaceuticals
Salad Dressing
Salad Oils
Sandwich Spreads
Shortenings

Technical Uses
Anti-Corrosion Agents
Anti-Static Agents
Caulking Compounds
Core Oils
Diesel Fuel
Disinfectants
Dust Control Agents
Electrical Insulation
Epoxys
Fungicides
Inks-Printing
Linoleum Backing
Metal - Casting/Working
Oiled Fabrics
Paints
Pesticides
Plasticizers
Protective Coatings
Putty
Soap/Shampoo/Detergents
Vinyl Plastics
Wallboard
Waterproof Cement

SOYBEAN LECITHIN

Edible Uses
Emulsifying Agents
Bakery Products
Candy/Chocolate Coatings
Pharmaceuticals
Nutritional Uses
Dietary
Medical

Technical Uses
Anti-Foam Agents
Alcohol
Yeast
Anti-Spattering Agent
Margarine
Dispersing Agents
Paint
Inks
Insecticides
Rubber
Stabilizing Agents
Shortening
Wetting Agents
Calf milk replacers
Cosmetics

GLYCEROL
FATTY ACIDS
STEROLS

SOYBEAN PROTEIN PRODUCTS

SOYBEAN MEAL

Feed Uses
Aquaculture
Bee Foods
Calf Milk
Replacers
Cattle Feeds
Dairy Feeds
Fish Food
Fox & Mink Feeds
Pet Foods
Poultry Feeds
Protein Concentrates
Swine Feeds

HULLS
Dairy Feed
Filter Materials
High Fiber Breads

SOY FLOUR CONCENTRATES & ISOLATES

Edible Uses
Alimentary Pastes
Baby Food
Bakery Ingredients
Beer & Ale
Candy Products
Diet Food Products
Food Drinks
Grits
Hypo-Allergenic Milk
Meat Products
Noodles
Prepared Mixes
Sausage Casings
Yeast

Technical Uses
Adhesives
Analytical Reagents
Antibiotics
Asphalt Emulsions
Binders - Wood/Resin
Cleansing Materials
Cosmetics
Fermentation Aids/Nutrients
Films for Packaging
Inks
Leather Substitutes
Paints - Water Based
Particle Board
Plastics
Polyesters
Pharmaceuticals
Pesticides/Fungicides
Textiles

Edible Uses
Seed
Stock Feeds
Soy Sprouts
Baked Soybeans
Full Fat Soy Flour
Bread
Candy
Doughnut Mix
Frozen Dessert
Instant Milk Drinks
Low-cost Gruels
Pancake Flour
Pan Grease Extender
Pie Crust
Sweet Goods
Roasted Soybeans
Candies/Confections
Cookie Ingredient/Topping
Crackers
Dietary Items
Fountain Toppings
Soynut Butter
Soy Coffee
Traditional Soyfoods
Miso
Soymilk
Soy Sauce
Tofu
Tempeh



Source: American Soybean Association

Figure 1.2 - Primary Products and Co-Products of Corn

PRIMARY PRODUCTS

STARCHES

CORNSTARCH

Industrial Uses
Abrasive Paper & Cloth
Adhesives
Binder or Binding Agents
Bookbinding
Briquettes
Cardboard
Ceiling Tiles
Chemicals
Coatings on Wood, Metal & Paper
Color Carrier (in printing)
Cork Products
Crayon & Chalk Binder
Detergents
Drilling Mud for Oil-Wells
Dry Cell Batteries
Fermentation Processes
Fiberboard
Fiberglass size
Fireworks
Insecticide Powders
Insulating Material
Latex & Poster Paints
Lubricating Agents
Oilcloth
Paper & Paper Products
Plastics (molded)
Plywood (interior)
Rubber Tires
Surgical Dressings
Textiles Sizing
Wallboard & Wallpaper

Food, Drug, or Cosmetic Uses
Antibiotics
Aspirin
Baby Foods
Bakery Products (bread, rolls, cakes, pies, crackers and cookies)
Baking Powder
Brewed Beverages (beer, ale)
Canned Vegetables
Chewing Gum
Chocolate Drinks
Confectionery
Cosmetics
Desserts (puddings, custards)
Drugs
Food & Drug Coatings
Gravies & Sauces
Meat Products
Pie Filling
Powdered Sugar
Precooked Frozen Meals
Prepared Mixes (pancake, waffle, cake, candy)
Prepared Mustard
Salad Dressing
Soaps & Cleaners
Soups

DEXTRINS

Industrial Uses
Adhesives
Bookbinding
Briquettes
Candles
Ceramics
Cork Products
Crayon & Chalk Binder
Dyes
Envelopes
Fiberglass Insulation
Fireworks
Insecticides
Labels
Leather
Linoleum
Magazines
Matches (head and box side)
Oil-well Drilling
Plastics (molding)
Plywood
Poster Paints
Printing Inks
Sandpaper
Shoe Polish
Silvering Compounds
Soaps
Straws (drinking)

SYRUPS

CORN SYRUP

Industrial Uses
Adhesives
Chemicals
Dyes & Inks
Explosives
Leather Tanning
Metal Plating
Paper (glassine, parchment)
Plasticizer
Rayon
Shoe Polish
Textiles
Theatrical Makeup
Tobacco & Tobacco Products

Food & Drug Uses
Baby Foods
Bakery Products (bread, rolls, biscuits, doughnuts, pies, cakes, cookies, pretzels)
Beverages (soft drinks, beer, ale)
Breakfast Foods
Catsup, Chili & Tomato Sauce
Cereals
Cheese Spreads & Foods
Chewing Gum
Chocolate Products
Coffee Whiteners
Condensed Milk (sweetened)
Desserts
Drugs
Eggs (frozen, dried)
Extracts & Flavors
Frostings & Icings
Fruit Butters, Juices & Drinks
Fruits (canned, candied, fillings, frozen)
Ice Cream & Sherbet
Jams, Jellies, Marmalades & Preserves
Licorice
Malted Products
Marshmallows

HIGH FRUCTOSE CORN SYRUP

Food Uses
Bakery Products
Canned Fruits & Juices
Condiments
Confectionery Products
Frozen Desserts
Jams, Jellies & Preserves
Soft Drinks
Wine
Yeast

MALTODEXTRINS

Food Uses
Bakery Mixes
Beverage Powders
Condiments
Dehydrated Foods
Dry Soup Mixes
Gum Confections
Icings & Glazes
Instant Teas
Instant Breakfast Foods
Low Calorie Sweeteners
Marshmallows
Nougats
Meat Products (bacon, bologna, hams, sausage, frankfurters, mincemeat)
Peanut Butter
Prepared Mixes (cakes, infant foods, pie fillings, puddings, powdered drink mixes, ice cream)
Pickles
Salad Dressing
Seafood (frozen)
Soups (dehydrated)
Syrups (table, chocolate, cocoa, fruit, medicinal, soda fountain)
Toppings
Vinegar

DEXTROSE

DEXTROSE

Industrial Uses
Adhesives
Amino Acids
Chemicals
Citric Acid
Dyes
Electroplating & Galvanizing
Enzymes
Lactic Acid Polymers
Leather Tanning
Lysine
Mannitol
Paper Manufacturing
Rubber (cold process)
Sizing Materials
Sorbitol
Textiles (dyeing, finishing)
Threonine
Tryptophan

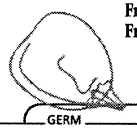
Food, Drug, or Personal Uses
Antibiotics
Baby Foods
Bakery Products (biscuits, bread, crackers, fillings, icings, macaroons, pretzels, cookies, crackers, wafers)
Berries (canned, frozen)
Beverages (soft drinks, beer, ale)
Breakfast Foods
Caramel Color
Cheese Foods & Spreads
Chewing Gum
Chocolate Products
Citric Acid
Condensed Milk
Cream (frozen)
Dairy Products
Desserts
Dietetic Preparations
Distillation Products
Doughnuts
Drugs (fermentation process)
Eggs (frozen, or dried)
Fish (pickled)
Flavoring Extracts
Food Coloring
Fruit Juices
Fruits & Vegetables (canned, candied, frozen)
Gelatin Desserts
Ice Cream & Sherbet
Jams, Jellies, Marmalades & Preserves
Lactic Acid
Meat Products (bacon, bologna, hams, sausage, frankfurters, mincemeat)
Medicinal Preparations & Intravenous (injections, pills, tablets, drugs)
Mouthwash
Peanut Butter
Peas, Canned
Pectin, Fruit
Pickles
Prepared Mixes (cakes, infant foods, pie fillings, puddings, powdered drink mixes, ice cream)
Sauces (catsup, tomato)
Seasoning Mixes (dry)

ETHANOL

Alcoholic Beverages
Industrial Alcohol
Octane Enhancer
Oxygenate in Motor Fuels

HYDROL

(Corn Sugar Molasses)
Leather Tanning
Livestock Field
Organic Acids
Organic Solvents
Tobacco



CO-PRODUCTS

CORN OIL, REFINED

Industrial
Chemicals & Insecticides
Lecithin (for pharmaceuticals, cosmetics, linoleum, printing inks)
Paint & Varnish
Rubber Substitutes
Rust Preventative (surface coatings)
Soap
Soluble Oil (leather, tanning use)
Textiles

CORN OIL & FREE FATTY ACIDS

Food & Drug Uses
Carriers for Vitamins and Medicines (capsule form)
Cooking Oil
Margarine
Mayonnaise
Potato Chips
Salad Dressing
Seasoning Sauces
Shortening
Soaps

SOLUBLES

(Steepwater)
Antibiotics
Chemicals
Pharmaceuticals
Yeast

GLUTEN & HULLS

Feed Uses
Corn Germ Meal
Corn Gluten Feed
Corn Gluten Meal
Corn Oil By-products
Corn Sugar (crude & refined)
Hydrol
Steepwater for Feed

Other Uses
Amino Acids
Fur Cleaner
Zein & Other Protein Products

The rice seed, seed hulls, and plant stems are all used components of the rice plant. The hull is removed from the rice seed leaving a bran layer surrounding the kernel. This brown rice is edible, but most rice is milled or further processed, removing the bran to make white or "polished" rice that most consumers prefer. White rice is mainly cooked and eaten whole, but is also processed into cereals, rice cakes, or starch used in other food products. The bran and germ from the rice seed can be processed into rice oil, which is a very fine cooking oil with no cholesterol. Rice seed hulls are often used for poultry bedding. Similar to wheat, the stem of the rice plant can be cut, dried, and baled as straw and used for livestock feed and bedding.

Alternative Uses of the Major Crops

All of the major crops can be grown for seed production, but additional care in planting, crop management, and harvesting must be taken in order to produce a quality, marketable product. With a global emphasis on using renewable resources and increasing production costs, producers and manufacturers are always looking for new or alternative uses for crops.

As previously shown in Figure 1.1, soybeans have more alternative uses than most other crops. This is only a small listing of current products developed from soybeans. Products of the future include hand and baby lotion, low-fat soy oil, and cytosol (a biosolvent used to clean up oil spills on shorelines). The United Soybean Board estimates the largest growth in products made with soybeans will be in solvents and cleaners, requiring an increase in production of more than 40 million bushels of soybeans by the year 2005.

Corn's alternative uses include industrial products such as starch, ethanol (a gas supplement), high fructose corn syrup, gluten feed, meal, and oil. As seen previously in Figure 1.2, the products made from primary and co-products are numerous. Corn can be found in everything from peanut butter to shoe polish and new uses are being discovered almost daily. Some of the newest uses for corn include plastics and antifreeze.

Although it originated as a food source, only 3% of Missouri's grain sorghum is processed into anything other than livestock feed. Ethanol is the only major by-product produced from grain sorghum starch, but currently most ethanol is generated from cornstarch.

Wheat straw can be fed as a roughage feed source to livestock when hay supplies are low. Before feeding, the straw is injected with anhydrous ammonia to give it a greater usable nutritional value. Some alternative uses for wheat include breakfast food, beer, whiskey, alcohol, and coffee substitutes. The future could see more use of wheat in building materials such as straw used in plywood or wheat starch mixed with concrete. These types of products are being tested to develop lighter, less expensive, and better building materials from renewable crop resources.

Old grass hay can be used as livestock bedding if the nutritional value has deteriorated and no mold is present. In addition, current ethanol research is experimenting with using hays, grasses, and even yard clippings as a possible source for this growing fuel product.

An alternative use of cotton fiber is lint, the term used for fiber after the seeds have been removed at the gin. Lint is used for padding in furniture, mattresses, and car seats. It is also used in the production of other cellulose products. Additional alternative uses of the cotton plant include cardboard, plastics, and U.S. paper currency. Most present-day research on cotton is done in an effort to improve the quality of the fiber, which in turn improves the quality of cotton products consumers may purchase. Cotton waste, or the remains of the milling process, is currently recycled into new products.

The by-products of rice, including the meal, bran, and rice polish, are used in livestock feed. From the milling process, broken kernels (less than three-fourths of the whole kernel) are used to brew beer and are ground for rice flour. Continued research is looking into using rice stems as another possible source for ethanol. Rice hulls can be used for livestock feed.

Other Important Crops Grown in Missouri

Variations in the topography and climate in the state contribute to production of many other crops in Missouri. Often considered "alternative" crops, the production of tobacco, vegetables, and fruits is very prominent in select areas of the state. These

crops make an important contribution to the state's economy.

Although only 3,000 acres of tobacco were harvested in 1997, this crop was valued at more than $13 million to Missouri producers. It is grown primarily in the fertile soils of the Missouri River bottoms along the northwestern state border and through central Missouri. Platte and Buchanan counties between St. Joseph and Kansas City produce more than 80% of the state's crop.

Most harvested vegetables are sold at farmers' markets, roadside stands, and pick-your-own farms throughout the state. Farmers' markets have become popular because consumers demand less processed and more natural foods. In 1998, potato and watermelon production brought in $9.7 and $6.1 million, respectively, for state vegetable producers. Although watermelon is really a fruit, it is classified as a vegetable commodity due to how it is grown. This traditional summertime treat ranked Missouri ninth among all other states in 1998.

Likewise, many orchards and vineyards maintain seasonal marketing stands to promote and sell their products. Apples, peaches, and grapes are used to make some of Missouri's finest jellies, jams, and wines as stated in the University of Missouri publication *Best of Missouri Farms*. This 1988 booklet lists more than 30 families in rural Missouri who produce everything from soup to nuts including 15 wineries in operation since the 1840s. Some of these businesses and many new ones have continued to grow across the state. A comprehensive directory is maintained by the Missouri Department of Agriculture, listing many farmer markets, roadside stands, and pick-your-own operations. The *AgriMissouri Buyer's Guide* can be viewed on the Internet at <http://www.mda.state.mo.us/bguide/htm>.

Companies That Use Major Crops or Crop Components

Many companies throughout Missouri and the United States use crops and crop components. These companies can be grain merchandisers at local elevators; international exporters; large livestock producers or feed mills; or processors of food, feed, or industrial products.

Grain merchandisers purchase grains from producers or other merchandisers. At local or terminal elevators, grain crops are dried, stored, and conditioned for resale. These grains are sold to feed mills; feed, food, or industrial processors; or exported to other grain merchandisers around the world. Grain merchandisers are often called "middlemen" because they make the market connection between producers and consumers. With current technology and marketing strategies, many producers can bypass the grain merchandiser and sell directly to feedlots, feed mills, or grain processors. MFA Incorporated, Cargill, ADM Milling, and Farmland are examples of companies that buy, process, or sell major crops or crop components.

MFA Incorporated, based in Columbia, Missouri, is a regional farm supply and marketing cooperative serving farmer/members in Missouri and adjacent states. A manufacturer, distributor, and supplier, MFA focuses on production of feed, grain sales, sales of seed, fertilizer, and crop protection chemicals.

Cargill Inc. is the largest grain company, employing more than 80,000 agricultural employees throughout the world. Based in Minneapolis, Minnesota, the corporation focuses on international marketing, processing, and distribution of agricultural food. This company maintains divisions in several areas of crop production including grain processing and seed and fertilizer production. The grain division is the largest grain-trading business in the country with enough wheat purchases annually to bake nearly 8.6 million 1-pound loaves of bread.

Archer Daniels Midland Company, based in Decatur, Illinois, has a network of over 205 domestic and internationally based plants. ADM focuses on processing cereal grains and oilseeds. As the link between producers and the food manufacturer, ADM provides a market for the producers' crops and, in turn, supplies feed ingredients for their animals. ADM processes corn, cottonseed, rice, soybeans, wheat, barley, canola, cocoa, peanuts, and sunflower seeds into value-added products.

Farmland, headquartered in Kansas City, Missouri, is the largest farmer-owned cooperative in North America. More than 600,000 independent family farmers own the 1,500 local cooperatives that encompass the Farmland Cooperative System.

Overview

Farmland does business in all 50 states and more than 80 countries. The company owns grain elevators, feed mills, beef and pork processing plants, fertilizer plants, and petroleum refineries. They provide crop production and crop protection products, livestock feed, petroleum, grain processing and marketing, and the processing and marketing of pork and beef products.

Large livestock producers mostly purchase feed grains or meal made from crops such as soybeans or cottonseed to be used in animal feeding rations. Livestock producers include Koch Industries, a large multifaceted company, headquartered in Wichita, Kansas, which is involved in several areas of agricultural production. Koch specializes in using crops or crop components to feed cattle at their company-owned ranches and feedlots. Koch also has business interests in animal feed processing and distribution; value-added seed genetics; producing, trading, and distributing fertilizer and other agricultural chemicals; grain storage and merchandising; and the milling and processing of oil seed grain and feed.

Food and industrial processors may purchase crops in a harvested or preprocessed state depending on what products they are manufacturing. For example, Nestle USA, a food processing plant in Trenton, Missouri, purchases corn sweeteners and starches, soy products, and flour from grain processors to add to the various food products they manufacture. Grain processing facilities include mills, elevators, and gins such those owned and operated by Ralston/Purina in St. Louis.

ConAgra, Inc. of Omaha, Nebraska, is the third largest diversified international food company. ConAgra, like Cargill and Koch, has a large stake in merchandising grain. Other large food processors such as RJ Reynolds, Nabisco and Sara Lee produce many popular brands of cookies, crackers, cakes, cereal, condiments, candy, and other food products made from crops or crop components. General Mills, Quaker Oats, and Pillsbury are other highly recognized food processors. Missouri is home to some of the nation's most famous food processors including the Colonial Baking Company and Kraft Foods in Springfield. St. Louis is home to Ralcorp Holdings, Inc., which produces breakfast cereals, and Frito-Lay, Inc., makers of chips and snack foods.

Summary

Major agricultural crops produced in Missouri include soybeans, corn, grain sorghum, wheat, hay, cotton, and rice. Soybeans are a primary provider of protein and oil. Livestock feed is the primary product produced from corn and grain sorghum. Wheat is used primarily for the production of flour. The major use of hay is for a livestock roughage feed source. Cotton production results in cotton fiber that is used for clothing and textiles for home furnishings. Rice is almost entirely used for human consumption.

Parts of the plants that undergo separate or additional processing are referred to as crop components. These components contribute to many other uses. There are also uses for crops that are referred to as alternative uses. Ongoing research is developing alternative uses for crops such as solvents, cleaners, and ethanol. Additional high-yielding crops in Missouri are tobacco, vegetables, and fruits.

Grain merchandisers in Missouri that purchase grains from producers and develop products for consumer use include MFA, Cargill, Archer Daniels Midland Company, Farmland, Koch Industries, and ConAgra, Inc. Many other large food processors also use Missouri crops to produce food for consumer use in the United States and internationally.

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Lesson 2: The Economic Importance of Crops

Missouri agriculture is very diversified and not dependent on any one or two crops. Over 20 crops are produced in the state, resulting in over half the state's agricultural receipts. For marketing purposes, crops grown in Missouri are categorized into five types: oil crops, feed crops, food grains, cotton, and miscellaneous. Although production acres of some crops are limited in the state such as cotton and rice, they still generate millions of dollars in cash receipts annually.

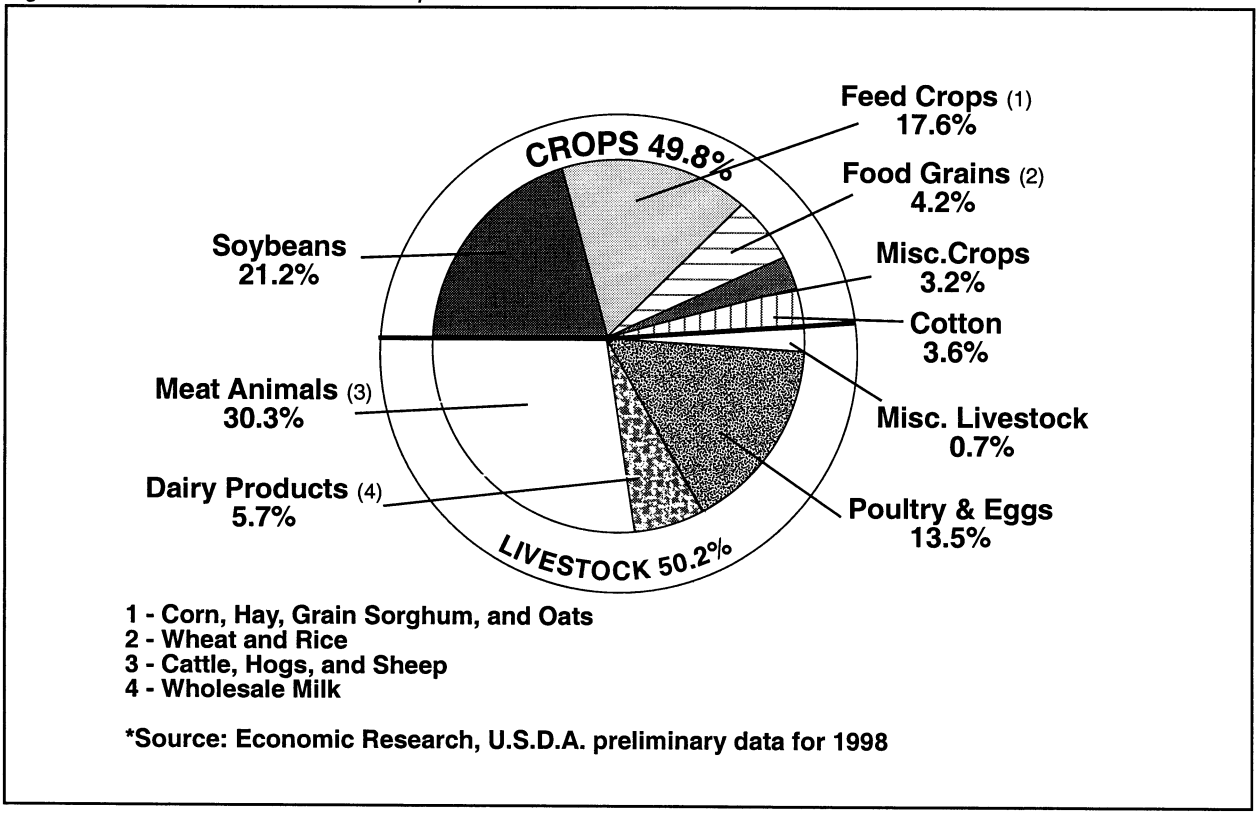
Economic Importance of Crops in Missouri

Missouri's agricultural industry is a key part of the state's economy, accounting for billions of dollars in cash receipts annually. In 1998, cash receipts totaled more than $4.68 billion, with crops making up almost half (49.8%) of sales as shown in Figure 2.1. The oil crop soybeans, Missouri's largest cash crop, accounted for 21.2%, over 1/5, of all cash receipts. Feed crops (corn, hay, oats, and grain sorghum) added 17.6% to the total. Food grains (rice and wheat), cotton, and miscellaneous crops made up the remaining crop cash receipts at 11%. These totals brought the value of crop production for Missouri in 1998 to $2.27 billion. Missouri agriculture employs 15% of the state's labor force, which translates to over 400,000 workers. Our state is home to over 2,000 agribusinesses. Missouri is also very prominent in the international marketplace and exported over $1.38 billion worth of farm goods in 1998 alone. In the same year, Missouri was the leading state in hay production (excluding alfalfa), 6th in the nation in the production of soybeans and rice, 10th in corn, 11th in winter wheat production, and 12th in cotton. Missouri grew 6% of all U.S. soybeans and grain sorghum.

Economic Importance of Crops in the United States

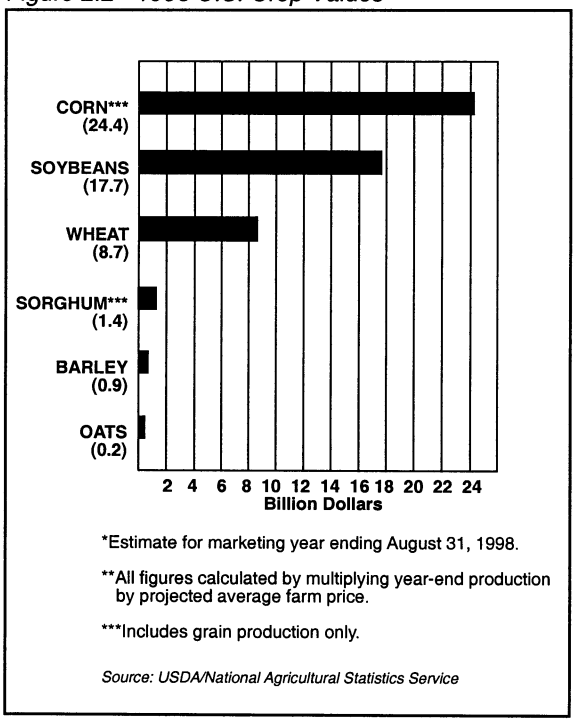
Crop production is not only important in Missouri, but just as important to our nation's economy. In 1998, the value of all crops produced in the United States totaled $98 billion dollars. This represented over 48% of the $196.8 billion for all farm cash receipts.

Figure 2.1 - 1998 Missouri Cash Receipts



Corn is America's largest crop. In 1998, corn production totaled 9.76 billion bushels with an annual average price reported at $2.43 per bushel. This crop alone added $24.4 billion to our nation's economy as is shown in Figure 2.2. Other leading crops in the United States based on cash receipts include soybeans at $17.7 billion, wheat at $8.7 billion, cotton at $5.9 billion, and hay at $13.3 billion. These figures illustrate that crop production in the United States is an integral part of our country's economy.

Figure 2.2 - 1998 U.S. Crop Values



*Estimate for marketing year ending August 31, 1998.

**All figures calculated by multiplying year-end production by projected average farm price.

***Includes grain production only.

Source: USDA/National Agricultural Statistics Service

Economic Importance of Crops in the World

As the population of the world increases and there are more mouths to feed, the need for world grain production continues to increase. In 1997 there were 5.6 billion people in the world, with the population increasing at a rate of 1.7% per year. Most of the protein received by people in underdeveloped countries comes from the grain they may be able to raise or receive from imports from countries such as the United States. Protein from grain is the most efficient way of satisfying that nutritional need. Most of the underdeveloped countries have difficulty meeting the grain needs of their populations due to several factors. These include a lack of knowledge of grain production; lack of funds for equipment and seeds; climate and weather disasters; as well as problems with their lack of infrastructure such as transportation, processing, and storage.

The production efficiency of the American farmer is increasing each year. At the end of the 20th century, one American farmer could produce enough food to feed approximately 150 people. The United States accounts for the largest percentage of the total crops produced. In corn production alone, the United States produces 46% of the 500 million metric tons grown worldwide. In 1997, the United States also produced 50% of the world's soybean supply, a total of 2.73 billion bushels. Other major grain-producing countries include Brazil, China, Argentina, Canada, and Australia.

Crop production uses only 1/5, or 382 million acres, of the nation's land. With this efficiency, it is apparent why the United States and Missouri crop producers play such powerful and important roles in world agriculture.

Major Grain Exporting Countries in the World

The United States is the world's leading agricultural exporter, with yearly exports valued at $69.7 billion in 1998. Grains accounted for the following amounts: corn - $9.3 billion, wheat - $6.9 billion, soybeans - $6.3 billion, and cotton - $3 billion. These grains are purchased by importing countries to meet the nutritional needs of their people. The other major grain exporters in the world include China, Argentina, Brazil, Canada, and Australia. The largest oil crop (soybeans) exporters in the world are the United States, Brazil, and Argentina. The United States competes against all of these countries worldwide in the export of whole or unprocessed grains such as corn and wheat. Improved production technologies in these countries are reducing the amount of exports from the United States.

Major Importing Countries of U.S. Crops

Importing countries generally lack crop production technology and usually do not have the required land area to produce the crops needed to feed their people and livestock. These countries depend on the United States and the other major crop exporters to produce and fairly market needed grains, often doing so in return for

products or raw materials from the importing countries. The major grain importers in the world include Japan, Mexico, Korea, Taiwan, and Middle Eastern countries.

The United States also imports crops that are either not produced in the United States or not available in sufficient quantities to meet public demand. U.S. imports include crops such as bananas, coffee beans, and cocoa beans.

Marketing Principles That Affect Crop Economics

As with all agricultural commodities, the law of supply and demand plays the major role in the economics of crop production. No one is more aware of this principle than the American crop producer. Surplus grains can cause prices to fall, leaving little or no margins. With communication developments, the American producer must deal with a global economy as never before.

The Chicago Board of Trade plays the major role in price discovery and determination for grains in the United States and the world. Established in 1848 (over 150 years ago), the CBOT was located at the base of the Great Lakes to bring some order to a chaotic marketing situation that existed at that time. Problems with storage, transportation, and supply and demand led to its establishment. Today the Board of Trade is the center for grain marketing. Here buyers and sellers come together through brokers to negotiate prices of commodities. Prices are affected daily with news from around the world concerning climate changes, agribusiness mergers, or grain orders from governments of other countries. This causes the producer to definitely develop a marketing plan for economic survival.

A successful marketing plan is a three-step process. The first step involves determining a cost of production and expected break-even price per unit of that commodity. All production activities involving the use of inputs and services must be listed. A good cost of production worksheet should be very detailed. In the absence of the producer's own cost estimates, a publication such as the *Missouri Farm Financial Outlook* available from the University Outreach and Extension is consulted.

The second step, developing the marketing plan, requires the producer to estimate the outcome of different pricing alternatives and to determine a target price and quantity to market. These pricing alternatives would include cash marketing, forward contracting, and using the futures and options market. One strategy may be to market the grain using more than one of these marketing options.

The last step is to develop a follow-through plan to determine when to market the grain. A key to this is to develop a method of following or tracking the markets. This may to done by securing grain prices daily through the use of the media (radio, Internet, etc.) or by giving one's broker or elevator manager the authority to conduct the trade. Economists agree that one key to success is to stick to an established plan.

Summary

The incredible production abilities of Missouri allow the state to play an important role in the import-export market. With continued crop prosperity and variety, Missouri can expect to retain its role as a major U.S. producer into the future. In subsequent lessons we will discuss the role and importance of fertilizers and assorted soil management techniques in keeping the state at its current levels of production and importance.

Credits

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Lesson 3: Careers in Crop Science

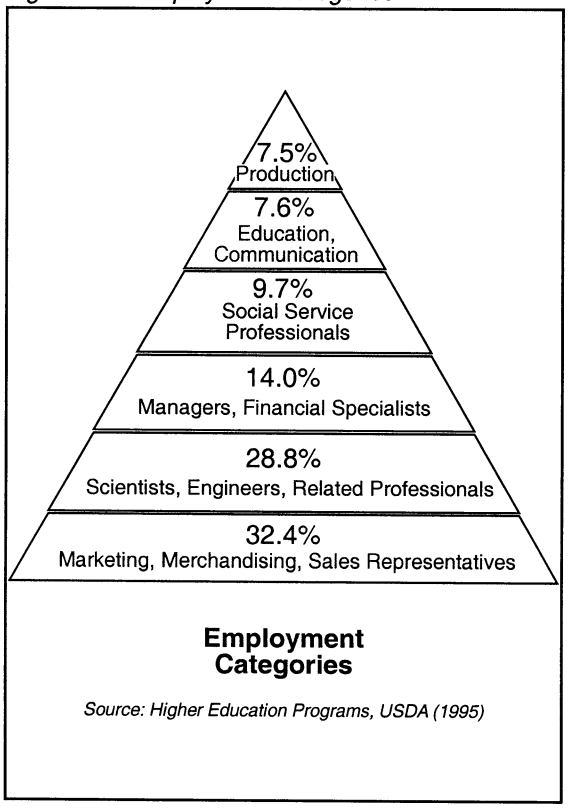
Employing nearly 25 million Americans, agriculture has a large impact in the United States. More than 20% of the jobs in today's market are related to agriculture. Farm exports alone generate nearly 800,000 American jobs. Since plants are the basis of all agriculture, there are career opportunities in crop science or crop-related agribusiness.

Career Opportunities

Agriculture jobs can be separated into six major employment areas: (1) marketing, merchandising, and sales, (2) science and engineering, (3) management and finance, (4) social service professionals, (5) education and communication, and (6) production. Figure 3.1 illustrates the employment categories and the percentage of jobs available in each.

Marketing, merchandising, and sales make up the largest percentage of people employed in agricultural jobs at 32.4%. People in these jobs work with producers and consumers to meet the daily demands for agricultural products. If a person is interested in sales and helping people find the goods or services needed, a career in agribusiness or agricultural marketing might be appealing.

Figure 3.1 - Employment Categories



Scientists, engineers, and related professionals comprise 28.8% of the available jobs. This is the fastest growing area within the industry. Careers in these fields are on the leading edge of agriculture. Crop science and crop-related agribusiness jobs require extensive knowledge of plant science. A college education and possibly additional research work and education are necessary in these careers.

Managers and financial specialists are often considered key to the sound operation of today's agricultural industry. Comprising 14% of the available jobs, these careers demand good business skills and extensive knowledge and understanding of agriculture.

At 9.7% of available jobs, social service professionals safeguard the public and assist people with individual, community, or world needs. An understanding of agriculture, especially crop science, is key to the success of nutrition counselors and Peace Corps representatives in teaching others about food use or food production. These jobs fill an important role in maintaining human health and well-being worldwide.

In this technological age, the agricultural industry needs to actively communicate with the rest of the world. Sharing news and information about agriculture is the main focus of careers in education and communication. This job sector represents 7.6% of available jobs. Careers as technical writers or editors for agricultural publications and agriculture instructors and trainers are always needed to keep the industry current.

Jobs in production represent the smallest percentage of available positions at 7.5% and they vary extensively from one job to the other. Many production jobs require knowledge and development of multiple skills such as operating various machines and equipment, handling chemicals safely, and understanding marketing strategies.

Overview

The following sections give examples with more specific information about careers in each employment category.

Marketing, Merchandising, and Sales

Field sales representatives can work in several areas of the agribusiness community. These areas include animal and feed products, mechanics and equipment, chemicals and pharmaceuticals, or crop production. This occupation requires knowledge of agriculture in general, knowledge of the product being sold, and good communication skills. It may be necessary for a person in this occupation to travel, act as a troubleshooter, understand computers, and be creative. A college degree is preferred but not always required.

A farmer's market or produce stand manager is a multifaceted job. The manager is usually both the producer of the product and the merchandiser. This job does not require a college education although bookkeeping skills may be useful for those individuals who own the produce stand. A knowledge of the produce sold, including which pesticides and herbicides were used, is as important as people skills, organization, and sales and marketing abilities.

<u>Marketing, Merchandising, and Sales</u>
Aerial Crop Duster
Agricultural Advertising Manager
Agricultural Association Executive
Agricultural Chemical Dealer
Agricultural Computer Software Salesperson
Agricultural Equipment Dealer
Biotechnology Documentation Specialist
Biotechnology Patent Administrator
Biotechnology Patent Agent
Chemical Distributor
Crop Insurance Agent
Diesel Mechanic
Farm Real Estate Broker
Feed Mill Operator
Feed or Fertilizer Truck Driver
Field Sales Representative, Animal and Feed Products
Field Sales Representative, Agriculture Mechanics
Field Sales Representative, Chemicals and Pharmaceuticals
Field Sales Representative, Crop Production
Food Broker
Food Processing Plant Technician
Fruit Distributor
Grain Buyer
Grain Elevator Operator
Grain Merchandiser
Groundskeeper
Insurance Agent
Landscape Architect or Contractor
Lawn and Garden Equipment Mechanic
Machinist
Pest Control Technician
Produce Buyer
Produce Stand Operator
Tobacco Buyer

Science and Engineering

An agronomist is an example of a career option in agriscience. Agronomists study soil and crops to gain knowledge of how to grow more productive crops. They usually specialize in a particular aspect of crops and soil, for example, the effects of vitamin C on various plants or how calcium deficiencies affect plants and soil. This career usually requires a master's or doctorate degree in agronomy or plant pathology. Agronomists are employed by private agricultural businesses, government entities, or they can be self-employed consultants.

Another occupation may be working with environmental management. Skills include observation, analysis, and interpretation. Environmental management jobs work with waste management, pollution, and wastewater treatment, just to name a few. These occupations involve people from all educational levels ranging from a high school education to a doctorate degree. Individuals in these careers may work indoors or outdoors and in an urban or a rural environment.

An agricultural machinery design technician designs machines and equipment that fulfill a variety of needs for the agriscience industry. This occupation requires working closely with agricultural engineers, crop producers, and equipment manufacturers to develop and test new designs. An agricultural machinery design technician should be experienced in the operation of agricultural machinery and knowledgeable of how the parts of the machine work together. Most technicians have a college degree and a good understanding of physics and mechanics.

Soil conservationists work with planning, conserving, and managing soil and water resources. They develop and implement land use practices to prevent erosion and protect the soil.

A soil conservationist should have a degree in agronomy, horticulture, or agricultural education. Many have master's or doctorate degrees. Soil conservationists typically work for governmental agencies, agribusinesses, or universities.

Scientists, Engineers, and Related Professionals
Agricultural Construction Engineer
Agricultural Equipment Designer
Agricultural Engineer
Agricultural Safety Engineer
Agricultural Engineer
Agricultural Statistician
Agriculturalist
Agronomist
Bacteriologist
Biochemist
Biophysicist
Biotechnology Manufacturing Technician
Biotechnology Product Development Engineer
Biotechnology Quality Control Engineer
Biotechnology Research Assistant or Associate
Biotechnology Validation Engineer or Technician
Botanist
Cell Biologist
Crop Consultant
Dairy Nutrition Specialist
Entomologist
Environmental Conservationist
Environmental Scientist
Feed Ration Developer
Food Chemist
Food Engineer
Food Scientist
Ground Water Geologist
Irrigation Engineer
Microbiologist
Molecular Biologist
Natural Resource Scientist
Nematologist
Organic Chemist
Parasitologist
Pharmaceutical Chemist
Plant Breeder
Plant Cytologist
Plant Ecologist
Plant Geneticist
Plant Nutritionist
Plant Pathologist
Plant Scientist
Plant Taxonomist
Range Conservationist
Rangeland Scientist
Research Engineer or Technician
Soil Conservationist
Soil Scientist
Toxicologist
Tree Surgeon
Virologist
Waste Management Specialist
Water Quality Specialist
Weed Scientist

Management and Finance

Nearly every career in the management and finance category requires at least a 4-year college education. An agricultural economist must be trained in both agricultural issues and economic issues. It is important to understand the role agriculture plays in the economy and its effect on agricultural prices and profits. Agriculture economists must be able to explain complicated economic issues to producers and address any concerns.

A winery supervisor must be capable of organizing employees and, in many cases, handling the bookkeeping duties of the winery. Winery supervisors may also be responsible for conducting tours of the facilities. They must be knowledgeable of the methods used in making the wine and of public relations techniques.

Managers and Financial Specialists
Agricultural Consultant
Agricultural Corporation Executive
Agricultural Credit Analyst
Agricultural Economist
Agricultural Financial Analyst
Agricultural Loan Officer
Agricultural Market Analyst
Biotechnology Regulatory Affairs Specialist
Commodity Broker
Export Sales Manager
Farm Investment Manager
Fertilizer Plant Supervisor
Financial Analyst
Food Processing Supervisor
Food Service Manager
Golf Course Superintendent
Land Bank Branch Manager
Produce Commission Agent
Quality Control Supervisor
Research Economist
Turf Manager
Water Resources Manager
Winery Supervisor

Overview

Social Service Professionals

The social service side of agriculture usually involves working for a governmental agency to ensure that produce is healthy and safe to eat. Many inspectors for areas as canning, preserving, and grain must have some college and technical training from the agency in which they are employed.

A Peace Corps representative is a job usually limited to individuals who have a great deal of experience in a specific area of expertise. Peace Corps workers usually travel to a foreign country and teach individuals in a country how to grow nutritious food and care for themselves and their children.

Social Service Professionals
Canning and Preserving Inspector
Christmas Tree Grader
Cotton Grader
Farm Appraiser
Federal Grain Inspector
Fiber Inspector
Food and Drug Inspector
Food Inspector
Fruit and Vegetable Grader
Game Warden
Insect and Disease Inspector
Land Surveyor
Park Manager
Peace Corps Representative
Safety Inspector
Weights and Measure Official
Wildlife Manager

Education and Communication

Journalists should be strong writers with a background in agriculture. Depending on the specialty area, skills in photography, graphics, broadcasting, and computer skills may be necessary. Opportunities exist in magazine publishing, newspaper editing, radio broadcasting, or television production. An agricultural journalist needs at least a community college education with a 4-year degree preferable.

A horticulture instructor must be knowledgeable of growing fruits, vegetables, and ornamental plants. This career requires a 4-year degree and teacher certification. Additional education is recommended. Individuals wishing to go into this field should enjoy working with students and talking about horticultural topics with others.

Education and Communication
Agricultural Computer Software Designer
Agricultural Educator/FFA Advisor
Agricultural Extension Agent
Agricultural Extension Specialist/ 4-H Leader
Agricultural Journalist
Agricultural Lawyer
Agricultural Mechanics Teacher
Agricultural News Director
Cooperative Extension Agent
Editor
Farm Auctioneer
Farm Broadcaster
Horticulture Instructor
Information Specialist/Crop Forecaster
International Trade Specialist
Public Relations Representative
Radio/TV Broadcaster

Production

A soybean producer is responsible for all activities involved in growing a successful crop of soybeans. He or she must decide how to prepare the land, what variety to plant, when to plant, and when to harvest. The actual day-to-day activities of the job depend on the season and the weather. Educational requirements vary; some producers have a high school education, others have up to 4 or more years of college. Important skills are familiarity with soybeans and experience with working on a soybean farm. Many soybean producers attend seminars and workshops to keep current with new production practices.

Cotton gin operators are responsible for a wide range of duties including managing the gin operation, hiring employees, and working with growers when the seed is delivered. Individuals in this job need mechanical skills, bookkeeping abilities, and skills in human relations. An operator usually begins as a gin worker and advances to a management position. Operators may have high school diplomas or 2- or 4-year college degrees.

A greenhouse manager/designer has the opportunity to work both indoors and outdoors. Greenhouse managers make sure the plants are growing according to schedule. A designer may either design greenhouses or arrange the plants according to the best growing location. Education

needed for the field varies depending on the technical level of the job.

Production
Certified Seed Grower
Custom Harvester
Custom Operator
Diversified Crop Producer
Farm Manager
Fruit Producer
Greenhouse Manager
Mushroom Producer
Nursery Operator
Nut Orchardist
Orchard Supervisor
Tree Producer
Turf Producer
Vegetable Producer

Educational Requirements

Most jobs in crop science require some type of education beyond high school. Although there are individuals who have obtained jobs without a high school diploma, this is becoming less common. With continuing advancements in precision agriculture, the demand for highly trained and educated individuals will increase. Anyone wishing to increase his/her chances of securing a job in crop science or a crop-related agribusiness should plan for and obtain the needed education.

An informal education (learning by observing) in crop science can be obtained from knowledge acquired growing up on a farm, working in production agriculture, or in an agribusiness environment. Formal education, or structured learning in a school setting, includes taking high school agriculture courses, vocational or technical training, or a required course of study to obtain a specific degree at a college or university.

Depending upon the career choice, a high school diploma, a certificate of vocational or technical training, or an associate, bachelor's, master's, or even a doctorate degree may be required. Table 3.1 lists the different levels of education and the name of the degree earned upon their successful completion. A major difference between a certificate program and a degree program is that a certificate program usually consists of a single course or several courses focusing upon a specific subject area, such as horticulture. A degree program is longer and includes general education classes along with course work in a specific subject area. Both types of education are classified as postsecondary education, or education that a person pursues after graduating from high school. Additional education and training are usually required to obtain a job in an advanced crop science career. For example, to become a crop physiologist, crop geneticist, or seed technician, one would need to obtain a master's degree in crop science.

Table 3.1 – Levels of Education

Level of Education	Certificate/ Degree Earned
Senior High School	Diploma
Postsecondary Education	
Technical School	Certificate
Community College	Associate's Degree
College/University	
4 years of study	Bachelor's Degree
5 to 6 years of study	Master's Degree
7 to 10 years of study	Doctorate Degree

Summary

Careers in crop science provide rewarding challenges in maintaining food, fiber, feed, and other crop production systems; protecting the quality of the environment; and conserving vital soil and water resources. Individuals in these positions can improve our communities, country, and world. Education requirements are varied depending on the career path chosen. Crop science or crop-related agribusiness jobs offer tremendous diversity and exciting challenges and pay salaries comparable to others in the job market.

Credits

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Lesson 4: Government Influence and Current Trends

The relationship between government programs and trade agreements to U.S. agriculture can be very complicated. This lesson will discuss what these programs are and provide some information on how they affect the production of crops in the United States. New trends in crop production that are playing a role in what farmers produce and how these items are produced will also be examined.

Government Programs and Trade Agreements

GATT (General Agreement on Tariffs and Trade), an international trade organization, started as an agreement among 23 nations in 1948. GATT members worked to minimize tariffs, quotas, preferential trade agreements between countries, and other barriers to international trade. During the organization's existence, GATT members sponsored eight separate rounds of trade negotiations. The last round ended in 1994, when GATT members and seven other nations signed a pact that will eventually cut tariffs and reduce or eliminate other obstacles to trade. This pact initiated the formation of the World Trade Organization (WTO), which took over GATT's functions. The WTO has stronger power to enforce agreements, including the authority to issue trade sanctions against a country that refuses to revoke an offending law or practice.

Before 1994 and the establishment of the WTO, there were many "holes" in the GATT agreement regarding trade restrictions on agricultural products. A significant accomplishment of the 1994 policy change was to close some of these holes by imposing disciplines on agricultural trade barriers and trade-distorting domestic farm policies. The United States is expected to experience a tremendous gain in trade in this global free trade environment due to its trade diversity.

NAFTA (North American Free Trade Agreement) is an agreement reached on January 1, 1994, among Canada, the United States, and Mexico. NAFTA is designed to foster increased trade and investment among its partners. It contains an ambitious schedule for tariff elimination and reduction of nontariff barriers between these three countries. As of January 1, 1998, nearly all tariffs on U.S.-Canada trade in originating goods were eliminated. Some tariffs remain in place for certain products in Canada's supply-managed sectors (e.g., dairy and poultry), as well as sugar, dairy, peanuts, and cotton in the United States. These tariffs are scheduled to be eliminated by January 1, 2003. Trade and investment between Canada, the United States, and Mexico have increased substantially since the NAFTA was initiated. Approximately $1.5 billion in goods and services now crosses the Canadian-U.S. border each day.

The development of an organized farm policy began in 1933 with the signing of the Agricultural Adjustment Act. This Act was designed to address the "farm problem" - low prices, supply surpluses, and low incomes in farm and rural communities. This legislation introduced commodity programs that included production and marketing controls and price and income support for many of the most important agricultural commodities. Farm policy legislation has seen several changes over the years but in 1996 major new legislation was introduced in the 1996 Federal Agricultural Improvement and Reform Act (FAIR).

FAIR, in effect until 2002, is a landmark in U.S. farm policy. First, it takes a major step toward phasing out commodity programs that have been in existence in some form since the 1930s. Second, it takes the United States to an almost fully market-oriented farm policy. This is designed to gradually reduce the government's influence in the agricultural sector through commodity programs.

With this new change, farm income could become more variable from year to year in response to supply and demand shocks. Marketing alternatives to manage risk will become more important for many producers. Increased planting flexibility and the elimination of annual supply management policies permit producers to alter production practices to more fully respond to changes in demand.

Another government program is the Conservation Reserve Program (CRP). CRP is a long-term, land retirement program designed to offset agriculture's adverse effects on the environment. When originally established in 1985, its purpose was to conserve and improve soil, water, and

wildlife resources. This was done by establishing cover on highly erodible and other environmentally sensitive land through 10- and 15-year leases. This program has been continued through 1990, 1995, and the new 1996 Federal Agricultural Improvement and Reform Act. The current renewal gave the Secretary of Agriculture the authority to conduct sign-ups through 2002 with a 36.4 million-acre cap on enrollment.

The two largest benefits of the CRP are the increases in the value of market sales of farm commodities and the reduction of commodity deficiency payments from the Commodity Credit Corporation (CCC). These effects are the result of higher market prices caused by the idling of formerly cultivated farmland. In addition to these effects on agricultural income, there have been benefits to the public sector of the economy and those individuals living off the farm. The CRP program has benefitted these individuals through improved water quality and improved wildlife species habitat, resulting in better hunting and fishing.

Current Trends in Crop Production

During the last decade, crop producers have witnessed several major changes in agriculture. New technologies and trends have developed. Some of these include the development of organic farming, the use of genetically modified crops, alternative or sustainable agricultural programs, the use of precision farming techniques, and the further development of Integrated Pest Management systems.

Organic Foods

The organic foods movement was developed by some crop producers to promote healthier foods and to protect the environment. This is being done by encouraging producers to use agricultural methods that neither deplete the soil nor hurt environmental systems or farm workers. Organic farming also promotes biological diversity and the recycling of resources through such methods as crop rotation, rotational grazing, planting of cover crops, intercropping, animal and plant waste recycling, tilling, and adding minerals to crops.

The National Organic Standards Board defined "certified organic" at its meeting in April 1995. They stated that organic is a labeling term that denotes products produced under the authority of the Organic Foods Production Act. The principal guidelines for organic production are to use materials and practices that enhance the ecological balance of natural systems and that integrate the parts of the farming system into an ecological whole.

Organic agricultural practices cannot ensure that products are completely free of residues; however, methods are used to minimize pollution for air, soil, and water. Organic food handlers, processors, and retailers follow standards that maintain the integrity of organic agricultural products. Much controversy has developed in trying to define those standards.

The USDA first proposed a set of national organic standards in 1997. They were withdrawn after producers and others in the organic industry strongly objected to provisions that could have allowed the use of sewage sludge as fertilizer and genetically engineered and irradiated ingredients.

In March 2000, the USDA released new national standards for growing and processing organic food that will prohibit the use of genetic engineering or irradiation. They will also prohibit the use of antibiotics in livestock production and require the use of organic feed. The Secretary of Agriculture said the new standards are the most comprehensive and the strictest organic rules in the world. The rules allow products that meet these standards to carry a seal of approval that says "USDA Certified Organic." The new rules will replace a mixture of state and private standards. Enforcement of the new standards will be left up to states and private certifying agencies.

Genetically Modified Crops

One of the most controversial subjects to arise in agriculture in the last few years involves the development of genetically modified organisms, or GMOs. Genetic research with crops is not new. For many years, new strains of wheat, corn, and other agricultural crops have been developed through selective plant breeding. However, agricultural scientists now have the ability, through sophisticated biotechnology techniques, to split genes, alter genes, and recombine plant DNA to make drastic changes to plants.

Possibilities for genetic engineering are endless. It remains to be seen how many visions scientists

have for our future will become commonly accepted practice but there is no doubt that genetic engineering is here to stay. Genetic engineering will help the world meet the challenges of a growing, hungry population.

In 1998, 15 years after the first gene was deliberately inserted into a plant and just 1 year after large-scale introduction, genetically engineered seeds are germinating on 65 million acres of prime farmland. Two of the most talked about outcomes of genetic engineering, Bt corn and herbicide-resistant soybeans, have initiated much debate worldwide as to the ethics of this technology. Bt corn can control the corn borer insect by creating a substance that is toxic to the worm when it attacks the corn plant. The herbicide resistance of soybeans allows for better control of weeds, improving soybean yields.

Genetic engineering and biotechnology have the potential for improving proteins, fat, and vitamins in crops grown for livestock feeds. It also has the potential to increase resistance to drought, frost, and bacterial damage to plants, which will result in an increased food supply for the world.

Critics contend that genetically modified seeds are a vast, uncontrolled experiment being carried out on millions of acres. They are concerned that transgenic seeds will benefit the large corporations selling the new seeds. These critics warn that large producers may benefit for a time, but organic farmers, the environment, and the consumer may suffer long-term damage. Those who oppose GMOs cite the possibility of Bt corn pollen being deadly on monarch butterflies. Some researchers report natural insecticides produce a toxin for nontarget species like the caterpillars that become the monarch butterflies. Other opponents say the long-term consequences for human health and the environment of these new technologies are unknown.

Alternative or Sustainable Agriculture

Alternative or sustainable agricultural practices are receiving more attention in the agricultural community. Many producers are adding or changing over to other sources of agricultural income. The raising of elk, bison, or other nontraditional animals for meat is becoming popular. New crops such as one of the many varieties of berries or shiitake mushrooms are being produced with excellent results.

These new agricultural alternatives require investigation into their production methods and a changing of marketing strategies. Each year, more producers are developing these new cropping methods to a large degree of success.

Precision Farming

Precision farming means carefully tailoring soil and crop management to fit the different conditions found in each field. Precision farming is sometimes known as "prescription farming," "site-specific farming," or "variable rate farming." It has created new uses for technologies such as remote sensing, geographic information systems (GIS), and global positioning systems (GPS). The costs of obtaining and using these technologies have been the biggest deterrent in their regular use.

The real value for the producer is that seeding rates can be adjusted, crop protection programs can be planned more accurately, tillage can be done in a more timely fashion, and yield variation within a field can be determined. These benefits will enhance the overall cost-effectiveness of the crop production. Producers are able to record observations during the growing season such as weed growth, unusual plant stress or coloring, and growth conditions. This information can be used to guide crop producers in operations like spraying, fertilizing, and irrigating.

Precision farming will make a strong impact on the way producers manage their farm operations in the future. There is expected to be a tremendous growth in the use of these technologies as a way to "farm by the inch."

Integrated Pest Management

Integrated Pest Management (IPM) is an approach to managing pests by combining biological, cultural, physical, and chemical tools in a way that reduces economic, health, and environmental risks. IPM is a systematic approach to pest suppression and management that uses increased information and improved decision making to reduce reliance on purchased inputs and to improve crop yield and quality. Integrated Pest Management decisions are based on ecological and economic principles.

Traditionally, a pest means any organism that interferes with the production of a crop. Generally, that includes insects, diseases, and weeds. There are many other types of pests including nematodes, arthropods other than insects, and vertebrates.

IPM includes pest management tactics such as biological control or the use of beneficial organisms (predators, parasites, diseases) to suppress pest organisms. Cultural control includes the use of crop rotations, cultivation, sanitation, and other farm practices that reduce persistent pest problems. Physical controls involve the use of barriers, traps, or the adjustment of planting location or timing to evade or diminish pest pressure. IPM may include the use of plant-resistant materials to avoid pest problems and includes the use of conventional pesticides, biopesticides, and other chemicals to prevent or suppress a pest outbreak.

IPM requires a grower to understand how the crop grows, how different pest populations develop, what control options are available in each specific management case, and what the return on investment is in relationship to the potential impact on the environment or health of consumers. This means that producers and their consultants will spend more time observing and interpreting the potential impact of pest populations.

Summary

Agricultural production has changed greatly during this last century. Government policy has also experienced these changes. These policies have been initiated to assist the agricultural producers through problems with production and marketing, and with marketing locally as well as in a global economy. The interaction and trade between countries are very complicated because many variables play a role in trade policies. New methods used in agricultural production are emerging. The use of Integrated Pest Management, alternative farming programs, the use of satellites for precision farming, and developing genetically modified crops is causing excitement as well as concern in the agricultural world.

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Lesson 1: Plant Physiology

Plants are often characterized by their structure and the various functions of their many parts. To produce crops effectively, producers must be able to identify the different types of seeds and plants. One of the best ways to learn about these differences is by comparing the parts and functions of seeds and plants.

Monocot and Dicot Crops

Agricultural crops can be classified by their many variations in seed and plant structure. One common classification is by the number of cotyledons, or first leaves, located in the seed. Monocotyledonous plants, frequently called monocots, have only one cotyledon in each seed. Dicotyledonous plants, or dicots, have two cotyledons and can bring forth a new plant bearing two seed leaves. Additionally, monocots are usually thought of as "simple" plants in contrast with the more "complex" dicots. The simple structured crops in the grass family are always referred to as monocots. Monocot crops produced in the state include corn, grain sorghum, wheat, grass hays, and rice. The most productive Missouri dicots include soybeans, cotton, alfalfa, and clover.

Parts and Functions of a Monocot Seed

Monocot seeds have a simple composition with three main parts: (1) the seed coat, (2) embryo, and (3) endosperm. (See Figure 1.1.) The embryo contains the single cotyledon, epicotyl, hypocotyl, and radicle. All seeds will also have a seed scar, a break in the seat coat, where it was attached to the plant. In corn, the seed scar is called the tip cap, and it was once attached to the cob. In the monocot crops of grain sorghum, wheat, grass hay, and rice, the seed is located in or attached to the inflorescence, or head of the plant.

The outer covering on a seed is called the seed coat and serves as a protector. It resists water and insects and maintains the seed's viability, or ability to grow. The names of the seed parts, such as the seed coat, may vary depending on the crop. For example, in corn the seed coat is known as the pericap; in wheat it is referred to as the bran.

The embryo of a monocot seed is a miniature plant that sprouts within the seed. It contains all the essential genetic information, enzymes, vitamins, and minerals for the seed to grow into a new plant. Each part of the embryo plays a role in the creation of the plant. The cotyledon, known as the scutellum in corn seeds, breaks down the starch in the endosperm, absorbs it, and moves it to the embryo. The epicotyl will develop into the first shoot with a leaf or leaves that emerge from the seed upon germination. It is located above the cotyledon. The hypocotyl, found below the cotyledon and connected to the radicle, is the first true stem of the plant. As the hypocotyl lengthens, the cotyledon and epicotyl emerge from the seed during germination. The radicle develops into the

Figure 1.1 - Parts of a Monocot Seed (Corn)

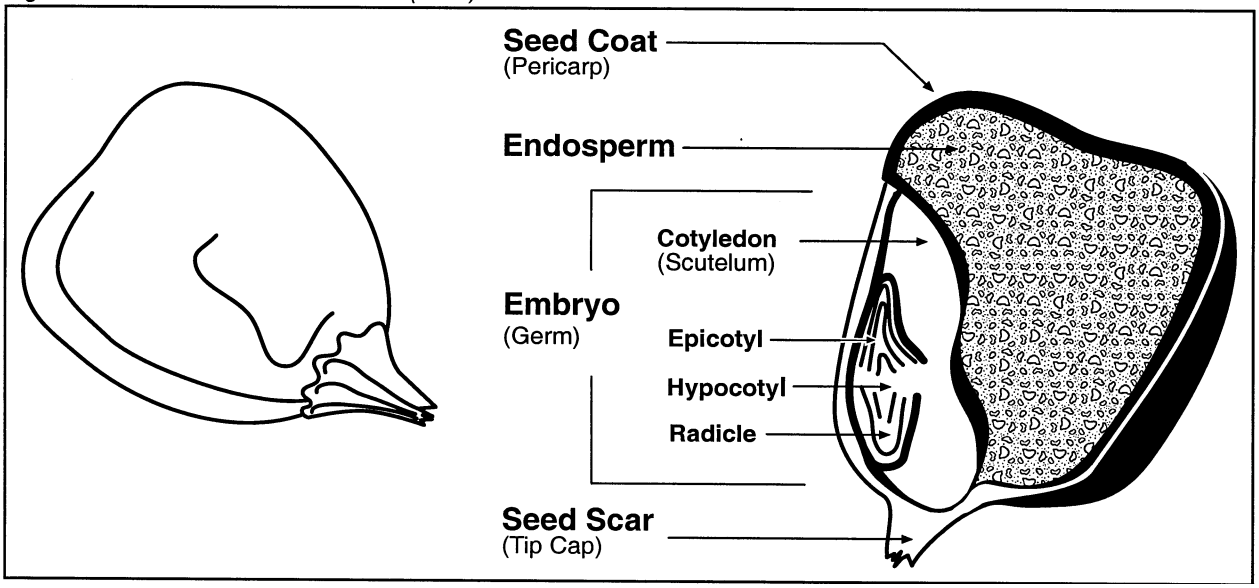
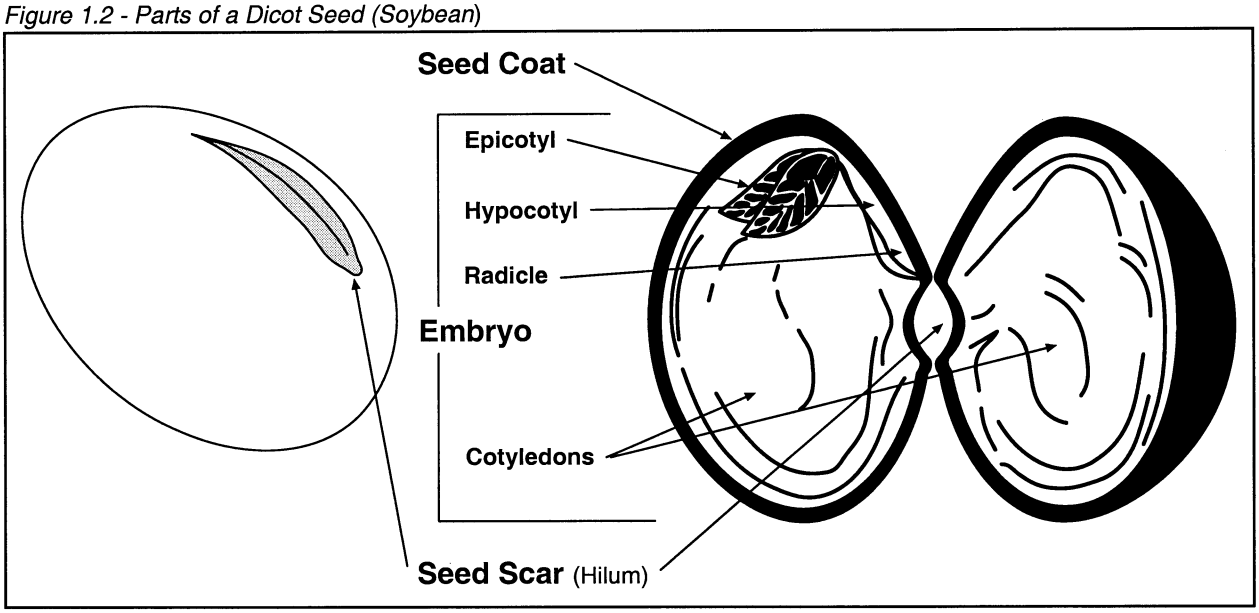


Figure 1.2 - Parts of a Dicot Seed (Soybean)



primary root, absorbing water and nutrients for the seed and dying later when permanent roots are formed. It is located below the hypocotyl. When monocot seeds such as wheat are processed as a food source, the embryo is called germ, which is ground separately or with the endosperm in whole wheat products.

The endosperm, found only in the monocot seedlings, serves as the energy source (starch) for the germinating seed. It comprises more than 75% of the entire seed. For example, in corn the endosperm is about 82% of a seed's dry weight. When seeds are used as a feed source for livestock or food source for humans, the endosperm provides carbohydrates, protein, iron, B-complex vitamins, and other essential nutrients.

Parts and Functions of a Dicot Seed

The parts of a dicot seed are basically the same as monocots, but they have a more complex structure. A dicot seed consists of the seed coat, embryo, and seed scar, or hilum. The seed coat serves the same protective function as in the monocot seed. Likewise, the embryo has similar parts with an epicotyl, hypocotyl, and radicle; however, a dicot embryo contains two cotyledons as shown in Figure 1.2. Each serves as a new part on a growing seedling.

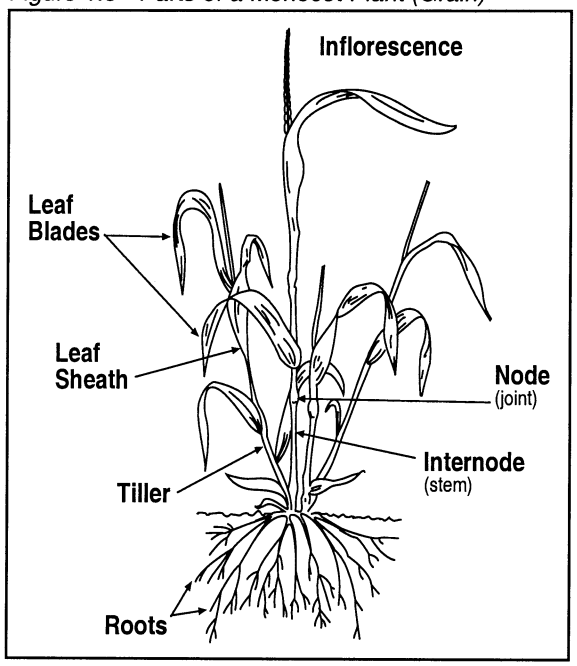
The epicotyl serves as the growing end of the plant's main stem. It is attached to the hypocotyl on one end and has tiny, undeveloped leaves (embryonic leaves) on the other end. The hypocotyl becomes the main stem of the plant. Its main function is to lift the cotyledons out of the soil so the new seed leaves can emerge. The radicle stays below the soil surface to become the new primary root. Cotyledons protect the epicotyl and provide food for the sprouting plant. They are usually fleshy in form and high in protein and oil.

Parts and Functions of a Monocot Plant

Regardless of the classification, plant parts are essential because each has a specific function to aid in the growth, maintenance, or reproduction of the plant. The primary parts of a monocot plant include the inflorescence, leaf blade, node, internode, leaf sheath, tiller, and roots. (See Figure 1.3.)

Recognized as the floral portion of the plant, the main function of the inflorescence in the monocot is reproduction. Leaf blades are essential for plant life as the manufacturer of food by photosynthesis. Respiration, transpiration, and food storage all take place in the leaf blade. The leaf remains connected to the stem by the node. The internodes, or stem sections between the nodes, support the plant and transport and store nutrients. The base of the leaf that wraps around the stem is the leaf sheath. Its function is to provide support and stabilization to the stem and protect the leaf axil, or base. At the bottom of a monocot plant is the growth of a secondary stem called the tiller. The tiller is a new shoot from the primary plant that

Figure 1.3 - Parts of a Monocot Plant (Grain)



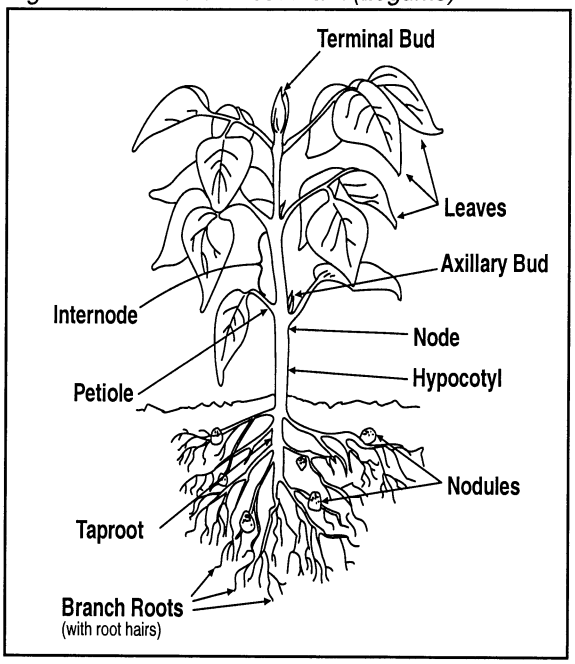
can grow and reproduce by itself. Tillers are one example of how monocots multiply, specifically in rice and wheat. Roots provide support, food storage, and nutrient absorption.

Parts and Functions of a Dicot Plant

Dicots consist of similar functioning parts including the terminal bud, leaf, petiole, node, internode, axillary bud, hypocotyl, branch or lateral roots, primary (or taproot), and root hairs as shown in Figure 1.4.

The terminal bud in the dicot plant refers to the growth point in the plant. Apical meristem tissues are located in the terminal bud and increase the length of the plant. The leaf serves the same function in the dicot as it does in the monocot. Leaves manufacture food through photosynthesis, conduct respiration and transpiration, and sometimes store food. The stalk of the leaf, called the petiole, attaches the leaf to the plant stem. The petioles provide support for the leaves and transport nutrients. The node is the attachment site of the petiole to the stem giving support to the petioles. The internodes, stem sections between the nodes, provide support to the aboveground plant. They also transport and store nutrients. An axillary bud,which will produce a new leaf or stem, is located along the side of the stem. The hypocotyl function identified in the dicot seed remains the same. The hypocotyl is responsible for lifting a new plant out of the soil after germination and serves as the stem base for the plant. Branch, or lateral, roots are those roots branching off the taproot, or primary root, to provide additional support and increase nutrient absorption. The taproot serves as the main anchor site and stores tremendous amounts of nutrients for the plant. Root hairs are common on both branch and taproots. The hairs increase the overall absorption area for the plant.

Figure 1.4 - Parts of Dicot Plant (Legume)



Summary

To produce crops effectively, producers must be able to identify the different types of seeds and plants. One way agricultural crops are classified is by the number of cotyledons, or first leaves, located in the seed. Monocots have one leaf and dicots have two leaves. Monocot and dicot seeds have the same basic parts, but the functions of each part differ; the dicots are more complex. Part names may also vary by crop.

Regardless of a plant's classification, every part of a plant is essential to its survival, growth, or reproduction. Monocot and dicot plants have some similar parts with similar functions such as leaves, nodes, internodes, and roots. Although the roots and leaves are structured differently in a monocot and dicot, they are important to the survival of a plant, assisting in support and photosynthesis, respectively.

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Lesson 2: Plant Growth and Nutrient Needs

Understanding the various stages of crop growth and development enables producers to exercise better management by allowing inputs to be used at the proper growth stage. Likewise, understanding the life cycle of plants allows producers to plan continuous or future production of the same or compatible crops. Soil is a storage facility holding minerals, chemicals, water, and air for plants to use. The nutrients soil provides play a key role in successful crop production.

Plant Growth Stages

Crops have four major growth stages between planting and harvesting: (1) germination, (2) vegetative, (3) reproductive, and (4) maturity. (See Figures 2.1 and 2.2.) The germination stage occurs when the embryo within the plant seed sprouts and begins its development into a plant. During the vegetative stage, the plant grows by stem extension and leaf multiplication. The reproductive stage occurs next and includes the production of flowers and seed formation, the most critical time in the life of most crops. If anything interferes with the plant's functions during this period, crop yields may suffer. The maturity stage starts once the plant has reproduced and the grain has ripened. The plant goes through a dry-down process when the leaves and stems lose their green pigment and turn yellow to brown. In some crops, such as soybeans, defoliation occurs when leaves dry up and fall from the plant stems. Chemical defoliation is used in cotton production to speed up the maturity stage. When the plant completes the ripening process and has reached the ideal dry weight or moisture content, harvesting occurs.

Growth stages may vary from crop to crop with different names for each of the main stages. In wheat, for example, the vegetative stage is broken into two stages: tillering and stem extension. Also, the reproductive stage of wheat is called the heading stage, as shown in Figure 2.3.

Plant Life Cycles

All plant growth stages combine to form a life cycle. The seed from a mature plant germinates into a plant that grows to maturity; the seed is harvested or returns to the ground when the plant dies. Therefore, a plant's life cycle is classified by the length of time required for the plant to complete its growth stages. For most production crops, the life cycle can be less than 1 year or as many as 3 years. Life cycles for plants are grouped into three general classifications based on how long it takes to complete their growth stage: annuals (spring and winter), biennials, and perennials.

Figure 2.1 - Growth Stages of Corn

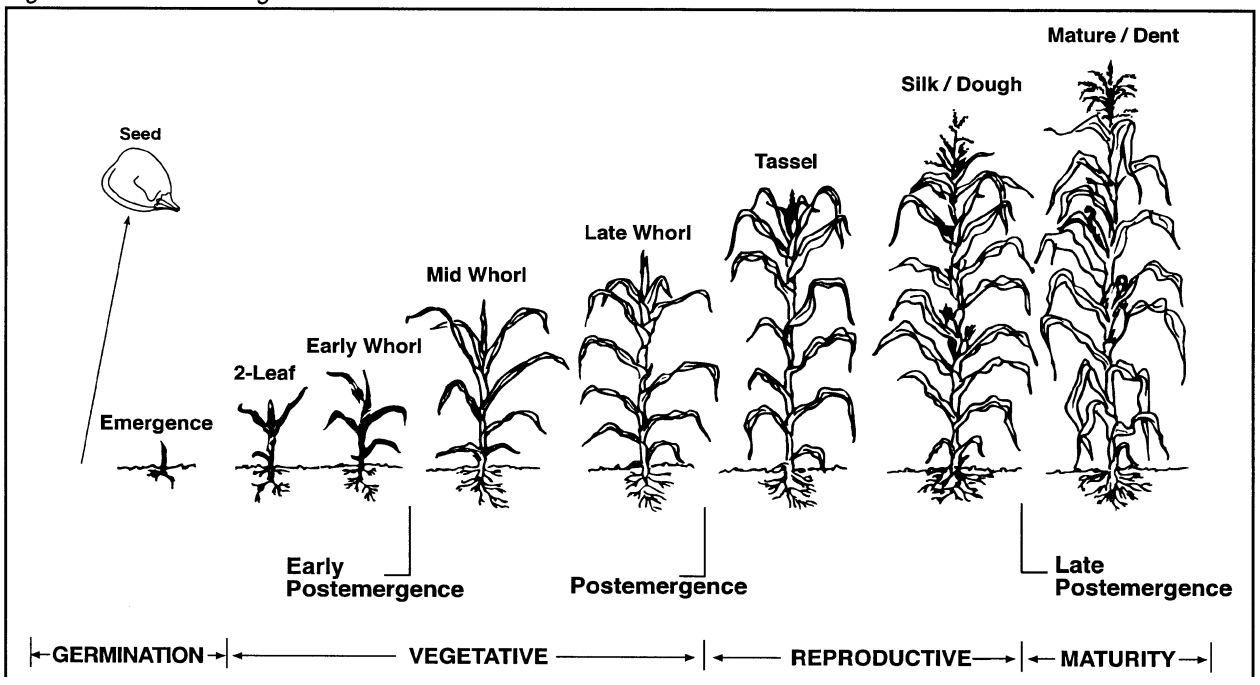


Figure 2.2 - Growth Stages of Soybeans

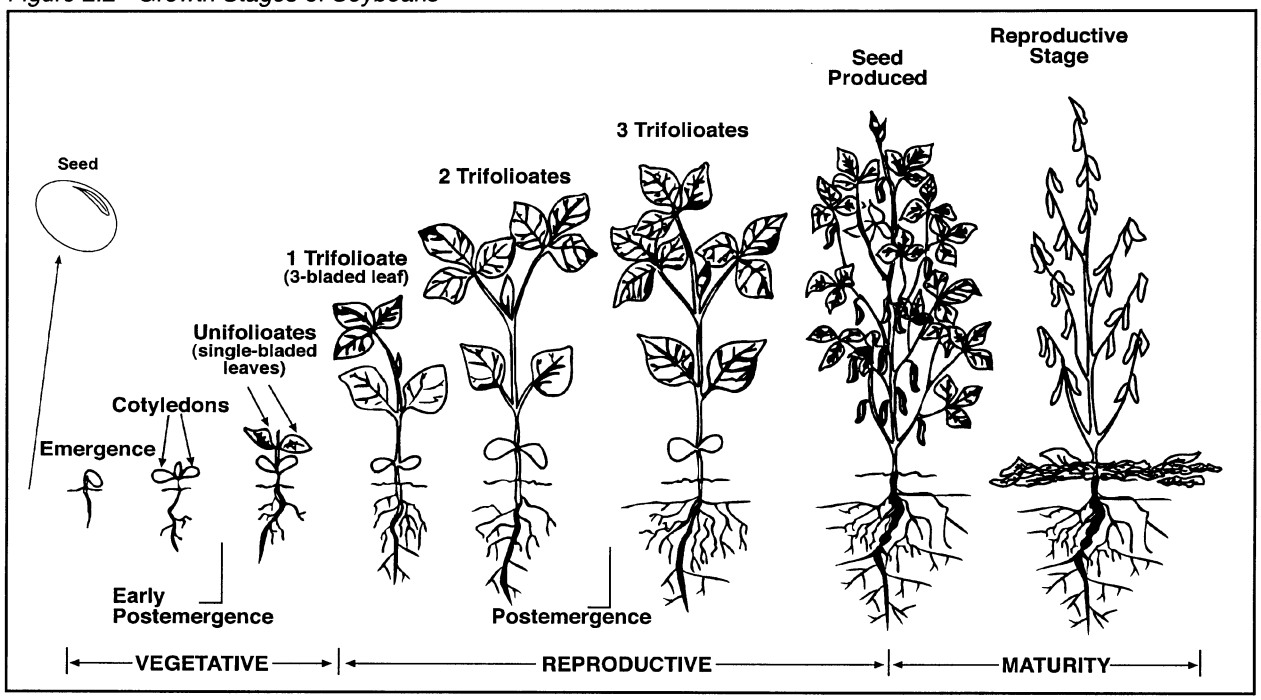
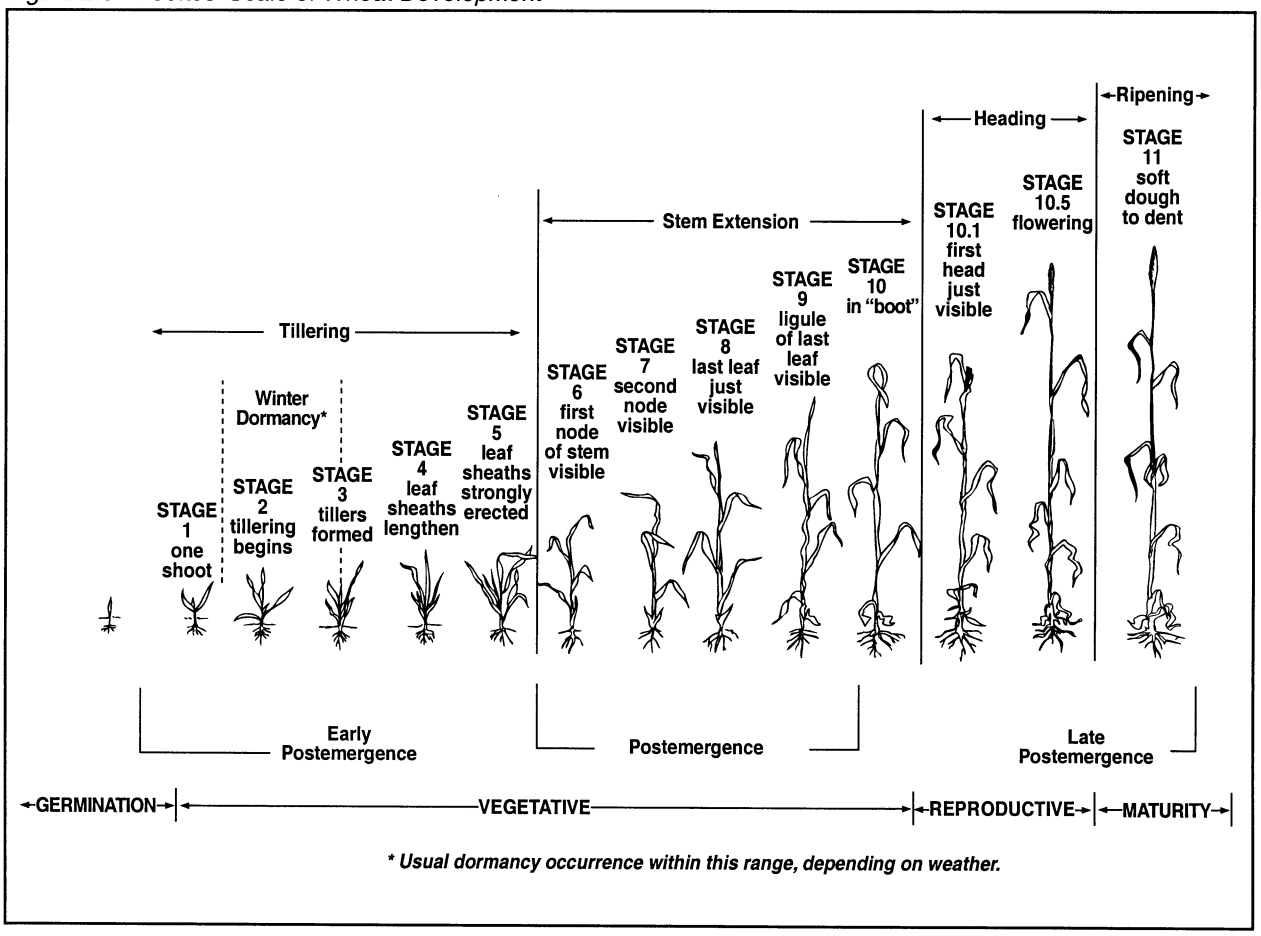


Figure 2.3 - Feekes' Scale of Wheat Development



Annuals are crops planted and harvested during a 1-year period or less. Refer to Figure 2.4. Annuals are subdivided into two groups depending on the time of year the crop is planted. Summer annuals are planted in the spring or summer and harvested in the fall of the same year. These crops include corn, grain sorghum, soybeans, and rice. Winter annuals are typically referred to as crops planted in the fall and harvested the following summer. Examples of winter annuals include winter wheat, winter oats, winter barley, and winter rye.

Biennials are crops that complete their life cycle during the second year after planting. Very few biennials are field crops with the exception of sweet clover, the most prominent biennial produced in the state. Biennials generally do not flower in the first year and are more common in vegetable crop seed productions.

Perennial crops or plants remain alive 3 or more years after planting. (Refer to Figure 2.4.) Forage crops, for example, include many species that live longer than 5 years. Fescue, alfalfa, and lespedeza are all perennial crops grown in Missouri. Perennial stands are maintained by the plant's ability to reseed or spread by vegetative reproduction. Life expectancy for these plants can be limited by weed pressure, disease, grazing intensity, and/or competitive species.

Essential Plant Nutrients

Plants cannot grow and develop without essential nutrition. Seventeen essential plant nutrients are needed for optimum plant growth and development. These essential plant nutrients are broken down into nine macronutrients (major) and eight micronutrients (minor) as shown in Table 2.1.

Macronutrients

Of the nine essential macronutrients, the three most basic elements found in all life-forms are carbon (C), hydrogen (H), and oxygen (O). These basic elements are all supplied by air and water. Plants also require additional macronutrients

Figure 2.4 - Life Cycles of Annual and Perennial Crops

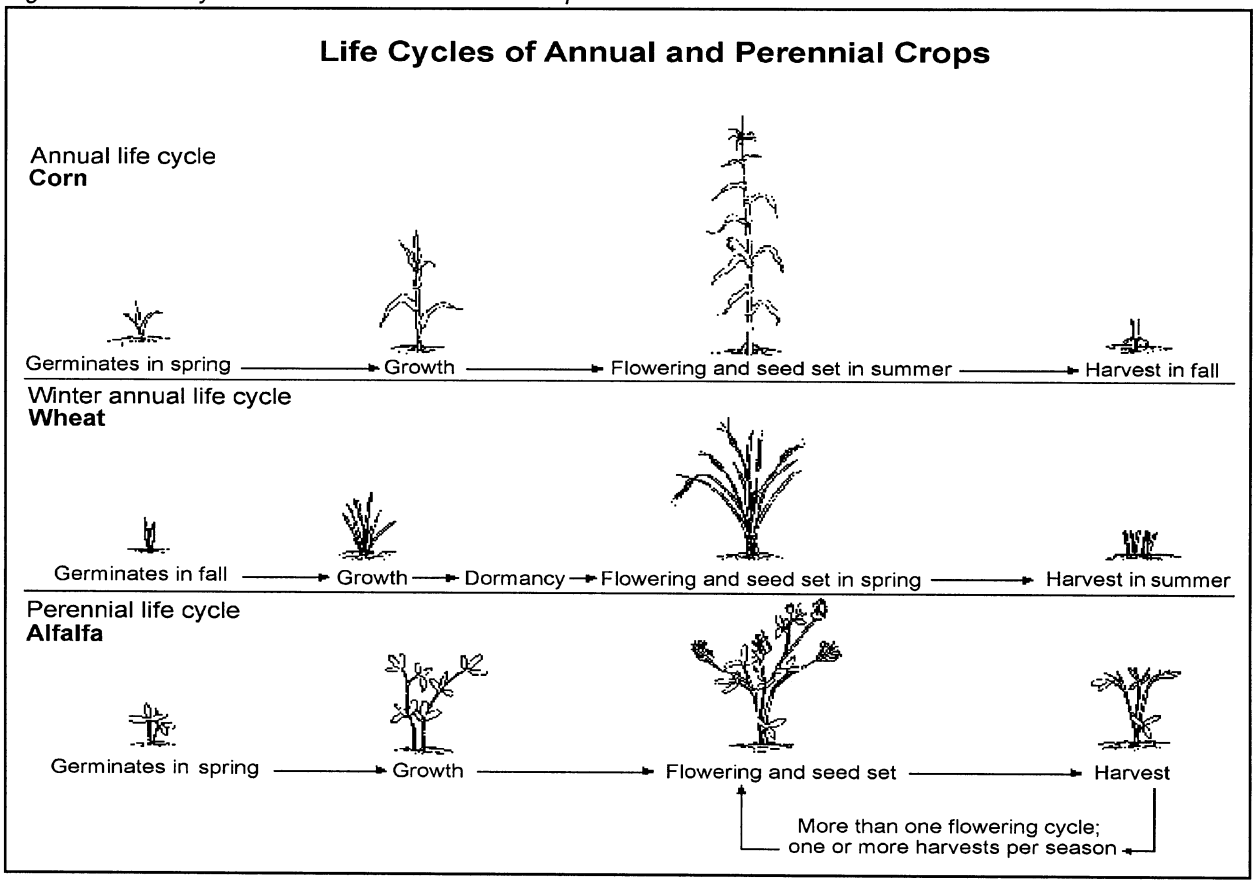


Table 2.1 - Seventeen Essential Elements for Most Plants

Macronutrients (9)			
Element	**Symbol**	**Comments**	**Source**
Carbon Hydrogen Oxygen	C H O	Carbon, hydrogen, and oxygen are obtained by plants from carbon dioxide and water found in the air and soil. They are called mineral elements.	Water and air
Nitrogen Phosphorus Potassium	N P K	These three nutrients are needed in greater amounts by plants. They are called the major or macronutrients.	Organic matter (primarily) Mineral solids and organic matter
Calcium Magnesium Sulfur	Ca Mg S	These three nutrients are needed by plants in lesser amounts than macronutrients. They are called secondary nutrients.	Mineral solids
Micronutrients (8)			
Element	**Symbol**	**Comments**	**Source**
Boron Chlorine Cobalt Copper Iron Manganese Molybdenum Zinc	B Cl Cu Co Fe Mg Mo Zn	These nutrients are needed in smaller amounts by plants. They are called the minor, or micronutrients.	Naturally in soil; can be added or increased with fertilizers

found in soil solids. Of these, three are classified as primary macronutrients, nitrogen (N), phosphorus (P), and potassium (K) because they are needed in greater amounts by plants. The secondary macronutrients of calcium (Ca), magnesium (Mg), and sulfur (S) are also available in mineral soils but are needed in lesser amounts by plants.

Nitrogen is a major component of the atmosphere. About 78% of the atmosphere is made up of nitrogen gas (N_2). Nitrogen is also found in the soil. Organic matter releases N into the soil through the activity of microbes, or microscopic organisms. Nitrogen is one of the most critical elements for plant growth. Plants use two forms of nitrogen: ammonium (NH_4^+) and nitrate (N_3O^-). Both ammonium and nitrate leach from the soil through percolating water (water moving downward through soil). Nitrogen is equally important in the breakdown of decaying plants by microbes to form humus, the brownish-black organic material in soil. If microbes run out of nitrogen, they stop working. This is noticeable when plant matter in the soil has not decomposed (broken down) after 1 year. Nitrogen cycles through various forms as it moves from the soil microbes and back to the soil. This is referred to as the nitrogen cycle and is illustrated in Figure 2.5.

Abundant nitrogen results in a dark green, lush growth. The pale green color of nitrogen-deficient plants results from a shortage of chlorophyll. This nitrogen deficiency is caused by inadequate soil moisture even though adequate amounts of nitrogen may have been supplied through fertilizer applications. Nitrogen deficiencies are most noticeable during long dry periods. Therefore, nitrogen should be applied deeply into the soil so that roots can get adequate supplies during dry periods.

All phosphorus (P) comes originally from rock. Phosphorus in the soil forms complex, negatively charged particles with oxygen (O). This makes the solubility (ability to be broken down by water) of phosphorous low and results in it being less available, often causing phosphorus deficiencies in plants. The availability of phosphorus to plants is very complex and is related to the soil pH level

(acidic or alkalinity level), soil moisture, nitrogen in the soil, and other chemical properties. One positive factor about the low solubility of phosphorus is that unlike nitrogen, it is not leached from the soil.

Phosphorus in soil comes in two forms, organic and inorganic. The organic form is held tightly and is not readily available to plants. It is broken down by microorganisms into forms of phosphorus (H_2PO_4 and HPO_4) that can be used by plants. The breakdown of phosphorus is most efficient when soils are warm and well aerated (filled with air). (The amount of available phosphorus in the soil depends usually on the soil pH, the types of fertilizers added, and how they are applied.) Phosphorus is found in the seed and growing parts of plants where it supplies energy for root development and maturation of the crop. Cool temperatures reduce the availability of phosphorus. Applications to correct phosphorus deficiencies should be based on a soil test. Plants with deficiencies will be slow to mature. Purple spots and streaks will appear in the leaf tissues, which are the result of slow conversion of sugar to starches and cellulose. Phosphorus is second only to nitrogen in fertilizer usage.

Potassium (K) is the third element in all complete fertilizers. Plants use potassium in the K+ ion form with most of the potassium being found in the upper 7-inch layer of topsoil. Because only a small percentage of potassium in the soil is available to plants and they absorb large amounts of potassium, the potassium level can be depleted quickly, especially when growing high foliage-producing crops.

Potassium assists in the uptake of nutrients and in enzyme systems, affecting metabolism and photosynthesis. It is important in the formation of carbohydrates and helps to regulate the opening and closing of stomata in the leaves, which are the openings, or slits, that allow for breathing and water transportation. It also assists root cells in absorbing water. Potassium is important for strong roots in corn, which is important during harvest when plants need to remain standing to cut or combine. If the soil is too wet and aeration is inadequate, potassium cannot be absorbed by plant roots.

Potassium deficiencies can be detected in plants as the edges of older leaves and areas between the veins turn yellow, then brown. Small brown spots develop while the veins are still green.

Three secondary macronutrients, calcium (Ca), magnesium (Mg), and sulfur (S), are also essential for plant growth. Generally, soils are not as deficient in secondary macronutrients as they are in primary nutrients.

Calcium (Ca) usually makes up more than 80% of the total bases present in the soil. The amount of exchangeable calcium is critical in changing soil pH, as is the availability of other elements. Calcium can be supplied to the soil through agricultural limestone that is high in calcium carbonate ($CaCO_3$). Calcium is essential for the plant to build cell walls and grow new roots and leaves. Calcium deficiencies are not visible by definite coloration changes as in other nutrient deficiencies. Deficiencies result mostly in low production, even in soils adequately supplied with the other major nutrients.

Magnesium (Mg) makes up about 15% of the bases in the soil and can be supplied through dolomitic limestone high in magnesium carbonate ($MgCO_3$). Magnesium is vital to the photosynthesis process. Most of the magnesium in plants is in chlorophyll or in seed. Like calcium, magnesium deficiencies are not visible through definite coloration changes in plants but result in low crop production.

Sulfur (S) is absorbed by plants as sulfate (SO_4) or from the air as sulfur dioxide (SO_2). It is also available through organic matter. Sulfur is a vital part of all plant proteins and some hormones. Plants use about as much sulfur as phosphorus. Sulfur can be applied as ferrous sulfate or aluminum sulfate (alum). It can be added to reduce high pH levels. Sulfur deficiencies slow protein production and formation of amino acids. It resembles nitrogen deficiencies in that leaves turn yellow during dry periods.

Micronutrients

Micronutrients are needed in smaller amounts by plants than macronutrients. Therefore, micronutrients are sometimes called the minor, or trace, elements. They include iron (Fe), zinc (Zn), chlorine (Cl), molybdenum (Mo), manganese (Mg), copper (Cu), boron (B), and cobalt (Co).

In the past, adequate levels of micronutrients were maintained in the soil because crop yields were lower and crop residue returned many needed micronutrients to the soil and fertilizers were not accurately applied. Current production practices

have heavy applications of highly specific fertilizers, and higher-yielding crops have quickly depleted micronutrients in many soils. Even though plants require small amounts of these nutrients, a deficiency can have a devastating effect on plant growth,

Some micronutrients function as part of enzyme molecules or aid in the enzyme function. Others assist in plant metabolism. Some micronutrients, such as copper (Cu) and iron (Fe), aid in the formation of chlorophyll. The amount of micronutrients needed is usually a few pounds per acre; therefore, they are generally included in complete fertilizer mixes. It is important that micronutrients are mixed thoroughly so that the small amount needed is applied evenly over a field. Overdoses can be toxic to plants, killing them or making them unfit for human consumption.

Management Practices Associated with Growth Stages

There are several management practices that need to be considered during the growth of the plant. These include nutrient management, repopulation or replanting, moisture management through irrigation, and the management of pests.

Prior to the growing season, it is recommended that the producer test the soil to determine nutrient content. Nutrients that are not available for the plant population to reach a certain level of production will need to be supplied for the plant. Some of the nutrients may need to be applied prior to planting. The use of lime would be an example. Lime would be used in an acidic soil to adjust the pH level for specific plants.

Some of the plant's nutrients are supplied through starter fertilizers. These are nutrients that are placed in the ground with the seed. The nutrients are placed in a specific location to the seed, usually 1 to 2 inches to the side, ready for root growth.

Some crops are fertilized after emergence. This may be done as side dressing or foliar fertilization. Side dressing applies the fertilizer on the soil surface close enough to the plant so cultivating or watering will carry the fertilizer to the plant's roots. Foliar fertilization feeds the plants through their foliage and is considered a supplemental method to feeding the plants through the root system. Foliar fertilization is not a practical method of applying large amounts of nutrients. Applications are expensive and if large amounts of a nutrient are needed, severe burning of the crop is likely to occur, resulting in reduced plant growth.

The amount and nutrients included in the fertilization process will vary greatly depending on the specific crop, the amount of nutrients already available in the soil, the amount of soil moisture, and the method of application.

Sometimes replanting decisions must be made. The failure to achieve desired plant populations may be caused by insect infestation, frost, hail, flooding, or poor seedbed condition. The first rule to observe is to not make a hasty decision. The cause of the problem must first be determined. Sometimes plants that are damaged by weather (hail, flooding) can make a comeback and develop leaf growth. When deciding whether to replant, growers should consider the following:

1. What was the original planting date and what is the desired plant stand?
2. What is the earliest possible replanting date that may be used?
3. Would the cost of the seed and pest control measures be economically justified?

Moisture is usually supplied in adequate amounts to the plants by rainfall. A small amount is needed to complete plant germination. As the plant develops during the growth phase, its moisture requirement greatly increases until after the grain or seed head matures. If additional moisture is needed, it may be supplied by some type of irrigation method. The ability to irrigate may be determined by the topography of the land, the availability of a water source, and the capital required to initiate the process. These determinations must be considered by the producer.

One final management practice that needs to be considered during plant growth stages is pest management. Pest management may be divided into three categories: weed management, disease management, and insect control.

Some soils and field locations lend themselves to more weed infestation problems. Once established, the producer must rely on mechanical, cultural, biological, or chemical methods for control. Mechanical methods include hand pulling, hoeing, burning, mowing, or

smothering with plastic mulch. Cultural methods include crop rotation, crop competition, and using weed-free crop seed. Biological control involves the use of natural enemies for weeds. For example, some beetles are natural enemies for certain weeds. Chemical control (use of herbicides) must be done by always following the label directions. Intelligent use of herbicides requires positive identification of the weed and recognizing their stage of growth. Chemicals may be applied as a broadcast treatment, in a band, as a spot treatment, or as a direct spray.

Plant diseases may affect the crop at any stage of growth. Every plant has some potential for a disease problem. These diseases may be caused by biotic (living) or abiotic (nonliving) agents. Living agents include fungi, bacteria, viruses, nematodes, and parasitic plants. Nonliving agents include weather, water or temperature stress, or a combination of these factors. Diseases may be attacked at the seed level with inoculants or during early growth stages with chemical, cultural, or biological control.

Insect damage and control may take place at every stage of the plant's growth. Insects may attack the seed or the vegetation of the plant during growth. Insect control may be divided into four groups: physical, cultural, biological, and chemical. Physical control may involve the direct removal of the insect by means of controlling light or changing temperatures to drive them away. It could also involve using sticky bands or traps to keep insects out of a field. Cultural control involves using crop rotations, tilling the soil, using resistant varieties, and removing plant vegetation that may act as a host or shelter to insects. Biological control is the use of other insects or pathogens to control a certain insect. Examples would include beetles that eat the larvae of aphids, parasitic wasps that attack other insects, and assassin bugs. Chemical controls employs the use of liquids, gases, powders, or granules to control insects. These chemicals may control the insects after they ingest the material, or it may come in contact with the outside of the insect.

Summary

Crops have four major growth stages between planting and harvesting, although the cycles may differ slightly between crops. Plants are classified by the length of their life cycles, which is the time required for a crop to complete its growth stages. Plants require 17 nutrients to achieve optimum plant growth and development. The nutrients are classified into two groups: macronutrients (Basic: carbon, hydrogen, and oxygen; Primary: nitrogen, phosphorus, and potassium; and Secondary: calcium, magnesium, and sulfur) and micronutrients (iron, zinc, chlorine, molybdenum, manganese, copper, boron, and cobalt). Management practices during certain growth stages of the plants would include nutrient management, population management through replanting, controlling moisture through irrigation, and the management of pests such as weeds, diseases, and insects.

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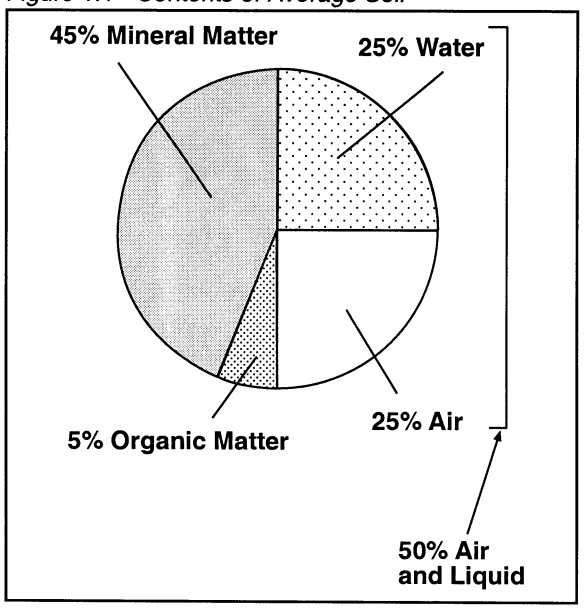
Lesson 1: Soil Composition

Soil scientists define soil as a living, naturally occurring, dynamic system at the interface of air and rock. The soil is considered "living" because it is full of living organisms such as roots, animals, insects, fungi, and bacteria. Equally important is organic matter, the decaying remains of plants and animals. Soil is "dynamic" because it is constantly changing. Natural elements such as temperature and rainfall are continually affecting and changing the soil as do the actions of living organisms and organic matter. These components work together in the soil "system," the thin, outer layer of the earth's surface. Soil forms at this "interface" of air and rock in response to the forces of climate and organisms (chemical changes) acting on the parent material (rock) over a period of time. It can take a thousand years for just 1 inch of soil to form, making it critical that soil is managed properly for the benefit of future generations.

Soil Components

Soil consists of minerals, organic matter, water, and air. The solid materials, mineral and organic matter, comprise about half of average soil (Figure 1.1), in a concentration of 45% mineral matter and 5% organic matter. Water and air complete the other 50% with each contributing approximately 25%, depending on how wet the soil is at the time. When water is added to soil, the air is driven out. As soil dries out, it contains more air.

Figure 1.1 - Contents of Average Soil

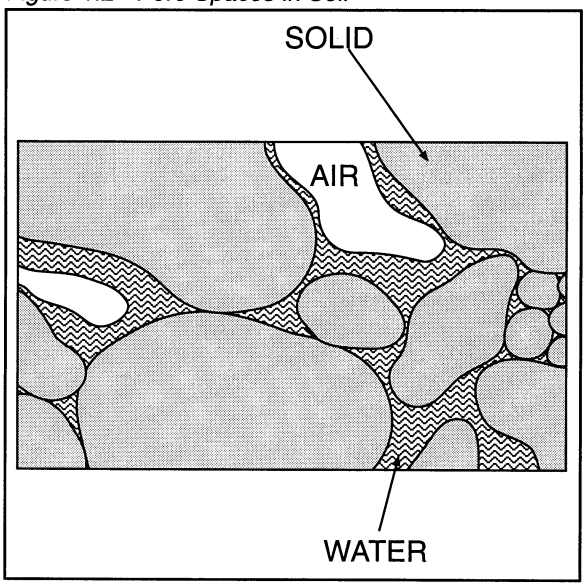


Mineral matter is inorganic material (rock) in soil and consists of three types of particles: sand, silt, and clay. Sand particles are the largest and range in size from .05 mm to 2 mm. Silt particles are smaller and range in size from .002 mm to .05 mm. Clay particles are the smallest and are less than .002 mm in size. The combination and amount of these three mineral particles determine the soil's ability to retain water and nutrients.

Organic matter is dead and decaying plant and animal material. Most soil organic matter found in crop fields is from the leaves, roots, and stems of plants. Biosolids (sewage sludge) can be spread on fields to increase soil organic matter levels. Some crops such as alfalfa are grown as green manure and plowed into the soil to accomplish the same results. All of these sources of organic matter provide essential nutrients for plant growth.

Mineral and organic matter solids fit loosely together forming pore spaces, or openings (Figure 1.2). The size of the pore spaces is determined by the size of the mineral particles in the soil. Sand particles create large pore spaces whereas clay has very small pore spaces. These pore spaces are filled with water and air.

Figure 1.2 - Pore Spaces in Soil



Water alone determines if soil can maintain plant life. The primary function of water in soil is to dissolve soil minerals, moisten plant roots, and provide a solution for plants to absorb essential nutrients. Three types of water are found in soil: gravitational, capillary, and hygroscopic.

Gravitational water percolates, or moves down, through the soil through pore spaces. It ends up as ground water below the soil surface. Capillary water is held by the soil above the water table by adhesion, or capillarity attraction, of soil particles. It is free to move from one soil particle to another. This water is the most readily available for plant use. Hydroscopic water forms a thin film around individual soil particles. It does not move about. This is the water that remains after the gravitational and capillary water have been removed. It exists in the driest soils but is unable to be absorbed by plants.

Air contains carbon dioxide and oxygen critical for plant photosynthesis and respiration. The ability of air to move in and out of soil is important in providing oxygen for healthy root growth. Rain fills the soil's pore spaces with water and air refills the pore space as the water is absorbed or drains away. Air occupies most of the soil's pore spaces in excessively dry, arid regions with sandy soils. The absence of air in water-holding clay soils or flooded fields reduces plant growth. Plants grow best when air and water levels in the soil are balanced.

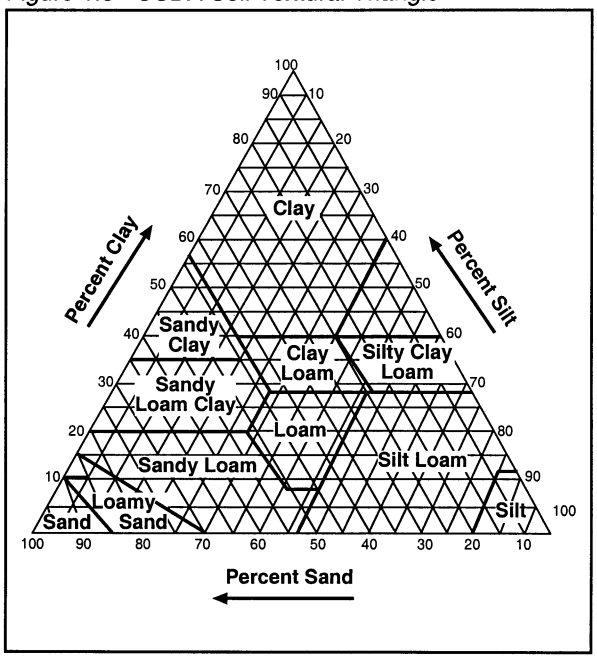
Soil Texture's Effect on Water-holding Capacity and Fertility

The relative proportions of individual mineral particles are referred to as soil texture. Soil texture is grouped in classes determined by the weight percentage of sand, silt, and clay in a soil. The USDA Soil Textural Triangle is used to classify soils. When sand, silt, and clay are in balanced amounts as shown in Figure 1.3, loam soil texture is created. Soil texture can be determined by a laboratory analysis or from a field estimate, which is working a small amount of soil between the fingers and thumb in a ribbonlike fashion.

Soil texture directly affects the amount of water a soil will hold due to differences in the sizes of soil particles. As noted earlier, water enters the soil through pore spaces and is held on the surfaces of soil particles. Fine clay particles have much more surface area per volume of soil than sand, with silt falling somewhere in between. Therefore, small soil particles hold more water than large ones.

Soil fertility (the amount of available nutrients for plant growth) is also affected when one particle is

Figure 1.3 - USDA Soil Textural Triangle



overly abundant in soil. As water percolates down through the soil, it carries with it dissolved nutrients. This nutrient-filled water is held on soil particles by surface tension. The force holding the water is closely related to the total surface area of the soil particles. Because the volume of small particles has more total surface area than the same volume of large particles, small particles exert a greater holding force. The larger pore spaces surrounding large particles quickly become filled with the nutrient-rich water. Due to the lack of surface tension of the large particles, the pore spaces are easily drained by gravity, and nutrients pass through the soil too quickly to be absorbed by plants. Likewise, water-holding, fine soil particles keep nutrients from plants by trapping them in the surrounding smaller pore spaces.

Sandy soils are made up of mostly coarse particles surrounded by large pore spaces. Water moves quickly through sandy soil giving it a low water-holding capacity and leaving it less fertile.

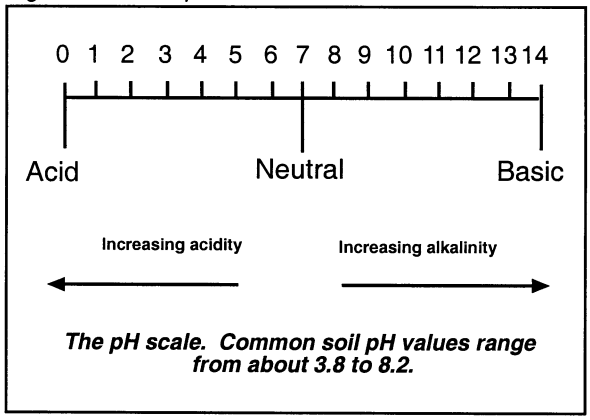
The very small pore spaces surrounding the multiple soil particles result in clay soils having a high water-holding capacity. In addition, when the small pores become filled with water, the lack of aeration limits plant root growth. Clay-type soils tend to swell when wet, reducing pore sizes even more and holding water so tightly that nutrients within the water are not easily available to plants.

Silty soils have a mixture of particle sizes and pore spaces. The qualities of silty soils range from the upper limit of clay to the lower limit of very fine sand. With this variation of particle sizes, silty soils have the best water-holding capabilities. Water drains gradually down through the soil, making silty soils more fertile because plants gradually absorb needed nutrients.

Soil pH and Nutrient Utilization

Soil pH (potential hydrogen) is the measure of acidity or alkalinity of the soil. A scale of 0 to 14 is used to express the concentration of hydrogen (H+) and hydroxide (OH-) ions as shown in Figure 1.4. Neutral pH (or pH 7) occurs when the concentration of H+ and OH- ions is equal. Neutral pH is neither acid nor alkaline. When the concentration of H+ ions increases, the pH is lower (acid, 0 - 9), and when the concentration of OH- ions increases, the pH is higher (alkaline, 7.1 - 14). Missouri soil pH ranges from 4.5 to 8.4.

Figure 1.4 - The pH Scale

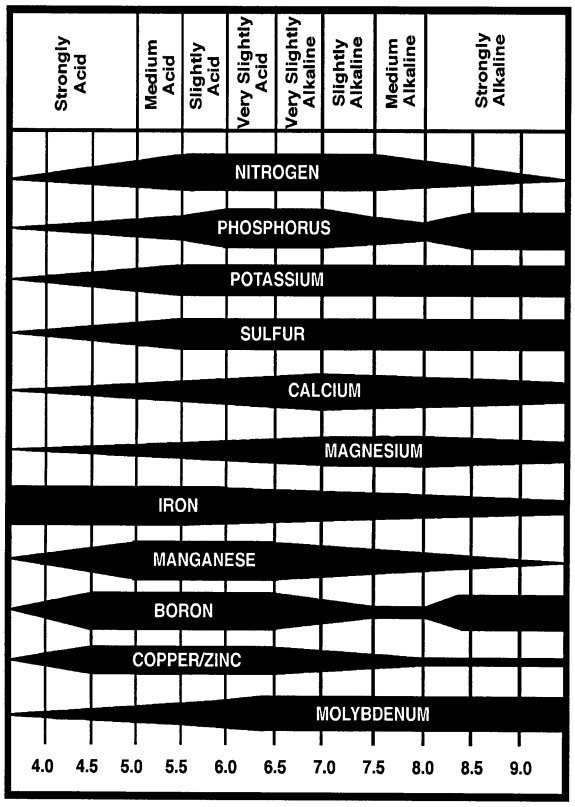


The pH scale. Common soil pH values range from about 3.8 to 8.2.

Plants require large amounts of available nutrients for growth. The ability of a soil to hold and exchange important nutrients to plants is known as the cation exchange capacity (CEC). Cations, or positive-charged ions, are attracted to negative-charged soil particles (especially clay). This is the same principle of attraction seen in magnets; the negative pole is attracted to the positive pole. Cations, such as potassium (K+), calcium (Ca+2), and magnesium (Mg+) can leave soil particles and be replaced by cations held in soil solution (soil water). Nutrients in solution are the most available for plant use. To obtain a soil's CEC, a soil test must be performed. Refer to Chapter 7 of the *Soil Science Student Guide* for detailed information on calculating the CEC.

Soil pH directly affects the CEC of a soil. For example, strong acidic soils high in H+ ions will generally have a low CEC of the positive-charged nutrients potassium, calcium, and magnesium. A crop such as corn that prefers a more basic (alkaline) soil will display nutrient deficiencies because it cannot use the potassium, calcium, and magnesium in the acidic soil. Soil acidity is caused by leaching (the removal of bases by water percolation), or the absorption of base nutrients by growing plants. Growing plants require large amounts of base nutrients; therefore, the depletion of calcium can be one of the greatest causes for increased acidity. The soil is unable to release important nutrients if the soil is too acidic or too alkaline. By knowing the pH of a soil, it can be determined if a neutralizing agent, such as lime, is needed to maintain the correct balance of nutrients for the optimum growth of a particular crop. The soil pH can generally be raised to any desired level by applying lime (calcium carbonate, or $CaCO_3$). Figure 1.5 lists several plant nutrients and how the pH level of the soil determines the availability of those nutrients.

Figure 1.5 - Soil pH Governs Nutrient Release



Soil pH Governs Nutrient Release
Acidity or alkalinity (pH) controls relative to nutrient availability.

Each growing crop has a preferred pH level. Most crops grow and produce the best in soils with a pH range of 5.0 to 7.5. Soils with a pH outside this range may inhibit the absorption of nutrients by growing plants. For example, legumes require more neutral soils (pH 6.8 – 7.3), whereas corn, small grains, and grasses prefer slightly acidic soils (pH 6.0 – 6.8). The pH level needed for individual crops can be determined only by a soil test.

Summary

Soil is composed of 45% mineral matter, 5% organic matter, and 25% each of water and air. Mineral matter consists of sand, silt, and clay particles. Organic matter consists of dead and decaying plant and animal material. Mineral and organic matter fit together, forming pore spaces that hold water and air in soil. The primary function of water in the soil is to dissolve soil minerals, moisten plant roots, and provide a solution for plants to absorb essential nutrients. The ability of air to move in and out of the soil is important in providing oxygen for healthy root growth.

Soil texture is the relative proportions of the individual mineral particles sand, silt, and clay. Soil texture directly affects the soil's water-holding capacity and fertility. Silty soils have a mixture of particle sizes and pore spaces that give them the best water-holding capabilities and fertility levels.

The acidity and alkalinity of soil are determined by the pH (potential hydrogen) of a soil. The pH scale ranges from 0 to 14, with 7 considered neutral, 0 acidic, and 14 alkaline (basic). Plants require large amounts of nutrients made available through cation exchange capacity (CEC). Soil pH directly affects the CEC of a soil. The pH of a soil is important in determining if a neutralizing agent is needed to maintain the correct balance of nutrients for optimum plant growth. Applying lime can raise the pH. Each growing crop has a preferred pH level; most crops grow and produce best in soils with a pH range of 5.0 to 7.5.

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Lesson 2: Soil Types and Limitations

Soil morphology is the composition, or makeup, of soil. The composition includes the texture, structure, consistence, color, and other physical, chemical, and biological properties of the soil. Soil surveys and soil survey books give extensive information about the soil morphology in a given location. This information is used by individuals, organizations, and government agencies to determine suitability of land tracts for farming, industry, and recreation. It is important to understand how soil morphology affects crop management decisions for farms, ranches, and woodlands.

Identifying Soil Types

The soil resources of Missouri are classified, mapped, and interpreted through county soil surveys. The published soil survey book contains maps of the locations and extent of important soils in each county. Each soil is described by its chemical and physical properties; classified by a national classification system; and interpreted for agricultural, engineering, recreational, and urban uses.

Soil surveys are made by soil scientists who examine aerial photographs to determine relationships among soil colors, native vegetation, and topography. Over time, soils develop special characteristics that help scientists predict the location of different soils. Scientists also examine soils by walking the landscape to gather additional specific data.

The published soil survey maps contain soil and road boundaries, water features, township sections, and cultural features such as schools and farmsteads. The survey also contains information about each soil, including interpretations helpful for selecting the best use and management practices. State residents may obtain free copies of county soil survey reports from the local soil and water conservation district or Natural Resources Conservation Service offices.

When using a soil survey book to determine soil types for a given location, choose a site to research. Good examples include a specific field, farm, or homestead. Once a site is determined, its location can be found on the Index to Map Sheets, which is in the center of the survey book before the soil survey sheets. This map shows the county townships by section and number. The number of the township corresponds with the soil survey sheets in the back of the book and shows an aerial view of the desired site. Explanations for the symbols listed on the soil survey sheets can be found in the Index to Map Units section in the front of the book or on the back of the Index to Map Sheets.

The General Soil Map is a color-coded map located adjacent to the Index to Map Sheets that shows the soil association groups for the county. Each association group has a distinctive pattern of soils, drainage, and relief (elevations in land surface). A description of these soil groups can be found toward the front of the book in the General Soil Map Units section. This section provides information useful in planning the use and management of large areas. It also explains the soil classification of each soil type within the association group. The Detailed Soil Map Units section provides descriptions of each individual soil type in the county and is also useful in determining the suitability and potential of a soil for specific uses. The Tables section provides additional data regarding specific land uses for each soil type. All of these maps, descriptions, and tables, as well as other general and historical information on the county, are provided to the public to make good land use decisions.

Limiting Factors for Crop Selection and Growth

Soil properties that limit a soil from producing crops are known as limiting factors. Many limitations or hazards exist for individual soil types. These can have devastating effects on crop production.

Seven limitations are identified in Table 2.1 and have been generalized for statewide use to satisfy state soil-judging contest requirements. Slope, erosion, available water capacity (AWC), surface drainage, internal drainage, rock fragment content (gravel, cobbles, channers, or flagstones), and surface stoniness are all hazards or limitations that affect crop selection and growth. These seven are considered the most significant and easiest to evaluate on a small site. Individual soils may have more severe or specific limitations noted in the soil survey book.

Table 2.1 - Guide to Determining Hazards or Limitations for Cropping

Possible Hazard or Limitation	Soil Characteristics That Indicate a Hazard or Liability
Slope	All land slopes longer than 90 feet and/or in excess of 2 percent slope
Erosion	Any eroded area where the upper 6-7 inches is either mixed topsoil and subsoil, mostly subsoil, or has gullies
Available water capacity (AWC)	Less than 10 inches of available water in the upper 60 inches of the profile
Surface drainage	High-water table less than 2 feet and nearly level with depressional spots, and sloping areas below seep spots
Internal drainage	High-water table of less than 3.5 feet
Rock fragments (volume upper 10 inches)	Greater than 15%
Stoniness (surface)	Large rocks less than 100 feet apart

Slope is the incline of the land. Percentage of slope is the vertical distance divided by horizontal distance, then multiplied by 100. Slopes less than 3% are considered an asset; those over 3% are considered a liability. Slope characteristics are the gradient, the length, the shape, and the aspect. Slope gradient is the steepness of the land surface. Operation of farm equipment and irrigation becomes more difficult on steeper slopes. The slope length will affect erosion. A long slope allows runoff water to gather more volume as it flows over the surface and increases erosion. The shape of the slope will also affect erosion. The shape is classified as linear, concave, or convex. Slope aspect refers to the effects of temperature and sun exposure on the soil and is dependent on compass direction.

Erosion is the wearing away of the land surface by water, wind, ice, or other geological agents. There are three main types of water erosion: sheet, rill, and gully. Sheet erosion is the detachment of soil particles by flowing water and is usually caused when rain hits wet soil. After soil particles are detached, they can be floated into rills and gullies and transported into low places or off the field. Rills are small steep-sided channels where runoff water concentrates. Gullies are miniature valleys where water usually runs only after rainfall and unlike rills are obstacles to farm machinery. *(For a more extensive explanation of soil erosion, see Lesson 6 of this unit.)*

Available water capacity (AWC) is the soil's capacity to hold water. It is commonly expressed as inches of water per inch of soil. Soils with low or very low available water are considered a liability.

Surface drainage is the runoff, or surface flow of water, from an area. Surface drainage is needed on all poorly drained soils regardless of their classification, soils that are nearly level in slope with depressional areas, or soils on sloping areas below seepy areas.

Internal drainage (depth to high-water table) is the rate at which internal free water leaves the soil to allow aeration. Gravitational water must move out of the profile quickly so the roots can obtain adequate aeration. Internal drainage is classified on seven levels: excessive, somewhat excessive, well, moderately well, somewhat poorly, poorly, or very poorly. Rock fragments are rock or mineral fragments with a diameter of 2 mm or more such as gravel, cobbles, or boulders. Rock fragments affect the amount of irrigation water the soil can absorb.

Stoniness refers to soil in which rock fragments 10 to 24 inches (25 – 60 cm) in diameter are exposed at the surface. Stoniness is evaluated according to the percentage of the soil surface covered by detached stones. Stony soil interferes or even inhibits tillage. Five general classes are as follows: not stony, stony, very stony, extremely stony, and rubbly. *(Refer to IML's* Soil Science Guide, *Chapter 11, for a review of these classes.)*

Summary

Soil surveys are developed by soil scientists who examine aerial photographs to determine relationships among soil colors, native vegetation, and topography. They also examine the soils by walking the landscape to gather additional specific information. This information is then compiled into soil survey books available to the general public. Guide pages assist the reader in understanding the information in the soil survey books.

The information found in soil survey books describes capabilities, limitations, and hazards that exist in the soil in a specific location. The most significant factors for cropping are land slope, erosion, available water capacity, surface drainage, internal drainage, content of rock fragments, and surface stoniness.

Credits

Biondo, Ronald J. and Jasper S. Lee. *Introduction to Plant and Soil Science and Technology*. Danville, IL: Interstate Publishers, Inc., 1997.

Minor, Paul. *Soil Science* (Student Guide). Ed. Barbara Rosenfeld. Volume 27. Columbia, MO: Instructional Materials Laboratory, 1995. Chapters 11 and 12.

Soil, Plant, and Crop Science (Teacher Edition). Oklahoma Department of Vocational and Technical Education. Stillwater, OK: Curriculum and Instructional Materials Center, 1996.

Lesson 3: Soil Testing

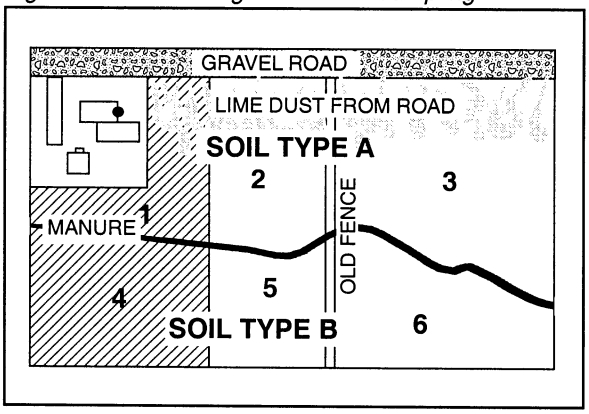
Soil fertility levels vary in fields due to size, soil type, crop management, fertilizer, or limestone history. Likewise, soil properties can vary over short distances, resulting in differences in plant growth, crop yield, and quality. Therefore, it is important to obtain a soil sample representative of the field, garden, or lawn to be planted in order to appropriately apply fertilizer.

Obtaining a Soil Sample

Traditional methods of obtaining a soil sample recommend testing an area of 20 acres or less. Research shows areas larger than 20 acres do not provide enough uniformity and the data collected is too burdensome to make good farming practice recommendations. Variation is naturally caused by climate, topography, parent materials, vegetation, time, and human influences. To account for variability, soil samples should be taken from different soil types within the test area. As stated in Lesson 2 of this unit, soil types for a given location can be found in the county soil survey book. Testing should be done on areas where different crops have been grown, various soil surface textures are present, and on wet or eroded production areas. Avoid taking soil samples from areas not representative of the entire field such as driveways, dead furrows, road edges, old barn lots, and severely wet or eroded areas where production is not feasible.

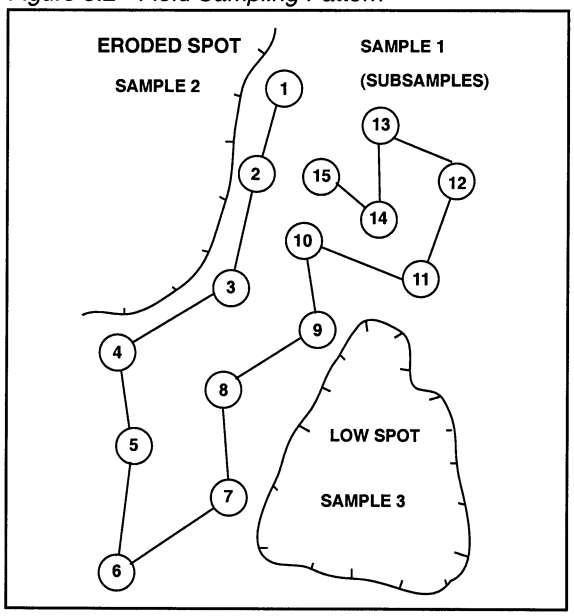
Figure 3.1 illustrates a field diagram for traditional soil sampling. The field was originally two 20-acre tracts with a fence and tree row between each tract. In this example, separate samples should be taken for changes in soil type, crop history, and manure applications to provide an accurate soil fertility map of the field.

Figure 3.1 - Field Diagram for Soil Sampling



University Extension personnel recommend taking an average of 15 to 20 samples from each soil type or special area. This will reduce variation and allow for the correct amount of fertilizer to be applied based on the average fertility of the field. Figure 3.2 shows a random, zigzag sampling pattern used to obtain a representative soil sample. These subsamples are mixed together thoroughly and a composite sample (about 1 pint) is taken from the mixture and sent for analysis along with soil from sample areas 2 and 3 as shown in Figure 3.2.

Figure 3.2 - Field Sampling Pattern



All soil tests should include the top 7 inches of topsoil obtained through the use of an auger, probe, or spade. Samples from all the areas of the field should be mixed thoroughly, air-dried, placed in a small bag or box, labeled, and taken to a testing facility. University Extension personnel recommend taking soil samples annually and preferably in the fall or spring under moist soil conditions. It is best to sample when the acreage is lying fallow.

Many of the same criteria are used for taking soil samples for use with Global Positioning Systems (GPS) except for a few points. GPS uses satellite technology capable of locating the exact location in a field from which field data was gathered. Mapping software will divide the field into sectors, or grids. Refer to Figure 3.3. A typical sector is 2 1/2 acres. One sample, which consists of 8 to 10 core samples 5 to 10 feet apart, should be taken every 2 1/2 acres. The exact location is tracked to

Figure 3.3 - Sampling Soil for Satellite Technology

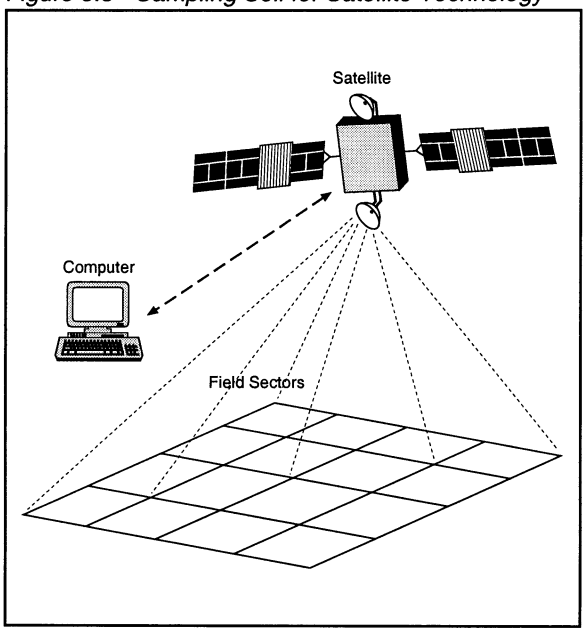
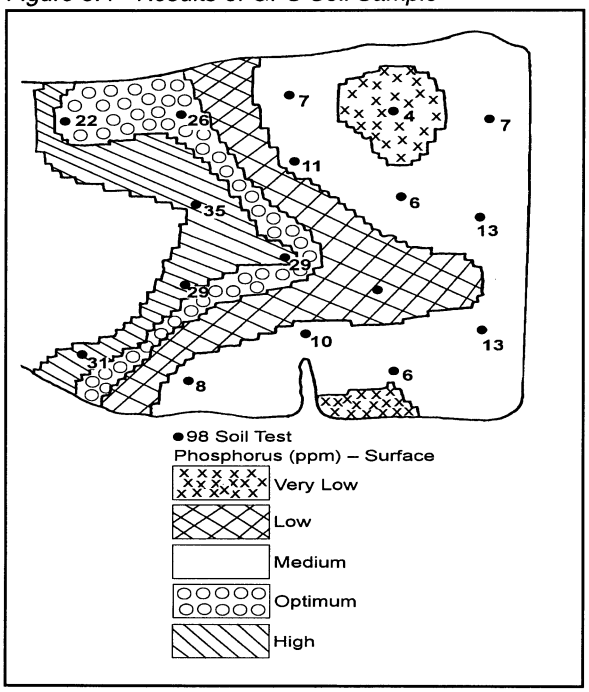


Figure 3.4 - Results of GPS Soil Sample



correspond with the location on the mapping software. The software will develop an application map for the entire field.

If a producer were to take the same 20-acre plot from a traditional soil sample and compare it with a 20-acre plot using GPS, the results could vary tremendously. Figure 3.4 shows the results of a soil test for phosphorus using the sampling technique for GPS. Note the detailed variances from very low to high in this 20-acre plot. A traditional soil sample, which takes samples throughout the plot and then mixes them together, would show the same phosphorus recommendation throughout the 20-acre plot.

Testing Soil Samples

Soil samples can be tested at University Extension Centers, fertilizer dealers, or private testing laboratories. A small fee is charged for the analyses. The majority of all soil testing is conducted by University Extension Centers or local, independent laboratories because of the necessary working knowledge of local soil types. It is better to have soil tested at an independent laboratory than by a fertilizer dealer to ensure objectivity and accuracy. Wherever a soil test is evaluated, the producer needs to feel confident that the results are reliable. Added production costs, possible crop losses, and even environmental damage from over- or underfertilization based on a bad soil test report can be devastating. Recommendations should always be made by a trained official to guarantee the reliability of the soil test.

Soil samples are tested for acidity, phosphorus, potassium, calcium, magnesium, and organic matter. The results will provide recommendations for the amount of limestone, nitrogen, phosphate, and potassium to be added to the soil. Tests are also available for sulfur, zinc, iron, manganese, copper, and salt content.

When testing for acidity levels, laboratories will use either a salt pH measurement or a water pH measurement. The University of Missouri Soil Testing Service uses a salt pH measurement. Most of the time, the water pH reading is about 0.5 unit higher than the salt pH reading. For example, if water pH is about 6.0, salt pH might be 5.5.

Key Parts of a Soil Test Report

A soil test report will include six parts: field information (field name, sample number, acres, last crop), soil test information, rating, nutrient requirements (cropping options, yield goal, pounds per acre), limestone suggestions, and special notes. This information is needed to make good management and fertilizer recommendations to

Figure 3.5 - Soil Test Report for a Soybean Field

OUTREACH & EXTENSION
UNIVERSITY OF MISSOURI
LINCOLN UNIVERSITY

Soil Test Report

Soil Testing Laboratory
23 Mumford Hall, MU
Columbia, MO 65211
Phone: (573) 882-0623

or

Soil Testing Laboratory
P.O. Box 160
Portageville, MO 63873
Phone (573) 379-5431

Serial no. P9039	Lab no. 18793
Area 15	County 010 Region 3
Submitted 11/18/98	Processed 11/24/98

Soil sample submitted by:

FIELD INFORMATION		
Field ID A1 SOIL	Sample no. 1	
Acres 22	Last Limed UNKNOWN	Irrigated NO
Last crop 115 SOYBEANS		

This report is for:

JOHN DOE
RURAL ROUTE 1, BOX 1
CENTERTOWN, MO

SOIL TEST INFORMATION				RATING					
				Very Low	Low	Medium	High	Very High	Excess
pH$_s$	(salt pH)	6.3		**********					
Phosphorus	(P)	86	lbs/a			**********			
Potassium	(K)	428	lbs/a				**********		
Calcium	(Ca)	5071	lbs/a					**********	
Magnesium	(Mg)	568	lbs/a					**********	
Sulfur	(SO_4-S)	6.0	ppm		**********				
Zinc	(Zn)	1.3	ppm			**********			
Manganese	(Mn)		ppm						
Iron	(Fe)		ppm						
Copper	(Cu)		ppm						

Organic Matter	2.9 %	Neutralizable acidity	1.0 meq/100g	Cation Exch. Capacity	16.6 meq/100g		
pH in water		Electrical Conductivity	mmho/cm	Sodium (Na)	lbs/a		
Nitrate (NO_3-N) Topsoil	ppm	Subsoil	ppm	Sampling Depth Top	Inches	Subsoil	Inches

NUTRIENT REQUIREMENTS							LIMESTONE SUGGESTIONS	
		Pounds per acre						
Cropping options	Yield goal	N	P_2O_5	K_2O	Zn	S		
103 CORN (GRAIN)	140 BU/A	155	0	20	0	0	Effective neutralizing material (ENM)	0
115 SOYBEANS	40 BU/A	0	0	20	0	0		
119 WHEAT	60 BU/A	95	0	20	0	0	Effective magnesium (EMg)	0
103 CORN (GRAIN)	140 BU/A	155	0	20	0	0		

Your sample has an estimated pH in water of 6.8.
The cation exchange capacity of this soil would suggest very low potential for sulfur response. Monitor the crop by plant analyses for potential need for sulfur.
Nitrogen requirements may be reduced by 30 pounds per acre for the first crop following soybeans. Not applicable for wheat.
Soils testing high in P or K should be retested annually to determine when maintenance fertilizer should be applied.

correct or maintain the desired balance of nutrients for the intended crop. Additional information regarding a specific test for other nutrients may be included if requested. Soil test report formats may vary due to differences in laboratories and their testing procedures. Figure 3.3 is an example of a soil test report on a soybean field from the University of Missouri Outreach and Extension Service.

Interpreting Soil Test Results

In order to interpret an individual soil test, all six components of a soil test must be evaluated. The Field Information section allows the producer to know exactly which field was tested. General information should include a field name, sample number, size, and previous crop planted.

Table 3.1- Determining Fertilizer Needs from Nutrient Ratings (MU G09112)

Rating						Probability of response to fertilizer
Very low	Low	Medium	High	Very high	Excess	
****						very high
**********						high
**********						medium
**********						low
**********						none
**********						none

The Soil Test Information section is the primary component of the soil test and provides the results of the sample analyzed. The salt pH indicates the level of active soil acidity. Missouri soils maintained at a salt pH between 5.5 and 7.0 provide a favorable environment for helpful microorganisms and root development. Phosphorus results are expressed in pounds of elemental P per acre. It is a measure of the relative availability of phosphorus for plant growth, not the total amount of phosphorus in the soil. Potassium results are expressed as pounds of exchangeable K per acre and estimates the potassium available to the growing crop. The calcium measurement is used to calculate cation exchange capacity (CEC) and is not based on the actual soil test calcium level. Calcium seldom limits crop growth in Missouri soils. Magnesium application based on a medium rating is not likely to increase yields in row crops and small grains but may improve forage quality. When sulfur is needed, 10 to 20 pounds per acre is suggested for row crops, small grains, and alfalfa. Most other forages in Missouri do not require sulfur. Zinc application is likely to increase corn and grain sorghum yields in Missouri; however, zinc is recommended for small grains and alfalfa only when the soil test is less than 0.5 ppm. Field research has not shown a need for applications of iron, manganese, or copper in Missouri. Organic matter estimates the potential nitrogen release to a crop throughout the growing season and determines proper herbicide application. The cation exchange capacity is a calculation of the exchangeable calcium, magnesium, potassium, and hydrogen measured by the soil test.

The Rating section of a report interprets the information provided in the Soil Test Information section. Each rating indicates the probability of a yield increase from fertilizer application for each nutrient tested. Table 3.1 shows how the probability of yield increases from fertilizer drops as the soil test ratings rise. For example, a Very Low or Low test indicates that crops would likely respond to the addition of the appropriate fertilizer. However, there are no economic advantages to applying fertilizer to soils testing Very High.

The Nutrient Requirements section of a soil test contains three parts: cropping options, yield goal, and pounds per acre. Cropping Options are the crops the producer is considering planting in the sampled location. If a producer is unsure, different crop option scenarios are available from University Extension personnel. The Yield Goal is the number of bushels per acre the producer needs to harvest from the field in order to be profitable. This goal should be based on soil type, field history, fertility level, irrigated versus nonirrigated land, and economic considerations. Pounds per Acre lists the fertilizer recommendation for the crops and yield goals intended. Recommendations are given for nitrogen (N), phosphate (P_2O_5), potassium (K_2O), zinc (Zn), and sulfur (S) for the number of pounds of each to be applied per acre on the field. Following these suggestions, a producer can attempt to meet yield goals as well as improve the soil's fertility over time.

The Limestone Suggestions section is used to indicate the amount of limestone needed to raise the pH level to the desired level for the intended crops listed under cropping options. This recommendation is always for the crop requiring the highest pH range and is reported as pounds of effective neutralizing material (ENM) per acre. The amount of lime needed is calculated by dividing the ENM by the amount of ENM per ton of fertilizer guaranteed by an agricultural lime supplier. For example, if a soil test ENM fertilizer

recommendation was 1,450 pounds per acre and the dealer guarantees 400 pounds ENM per ton, then the amount of lime needed per acre equals 3.63 pounds (1,450 lb./acre ÷ 400 lb.ENM/ton = 3.63 lb.).

ENM Suggestion	÷	EMN Guaranteed	=	Lb. of Lime Needed per Acre

1,450 lb./acre ÷ 400 lb. ENM/ton = 3.63 lb.

Special Notes are sometimes posted at the bottom of the soil test report to aid in interpreting results and to list additional recommendations.

Summary

Soil samples should be taken in an area of 20 acres or less to increase the chances for an accurate soil fertility rating. Variations are caused by climate, topography, parent materials, vegetation, time, and human influences. Separate samples should be taken from each soil type or special area in order to obtain the average fertility of the soil. It is recommended that yearly soil samples be taken under moist soil conditions. University Extension Centers and private soil testing laboratories will test soil samples, and a trained official will provide recommendations. Adding the wrong amount of fertilizer as a result of an inaccurate soil test can add to production costs and cause crop losses.

A soil test report includes information about the field tested. The soil test information section provides results on salt pH levels, phosphorus, potassium, calcium, magnesium, sulfur, zinc, organic matter, neutralizable acidity, and cation exchange capacity. The rating section of the soil test report indicates the probability of a yield increase from fertilizer application for each nutrient tested. The nutrient requirements include cropping options the producer can choose from, along with the yield goal and recommended pounds per acre of fertilizer for the intended crops. The Limestone Suggestions section indicates the amount of limestone needed to raise the pH to the desired level. Interpretations and recommendations are sometimes posted in the Special Notes section.

Credits

Biondo, Ronald J. and Jasper S. Lee. *Introduction to Plant and Soil Science and Technology.* Danville, IL: Interstate Publishers, Inc., 1997.

Buchholz, Daryl D., James R. Brown, and Roger G. Hansen. *How to Get a Good Soil Sample* (Guide G9110), Columbia, MO: University Extension, University of Missouri-Columbia. 1993.

Buchholz, Daryl D., James R. Brown, and Roger G. Hansen. *Using Your Soil Test Results* (Guide G9111), Columbia, MO: University Extension, University of Missouri-Columbia. 1993.

Jennings, John A., John A. Lory, Peter Scharf, and Manjula V. Nathan. *Interpreting Missouri Soil Test Reports* (G9112), Columbia, MO: University Extension, University of Missouri-Columbia. 1996.

Minor, Paul E. *Soil Science* (Student Guide). Ed. Barbara Rosenfeld. Volume 27. Columbia, MO: Instructional Materials Laboratory, 1995, Chapter 9.

Lesson 4: Fertilizing Soils

Nutrients are removed from the soil through cultivation, topsoil erosion, and harvesting crops. The continuous use of soil without replenishing the essential nutrients will lead to lower crop productivity. Fertilizers applied to the soil will increase fertility and provide a means of maintaining high fertility levels. With improvements in technology, fertilizer manufacturers have developed concentrated high analysis fertilizers that provide more nutrients per ton of fertilizer. Producers, in turn, see higher crop yields and profit.

Fertilizer Types

All fertilizers can be categorized as three basic types: mineral, organic, or chemical (inorganic). These fertilizers are applied to soils to supply the required level of essential nutrients needed for optimum plant growth, yield, and nutritional quality. The following paragraphs list the advantages and disadvantages of using each type.

Mineral fertilizers are rocks containing nutrients that are ground up and applied to soil. Rocks contain mineral nutrients that are vital to healthy soil. However, most minerals dissolve slowly in soil and their usefulness as a fertilizer is limited. They are typically applied after harvest with fall tillage operations, making them available for spring-planted crops. Mineral fertilizers can also be added with spring or double-crop tillage operations, to build up nutrients for future crops. Minerals are seldom found in a pure state. The two most common minerals found in Missouri are limestone and phosphate rock.

Limestone is an example of a multi-element mineral fertilizer. It is mainly used to neutralize soil acidity but is also a good source of calcium, magnesium, and sulfur. Ground limestone, or calcium carbonate (CaO_3), is the most commonly used type of liming material. Other limestone materials used to correct magnesium and sulfur deficiencies are magnesium carbonate ($MgCO_3$) and magnesium sulfate ($MgSO_4$).

The most common form of phosphorus in nature is phosphate rock (PO_4). Rock phosphate is the basic material used in nearly all phosphorus fertilizer. Phosphate rock does not dissolve easily in liquids; therefore, it is processed into more soluble fertilizer sources. Finely ground phosphate rock can be applied to soil but is used only on soils with a definite phosphorus shortage. It should be used only on acidic soils (pH below 6.0) and it should be applied at rates three to five times greater than those of other more soluble phosphate fertilizers.

Organic fertilizers are plant or animal tissues that have become waste materials. Plant residue; animal manure; bone, cottonseed, and soybean meal; and biosolids (sewage sludge) can all be recycled and used as fertilizers. Table 4.1 gives the nutrient content found in these organic fertilizers except plant residue. As plant residue is worked into the soil, it breaks down slowly and returns nutrients to the soil, thus reducing the need to add nutrients as determined by soil tests.

Table 4.1 - Nutrient Content of Some Organic Fertilizers

Percent of Nutrient Content Per Pound of Organic Fertilizers			
Organic Material	**% of N**	**% of P**	**% of K**
Cattle Manure	0.5	0.25	0.5
Sheep Manure	1.4	0.5	1.25
Swine Manure	0.5	0.25	0.5
Poultry Manure	1.5	1.0	0.5
Horse Manure	0.7	0.25	0.7
Bone Meal	4.0	23.0	0.0
Cottonseed Meal	6.0	2.5	1.5
Soybean Meal	7.0	1.2	1.5
Biosolids (sewage sludge)	3.0	2.5	0.4

The nutrients from organic fertilizers are obtained slowly by plants as the material decays. These slow-releasing nutrients are less likely to cause root damage because salts do not build up in the surrounding soil. In addition, organic wastes are long lasting and a great source of the live bacteria needed to convert natural soil minerals and chemical fertilizers into useable forms for plants. Organic fertilizers do have disadvantages; they are low in the major nutrients, the material is bulky, and the exact amount of fertilizer applied is sometimes difficult to measure. However, organic fertilizers are considered more natural than chemical fertilizers and continue to be used by producers as they have been for thousands of years.

Since chemical (inorganic) fertilizers were first widely used in the middle 1900s, crop yields have greatly improved. Some chemical fertilizers may be mined but many are manufactured from a nonliving source. The most common chemical fertilizers are formulations of nitrogen (N), phosphorus (P), and potassium (K).

Nitrogen fertilizers applied to soils include anhydrous ammonia, urea, ammonium nitrate, ammonium sulfate, and sodium nitrate. Phosphorus is applied as ammonium phosphate, superphosphate, or in fertilizer mixes containing finely ground phosphate rock. The most common fertilizer element, potassium, is applied as potassium chloride (sometimes known as potash).

Chemical fertilizers generally have a higher proportion of useable nutrients than mineral or organic fertilizers. (See Table 4.2.) These nutrients are more soluble and therefore immediately available for plant use following application. They are easier to measure, making application of the exact amount of a specific nutrient possible. Chemical fertilizers, however, are more costly and errors in application can damage crops and the environment.

Forms of Fertilizers

Mineral and chemical fertilizers can generally be purchased in four forms: (1) fluid fertilizers, (2) pressurized liquids, (3) dry fertilizers, and (4) slow-release fertilizers. The form of fertilizer a producer uses will be dictated mostly by what form is available, cost, available application equipment, individual producer practices, and current weather conditions.

Fluid fertilizers There are two main categories: (1) true liquids and (2) suspension fertilizers. The nutrients in true liquids are completely dissolved and can be sprayed or dribbled directly on soil or plant surfaces, injected into the soil, or mixed with irrigation water. Suspension fertilizers are mixtures of liquids and finely divided solids in which the solids do not settle rapidly and can be redispersed easily by agitating to give a uniform mixture. Suspension fertilizers are applied to the soil surface. Most nitrogen fertilizers are prepared in fluid form. Powdered forms of phosphorus and potassium fertilizer compounds are also soluble enough to be mixed with water and used as fluid fertilizer. Potash is typically applied as a suspension fertilizer. It is becoming common practice to apply herbicides along with the liquid fertilizer to reduce trips across the field.

Table 4.2 - Nutrient Content of Some Chemical Fertilizers

Percent of Nutrient Content per Pound of Chemical Fertilizers			
Inorganic Material	**Nitrogen**	**Phosphorus**	**Potassium**
Nitrogen Sources			
Anhydrous Ammonia	82	0	0
Urea	45	0	0
Ammonium Nitrate	33.5	0	0
Ammonium Sulfate	21	0	0
Sodium Nitrate	16	0	0
Phosphorus Sources			
Ammonium Phosphate	11	48	0
Diammonium Phosphate	34	0	0
Superphosphate	0	20	0.2
Potassium Sources			
Potassium Chloride	0	0	60
Potassium Sulfate	0	0	50
Potassium Nitrate	13	0	44

Pressurized liquids are applied by injection directly into the soil from tanks. Pressure in the tank forces the liquid through chisels that are pulled underground. When the liquid reaches the soil it adheres to the soil moisture. Anhydrous ammonia, the most common nitrogen fertilizer, is sold as a pressurized liquid. Biosolids from lagoons and treatment plants are generally applied using pressurized spray or gravity-fed equipment designed for such purposes.

Dry fertilizers are applied mechanically and absorbed into the soil through rainfall. They generally are the most economical and are available as powders, granules, or prills. Prills are formed by hot liquid fertilizer flowing through a cooling tower where they are formed into a round pellet and coated with a conditioning clay. The clay slows moisture absorption from the air and reduces caking (forming into hardened clumps). Ammonium nitrate is supplied as dry prills. Nitrogen is considered to be the most common fertilizer used in granular form. Dry fertilizers can also be mixed with liquid and applied as a fluid fertilizer.

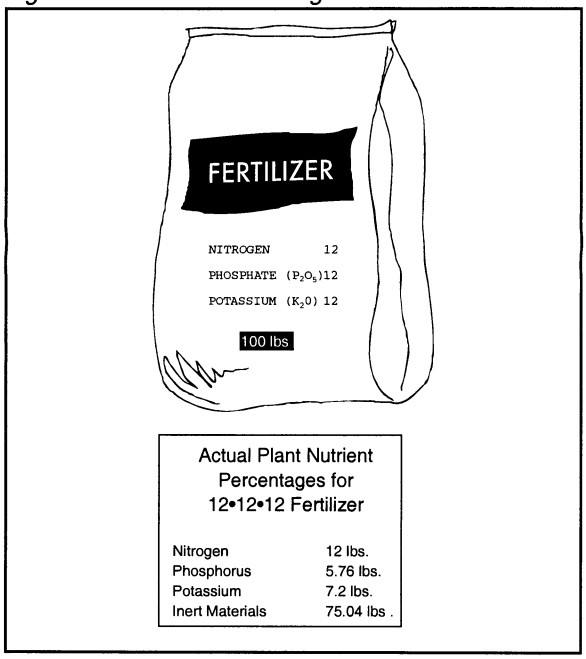
Slow-release fertilizers contain nutrients that dissolve into the soil solution slowly. They are available in dry or liquid form. The time period for this form of fertilizer to become available for plant use generally ranges from several weeks to a few months. Slow-release fertilizers are most commonly used in horticulture or vegetable production.

Obtaining Fertilizers

Chemical fertilizers used on cropland are typically obtained in large, bulk quantities from agriculture supply centers or dealers. The fertilizer mixture required is determined from the results of a soil test performed on the cropland. To help explain the breakdown of the primary macronutrients used in large quantities, it will help to determine how the chemicals in a 100-pound bag are broken down.

The three primary macronutrients, nitrogen (N), phosphorus (P), and potassium (K) are seldom found in sufficient levels for crop production and must be supplied by fertilizers or manure. Complete commercial fertilizer mixtures must contain all three nutrients. The proportions of nitrogen, phosphorus, and potassium are known as the fertilizer grade and are expressed on a bag of fertilizer as the percentages of the contents of the bag by weight. Therefore, a 100-pound bag of fertilizer (Figure 4.1) with a grade of 12-12-12 contains 12% nitrogen, 12% phosphorus, and 12% potassium. The nutrients are always listed in the same order (N, P, and K) and the listed percentage is guaranteed by the manufacturer.

Figure 4.1 - Contents of a Bag of Commercial Fertilizer



Multiplying the total amount of fertilizer (100 pounds) by the percentage of each ingredient will provide the total pounds of each active ingredient. Therefore, 100 (total pounds of fertilizer) x 0.12 (percent of nitrogen) = 12 pounds of nitrogen. The amount of phosphorus and potassium is also 12 pounds each. The phosphorus (P) in a bag of fertilizer is actually an oxidized phosphate (P_2O_5). One of the most widely used phosphates is diammonium phosphate, which contains only 48% phosphorus. Likewise, a common source of potassium is potassium chloride (KCl), which contains only 60% potassium. (Note: Many commercial fertilizers use the old term for potassium (K_2O) to list the potassium content even though there is actually no K_2O compound in the fertilizer.)

To determine the actual amount of phosphorus and potassium applied from a bag of fertilizer, multiply the percentage of each by 0.48 and 0.60, respectively. The actual phosphorus contained in the 100-pound bag in Figure 4.1 is 12 x 0.48, or 5.76 pounds and the actual potassium is 12 x 0.60, or 7.2 pounds. If a producer were to use this

bag of 12-12-12 fertilizer on an acre field, he or she would be applying 12 pounds of nitrogen, 5.76 pounds phosphorus, and 7.2 pounds of potassium per acre. The remaining materials in the bag of fertilizer (75.04 pounds) are other elements that act as carriers of the nutrients. Fillers and conditioners also make up a small percentage of the contents.

Most forms of fertilizers can be purchased from a local agriculture supply center. The mixing and spraying of fertilizers are highly technical skills needing correct calculations. Supply centers have trained personnel who can prepare the fertilizer mix according to the results on the soil test. Some supply centers may have personnel who can apply fertilizers to producers' fields. Many materials are hazardous and require specialized equipment, clothing, and gear to maintain individual and environmental safety. Producers may find added benefits in time, safety, and liability by paying for application services. If a producer chooses to transport and apply chemical fertilizers, then a license to do so must be obtained and records must be maintained as determined by state law.

An alternative source of mineral fertilizer, such as limestone, can be purchased from a local quarry. However, the producer would generally need to have the equipment to apply this type of fertilizer because most quarries do not offer this service.

Organic fertilizers can be found in producers' barnyards, livestock waste pits or lagoons, or at a local sewage treatment facility. If the producer is not a livestock producer, neighboring producers may have ample supplies. Again, special equipment such as manure spreaders, pumps, and hoses are needed to perform applications of dry or liquid organic fertilizers. Like chemical fertilizers, wastewater from pits, lagoons, and treatment facilities is considered hazardous material. Producers must secure licensing to transport it and must comply with any state regulations required to apply organic fertilizers.

Application Techniques

Fertilizers can be applied to soils in a number of ways. Most often they are applied using spray equipment attached to a tractor, tillage implement, or airplane. Fertilizers should be applied so that growing plants can use the nutrients efficiently, there is little or no injury to the plants, and the process is done quickly and economically. The methods for fertilizer application include broadcasting (spreading), soil injection or knifing, banding, starter, side- or top-dressing, foliar, and fertigation.

The broadcasting method is done by spreading dry fertilizer evenly over the surface of the soil prior to planting using mechanical equipment or aircraft. Broadcasted fertilizer, especially lime, is used on fallow fields before planting and may be disked or mixed into the soil to increase the nutrient breakdown process. Spreading solid animal waste on crop fields before tillage is considered broadcasting, but when it is spread over pastures or hay fields it is referred to as top-dressing.

Soil injection or knifing is another method of fertilizer application used before or during planting. Anhydrous ammonia must be injected directly into the soil because ammonia evaporates quickly. Other liquid fertilizers have been injected with success, but due to the specialized equipment required many producers still use other methods. Injection is developing into a preferred option to apply liquid manure because it reduces odor and maintains air quality, a growing issue with large-scale livestock production.

Banding places dry fertilizers directly into the soil about 2 inches to each side of and below the seed. This method is used extensively for row crops during planting. The placement of the fertilizer is far enough away to avoid damaging the seed but close enough that the young roots can find the band of fertilizer. Starter applications apply fertilizer in a band 1 or 2 inches from one or both sides of the seed and below only at planting time. This method of application is commonly used on corn and cotton to stimulate early growth. Starter fertilizers normally contain only the necessary amounts of nitrogen, phosphorus, and potassium to aid plant growth. They are applied as either dry or liquid materials.

Side-dressing is performed by placing fertilizer in bands about 6 to 8 inches from the row of growing plants. This method is very common in row crops such as corn, cotton, and vegetables when additional nitrogen is needed. Dry or liquid fertilizer is placed directly into the soil on one or both sides of the plants. Sometimes the crop is cultivated to mix the fertilizer into the soil. In other situations, the fertilizer is placed on top and carried into the soil by rain or irrigation water. Side-dressing fertilizers in sandy soils may be used to minimize leaching during both planting and

cultivation operations. Caution must be used to avoid damaging plant roots, stems, and leaves when side-dressing.

Top-dressing is a surface application method where dry or fluid fertilizer is broadcast lightly over close-growing plants. It is the most common method for applying nitrogen fertilizer to wheat, small grains, hay fields, pastures, and lawns. Rainfall dissolves dry fertilizer and soaks it into the soil. Nitrogen is often top-dressed due to its ability to penetrate the soil easier than other nutrients.

The foliar method is the application of liquid fertilizer directly on the foliage or leaves of plants. Soluble nutrients are broadcast on growing plants for rapid utilization. This method has been used to correct iron and manganese micronutrient deficiencies in certain field crops. Foliar applications have caused severe burning of leaves if sprayed too heavily. This method is not recommended to supply the nitrogen, phosphorus, and potassium needs of plants.

Fertigation is the application of fertilizer in irrigation systems. Liquid fertilizers are normally used, although dry fertilizers may be dissolved and dispersed by the system. Various metering devices are available to distribute the desired quantity of fertilizer into the irrigation water. The type of irrigation system (open ditch, grated pipe, or sprinkler) will dictate the type of fertilizer used.

Time of Application

The time of fertilizer application depends on the soil temperature, air temperature, moisture, crop to be grown, and nutrient applied. Nutrients, particularly nitrogen, are very susceptible to losses that render them unavailable for plants if not applied under appropriate conditions. Missouri's four seasons provide opportunities to apply fertilizer at the most beneficial times.

Soil temperature affects the rate (speed) of chemical activity generally by the indirect effect on microorganism activity in the soil. Microorganism activity, in turn, is responsible for organic matter breakdown, nitrification, and denitrification. Nitrification begins slowly, just above freezing, and continues to increase as soil temperature increases up to about 85°F. Rates decrease at temperatures above 85°F.

The amount of moisture between time of fertilizer application and plant utilization will affect the efficiency of the applied material. Nitrifying bacteria remain active in very dry conditions but are inactive in waterlogged soils. Soils with sufficient moisture to grow crops will have the optimum moisture level for normal nitrification. Saturated soils do not contain enough oxygen for nitrifying bacteria. If water stands on the soil for only 2 or 3 days during the growing season, much of the nitrate nitrogen can be lost by denitrification. Phosphorus is more available to plants when soil moisture is at high levels. Excess moisture prohibits oxygen, limits root growth, and reduces phosphorus uptake.

The type of crop to be grown may determine a specific time for fertilizer application. A single application of primary nutrients is usually satisfactory for most fast-growing annual crops, such as corn, grain sorghum, and soybeans. However, split applications of nitrogen, one in the spring and one in the fall, may be desirable for perennials, cool-season grasses such as fescue and bromegrasses, and warm-season grasses such as Bermuda grass.

The plant nutrient applied, as well as its source, may also influence the application time. Mobile nutrients, such as nitrates and sulfates, are more susceptible to leaching losses than phosphates or potassium. Nitrogen applied in the ammonia form must be nitrified before leaching or denitrification can occur. Nitrogen efficiency is improved when applied near the time plants are growing rapidly. Limestone may be spread at any time of the year when the soil is firm enough to support the spreading equipment and when crops do not interfere.

Producers need to consider the soil temperature, moisture, crop, and nutrients when choosing the most favorable season for application of fertilizer. Fall application of nitrogen is susceptible to leaching loss under conditions of adequate rainfall. However, the texture of the soil, average fall and winter temperatures, and the nitrogen carrier all influence possible leaching losses. Application of any nitrogen materials in the fall to sandy soils is normally discouraged. Coarse-textured soils allow more rapid percolation of water than do clay soils. Anhydrous ammonia is an excellent material recommended for use in fall applications in most locations in Missouri. When applied to soils of medium to heavy texture, the nitrogen remains in the ammonium form and resists leaching until

converted to the nitrate form. If applied after the soil temperature is below 50°F at a depth of 4 inches, the conversion to nitrate is relatively slow and of little consequence. Fall application of phosphorus and potassium is relatively safe in most areas. These elements are rather immobile and the chances of leaching losses are quite small. Soil texture and fall or winter precipitation will have little influence on the losses of these nutrients.

Winter application of fertilizer is normally slow during this period. Plow-down applications and anhydrous ammonia application can continue until the ground freezes. In some areas, these methods of application continue throughout the winter.

Spring application is the most popular period for applying fertilizers. Broadcast applications for plow-down or disk-in on row crops, preplant applications of anhydrous ammonia for row crops, and starter applications for spring small grains or row crops are commonly applied at this time of the year. Many producers find it more desirable to apply fertilizer prior to this period so that they can concentrate on seedbed preparation and crop planting.

Summer applications of fertilizer are mainly confined to providing supplemental amounts of plant nutrients not applied previously. Side-dressing with nitrogen during irrigation applications is normally used.

Calculating Application Rates

Most fertilizer application rates (also called spread rates) are calculated in pounds per acre, except for lime. The spread rate for dry chemical fertilizer is determined by dividing the total pounds of fertilizer materials to be applied by the total acres to be fertilized. When fertilizer is purchased from and applied by a local agricultural supply center or dealer, the spread rate is listed on the bill of sale. If producers are applying their own fertilizer, the spread rate is necessary to calibrate application equipment. The application rate of liquid organic fertilizers is regulated by state and federal laws and the producer must be familiar with the regulations before application.

Lime is the only fertilizer that requires measuring based on a rating system. The rating system measures the ability to reduce soil acidity and is referred to as ENM (effective neutralizing material). The ENM of agricultural limestone is determined by the purity of the material used and its fineness. A producer can call an agricultural lime dealer at a quarry to find out the local ENM per ton of agricultural lime.

Lime is always applied in pounds of ENM per acre. Soil test results make liming recommendations in pounds of ENM per acre. To determine the amount of lime needed in tons per acre, divide the ENM value from the soil test by the ENM of the limestone. For example, if a soil test ENM fertilizer recommendation was 1,450 pounds per acre and the dealer guarantees 400 pounds ENM per ton, then the amount of lime needed per acre equals 3.63 pounds as shown below.

1,450 lb./acre ÷ 400 lb. ENM/ton = 3.63 lb.

A pound of ENM is a pound of ENM, regardless of the source of liming material. For example, say the soil test recommends 1,200 ENM. A limestone dealer says he has 400 ENM lime. Dividing 400 into 1,200 will equal 3 tons of that limestone per acre needed to satisfy the lime requirement. If another limestone dealer had 600 ENM lime, only 2 tons per acre of that lime will be needed to satisfy the field requirements. Producers should use the least expensive source per pound of ENM for their management systems.

Summary

Mineral fertilizers, organic fertilizers, and chemical (inorganic) fertilizers can be applied to soils to supply the nutrient elements needed for maximum plant growth. The two most common mineral fertilizers are limestone and phosphate rock. Organic fertilizers are plant and animal tissues that have become waste materials. The most common chemical fertilizers are nitrogen (N), phosphorus (P), and potassium (K). Chemical fertilizers have more useable nutrients than the other types but are more costly and can damage the crop if not applied correctly.

Fertilizers are available as fluids, pressurized liquids, dry, and slow release, which is available in either dry or liquid form. When choosing the form to use, the producer must consider the form available, cost, available application equipment, current weather conditions, and preferred practice of the individual producer.

The primary source for purchase of fertilizers is the agricultural supply center. They have trained personnel who can mix and apply the fertilizers. Commercial fertilizer mixtures contain proportions of nitrogen, phosphorus, and potassium as indicated by a soil test. Mineral fertilizers may be obtained from quarries. Barnyards, livestock waste pits and lagoons, and sewage treatment facilities can also provide organic fertilizers.

The primary factors affecting the time of fertilizer application are the soil temperature, moisture, crop to be grown, and nutrients applied. The soil temperature and moisture levels need to be at an appropriate level for the fertilizer to be efficient. The crop grown may require a single application or split applications during the fall and spring. The nutrient may be susceptible to leaching and denitrification if soil conditions are not appropriate. The spring season is the most popular time for fertilizer application. In most parts of Missouri, the fall season is a good time to apply anhydrous ammonia, phosphorus, and potassium.

Application rates for dry chemical fertilizer are determined by dividing the total pounds of fertilizer material to be applied by the total acres to be fertilized. Application rates for lime require measuring on a rating system referred to as the effective neutralizing material (ENM). The ENM of lime measures its fineness and purity. Lime is applied in pounds of ENM per acre. Divide the ENM per acre suggested on the soil test by the guaranteed ENM per pound to determine the pounds of lime needed per acre.

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Lesson 5: Soil Management Practices

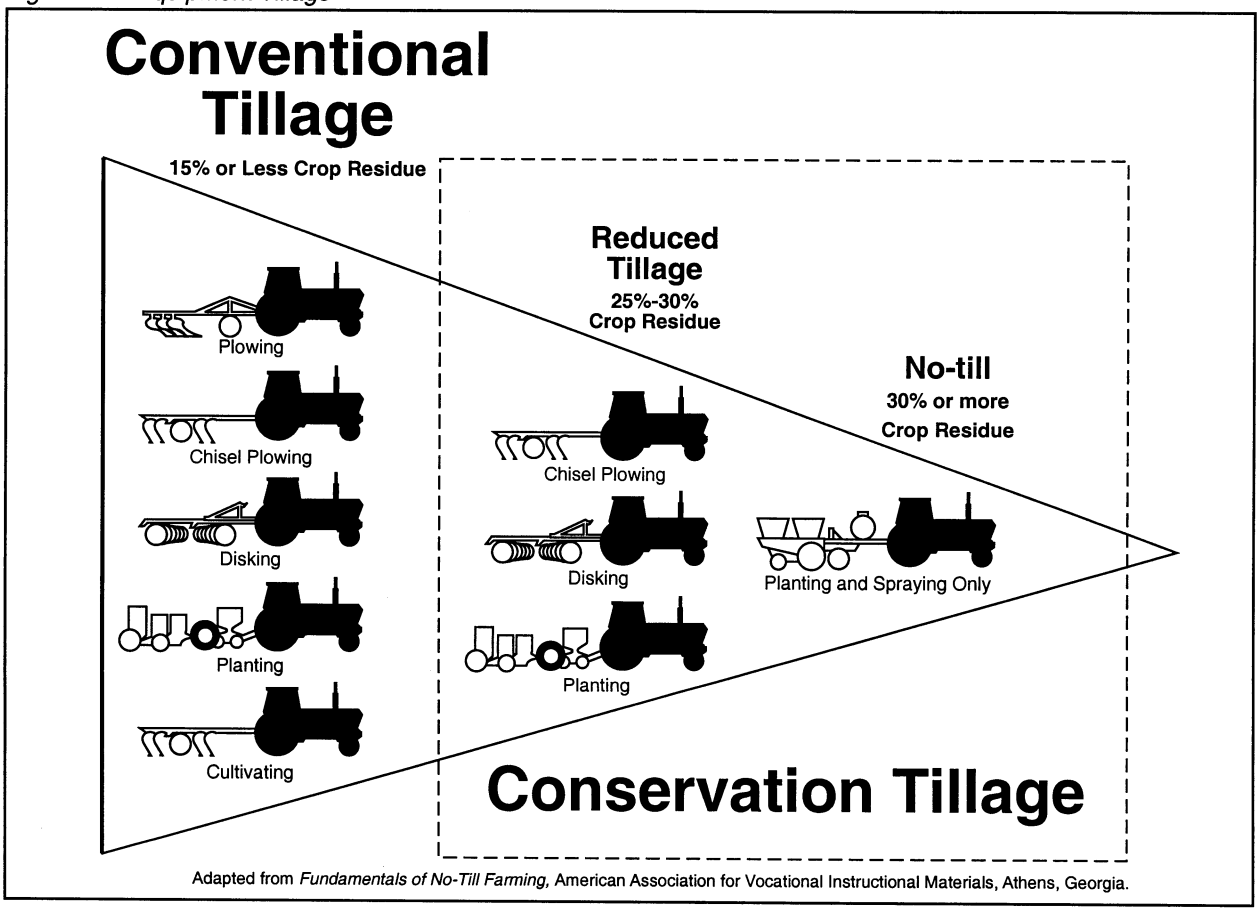
Soil is a precious natural resource. With increased farm production, the earth's soil supply is being slowly depleted. Alternative soil management practices have been tested and implemented to reduce the problem. However, to ensure the productivity and profitability of cropland, producers must continually seek ways to control soil erosion and maintain soil fertility. A key aspect of this is knowing the advantages and disadvantages of different tillage and planting methods and understanding how each of these affects the soil. With this knowledge, producers can select soil management practices that enhance and protect the soil.

Tillage Methods

Tillage, the act of moving soil particles or cultivating the land, is important in the establishment of a good crop stand. Tillage is used to prepare a suitable seedbed, eliminate weed competition, and improve the physical condition of the soil. Crop residue left on the surface of the soil acts as a protective blanket that improves surface water quality, increases the diversity of plant and animal life in a field, and reduce soil erosion. Thus, tillage practices are defined or distinguished by the level of crop residue left on the soil surface. Practices are classified as either conventional or conservation tillage. As shown in Figure 5.1, conventional tillage maintains crop residue levels of less than 15% on the surface due to the number of mechanical operations needed to plant the crop. Conservation tillage maintains crop residue levels of at least 30% because fewer operations are used to plant the crop. However, conservation tillage may be broken down into another component referred to as reduced or minimum tillage. This type of tillage will generally have a residue level between 15 and 30%.

Conventional tillage is the practice of tilling the soil using a moldboard plow, disk, or chisel plow to

Figure 5.1 - Equipment Tillage



Adapted from *Fundamentals of No-Till Farming,* American Association for Vocational Instructional Materials, Athens, Georgia.

prepare the seedbed. The method completely inverts the soil leaving the surface soil clean and smooth and promoting organic matter oxidation, the mixing of oxygen with soil to speed up the breakdown process. Conventional tillage was once the primary tillage practice in the United States, and many producers located in areas of minimal soil erosion continue to use this method.

There are several advantages to this system: (1) the machinery is familiar and widely available, (2) it is adaptable to a wide range of soil and crop conditions, (3) it allows for weed control by cultivation throughout the growing season, and (4) soil warms faster when soil residues are incorporated. Disadvantages of conventional tillage are (1) increased fuel and labor costs, (2) high erosion risks, (3) reduced organic matter, and (4) occurrence of soil compaction due to increased field traffic.

Conservation tillage is any tillage and/or planting practice designed to reduce soil erosion caused by wind or water. By minimizing soil disturbance and maintaining crop residue levels, conservation tillage increases soil organic matter and greatly reduces soil erosion. Conservation tillage acres are generally concentrated in the Midwest and Northern Plains where years of intensive farming have depleted soil resources.

Numerous conservation tillage methods provide various advantages and disadvantages; however, all forms provide a number of advantages over conventional tillage methods. Conservation tillage (1) reduces soil erosion 50 to 90% depending on the tillage practice, (2) increases water infiltration and conserves soil moisture, (3) reduces sediment runoff from reaching streams and lakes, and (4) reduces production costs with fewer trips across the field and less equipment maintenance. The disadvantages are (1) more cost is incurred with increased dependence on herbicides and specialized equipment, (2) current equipment may need modification, (3) amount and types of fertilizers and chemicals applied require specific timing and sequencing of field operations, and (4) planting time is generally delayed due to moist conditions and a cool soil temperature from the added crop residue. The most common methods of conservation tillage used in Missouri are no-till, mulch-till, and ridge-till.

The no-till method is the least disruptive form of conservation tillage. This method leaves the soil undisturbed before and after planting except for a narrow seedbed that is prepared by using a planter or drill that disturbs no more than 10% of the surface. By leaving the soil surface covered with crop residue from the previous year, soil losses from water and wind erosion are reduced, soil moisture is conserved, equipment and fuel expenses are reduced, and planting time is shortened. The no-till system requires skillful management and may cause soil compaction in the upper soil zone. A producer may encounter a greater variety of insect, disease, and weed problems because control depends upon the effectiveness and timing of limited chemical applications. Planting may be delayed because of lower spring soil temperatures and greater moisture under heavy residue. Strip-till is a specialized form of no-till that is increasing in popularity in northern Missouri. This method uses a narrow 2-inch strip cultivated in a row by a rototiller, an in-row chisel, or other row cleaner. The crop seed is planted during this tillage operation.

The mulch-till method disturbs the entire surface of the soil using tillage tools such as the chisel plow, field cultivator, or disk. The primary goal is to increase crop residue and protect soils from excessive erosion with decreased tillage and other soil-disturbing activities. More than 30% of the soil surface is covered with crop residue. Weeds are controlled by herbicides or cultivation. Mulch-till maintains sufficient crop residue to reduce surface erosion while incorporating a percentage of the crop residue into the soil. The practice applies to many types of soil, presents an easy transition from conventional tillage, and increases soil roughness and filtration. Mulch-till also allows for surface-applied fertilizer and pesticides. Some disadvantages are similar to conventional tillage: increased fuel and labor costs and more field traffic causing soil compaction. Also, some residue is buried, limiting erosion-reducing potential.

The ridge-till method has soil pushed into ridges between rows. Ridges are preserved and rebuilt during cultivation and planting that is done on the same ridge year after year. (Conventional tillage is used the first year to build the ridges.) The ridge-till method is useful on flat ground to aid in water drainage. The seedbed is prepared with sweeps, disks, or other row cleaners. Weeds are controlled by both cultivation and herbicide usage. A significant reduction in erosion is possible by ridge-till because soil sediment and crop residue

are channeled into the furrow, reducing planting interference and allowing ridges to warm up and drain faster. The added residue also helps support tractors in wet spots while still providing an ideal seedbed on the ridge. General conservation benefits include reduced evaporation and increased moisture, reduced weed pressure and soil compaction, and food and shelter for wildlife. Disadvantages include the need for special planters and attachments; wheel adjustments on applicators, tractors, and combines; and equipment turning on end rows.

An additional tillage practice referred to as subsoiling is used throughout the state except for the northeast and southwest sections. Subsoiling involves breaking up the compacted subsoil layer to help root growth extend into more fertile soil. The process requires heavy-duty equipment, additional fuel, and time but has proven beneficial when growing root crops such as potatoes. Subsoiling can be used in a no-till system because it does not disturb the topsoil. It is typically used during spring tillage but can also be used after harvest.

The tillage practice that a farmer chooses will depend on costs, location, soil type, crop, and other site-specific factors. Tillage costs money not only for equipment, but in fuel, labor, and maintenance of equipment. Reducing the number of tillage operations and tillage depth can minimize these costs. Producers needing technical assistance to select the best tillage method can contact several sources including the Natural Resources Conservation Service (NRCS), University Cooperative Extension and Outreach, The Conservation Technology Information Center, or their local soil conservation district office. Some local district offices may even have equipment available for rent.

Planting Methods

After choosing a tillage practice, the seedbed should be prepared and the field readied for planting. The planting method must then be selected to cut a seed slot at the proper depth, deposit the seed at the desired spacing, and cover the seed for germination. There are several planting methods available, but the most commonly used by producers in Missouri are row, drill, broadcast, and aerial.

With row planting, seeds are evenly spaced in parallel rows. Crops such as corn, grain sorghum, soybeans, cotton, and vegetables are planted in rows to allow for tilling of weeds and reduced herbicide costs. Rows can range from ultranarrow to wide depending on the equipment available, crop needs, and size of the seed. Seed germination rates are highest when planting in rows because the seedbed is ideal and the seed is placed in direct contact with the soil. A disadvantage to row planting is increased days until the leaves develop and provide a canopy to protect moisture levels in the soil. Also, plant population counts are limited due to spacing requirements between plants and rows.

Drilling places seeds in narrow rows at high population rates and gives a better plant distribution. Under conventional tillage methods, intensive tillage and seedbed preparation is necessary. Specialized no-till equipment can be used without tillage. Small cereal grain crops such as wheat, oats, and alfalfa are most often planted with this method. Soybeans, grain sorghum, and rice can also use the drill method. When using the drill method, attachments can be used to place fertilizer at the same time, saving time and trips across the field. Planting seeds by the drill method makes mechanical cultivation impossible and therefore increases the dependence on herbicides. A major advantage to drilling crops in ultranarrow rows is that the crop canopy (upper extended leaf-covered stems) grows together faster and limits sunlight to weeds growing below. This benefit is significant enough to reduce herbicide use. Also, most growers feel that narrower rows reduce the weed pressure and save moisture.

Broadcast planting involves scattering seeds in a random pattern across the top of the soil. This method is usually the cheapest, provides for faster canopy, helps in preventing erosion, and controls weeds. Seeds may be broadcast with a variety of equipment including pulled and hand-held seeders. Crops generally broadcast-seeded are grasses and legumes used to improve hay and pasture crops, and some small grains. Light tillage is often used to cover seeds with a thin layer of soil on conventionally tilled fields but is seldom used with conservation tillage. Poor germination may occur due to inferior seed to soil contact as well as limited crop selection due to seed size. This will result in uneven plant distribution.

Aerial planting involves randomly scattering seeds across the top of the soil by an airplane or

helicopter. It is merely a specialized broadcasting method. This method is used when the soil is too wet to till or plant by traditional methods, when the area is too rough, or where obstacles exist that hinder the use of surface equipment. It is commonly used to plant rice in flooded fields.

Effects of Tillage and Planting Methods on Soil Structure

The structure of the soil can be greatly improved or destroyed depending on the tillage and planting method selected by a producer. The soil's physical condition is affected by many factors including crop residue, soil compaction, and moisture levels. Each of these factors directly impacts the others.

Crop residue has good and bad effects on soil structure. Although it reduces erosion, residue insulates the soil, which makes it cooler and wetter. It also shifts the physical properties of the soil to a more natural state, leaving it with higher concentrations of nutrients, pesticides, and organic matter. These can in turn lower soil pH, adjust population levels of beneficial and harmful insects, and increase the roughness of the soil surface.

Soil compaction from farm equipment traffic results in soil with smaller pores and fewer channels, which reduces water infiltration. This causes greater surface wetness, more runoff, and a longer drying time. Figure 5.2 shows how soil moisture affects compaction depth. A given load and tire size cause much deeper compaction on wet soil than dry. In the past, sod-forming crops such as alfalfa and clover were usually included in crop rotations and provided greater support at the soil surface than bare soil. The trend toward continuous row cropping has eliminated sod-forming crops and therefore encouraged current soil compaction problems.

Compaction is directly affected by field machine weight, tire size, and tire inflation pressure. Machines weighing up to 30 tons not only cause compaction near the surface but also at depths unreachable by tillage. All tillage and planting systems, except aerial, require some field traffic. Choosing a tire pressure that will cause the least damage and trying to reduce field traffic are key to controlling soil compaction. Testing equipment, as shown in Figure 5.3, is available to determine how severe and how deep the compaction layer is.

Figure 5.2 - Effects of Soil Compaction

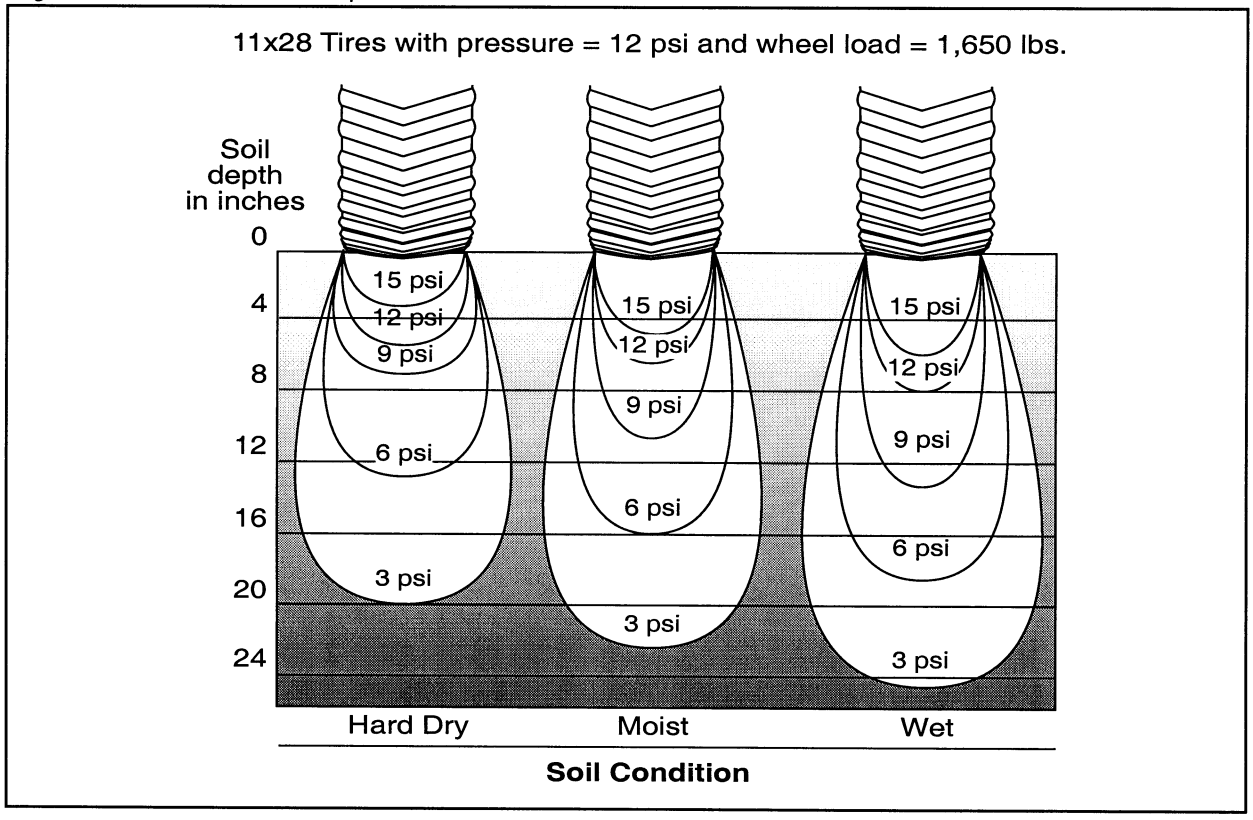
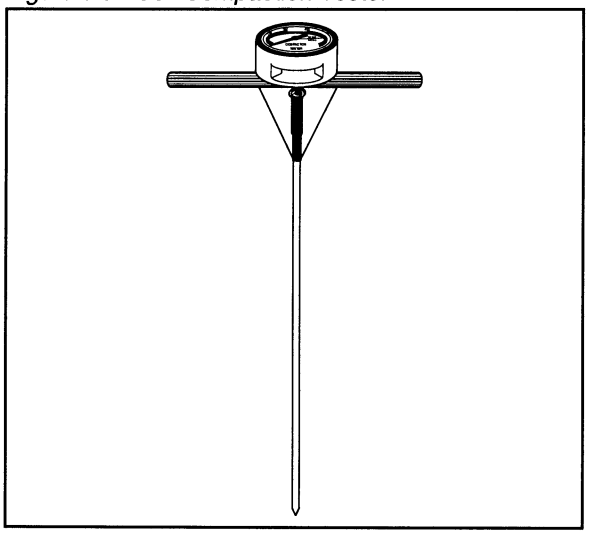


Figure 5.3 - Soil Compaction Tester



Additionally, tilling and harvesting should be avoided when the soil is wet. Soil moisture levels are affected by the amount of crop residue, the degree and depth of soil compaction, and the drying that occurs from turning over soil during tillage. Soil temperatures increase 10^0F to 15^0F in the spring during mid-afternoon at a depth of 1 inch, increasing evaporation and further reducing soil moisture levels.

Crop Rotation

Crop rotation is growing different crops in recurring succession on the same land. Crop rotations may be multiple crops in one year (six radish crops in one growing season) to multiple crops over many years (12 crops in a sequence of 18 years). Crop rotations in Missouri may commonly include corn, soybeans, wheat, oats, grain sorghum, meadow, alfalfa or other legumes, vegetables, cotton, or rice in the Bootheel region.

By rotating crops, producers can limit competition from weeds for soil nutrients. Fields planted to the same crop every year may experience severe infestations of specific weeds. This often leads to increased usage of herbicides. Crop rotations through normal tillage requirements will keep weed infestations in control and increase nutrient use for the crop.

The organic matter of the soil is greatly improved when implementing crop rotations, especially when grasses or legumes are included in the rotation. Legumes have been used in crop rotation practices for many years. Legumes have nodules located on the roots that aid in gathering nitrogen from the air and converting it into a useable form. This natural process reduces the need for commercial fertilizers by providing nitrogen for the next crop. A common example of this type of rotation is using a legume crop of soybeans followed by corn.

Soil nutrients are utilized more effectively with crop rotations. Crops differ in the amount and proportion of nutrients they require and use. One crop may require very few nutrients, while another requires several, neither dependent on the same nutrients. Carefully selecting complementary crops in a rotation leads to better use of soil nutrients.

Fertilizer utilization is also improved through crop rotation. A variety of fertilizers may be used including lime, commercial fertilizers, or biosolids, which allow a producer more options in selecting the best fertilizer for a specific crop. How and when fertilizer is applied, along with the tillage method, determine how much, if any, is available for the next crop. Crop rotation can utilize any carryover fertilizer (fertilizer that remains in the soil after a crop has been harvested) that reduces production costs and waste.

Erosion may be minimized in crop rotation practices by seeding grasses and legumes to protect erodible soils from wind and water. Conservation practices included for specific crops in a rotation will also maintain crop residues and limit erosion.

Summary

Using appropriate soil management methods is vital to crop production, profitability, and erosion prevention. The selected methods must provide a suitable seedbed as well as control crop pests. While accomplishing this, the physical condition of the soil must be maintained to ensure continued fertility and avoid additional soil depletion.

Tillage methods are classified as conventional or conservation tillage and are differentiated by how much crop residue is left on the soil. The conventional tillage method leaves less than 15% crop residue, whereas conservation tillage methods maintain at least 30% crop residue. Reduced or minimum tillage is a component of conservation tillage that leaves between 15 to 30% crop residue. The methods of conservation tillage

used in Missouri are no-till, mulch-till, and ridge-till. There are advantages and disadvantages to all tillage methods with selection based on costs, location, soil type, crop, and other site-specific factors.

Planting methods commonly used by Missouri farmers are row, drill, broadcasting, and aerial. Row planting places the seeds in evenly spaced parallel rows. Seed germination rates are high, but population counts are reduced due to spacing requirements. Drilling places seeds in narrow rows at high population rates. Because cultivation is not an option, herbicides are used to control weeds. The broadcasting and aerial methods provide faster coverage and reduced erosion; however, poor germination may occur due to inferior seed to soil contact.

Crop residue, soil compaction, and soil moisture are the primary factors altered by tillage and planting effects on soil structure. Crop residue has good and bad effects on soil structure such as reduced erosion but makes soil cooler and wetter. Soil compaction is more common due to the trend toward continuous row cropping. Compaction is directly affected by field machine weight, tire size, and tire inflation pressure. Soil moisture levels are affected by crop residue, soil compaction, and drying from tillage.

Crop rotation helps maintain the fertility of the soil and productivity of a crop. Crop rotation aids in limiting competition from weeds for nutrients. Organic matter resulting from crop rotation reduces the need for commercial fertilizers by providing nitrogen for the next crop. Fertilizer carried over in the soil from the previous crop can save the producer additional costs. Crops have to be carefully selected to complement each other and produce the best nutrients. Grasses and legumes are included in the crop rotations to minimize erosion.

Credits

Designing, Implementing, and Controlling Mulch-Till Systems. U.S. Department of Agriculture, Soil Conservation Service, Cooperative Extension Service. Booklet One. Urbana-Champaign, IL: University of Illinois. 1993.

Designing, Implementing, and Controlling No-Till Systems. U.S. Department of Agriculture. Soil Conservation Service, Cooperative Extension Service. Booklet Two. Urbana-Champaign, IL: University of Illinois. 1994.

Frisby, James C. and Donald L. Pfost. *Soil Compaction: The Silent Thief* (G1630), Columbia, MO: University Extension, University of Missouri-Columbia. 1993.

Minor, Paul E. *Soil Science* (Student Guide). Barbara Rosenfeld, Editor. Volume 27. Columbia, MO: Instructional Materials Laboratory, 1995.

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Lesson 6: Soil Conservation Practices

Selecting the proper use of farmland is the first and most important step in conserving soil. The success of all other phases of a farm's conservation program will depend on selecting a land use pattern that is within the land's capability. Soil survey maps, as discussed in Lesson 2 of this unit, contain the informational building blocks for land use planning. It is an ongoing challenge for producers to adjust their practices of tillage, planting, and fertilizing to protect our natural resources and our wildlife.

Soil Erosion

A producer's biggest challenge in soil conservation is the reduction and prevention of soil erosion. Soil erosion is the wearing away of the land surface by water, wind, ice, and other geologic agents such as earthquakes, floods, and the natural wearing away of rock. Crop producers have no control over ice or geological soil erosion. Wind erosion occurs in areas of high prevailing wind speeds and low annual rainfall.

Water is the single most destructive force to Missouri's soil, especially raindrop splash and flowing water. Soil erosion by water occurs in two steps: (1) the detachment of the soil particles and (2) the transporting of those particles. The first step is caused by a raindrop splash or impact. As indicated in Figure 6.1, a drop of rain is a high-energy force falling as fast as 20 mph that can splash more than 2 feet high and 5 feet to the side. In the second step, soil particles are carried off by flowing water on the soil surface. The goal of soil conservation practices is to interrupt one or both of these steps.

Figure 6.1 – Raindrop Impact



Water erosion falls into three main categories: sheet, rill, and gully. Sheet erosion is defined as the uniform removal of soil from an area by raindrop splash or water runoff. Water moves across the field surface at a very shallow depth and the soil is removed in thin layers or sheets. When sheet erosion occurs, the soil is removed in such thin layers that it is often unnoticed.

Rill erosion occurs primarily in recently tilled fields where runoff water forms into small, well-defined channels. The channels are typically less than 12 inches deep and can be easily filled in by tillage.

Gully erosion occurs where trenches are cut to a depth greater than 12 inches. In general, ditches that are too deep to cross with farm machinery are considered gullies. These gullies can range from a depth of 1 to 100 feet. They develop where steep, erodible land has been farmed. Gullies also develop when water concentrates in areas where the vegetative cover has been disturbed, such as livestock trails, field roads, or plow furrows.

Wind erosion, unlike water, cannot be divided into distinct types. Occurring mostly in flat, dry areas and moist, sandy soils along bodies of water, wind erosion removes soil and natural vegetation. It causes dryness and deterioration of soil structure. All mucks, sands, and loamy sands can easily be detached and blown away by the wind. Regular loams, silt loams, clay loams, and clay are not damaged by the wind, but on wide, level plains, there may be a loss of fine silts, clays, and some organic matter.

Factors Contributing to Soil Loss

Reducing soil erosion is important to maintaining healthy soil. Healthy topsoil is the foundation in which plants' roots take hold. Topsoil also contains nutrient-rich organic matter that serves as plant food. The topsoil that is carried away by erosion can cause other environmental problems by impairing air and water quality. When soil washes off a field, it may flow into a lake or stream and impose economic and health risks by lowering the quality of a community's water system. Topsoil loss on cropland in Missouri averages about 5.5 tons per acre per year. This is a significant decrease from the 1987 figures of 10 tons per acre per year. This decrease is a result of government conservation programs and adoption of residue management systems.

Six factors generally contribute to soil loss from water erosion: rainfall, soil erodibility, slope length, slope degree, cropping practice, and conservation practices. The Universal Soil Loss Equation (USLE), developed by the U.S. Department of Agriculture (USDA), is used to calculate these factors that contribute to sheet and rill erosion. The equation is A=RKLSCP with A being the computed soil loss per unit area.

The rainfall factor (R) is a measure of rainfall energy rather than just rainfall. A short, intense 4-inch rainstorm will cause much more erosion than a slow, steady 4-inch rain. Southern portions of Missouri are more prone to having heavy thunderstorms that create more rainfall energy and hence erosion problems.

The soil erodibility factor (K) is a measure of the soil's relative resistance to erosion. Sandy soil particles are easily detached by rain drop impact but are not easily transported due to their large size. In addition, water infiltration is high, which increases runoff from the site. Therefore, soil erodibility for sandy soil is low. Clay soils are held together with chemical bonds that are not easily broken by the erosion process; any free particle is small enough to be subject to erosion when broken free of the bonding. This makes clay soils moderately erodible. Silt soil particles are not chemically bonded so detachment and transportation by water erosion is quite easy. Therefore, silty soils are highly erodible.

Slope is the inclination of the land surface from each 100 feet of horizontal distance. The slope length (L) and slope degree (S) factors influence the amount of runoff and the rate of water infiltration. Table 6.1 indicates the classification categories for determining slope. Erosion increases sharply when either slope length or steepness increases. In steep areas, runoff is rapid and very little water passes through the soil, leaving it less fertile. In areas with a more gentle slope, runoff is slow, erosion is minimal, and most of the water passes through the soil. Slope length and gradient need to be considered together. For example, a steep slope may not be a concern if the length is only 5 feet. However, a gentle slope of 3% may be a concern if the slope length exceeds 200 feet. Additionally, the shape of a slope, whether concave, continuous, or convex, will affect the soil erosion that occurs. Sheet and rill erosion will more likely occur on a convex slope than on a concave or continuous slope. Slope percentage is determined by dividing the slope's vertical distance by the horizontal distance, then multiplying by 100.

$$\text{Slope percentage} = \frac{\text{Vertical distance}}{\text{Horizontal distance}} \times 100$$

Table 6.1 - Slope Classification

Classes	Description	% of Slope
Nearly level	Flat or nearly flat	Less than 2%
Gently sloping	Slopes very gently and usually has no abrupt changes	2 – 5%
Moderately sloping	Considerable slope and usually some irregularity	5 – 9%
Strongly sloping	Has considerable irregularity	9 – 14%
Moderately steep	Breaks sharply	14 – 25%
Very steep	Slopes very abruptly	More than 25%

The crop practice factor (C) determines if there will be soil cover from prior crops. Any crop that covers the soil during at least part of the year will reduce the erosion occurring on that soil. Crop practice factors include tillage practices, vegetative cover, crop rotation, fertility level, crop residue management, and any other factors that will have an effect on erosion.

The conservation practice factor (P) is a management tool that changes the flow pattern of water runoff on the soil and further reduces the effects of erosion, such as terracing, contouring, strip-cropping, and minimum tillage.

A factor not given in the USLE is the soil loss tolerance factor (T). This factor indicates the amount of soil that can be lost each year without seriously reducing productive capability. For the numerical equivalents of these USLE factors, NRCS personnel use special charts and information such as shown in Table 6.1. With this information, the actual soil loss of a specific site can be determined. Although soil erosion can never be stopped, good management practices, along with soil replenishment through natural regeneration, can control erosion to a tolerable productivity level.

Management Practices

The appropriate erosion control management practice for a specific field or farm can be determined by an on-site inspection. The NRCS provides technical assistance to guide producers in the installation of conservation management practices. Individual conservation plans are based on recommendations from soil maps that have been interpreted according to the information in soil survey reports.

The basic goal of conservation practices is to give the soil more protective cover or to shorten a slope to reduce the speed of the flowing water. Soil loss from a field with good grass or legume cover is very minimal. When sod or legumes are tilled under, the residue helps improve water absorption and retention capacity of the soil, thus reducing its erodibility. Figure 6.2 illustrates and defines conservation practices approved and recommended by the NRCS.

Residue management leaves the past year's crop residues on the soil surface to reduce erosion. It is most effective when high residue-producing crops are used in the crop rotation and tillage passes are kept to a minimum. Chisels and disks should be set to a shallow work level to keep the residue at tillage depth. No-till planting is recommended because it disturbs only residue in the row.

Contour farming is preparing the soil, planting, and cultivating crops around a slope, rather than up and down the slope. The row pattern of the contours is dependent on the lay of the land (the shape and steepness of the slopes). It is most effective on slopes of 2% to 8%. Contour farming reduces erosion, controls runoff water, and increases moisture infiltration. If rainfall amounts exceed the ability of the contours to remove the runoff, erosion can increase. Therefore, it is important to use this practice in conjunction with other conservation practices.

Cross slope farming is to farm across the slope. It allows deviation from the contour line and provides an option for slopes that are very difficult to farm. However, it is not as effective at saving soil as contour farming.

Contour strip cropping is a system of growing crops on the contour in approximately even-width strips or bands. Crops are arranged so that a strip of row crop is alternated with a strip of meadow or close-growing crop. To be most effective, no more than half a field should be planted in a row crop in any 1 year.

Contour buffer strips alternate contoured perennial vegetation strips, which are at least 15 feet wide, with wider cultivated bands. The vegetation will slow runoff and trap sediment. Buffer strips are the most effective when used with conservation tillage and crop rotation.

Field borders planted with grass or legumes stop erosion on end rows. The field border should be at least 16 feet wide. The border is useful as a turn row and often qualifies as set-aside acres.

Crop rotation involves growing crops on the same land in an orderly sequence, including row crops, grasses, and legumes. Crop rotation provides soil cover to help reduce erosion and improve soil fertility. The effect on soil erosion will depend on the land capability, the crops used, how they are grown, and how the residue is managed.

Terraces are earthen embankments designed to slow down and catch runoff on moderate to steep slopes. Terraces allow soil particles to settle without forming erosion channels. They should fit the contour of the land with spacing determined by the soil type, slope, and tillage practices used. Types of terraces include the storage terrace and the gradient terrace. Storage terraces collect and store water until it can penetrate into the ground or release through underground outlets. Gradient terraces slow runoff water and channel it to a grassed waterway.

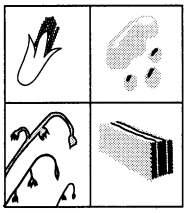
Water and sediment control basins are used in areas not suited to terrace systems. Short earthen dams are built across the slope and minor drainage ways. The basins trap sediment, reduce gully erosion, and reform the land surface. Basins should be used in combination with conservation tillage, crop rotations, field borders, and cross slope farming.

A diversion is a channel or ridge similar to a terrace that diverts excess runoff from an area. The runoff is directed for use or safe deposit in another area. Diversions are useful to divert water from cropland, farm buildings, feedlots, or active gullies.

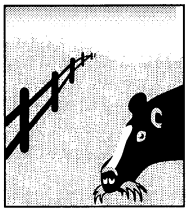
Figure 6.2 – Soil Conservation Practices



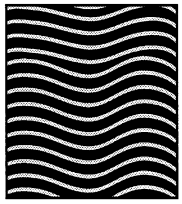
Residue Management
Protecting the soil from erosion by limiting tillage to leave last year's crop residue on the soil surface. Includes no-till, mulch-till, and ridge-till.



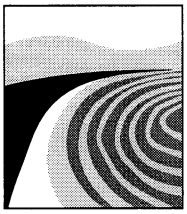
Crop Rotations
Changing the crops grown in a field, usually year by year.



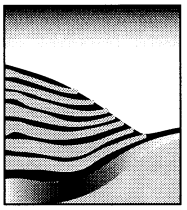
Planned Grazing Systems
Using grassland efficiently, considering food, water, and herd size.



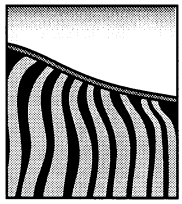
Contour Farming
Making one long slope into hundreds of small slopes by farming nearly level around the hill-not up and down hill.



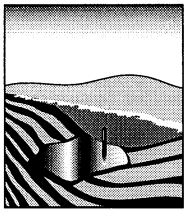
Terraces
Earthen embankments around a hillside that stop water flow and store it or guide it safely off a field.



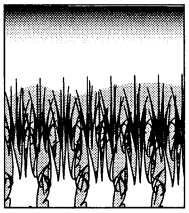
Filter Strips
Bands of grass or legumes that filter runoff and other contaminants before they reach water bodies or sources.



Cross Slope Farming
Farming across the slope, nearly on the contour.



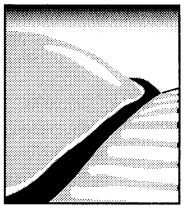
Water and Sediment Control Basins
Short earthen dams built across a drainageway; used where terraces are impractical.



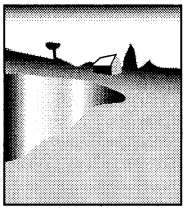
Cover Crops
Close-growing crops that temporarily protect the soil where major crops don't provide cover.



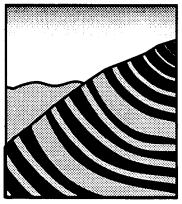
Contour Stripcropping
Combination of crop rotation and contouring. Equal width strips of corn, beans, oats, grass or legumes planted on the contour.



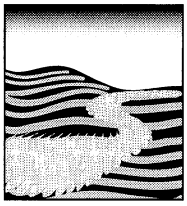
Diversions
Earthen embankment similar to a terrace that diverts runoff water from a specific area.



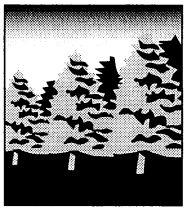
Farm Ponds
Formed by a dam or pit, farm ponds supply water for livestock and control gully erosion.



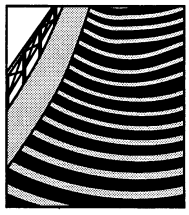
Contour Buffer Strips
Bands of grass in a contoured field, similar to stripcropping.



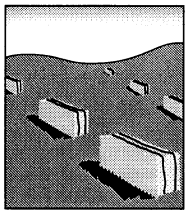
Grassed Waterways
Shaping and seeding a natural drainageway to prevent gullies from forming.



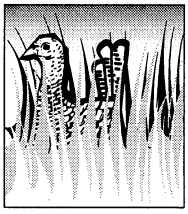
Windbreaks
Rows of trees and shrubs that protect areas from wind and provide food and cover for wildlife.



Field Borders
A band or grass or legume at the edge of a field used in a place of end rows.



Pasture, Hayland Planting
Establishing grass or legume for pasture or harvesting hay.



Wildlife Upland Habitat
Establishing a variety of food and cover suitable for wildlife.

Grassed waterways are grassy areas where flowing water gathers and is slowed as it is guided off the field. The waterway should begin slightly above the point where the gully begins and end where it spreads out into the field. End rows should not be planted along the waterway.

Pasture and hayland planting build topsoil and organic matter, making the soil better for crop growth. Disease, insect, and weed cycles that occur with continuous row crops are disrupted, reducing the need for pesticides.

A planned grazing system allows a resting time between two or more grazing areas in a planned sequence. Grazing affects both the plants and the soil in pastures. Continuous grazing reduces plant growth and results in pasture deterioration. Rotational grazing lets the soil rest, and the plants are allowed to grow and multiply. Improved grass reduces soil erosion, increases livestock production, and improves water quality.

Filter strips are strips of vegetation that can be used on cropland lying next to streams, ponds, and lakes. The strips remove sediment, organic matter, and other pollutants from runoff before reaching the waterways. The vegetation strips should be a minimum of 15 to 25 feet wide.

Cover crops can be planted to control soil erosion during periods when the major crops do not furnish enough ground cover. They are often seeded in the fall to protect the soil until the next spring's planting. They may also add organic matter to the soil and trap excess plant nutrients. Close-growing grasses, legumes, or small grains are examples of cover crops.

Farm ponds control gully erosion and provide water for livestock. Ponds are also considered a conservation practice that enhances wildlife habitat by providing a water source for birds and animals. Ponds can be developed by building a dam or digging a pit. A pond should be located in an area that has a dependable source of noncontaminated water, is protected from silt deposits, has a proper outlet, and has appropriate capacity and storage.

Windbreaks are a row of trees and shrubs planted to protect the soil, conserve energy, control snowdrifts, give shelter to livestock, and provide food and shelter for wildlife. Windbreaks should be planted on the north and west sides of the area to be protected. Space should be left downwind of plantings for air circulation. A variety of tree and shrub species will lessen the chance of total loss from drought, insects, or diseases.

Enhancing Wildlife Habitats

Conservation practices that reduce soil erosion can also be an effective means of enhancing wildlife habitats. Although the specific needs of each type of wildlife vary, the three basic components needed to sustain wildlife are water, food, and cover.

Cropland that uses conservation tillage methods produces crop residue that feeds and protects wildlife. Waste grain and weed seeds left after harvesting are staple foods for wildlife in winter. Crop rotation practices provide plant diversity, nesting cover, and food for wildlife. Planned rotations should include residue producing crops, small grains, or a grass/legume meadow. A wildlife food plot established within an existing crop field can help wildlife through the winter when food supplies are short. It may be as simple as leaving four rows of corn standing after harvest to provide food over the winter.

Grassland areas created for soil erosion control provide food, water, and cover areas for wildlife. Contour strip cropping, contour buffer strips, field borders, terraces, water and sediment control basins, diversions, grassed waterways, pasture and hayland planting, planned grazing systems, filter strips, and cover crops all include grassland areas that can be seeded to a grass/legume mixture that is beneficial to wildlife. These grassland areas provide nesting and roosting cover and, if possible, should not be mowed until mid-July.

Idle lands such as field borders, fence rows, turn-rows, and areas around farm ponds can be planted to warm-season grasses and other grasses such as redtop and timothy. These areas can serve as valuable nesting, brood rearing, and concealment cover for wildlife. These grasses may be cut in July when the adjoining crops provide cover. These areas should be protected from livestock grazing.

The NRCS provides recommendations to landowners for implementing conservation practices that support wildlife as well as crops and livestock. In many cases, federal or state cost-share funds are available for installing conservation practices.

Summary

Erosion removes vital topsoil and lowers the basic productivity of the land. When evaluating soil loss for a specific area of land, the factors to consider are rainfall, soil erodibility, slope length and degree, crop practice, and conservation practice. All of these factors must be considered when determining the appropriate soil conservation methods that are most suited for the soil. The Natural Resources Conservation Service assists

landowners to determine the most appropriate conservation practices to reduce soil erosion and maintain the fertile topsoil necessary to produce crops. Conservation practices that reduce soil erosion can also be an effective means of enhancing wildlife habitats.

Credits

Conservation Catalog for the 1990's. USDA Soil Conservation Service. Des Moines, IA, October 1991.

Humphrey, John Kevin. *Crop Science* (Student Reference). University of Missouri-Columbia: Instructional Materials Laboratory, 1995, Lesson 6.

Pitts, David E. and William McGuire. *Wildlife Management for Missouri Landowners.* Conservation Commission of the State of Missouri, 1991.

Lesson 1: Crop and Weed Identification

Crop fields include a variety of different plant species. The ability to identify crop and weed seeds and plants is necessary to effectively manage crop production. Weeds rob crops of sunlight, nutrients, and water that are needed for proper crop growth and development. To effectively control weeds, early detection is necessary. Unfortunately, weeds are not always easy to identify. In Unit I, plants were identified by their uses. In Unit II, plants were identified by their life cycle. In this lesson, the concept of identifying seeds and plants by their general physical characteristics is discussed.

Plant Type and Characteristics of Crop and Weed Plants

In plant type classification, plants are categorized according to their physical characteristics. Each species within a plant type has characteristics similar to other species of the same plant type. Four different plant types are found in most crop fields, grasslands, and ranges. The plant types include (1) grasses and grasslike plants, (2) legumes, (3) forbs, and (4) woody plants. Detailed discussion of these plant types can be found in the *Crop and Grassland Plant Identification Manual.*

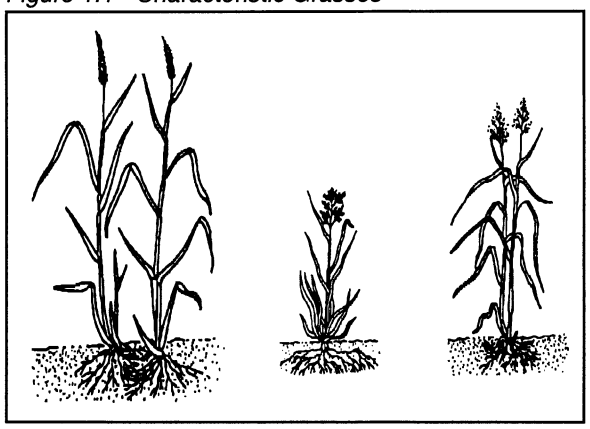
There are five main characteristics used to identify crop and weed plants. These characteristics include (1) leaf shape, (2) stem, (3) flower, (4) root, and (5) other characteristics. Differences in leaf characteristics are the most variable in number compared to any other part of the plant. Leaves can be identified by leaf parts, arrangements, types, shapes, margins, tips, venations, and base shapes.

Characteristics of Grass and Grasslike Plants

Grasses are one of the four dominant plant types found in crop fields, grasslands, and ranges. They serve many purposes such as food for humans (cereal grains), livestock (grains and forage), and erosion prevention. Common field crops that are considered grasses include corn, rice, wheat, and barley.

The grasses of the Midwest are herbaceous, or without woody stems. The stems are usually hollow and resist compaction. Leaves or blades connect directly to the stem at the sheath, which surrounds the stem. All leaf blades have distinctive parallel venation in which the veins run side by side along the length of the blade of grass. These visual characteristics make it possible to separate the grasses from the other plant species. Figure 1.1 shows characteristic grasses.

Figure 1.1 - Characteristic Grasses

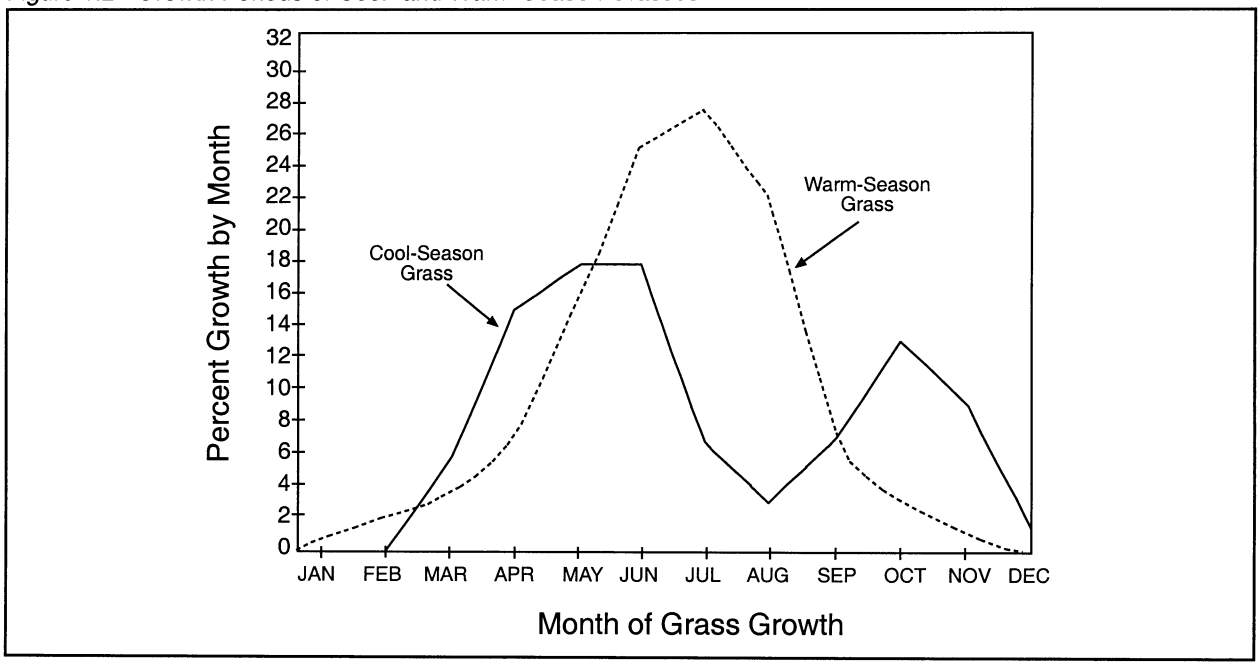


The two major groups of grasses are cool season and warm season. Cool-season grasses tend to grow best during the spring and fall. These plants begin their growing season when the soil temperature reaches 40°F, but optimum growth occurs when air temperatures increase from 59 to 77°F. They may remain green all winter, but during the summer months they tend to become brown and dormant. They may be annuals or perennials. Examples of cool-season grasses include Kentucky bluegrass, orchardgrass, and smooth bromegrass.

Warm-season grasses are just the opposite; they grow best during periods of warm temperatures. These grasses are more tolerant of heat and drought than cool season grasses. Their growing season begins when soil temperature reaches 60°F, and they grow best during the summer when temperatures range from 77 to 104°F. They are dormant in the winter and do not begin to turn green until late spring or early summer. They also may be annuals or perennials. Some examples of warm-season grasses are indiangrass, big bluestem, and switch grass.

Missouri has the right climate and amount of rainfall necessary for both cool-season and warm-season grasses. Figure 1.2 shows how the growth periods of these two grass types complement each other and extend the length of crop production in the state of Missouri.

Figure 1.2 - Growth Periods of Cool- and Warm-Season Grasses



Characteristics of Legumes

Legumes and grasses are the dominant plant types found in crop fields, grasslands, and ranges. Both are used as forage crops and are beneficial to agricultural production. Figure 1.3 shows characteristics of common Missouri legumes. Examples include soybeans, alfalfa, clovers, and birdsfoot trefoil.

Legumes have several identifying characteristics. One characteristic is the fruit or pod legumes produced. This pod has one chamber with seeds lined in a single row. The seed number and size vary for different plants. All legumes have leaves alternating in stem arrangement and connecting to the stem by a stalk called a petiole. Unlike the grasses, venation in a legume consists of a network of veins instead of veins that run parallel to each other. Legumes may be annuals, perennials, or biennials.

Most legumes have the unique ability to take nitrogen from the air between soil particles and change it into a form of nitrogen plants can use. This process is known as nitrogen fixation and is

Figure 1.3 - Characteristic Forage Legumes

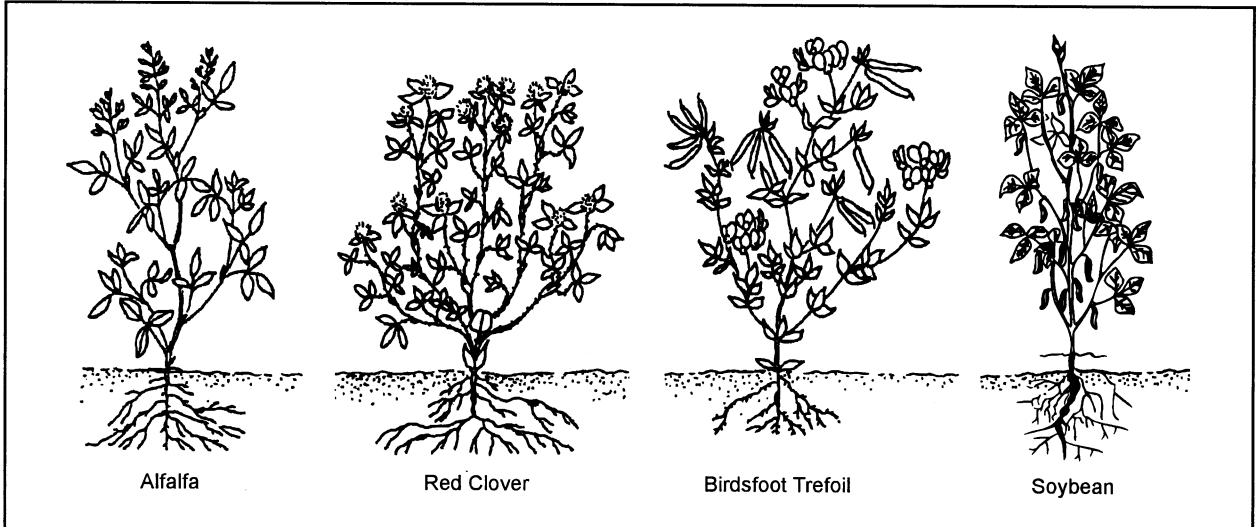
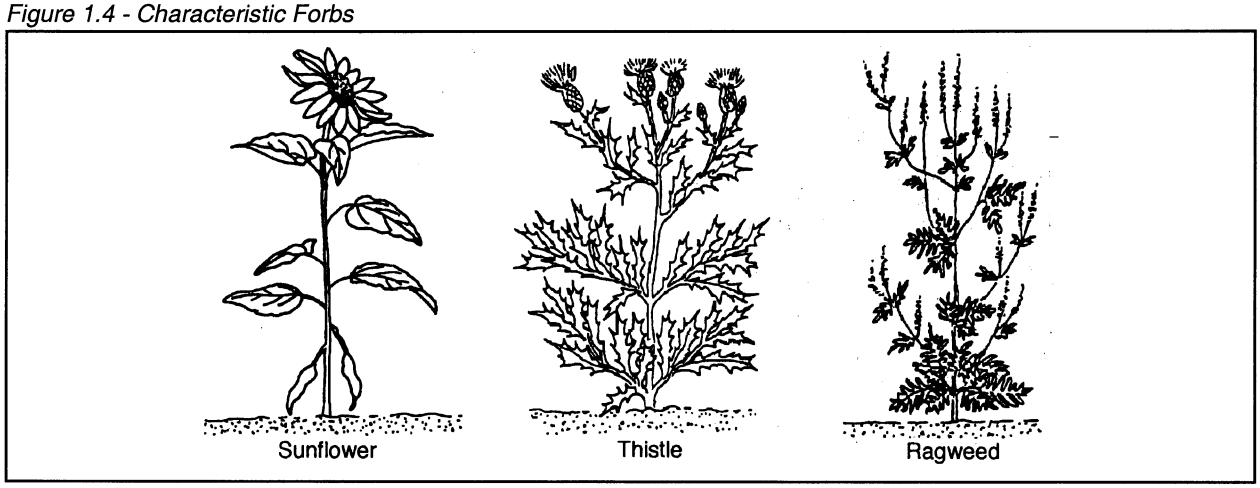


Figure 1.4 - Characteristic Forbs



conducted by symbiotic bacteria found in nodules on the roots. Nitrogen decreases fertilizer needs, reduces costs, increases yields, and enriches the soil.

Characteristics of Forbs

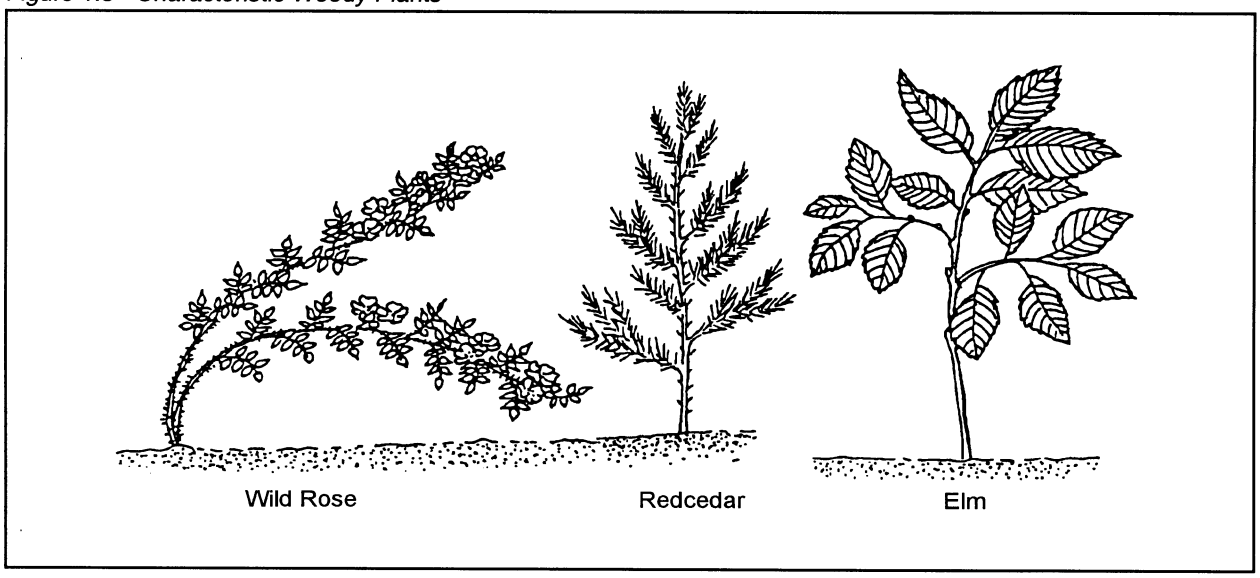
Herbaceous (not woody) plants that are neither grasses nor legumes are forbs. Most forbs are broadleafed, making it possible to distinguish them from grasses or grasslike plants. With the exception of cotton and tobacco, forbs are not usually cultivated for agricultural production, but they commonly appear in pastures, fields, and native plant habitats. Many forbs have value as wildlife food and cover or for prevention of soil erosion. Others are considered noxious weeds. Forbs may be annuals, perennials, or biennials.

Examples of forbs, sunflowers, thistle, and ragweed, are pictured in Figure 1.4.

Characteristics of Woody Plants

Woody plants are probably the easiest plants to identify in grassland because of their tough, woody (nonherbaceous) stems. They are either shrubs, vines, or trees. Woody trees found in grasslands are usually immature due to the nature and use of the grassland. They are kept small by animals grazing on terminal branches, fires that stunt growth, mechanical cutting, or chemical treatments used to maintain the grassland. Woody plants are all perennials. Woody plants found in grasslands include wild rose, red cedar, and elm, as shown in Figure 1.5.

Figure 1.5 - Characteristic Woody Plants



Characteristics of Common Weed Plants

Weeds cause loss of and damage to crops and cost American producers millions of dollars each year. These losses increase production costs and reduce profit. Weeds also serve as hosts to insects and diseases. The presence of weeds in a field can weaken crop plants, making them more susceptible to diseases. Certain weeds can also be harmful to animals and people, causing severe illness and even death when eaten. Steps have been taken to properly identify and classify weeds posing health problems. Three classifications of weeds are common, noxious, and prohibited. Numerous common weed plants with new species variances are identified constantly.

Common weeds are all weeds not classified as noxious or prohibited. These weeds are relatively easy to control, but they interfere with agricultural production by reducing crop yields and increasing production costs. Common weeds include both perennials and annuals, as well as forbs and grasses. Additional information on a plant's life cycle, height, and where the plant is most commonly found is also helpful in plant identification. Examples of common weeds include cocklebur, morning glory, ragweed, milkweed, and velvet leaf. Refer to the *Crop and Grassland Plant Identification Manual* for detailed characteristics of common weed plants. They can also be found in IML's *Crop Science* reference.

Characteristics of Noxious Weed Plants

A noxious weed crowds out desirable crops, robs them of plant nutrients and moisture, and causes extra labor in cultivation. In an effort to control the spread of noxious weed plants, these seeds in agricultural crop seed are restricted in Missouri. Noxious weeds can include perennials, biennials, and annuals, as well as forbs and grasses. The characteristics of noxious weeds in Missouri are summarized in Table 1.1

Certain "growing" plants in Missouri are listed by the Missouri Department of Agriculture as being on the state noxious list of weeds. Those weeds listed as noxious include musk, Scotch, and Canada thistles, multiflora rose, bindweed, purple loosestrife, marijuana (*cannabis sativa*), and Johnsongrass. It is, however, left to the county weed board to determine which weeds will be listed as noxious in its county. Therefore, there are several variances across the state. Complete information may be obtained by reading the state statutes beginning with 263.190.

Characteristics of Crop and Weed Seeds

Seed identification is important for seed selection and weed control. The Bureau of Feed and Seed administers laws and regulations to ensure that seeds are labeled consistently and accurately. Weed seeds include the seeds of all plants generally recognized as weeds within the state and include noxious and prohibited seeds.

Some seeds vary greatly, whereas others are very much alike. The five characteristics used in seed identification are size, shape, color, surface markings, and other botanical characteristics. Review IML's *Crop Science* Student Reference to identify the characteristics of common crop and weed seeds.

Restricted Noxious Weed Seeds

When identifying "seeds," refer to the Missouri Seed Law and Regulations for current information concerning weed seeds listed as noxious. As determined by law, restricted noxious weed seeds are defined as highly objectional in fields, lawns, or gardens of Missouri and are difficult to control by good cultural practices. Noxious weeds must be listed on the seed label sold by seed companies as none or zero, or must be expressed in numbers per pound by the maximum allowed tolerance as outlined in the *Missouri Seed Law and Regulations* manual. Noxious weed seeds in Missouri include red sorrel, curly dock, dodder, buckhorn, black nightshade, giant foxtail, hedge bindweed, leafy spurge, hoary cress, purple moon flower, quackgrass, Russian thistle, slender oats, wild garlic, wild onion, wild oats, and yellow star thistle.

Restricted Prohibited Weed Seeds

Restricted prohibited weed seeds are defined by law as the seeds of weeds that when established are highly destructive and difficult to control in this state by good cultural practices.

According to current *Missouri Seed Law and Regulations*, the following weed "seeds" are listed as prohibited in Missouri. They are balloon vine, Canada thistle, field bindweed, Johnsongrass, musk thistle, serrated tussock, and sorghum almum. Each state determines its own prohibited

Table 1.1 - Characteristics of Noxious Weed Plants

Weed Plant	Life Cycle	Plant Height	Leaves	Stem	Flower	Root
Canadian Thistle	perennial	2 - 5 ft.	crinkled edges and spiny margins	grooved, slightly hairy	male and female on different plants, usually numerous and compact, 1.9 cm or less diameter	extend several feet down and horizontally
Musk Thistle	biennial	3 - 6 ft.	alternate, coarsely toothed	erect spiny wings lower portion branched	heads as much as 2" across, drooping, purple to lavender	large thick root stock
Scotch Thistle	biennial	6.5 ft.	inversely lance shaped, lobed margins	winged at the bases of leaves, 2 " broad	globe shaped, 1-2" diameter, reddish purple	
Multiflora Rose	perennial	4 - 6 ft.	compound, pinnate with three to nine leaflets	green or brown with many prickles	large bulbous flower bud, small green leaf buds	
Field Bindweed	perennial	2 - 7 ft.	ovate with spreading basal lobes	smooth, slender, twining or spreading over ground	white or pink, funnel-shaped 2.5 cm across, single in the axis of the leaves	extensive down 20 - 30 feet
Johnsongrass	perennial	1.5 - 6 ft.	alternate, simple, smooth, 6-20" long 1/2-1 1/2" wide	erect, stout	panicles-large, purplish, hairy	freely branching, fibrous, rhizomes, stout, creeping
Purple Loosestrife	annual	1 - 4 ft.	narrow, 1/2 " wide, 1-4 " long	four-angled, branch extensively	four petals, bright rose or whitish	
Marijuana	annual	2 - 10 ft.	palmately divided, 5-9 hairy leaflets w/notched edges	coarse, somewhat grooved, rough, and hairy	male and female on separate plants	branched taproot

seed list (seeds that are not to be included in seed sold in its state). This indicates it does not want these plants in its state. It is interesting that one eastern state (Maryland) has fescue and certain varieties of bluegrass on its prohibited list. Seed companies must design seeds to certain state specifications.

Summary

By understanding plant types and their life cycles, producers can manage their pastures and fields for many purposes. Crops may be annuals, biennials, or perennials; they may also be grasses legumes, forbs, or woody plants. To effectively manage crop production levels, the producer must have the ability to identify noxious and prohibited plants and weed seeds.

Credits

Growers Weed Identification Handbook (Publication 4030). Cooperative Extension. University of California, Division of Agriculture and Natural Resources, 1991.

Humphrey, John Kevin. *Crop Science* (Student Reference). Columbia, MO: University of Missouri-Columbia: Instructional Materials Laboratory, 1992, Lesson 3.

Missouri Seed Law and Regulations. Missouri Department of Agriculture, Bureau of Feed and Seed Plant Industries Division, Jefferson City, MO, January 1998.

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Lesson 2: Crop Selection

When producers are choosing what crops to produce, there are many factors that need to be considered. This lesson will discuss growing regions, maturity groups, economic factors, and management practices that are determining factors in crop selection.

Crop Selection

When selecting a crop to produce, several factors must be considered before making a decision. The greatest influencing factor is climate. Climate includes annual rainfall and temperature. Crops requiring an abundance of rainfall would not be considered in arid areas unless irrigation was an option. For example, rice would not be planted in the southwest region of the United States because of the lack of rainfall. In addition, many crops are tolerant to very warm temperatures but some are not. For example, winter wheat is generally not planted in the southeast region of the United States. The weather and climate of the Midwest are generally the most appealing to the production of row crops including corn, wheat, and soybeans. Rice and cotton are more suited to the climate of the southeastern portion of the United States.

Soil conditions are another consideration. Soil conditions include the soil type and fertility of the soil. Soil test recommendations are made based on crops that are conducive to existing nutrient supplies and fertilizer recommendations.

Field history is important in selecting a crop for production. Past rotations and current cropping options are important. A field currently sown to grass would require extensive herbicide and tillage if one chose to plant a row crop, or vice versa. Current cultural and biological conditions concerning insects, diseases, and weeds must be evaluated as well.

Equipment resources often help the producer select a crop. If a crop required specific equipment to plant and harvest and the producer did not own or have access to the equipment, the crop would probably not be considered.

Economic demands of producing a crop are often the deciding factors for the producer. Input costs such as fuel, seed, herbicides, pesticides, and fertilizers can become very expensive depending on the type of crop considered. Producers must continually monitor different crop values to determine if the market value of the crop is greater than the input costs. Crops with little value or demand are generally not considered if the possible income from the crop does not cover the cost of production. Furthermore, if a crop was produced for livestock feed, it should be a good nutrition source for the animal.

Market access is important for producers to consider in selecting a crop to produce. The cost of transporting the crop to the nearest market generally is of greatest importance in regard to market access. It is unlikely a producer would opt to raise cotton if a gin was not found locally.

Growing Regions

Growing regions across the United States for specific crops are generally determined by temperature, rainfall, and soil composition. Each of the major crops needs optimum conditions in these three areas for proper growth. States considered to be in the "wheat" or "corn" belt have conditions of temperature, rainfall, and soil types that make it ideal for their growth.

Common agricultural crops are divided into cool-season and warm-season plants. Cool-season plants survive mild spring frosts and may be planted early in the spring or late in the fall. Examples of cool-season crops include wheat, oats, barley, rye, and fescue. Warm-season crops include corn, soybeans, cotton, grain sorghum, as well as truck garden crops of watermelon, tomatoes, and peppers. Examples of planting dates to avoid frost damage for warm season crops are illustrated by Figures 2.1 and 2.2.

Growing regions with specific amounts of annual rainfall also determine the type of crop selected for a specific region. Table 2.1 below gives examples of the amount of annual water usage of crops.

Table 2.1 - Annual Water Usage

Crop	Inches/year
Corn	23 - 28
Soybeans	20 - 25
Grain sorghum	18 - 23
Winter wheat	16 - 18
Alfalfa	31 - 36

Figure 2.1 - Average Spring Frost Dates

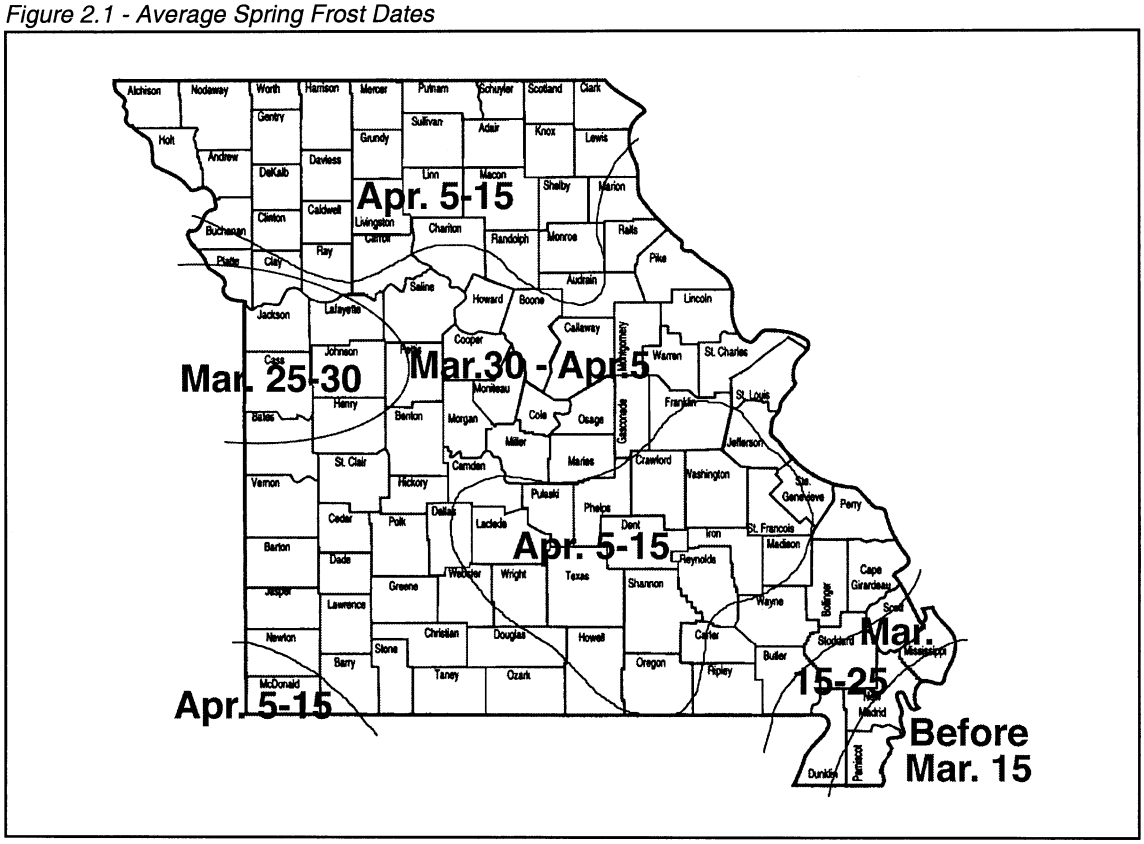
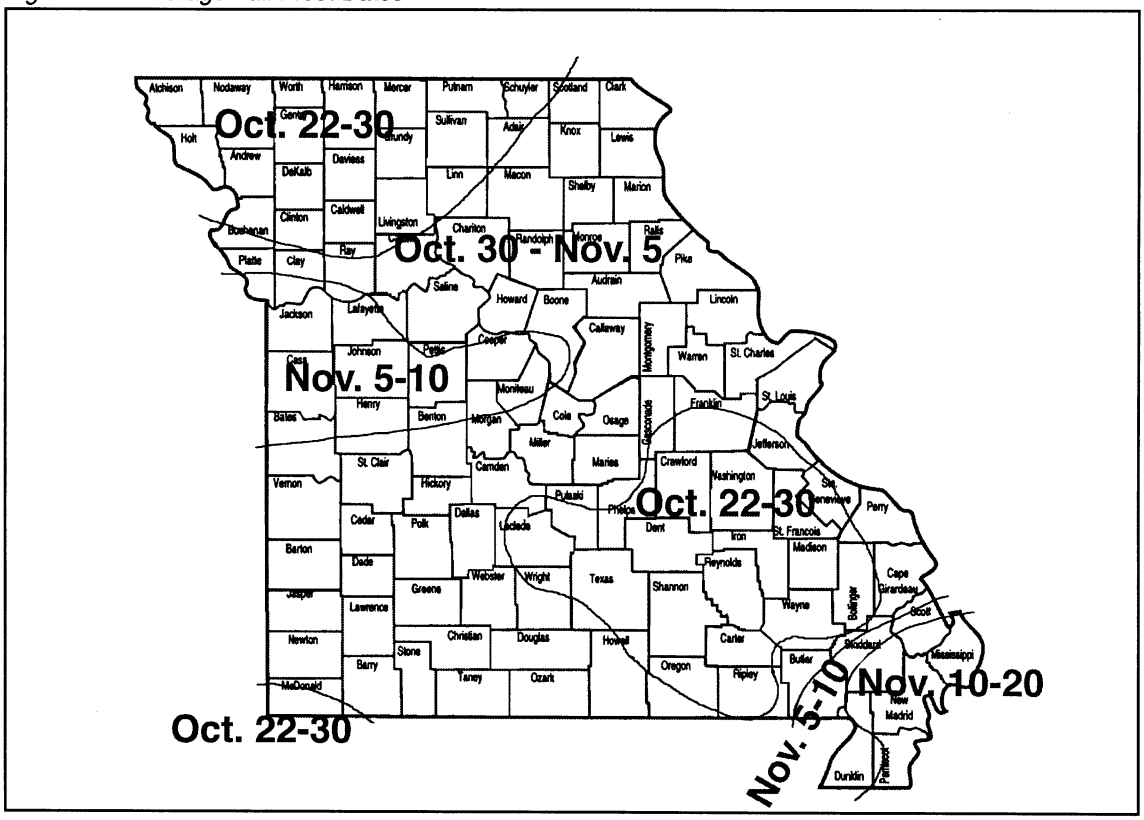


Figure 2.2 - Average Fall Frost Dates



Within a given temperature zone, the availability of water is the most important factor in determining which plants will grow and how productive they will be. If the temperature is adequate but annual rainfall is lacking, some type of irrigation method should be considered for the selection of a specific crop. Figure 2.3 indicates the average annual rainfall for Missouri.

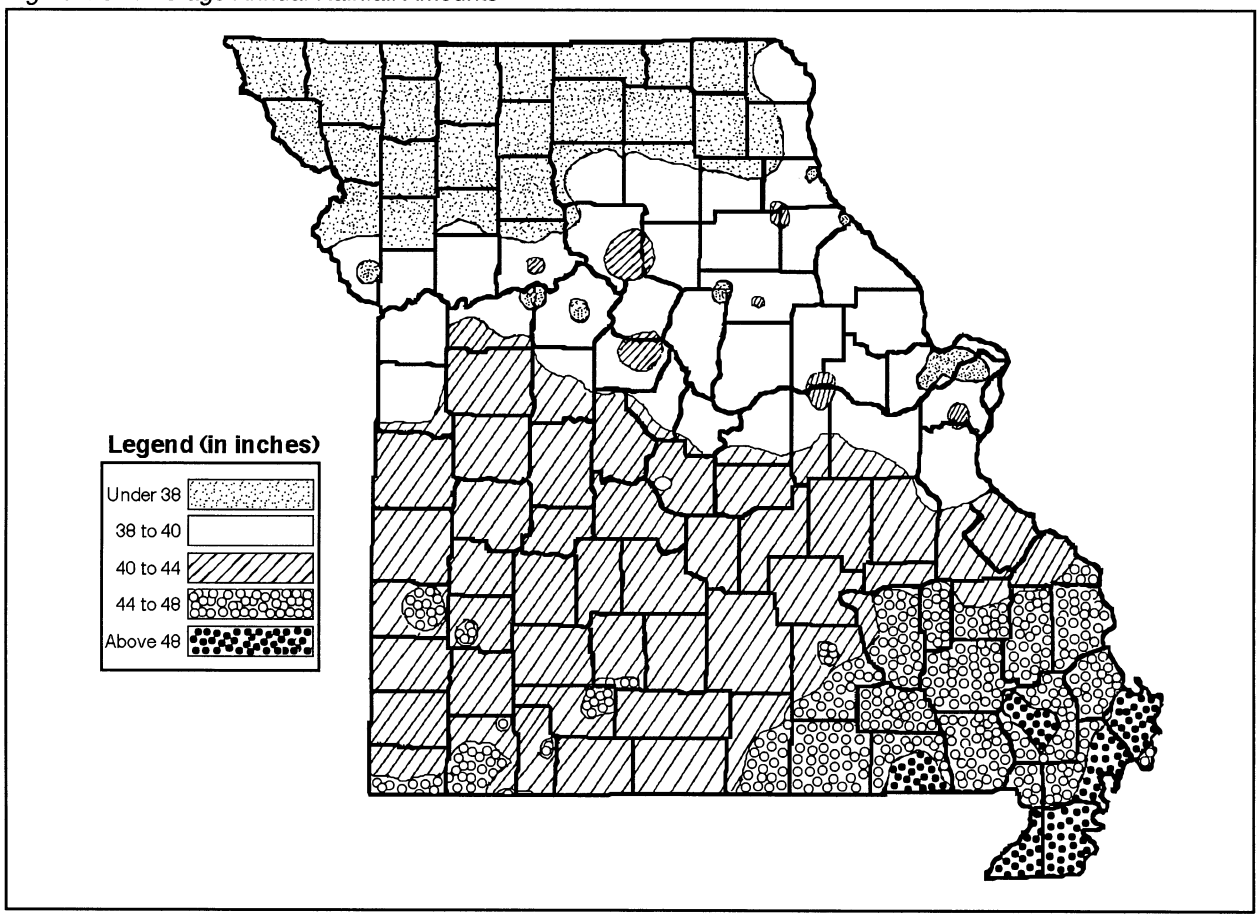
The third major factor that determines crop selection in a given region is soil types and conditions. The selected crop must be adaptable to the soil types in the region. A more in-depth discussion of soils was presented in the previous unit.

Maturity Groups

Corn - Corn varieties are divided into three basic maturity groups: full season, mid-season, and late season. Research shows that most corn is planted from mid-April to mid-May, depending on the growing region. Soil temperature is important. An early morning soil temperature of 50°F at the 1/2- to 2-inch depth usually indicates that the soil is warm enough to plant. The latest practical date to plant corn ranges from about June 15 to July 1. Planting a full-season hybrid first and then planting a mid-season hybrid allows the grower to take advantage of maturity ranges and gives the late-season hybrids the benefit of maximum heat unit accumulation. Planting hybrids of different maturities reduces damage from diseases and environmental stress at different growth stages and spreads out harvest time and workload. Even with high-capacity modern equipment, most growers cannot plant their full acreage in just a few days. A planned scheduling of planting different maturity groups is often referred to as "calendarizing" the corn crop.

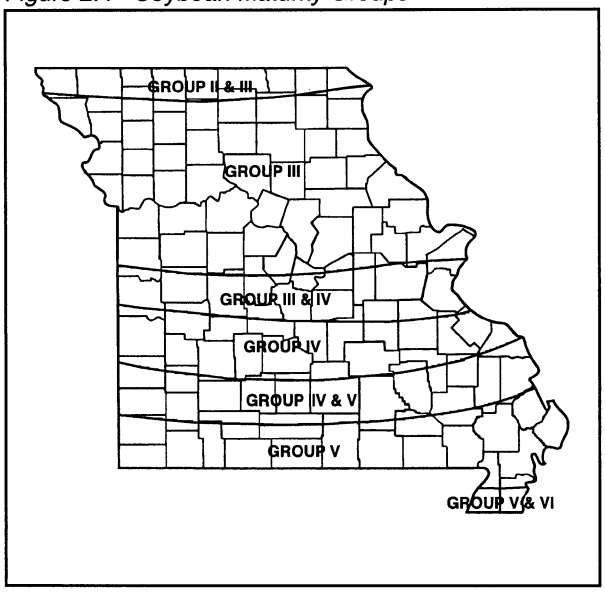
Soybeans - Classification of soybeans into maturity groups has helped producers choose the correct varieties for their regions. Planting a maturity group of soybeans not suited for the production area will affect the plant's flowering and

Figure 2.3 - Average Annual Rainfall Amounts



reproductive stage, thereby affecting or reducing the production potential of the plant. If a variety of a northern maturity group is planted farther south, it will encounter longer nights earlier during its vegetative stage. As a result, the plant will flower and set pods before it has reached its full vegetative growth, leading to a reduced yield. Figure 2.4 shows what maturity groups are recommended for Missouri.

Figure 2.4 - Soybean Maturity Groups



Varieties of soybeans that mature earlier may be used in Missouri when following small grains. Many growers will plant soybeans after wheat harvest as a method of "double cropping."

Wheat - This grain crop differs from most grains. Instead of maturity groups, wheat is divided into wheat types. The type of wheat grown in an area is determined by its growing season and climate. The three basic wheat types are hard red spring wheat, soft red winter wheat, and hard red winter wheat. Most hard red spring wheat is grown in the Northern Plains: Montana, North Dakota, and South Dakota. Most soft red winter wheat is grown in areas of Ohio, Indiana, lower Illinois, and some on the east coast states from North Carolina through parts of Georgia. Missouri is adapted for hard red winter wheat production as is the major hard wheat production areas of north Texas, Oklahoma, and Kansas.

Grain Sorghum - Grain sorghum closely follows the planting recommendations of corn. There are four basic maturity groups of grain sorghum. The recommended planting date is about 1 week later than that of corn. Some early maturing varieties (75 to 80 days to maturity) are available for emergency planting situations.

Cotton - Although scientists have identified 39 species or kinds of cotton, only 4 of the 39 are cultivated. These four kinds are divided into two groups: New World cotton and Old World cotton. The New World cotton includes upland and pima cotton. Upland is cultivated in many parts of the world, including the United States. Pima is one type of species grown on the coasts of Peru and Ecuador. Old World cotton includes tree cotton and Levant. These are grown in northern Africa and parts of Asia.

Rice - There are three basic maturity groups of rice. Very early maturing rice only requires 90 days from germination to harvest; early maturing varieties require 90 to 97 days to harvest; and intermediate or late maturing varieties require 98 to 105 days from germination to harvest. Rice thrives under the hot and humid conditions that characterize the southern United States during the summer months. In addition to Arkansas, Louisiana, Texas, and Mississippi, some southern regions of the Bootheel of Missouri are adapted to rice production.

Forages - Forage grasses and legumes are divided into cool-season or warm-season classifications instead of maturity groups. Cool-season grasses include fescue, orchard grass, ryegrass, and timothy. Examples of cool-season legumes include birdsfoot trefoil, alsike clover, and ladino clover. These grasses and legumes thrive when moisture is adequate and temperatures are between 65 and 75°F. They exhibit vigorous growth habits in the spring and fall months. Warm-season grasses and legumes have the potential for producing good hay and pasture growth during the warm and dry midsummer months. These grasses and legumes initiate growth during late April or early May and produce 65 to 75% of their growth from mid-June to mid-August. Warm-season grasses produce well on soils with low moisture-holding capacity, low pH, and low phosphorus levels. Examples of warm-season grasses include big bluestem, Indiangrass, and switchgrass. Warm-season legumes include alfalfa, crownvetch, and lespedeza.

Economic Factors

When crop producers are beginning to determine what crop they may select for their operation, the first step is to develop a marketing plan for their selection. Farm management specialists refer to this as "taking an inventory of resources." These resources are divided into four main groups: land, labor, capital, and management.

Land is the resource provided by nature. Producers will need to sketch or map the farm showing ditches, ponds, fences, streams, and any other physical features that would affect their crop selection plans. Soil tests should be made on all fields to show basic soil fertility needs for specific crops and levels of expected production. A land use capability map should also be prepared.

Labor refers to the number of people available for performing the physical work necessary to produce and harvest specific crops. The labor available would include not only the producer but family members and possible hired labor.

Capital refers to the amount of money required for the input costs of producing that crop. Items such as buildings, machinery and equipment, fertilizer, fuel, and seed must be included. Some producers like to include money or financial credit as a capital item whereas others include this as a part of management.

Management consists of the knowledge, experience, and effort of the person making the decisions concerning the planning and everyday operations of the cropping system. Some producers own and manage their own farms, whereas some landowners employ professional farm managers to provide this service for them. The likes and dislikes (personal preferences) of the producer and his or her family with regard to specific crops should be considered.

Summary

There are several factors that play a part in crop selection for the grower. These include climate, soil conditions, field history, equipment resources, economic demands, and available markets. The regions of the United States that are considered optimal growing regions for specific crops are determined largely by temperature, rainfall, and soil conditions. Growers are also faced with the decision of what maturity group or type of crop to plant. This is largely decided by planting times. The length of available growing times will make this determination. Land, labor, capital, and management are four economic factors that influence crop selection.

Credits

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Lesson 3: Crop Seed Selection

Agricultural researchers have devoted considerable time and effort to providing dependable, quality seed to producers. It is important for the producer to understand the different seed options that are available to ensure the best quality crop.

Characteristics of Quality Seeds

Careful consideration should be given to selecting crop seed. Quality crops possess specific characteristics as do quality seed. Quality crop seeds should exhibit uniformity. Seed should be examined for shape, color, size, and standard surface markings. Using quality seed improves crop yields an estimated 10 to 20% over crops produced from poor seed.

When purchasing seed, producers should select seed from a good variety. A good variety would be one that has a reputation of producing a quality crop. Good germination is another desirable characteristic. Seeds that fail to germinate are worthless. Other characteristics of quality seed are proper size and development; uniformity in size and shape; absence of seedborne diseases and insects; absence of prohibited, noxious, and other weed seeds; absence of mixtures with other crop seeds and other varieties; and absence of inert materials. Information on the performance of a specific variety and the germination percent should be readily available from reputable seed dealers.

Two of the major factors that aid in the viability (ability to germinate) of the seed are the age of the seed and the conditions under which it is stored. Most seeds remain viable longest if stored under cool, dry conditions.

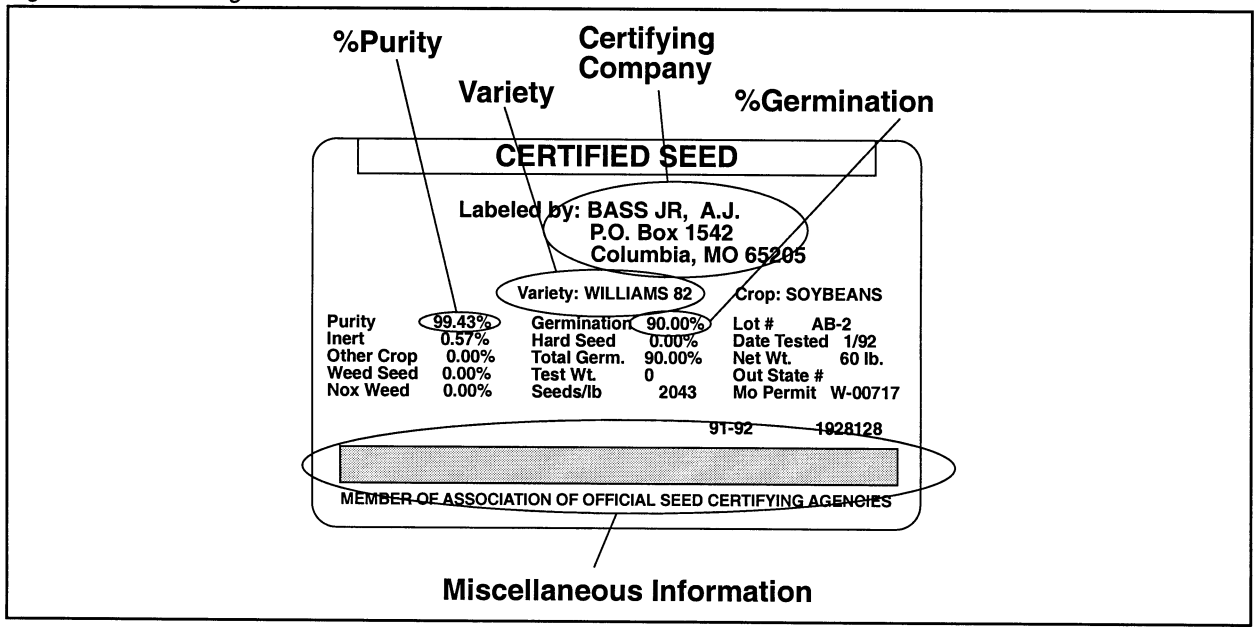
Information Included on a Seed Tag

Bags of seed are labeled with a seed tag. Each seed tag contains important seed quality information. The information is critical for producers to determine seeding rates and overall seed quality of the seed that will be planted. A seed tag includes these basic components:

- Percent pure seed
- Percent inert matter
- Percent other crop
- Percent weed seed
- Percent germination
- Percent hard seed
- Percent total germination
- Net weight
- Lot number
- State of origin
- Test date
- Kind and number of noxious weeds

The seed count is often included on many labels. It is also important to note that the law requires labeling for any seed treated with fungicide,

Figure 3.1 - Seed Tag



insecticides, or any chemical substance to enhance the performance of the seed. Figure 3.1 is an example of a seed tag containing the seed quality information.

Optimum Seeding Rates

Many factors relate to a productive stand. Using good management practices, crop producers can increase their potential yield. Plant population refers to the number of growing plants in a given area. The density of growing plants directly influences the yield potential. Desired plant population depends upon several factors, one of which is the seeding rate.

Seeding rate refers to the amount of seed planted in a given area (per foot, per acre, etc.). Accurate seeding rates are important. Overseeding wastes seed and underseeding reduces yields. By underseeding, the utilization of available light, moisture, and nutrients is inefficient. Overseeding creates excess competition among the plants, thus reducing yield. Optimum seeding rates should be based on the type of crop, use of crop, pure live-seed ratio, seed quality, soil moisture, soil productivity, time of seeding, method of seeding, row width, and expected average rainfall.

The type of crop planted influences the desired seeding rate. Corn can be planted at populations of 18,000 to 32,000 seeds per acre, whereas soybeans are typically planted at 130,000 to 170,000 seeds per acre. The intended use of the crop is also a factor. Corn silage is generally planted at a higher plant population than corn harvested for grain.

The pure live-seed ratio refers to the ratio of weight of the viable seed of the cultivar (variety within a plant species) being seeded to the total weight of the seed stock, which may include nonviable seeds, weed seeds, and inert matter. If 80% of the seed is viable (able to germinate) and it is 95% pure, the pure live-seed ratio is 76% .

0.80 viable seed x 0.95 pure = 0.76 pure live seed ratio

If an individual has 100 pounds of seed, there would be 76 pounds of pure live-seed of the desired cultivar to plant. To calculate the correct seeding rate from pure live-seed ratios, refer to the cultivar's recommended seeding rate. An example is presented as follows.

A recommended seeding rate based on 100% pure live-seed is 6 pounds per acre. This rate is common for small-seeded range grasses. The appropriate seeding rate would be slightly less than 8 pounds per acre based on the following calculations:

$$\frac{\text{Rate based on 100\% pure live-seed}}{\text{[pure live seed (ratio)]}} = \text{Seeding rate}$$

$$\frac{6}{0.76} = 7.9 \text{ pounds per acre}$$

Seeding rate can also be affected by seed quality. Seed quality is based on germination rate and other factors. If seed quality is low, it is advisable to increase the rate of seeding to ensure a good stand. Seeding time refers to seeding the stand at the appropriate time of the season (e.g., fall or spring). Climatic conditions can reduce stand establishment if planted after the optimum time. Increased seeding rates are suggested when planting before or after optimum planting dates.

Soil productivity and soil moisture also affect the optimum seeding rate. Productive soils may sustain the recommended seeding rates, whereas poor soils may sustain production only at lower seeding rates due to the less fertile soil condition. Excessive soil moisture can retard germination. Most seeds cannot tolerate excessive moisture and may rot. If there is excessive moisture, seeds should be planted at a shallower depth and at a higher seeding rate. This will promote faster germination and compensate for loss due to wet conditions.

The method of seeding and row width also affects the seeding rate. Row planting usually involves relatively lower seeding rates than the drill method. Broadcast seeding is used when high seeding rates are desired. Generally, as row width narrows, the number of seeds planted can be increased to some degree. Conversely, planting seeds in wide rows should be completed at lower seeding rates.

Seeding Rate and Equipment Calibration

After the desired plant population is determined, the next step is to properly calibrate the planting equipment. This varies with the type and brand of equipment. The first and probably most important instruction to the producer is to read the owner's manual. The manual explains how to adjust the

planting equipment to achieve the desired seeding rate. It is also an excellent guide in determining the planter's maximum speed for a given planting rate. Do not exceed the recommended planting speed or the metering mechanism will turn too fast for accurate control of the planting rate.

Planting equipment should also be checked for worn parts. Worn parts will interfere with achieving desired seeding rates. Planting depth should also be adjusted at this time to match seed recommendation and moisture conditions.

The next step would be to do a calibration check in a barn lot or dirt roadway before going to the planting field. This "practice" planting involves uncovering planted areas to count seed populations (number of seeds in a given distance), checking to see if the seeds are being accurately delivered into the soil.

The final step would be to conduct the calibration in the actual planting field. This should also be done one to two times each planting day to ensure no change has occurred that will affect the equipment's performance.

Availability Options for Seed

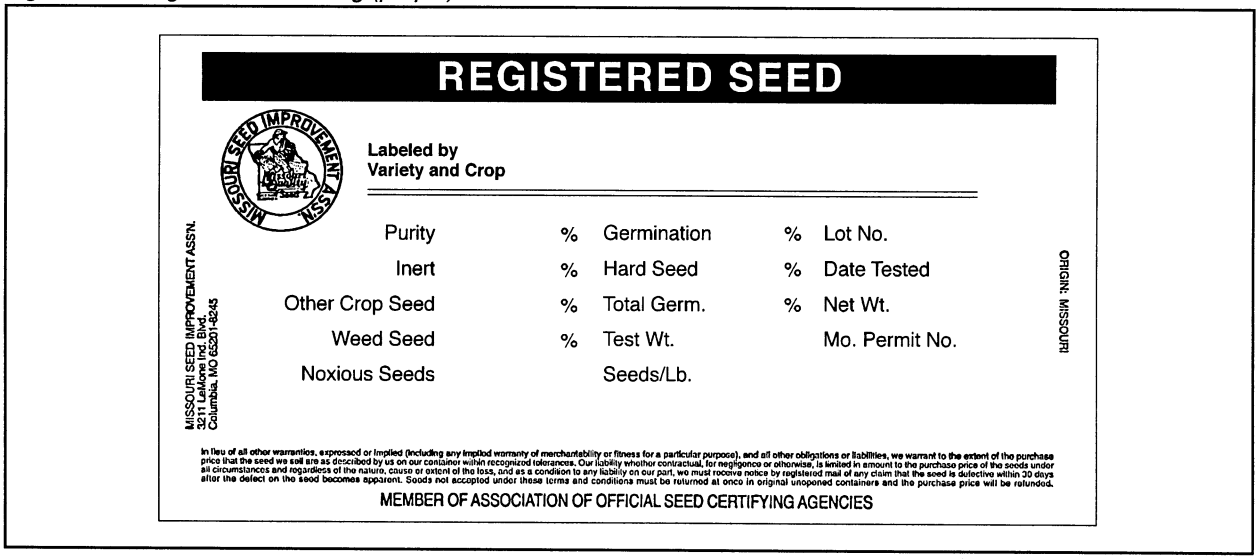
Certified seed is sold to producers with strict production guidelines to ensure genetic purity. Certification programs have four classes of seed: breeder seed, foundation seed, registered seed, and certified seed. For seed to be certified, specific criteria must be met. Criteria for certified seed are (1) the seed must be grown from registered or certified seed stock; (2) the crops produced must pass an inspection for mixtures, weeds, and diseases in the field; and (3) the harvested crop must attain the standard of perfection set by the seed association. Seed that fails to meet any of these three requirements cannot be sold as certified seed in the state.

Each seed class must meet specific requirements for certification. Breeder seed is controlled by the originating plant breeder it used in producing foundation seed and does not require identification tags or labels. Only small quantities of breeder seed are produced by commercial seed companies. Foundation, registered, and certified seeds require tags or identification labels.

Foundation seed is owned and supervised by the original plant breeder (usually an agricultural experiment station). It is the parent line for registered and/or certified classes of seed. Foundation seed requires a white identification tag or label. All foundation seed is grown and traded between the company and breeder.

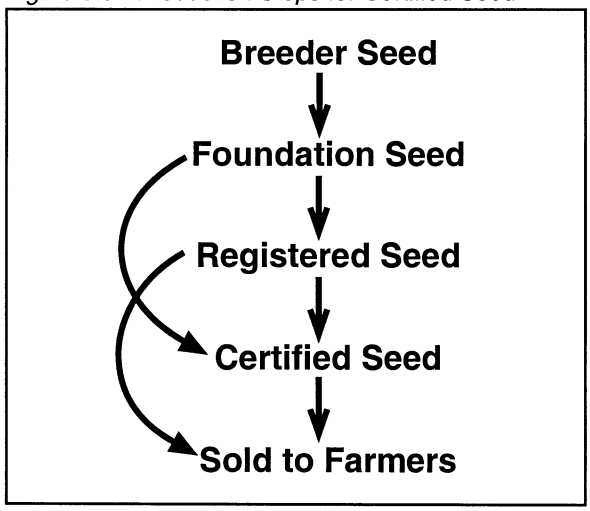
Registered seed is produced from foundation seed that meets genetic purity and identity guidelines. It may be used to produce certified seed or sold directly to farmers. Contracts are generally established with producers to grow the type of seed for the company. Registered seed is tagged with a purple identification tag or label as shown in Figure 3.2. Certified seed is produced from foundation or registered seed that meets genetic

Figure 3.2 - Registered Seed Tag (purple)



identity and purity guidelines. Certified seed is tagged with blue identification tags or labels. Seed trade of certified seed always occurs between a company seed dealer and a producer. The steps in the production of certified seed are diagramed in Figure 3.3. The arrows indicate where the seed is used. For example, registered seed can be sold for producing certified seed or for producing field crops by farmers.

Figure 3.3 - Production Steps for Certified Seed



Many states produce seed for export to other countries. The Organization for Economic Cooperation and Development (OECD) has set forth specific minimum requirements that must be met by the seed producers to receive an OECD tag. The Missouri Seed Improvement Association, working with the Missouri Agricultural Experiment Station and the USDA Agriculture Research Service, provides the needed information to Missouri seed producers regarding this certification.

Farmers are also able to purchase seed from local producers. The practice of selling saved seed allows a producer to earn premiums above market price for the quality seed. However, this practice has been limited in recent years due to plant patents. It is important to check plant variety protection laws before purchasing seed from local producers. Producers may also sell brown bag seed. Brown bagged seed is considered generic or no variety stated (NVS) because no quality or performance data is labeled on the bag. Individuals purchasing seed should check with the local producer on the quality of the seed before making any purchases.

Plant Patents Effect on Seed Selection

Before discussing how plant patents affect seed selection, it is important to understand what a patent is. A patent is an exclusive property right to an invention as issued by the Commissioner of Patents and Trademarks, U.S. Department of Commerce. The rights granted are limited to the claims of the patent. Plant patents are granted for 17 years for plants when they are asexually reproduced with the exception of tuber-propagated plants or plants found in an uncultivated state. Patentable plants must have been reproduced by means other than seeds, such as by the rooting of cuttings or by grafting. A patent has the potential of providing tremendous wealth to its owner. The owner can prevent all others from using, making, or selling the patented item throughout the United States for 17 years.

Plant patents have limited some options for producers for seed selection. Producers are not allowed to save back seed from genetically superior seed that is patented. The purchase of seed must be made yearly, and many companies may require special contract agreements requiring the producer to produce and market the crop in a specific marketing program.

Using Certified Seed

Producers have found that using certified seed provides specific benefits. Certified seed is guaranteed to be the variety advertised with no unexpected varieties. The minimum germination rate is also guaranteed and listed on the tag. Therefore, the buyer is ensured of the viability of the seed purchased. Using certified seed guarantees a high-quality seed free of weed seeds, disease organisms, and insects. Many argue that the cost of certified seed is a disadvantage; however, considering the improved performance, it is really an advantage.

Summary

Quality seed will exhibit specific characteristics. Seed tags provide information that is critical for producers in choosing the seed that will give a productive stand. Optimum seeding rates must be determined to avoid over- or underseeding. Factors that should be considered for optimum seeding rate are the type and use of the crop, pure live-seed ratio, seed quality, soil and moisture productivity, timing and method of seeding, row

width, and average rainfall. An important step before actually planting the seed is to properly calibrate the planting equipment according to the owner's manual. Certified seed is available in four classes: breeder seed, foundation seed, registered seed, and certified seed. The producer needs to be aware of the advantages and disadvantages of using certified seed.

Credits

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Lesson 1: Protecting Ourselves and Others

Crop production is one of the most dangerous occupations in the United States. It is very important that all farm workers know and understand all aspects of the risks involved in crop production. This lesson will discuss dangers and safety precautions when handling chemicals, operating equipment, and handling and storing crops.

Potential Dangers When Handling Chemicals

With more poisonous (toxic) pesticides and insecticides being manufactured, the use of personal safety equipment is necessary to prevent accidental exposure to these chemicals through clothing, body openings, and skin. Contacting the skin is the greatest cause of chemical poisoning. Not all body parts absorb these chemicals at the same rate. Therefore adequate equipment in one situation may not be satisfactory in another.

Exposure or contact with the skin may occur when pesticide and insecticide packaging material has become damaged through improper storage or handling. Exposure could also occur when handling the chemical or when filling application equipment. Drift hazards when spraying may also expose chemicals to the skin or body openings of the producer.

Problems also occur when the producer is exposed to fumes created by the chemicals. This can occur in the storage area or when adding the wettable powders, dust, or granules to the sprayer tank. When adding chemicals to the sprayer tank, air is forced out and carries some of the chemical particles with it.

Pesticide and insecticide chemicals should also be handled carefully at all times when moving the product into and out of storage. Care must also be taken to avoid accidental spills when mixing chemicals for the application process. Due to its properties and the manner in which it is stored, anhydrous ammonia can create a dangerous situation when it is accidentally released. Under atmospheric temperature and pressure, anhydrous ammonia is a colorless gas with a sharp penetrating odor. For use as an agricultural fertilizer, it is compressed into a liquid that resembles water. In this liquid state, it is stored in specially made tanks that are strong enough to withstand internal pressures of a minimum of 250 pounds per square inch (psi). Outside temperatures cause the vapor pressure in the tank to increase. At an outside temperature of 60°F, the tank pressure will be 93 psi, and at 100°F the internal pressure may reach to nearly 200 psi.

When injected into the soil, the liquid ammonia expands into a gas and is readily absorbed by the soil moisture. Similarly, the liquid or gas that contacts body tissue, especially the eyes, skin, and respiratory tract, will cause dehydration, cell destruction, and severe chemical burns. At high concentrations, ammonia combined with moisture in the lungs may damage the lung lining and reduce the lung's ability to transfer oxygen to the bloodstream. Victims exposed to even small amounts of ammonia require immediate treatment to avoid permanent injury. Table 5.1 gives examples of the effects of various concentrations of anhydrous ammonia vapor on the human body.

Table 5.1 - Concentration of Anhydrous Ammonia Vapor

ppm (parts per million)	Volume (%)	Effects on the Human Body
5	0.005	Detectable by almost all persons. Some people complain of nose irritation after 5 minutes of exposure.
134	0.0134	Most people experience dryness and irritation of nose, throat, and eyes.
700	0.07	Coughing. Severe eye irritation, if not treated, may lead to partial or total loss of sight.
1700	0.17	Serious lung damage; death unless treated.
2000	0.2	Burns and blisters skin after a few seconds of exposure.
5000	0.5	Death by suffocation within minutes.

Commonly, anhydrous accidents occur when:

- Filling tanks beyond recommended capacity.
- Knocking open the hose-end valve accidently.
- Moving the applicator tank before filling hoses have been disconnected from the nurse tank.
- Venting pressure release value while a person is in line of the discharge.
- Breaking the transfer hose, especially if it is old and misused.
- Failing to bleed hose coupling before disconnecting.
- Releasing ammonia when unplugging knives.

Potential Dangers from Equipment Operation

The most serious injuries and fatalities on the farm involve machinery and equipment. About half of the farm deaths result from working with or around agricultural equipment. Although some injuries occur in recognized danger areas, such as around power take-off shafts, many others occur in areas where hazards are not readily apparent. For example, more producers are injured while operating skid steer loaders than with hay balers. Farm operators who work with balers know the dangers of getting caught in the windrow pickup area and take appropriate precautions, whereas skid steer operators fail to recognize the hazard of being crushed by the hydraulic loader arm. Skid steer loaders are being used more each year in crop operations.

Most machinery accidents result from human error. The operator either forgot something, took a shortcut, ignored a warning, was not paying close attention, or failed to follow safety rules. Operator manuals list safety rules for a specific piece of farm equipment. Be familiar with the operator manual to know the limitations of the equipment and have the ability to follow the safety measures automatically.

Possible danger points when working with crop production equipment include the belt, gear, or chain drives on many types of equipment. Rotary or auger intake areas on grain handling equipment and grain heads also are dangerous. Consider feed rolls, gathering chains, and similar equipment used to pull crops into a machine as areas where extra caution is required. A slow-moving hydraulic arm can be as hazardous as a rapidly rotating power take-off shaft.

Many crop producers may recognize hazardous situations, but they misjudge the seriousness of the hazard because of secondary factors. For example, spilled grain, debris, or slick substances such as oil spills in an unloading area could cause a slip and fall into the intake auger. Icy, muddy, or manure-covered surfaces make the work area slick and increase the risk of injury.

Farm operators can overestimate their ability to stop or avoid a dangerous situation. This is common when operators work around powerful equipment every day and become comfortable with their ability to control the machinery. Operators are limited by their reaction time. The human reaction time to a stimulus commonly ranges from 1/4 to 3/4 of a second. Times varies with the individual and with age and physical condition. Human reaction time is not quick enough to avoid accidents with machinery.

Equipment that produces large round bales provides an efficient and economical way to harvest hay. However, it also poses unique safety problems for the operator. Large round bales weigh 1,500 to 2,000 pounds each, the same as a small car. Harvesting hay with wetter than optimum moisture content may cause the hay to clump and clog the baler. Hay is harvested during hot conditions, which may also cause operator fatigue and frustration. Add these factors to the misjudgment of reaction time around dangerous equipment, and the result could present a hazardous situation for many farm operators. Injuries occur when operators get caught in the pickup mechanism while trying to unplug the machine or hand tie the twine on the bale. Injuries have also been reported when operators are crushed from bales rolling down the raised front-end loader arms. Other injuries occur when the weight of the bale causes tractors to overturn.

Other farm accidents with crop production equipment include fires and explosions when mishandling fuels and petroleum products, fires from crop debris collecting on hot engine blocks of combines, and accidents on the roadway when moving crop equipment from farm to farm on public highways.

Potential Dangers from Handling and Storing Crops

Increased storage capacities, larger and faster handling grain handling equipment, and

automation contribute to many potentially hazardous situations during the harvest and storage seasons. Millions of bushels of grains flow from field to storage during the harvest season but one person trapped in grain can stop the flow in a matter of seconds. All too often, farm workers or family members suffocate beneath the surface of grain.

These suffocation accidents typically occur when the victim enters a bin of flowing grain, is unaware of the potential hazard, and is pulled under and covered with grain in a matter of seconds. For example, a high capacity auger can move 5,000 bushels of grain an hour. At that rate, a 6-foot tall person would become submerged in only 15 seconds. Children are at a greater risk. They are shorter, not as strong, and become submerged quicker than adults.

A grain surface may appear solid, but it is not and can act like quicksand. When a single grain is removed from the bottom of a bin or grain wagon, kernels directly above it rush to fill the void, creating a liquid motion. Objects on the surface sink and heavy objects sink faster than light ones. Even if grain is stopped flowing, submerged objects or people are difficult to extract. The force required to remove someone buried below the surface of grain easily can exceed 2,000 pounds, which is about the same as trying to lift a small car.

Gases developing in some grain or silage storage can also present a dangerous situation. When wet grain or high moisture silage is stored, it ferments. Fermentation produces carbon dioxide (CO_2), a colorless, odorless gas. Carbon dioxide is heavier than air and pushes air out of the bin. This results in an oxygen-deficient atmosphere. If you enter a grain bin where CO_2 is present, it gets into a person's bloodstream, slows down breathing, causes drowsiness, headaches, and even death by suffocation.

Producers should also be aware of other substances that could be harmful to their respiratory system. Crop producers are exposed to a large amount of airborne substances. Dust from crop residue and equipment is an ever-present problem. Molds and fungi from spoiled grain may enter lungs of farm workers. Care should be taken to reduce the amount and kind of particles that may enter the respiratory system. Permanent damage to lungs or allergies may be the result.

Sun safety is probably the most overlooked and least discussed problem with those people in agriculture who work outside, especially in the production of crops. Many people recognize the importance of protecting their skin from the sun's harmful rays, but crop producers are probably the largest group of individuals to abuse their skin and expose it to sun damage. Sun safety practices should include reducing skin exposure by wearing protective clothing and/or sunscreen.

Precautions to Prevent Personal Injury from Chemicals, Equipment, and Crop Handling and Storage

The following list of precautions are prepared for crop producers' consideration when working with chemicals, equipment, and the handling and storing of crops.

Chemicals

1. Store pesticides and insecticides in locked and posted facilities where children and other untrained people cannot get to them.
2. Storage areas should be on the first floor to prevent contamination from a possible leaky container.
3 The storage area should be cool, dry, and out of the direct sunlight.
4. Sacks, cartons, and fiberboard boxes of chemicals should be on pallets or shelves off the floor.
5. An exhaust fan for ventilation should be available in storage rooms.
6. An adequate supply of water and detergent should be available for routine use for cleaning equipment and people working with the chemicals.
7. Material such as vermiculite, absorbent clay, sawdust, or activated charcoal should be on hand for cleanup of possible spills or leaks.
8. A shovel, dust pan, and proper type of fire extinguisher are other essential items.
9. Do not store or use chemicals near food for human consumption, animal feed, or veterinary supplies.
10. If spills or leaks occur, contact extension specialists or a DNR representative after cleanup.
11. Make sure all spray equipment is in good working order and check valves, lines, and seals.

12. Wear approved safety equipment and clothing when working with open containers and mixing and spraying.
13. Use recommended cleanup procedures on equipment, clothing, and protective devices after application is complete.
14. Follow the rules for properly disposing of pesticide and insecticide containers after they are emptied.
15. Avoid surplus chemicals; mix only enough for the intended job.
16. Make sure the proper handling and safety equipment is used when working with anhydrous ammonia.
17. If ammonia contacts skin or eyes, flush the exposed area immediately and constantly with fresh water. Water containers should be kept on hand when in the field.
18. If ammonia contacts the body or is breathed, contact a physician immediately after preliminary treatment.
19. Make sure all hoses and valves used in the transfer of anhydrous ammonia are in good working order.
20. Let someone know where and when you are working with anhydrous ammonia and have them check on you during the day.
21. Make sure nurse tanks are secured to the towing vehicle and moved properly.

Equipment

1. Carefully read the safety section of operator manuals.
2. Inspect equipment completely and often for safety hazards, also while in operation.
3. Make sure all operators are properly trained in the operation of the equipment.
4. Use equipment for only the purposes for which it is designed.
5. Check all guards and safety equipment to be in place and working.
6. Do not take shortcuts or ignore safety warnings (lights, noises, etc.).
7. Look for and eliminate secondary hazards (spills).
8. If a hydraulic line breaks, recognize that gravity may allow equipment to move.
9. Do not allow children to play on equipment or ride with operators.
10. Check hay baler's manuals for charts regarding the size of tractor or loader to safely lift and transport large round bales.
11. Drive on a contour when baling to prevent a released bale from rolling down a slope.
12. Never try to stop a rolling bale.
13. Use a tractor with a protective cab or four-post rollover structure.
14. Always disengage power take-offs and shut off the tractor before dismounting.
15. Be prepared for fire by carrying a Class ABC extinguisher on equipment.
16. Maintain proper settings and speed on all power equipment used in planting and harvesting.

Storing and Handling Grain

1. Always lock all access doors to grain storage structures.
2. Never allow children to play on or ride grain wagons. This applies to grain storage areas also.
3. Lock out all power to grain handling equipment when not in use. This also discourages grain theft.
4. Always use the buddy system when unloading and loading grain. Notify a second person where you are at all times.
5. Never enter a bin when grain is caked or spoiled. This creates a grain bridge that can collapse at any time.
6. Apply suffocation hazard decals to all grain wagons, bins, and other storage structures.
7. Be prepared with safety equipment to rescue workers who may have been caught in flowing grain.
8. Train farm workers in proper rescue techniques. This includes CPR training.
9. Wear protective ear equipment around grain dryers because of the noise they create.
10. Be prepared for fires around grain drying equipment with approved fire extinguishers.
11. Be careful when transporting portable augers as to not create a hazardous condition. This would include not making tight turns and contacting electrical wires.
12. Wear tight-fitting clothing when working near power augers.
13. Wear protective breathing apparatus when using fumigants in empty grain bins.
14. Also wear the breathing equipment when working with dusty or moldy grain to prevent allergic reactions.
15. The most successful way to rescue victims from grain bins is to cut large holes in the bin 4 to 5 feet off the ground. Use an abrasive saw, an air chisel, or the front end of a bucket loader to gain access. Only use a cutting torch as a last resort because of the dangers of fire and explosion.

Government Agencies That Regulate and Enforce Environmental and Safety Issues

The Occupational Safety and Health Administration (OSHA) establishes standards of compliance for safe and healthful working conditions. OSHA provides free, on-site consultations to businesses that include education and safety assistance to identify and eliminate workplace hazards. A producer who employs one or more persons has the legal responsibility to ensure safe and healthful working conditions under the Williams-Steiger Occupational Safety and Health Act of 1970. An amendment to the act also prevents OSHA from spending any funds to issue or enforce any regulations that apply to any person who farms and employs 10 or fewer employees.

This amendment does not eliminate the requirement that an agricultural producer comply with the Act since the amendment does not eliminate rules or regulations. This amendment does not eliminate the possibility that an employee could use the regulations in a lawsuit against the employer. For this reason, all farm employers should comply with the Act and provide their employees with a safe and healthful place to work.

The Natural Resources Conservation Service (NRCS), a division of the U.S. Department of Agriculture, helps prevent soil erosion from wind and water. The NRCS works with local soil and water conservation districts who assist in developing individual conservation plans and other conservation measures.

The Environmental Protection Agency (EPA) protects the nation's land, air, and water systems. The EPA formulates environmental standards and enforces federal environmental laws.

The Department of Natural Resources (DNR) fosters the prudent use and protection of air, land, water, cultural and energy resources. The DNR also aids in preventing pollution and protects the public from harmful emissions and waste disposal practices.

Summary

Statistics show that agricultural workers are in one of the most hazardous occupations. Too many crop producers suffer injuries each year. The major cause is the worker's lack of education regarding proper safety practices to observe with agricultural chemicals, equipment, and the handling and storing of grain. After studying this lesson, students should be more aware of the many dangers in agriculture and the importance of safety instruction.

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Lesson 2: Protecting the Environment

Crop production has a large impact on our environment. Producers need to be aware of how production activities affect the environment and implement management practices to minimize the impact. Government agencies are available for assistance to producers to help regulate environment issues.

Crop Production Activities That Affect the Environment

Crop producers today are probably more informed and concerned about the environment than in any other time in history. Environmental problems in agriculture are reported in the media almost every day. There are four major resources polluted by agriculture. They include air, water, soil, and the aesthetic value (natural landscape beauty) of the rural environment.

If pollution is to be stopped, important steps must be taken to correct the problem. The first step is to become aware of the major sources of pollution. The five largest contributors to agricultural pollution are toxic products, soil loss, waste products, discharged water, and litter. Old chemical containers and tractor tires would be two examples of litter that concern agricultural environmentalists. Of these five contributors, toxic products and soil loss are the two major causes of pollution affecting the agricultural environment.

Toxic products are substances that contain poisons or have the potential to poison animals or plants. These include pesticides and insecticides used by crop producers. It can also include engine exhaust from large farm equipment. The exhaust released into the air contains harmful substances. The smoke from farm engines is not as concentrated as the exhaust in cities; therefore, few think of this as an air-polluting source. However, as with emission controls on automobiles, it may be a matter of time before exhaust fumes on farm equipment are controlled and filtered.

Agricultural chemicals can give off toxins if not used properly. Excessive fertilizer use should also be considered a source of toxic pollution. Excessive fertilizer can get into rainwater and wash into streams. If overused, insecticides and herbicides can drift into streams and lakes and build up in the soil. Always use agricultural chemicals and fertilizers according to directions and never use them when they are not needed.

Soil loss is attributed to the overuse or incorrect use of tillage methods in crop production. Wind and water can blow or wash exposed soil away. In addition to fertility loss, soil particles can cause pollution by getting in the air, streams, and lakes. Living organisms in the water may be damaged by muddy water because the natural processes of the water are disturbed. Oxygen levels may be too low to support aquatic life. Soil particles can even end up in the ocean where they change the environment of sea life.

Management Practices to Minimize Environmental Impact

Using appropriate management practices on farms and ranches can limit the pollutants removed by runoff that can infiltrate groundwater and streams. Examples of management practices include soil conservation management, waste management, and nutrient management.

Soil conservation management includes tillage practices that can reduce the movement of pollutants and diminish soil particle detachment by protecting the soil from the adverse effects of wind, rain, and runoff. Tillage practices can increase the infiltration and movement of soluble nutrients and pesticides to the root zone. Examples include conservation tillage, contour farming, filter strips, and strip-cropping. Structural practices such as terraces, grassed waterways, and diversions are designed and built to control the flow and volume of runoff water. This can increase the infiltration and movement of soluble nutrients and pesticides to below the root zone.

Waste management practices on farm operations are mostly directed to livestock producers. Livestock produce tons of waste each year and are particularly problematic on large hog confinement operations. However, crop producers as well should be concerned about controlling the waste or overuse of possible toxic substances used for pest and weed control. Again, the major management practice to observe with these products is to follow directions on usage and dispose of the plastic jugs, bags, or cans properly after product use.

Crop producers should be concerned about nutrient management. Plants can only use a certain amount of fertilizer for optimum growth. Overusage of fertilizers may not only harm the plant but also carry over in the soil or be transported with rainwater to ponds, streams, and lakes. Many fish kills have been reported by excessive fertilizer usage. Another major concern is the effect excessive nutrients of fertilizer may have on groundwater. Many cities or towns rely on groundwater as their primary drinking source.

Government Agencies That Regulate and Enforce Environmental Issues

There are several governmental agencies that play a part in regulating and enforcing environmental regulations that affect crop producers. This discussion will be limited to four major agencies. They are the Natural Resources Conservation Service, the Missouri Department of Natural Resources, the Environmental Protection Agency, and the Missouri Department of Conservation.

The Natural Resources Conservation Service (NRCS) is a division of the U.S. Department of Agriculture. There are 19 programs within the NRCS that may play a part in the conservation and protection of our country's natural resources. Some major programs that would affect crop producers are listed below.

Conservation Technical Assistance - This program helps landowners plan and implement practices to reduce soil erosion, improve soil and water quality, improve and conserve wetlands, enhance fish and wildlife habitats, improve air quality, improve pasture and range conditions, reduce upstream flooding, and improve woodlands.

Conservation Farm Option - This is a pilot program for feed grain, wheat, cotton, and rice producers to improve the soil, water, and related resources on the farms. This is a voluntary program. Producers sign a 10-year contract and receive annual payments for implementing measures developed in their conservation plan.

Conservation of Private Grazing Land Initiative - This program provides technical and educational assistance to those who own private grazing land. Assistance is provided to improve grazing land, protect soil from wind and water erosion, use energy-efficient ways to produce food and fiber, conserve water, and improve habitats for wildlife.

Conservation Reserve Program (CRP) - The CRP program is established to encourage producers to convert highly erodible cropland to vegetative cover. This is done to enhance forest and wetland resources, reduce sedimentation in streams and lakes, improve water quality, and enhance wildlife habitats.

Farmland Protection Program - This program provides funds to help purchase development rights to keep productive farmland in agricultural uses.

For more information about the other programs available through the NRCS, crop producers may contact a local USDA office and ask for the Natural Resources Conservation Service informational booklets.

The Missouri Department of Natural Resources works with producers through their Agricultural Assistance Unit. This technical assistance program assists producers with their environmental needs. Much of their assistance includes guidance for environmental permits, natural resource stewardship advice, third-party site environmental assessments, and aid with referrals to other government agencies and programs when and where they are appropriate. Assistance may include helping crop producers find information to aid them with environmental problems, provide assistance in analyzing activities for regulation compliance, provide workshops to inform producers of environmental regulations, and help coordinate the producer's activities with other environmental organizations.

The Environmental Protection Agency (EPA) has the mission to protect human health and to safeguard the natural environment (air, water, and land) upon which life depends. The EPA deals heavily with enforcing state and federal laws developed to protect the environment, regulations that were developed using the best available scientific information.

The Missouri Department of Conservation (MDC) has the primary mission of protecting and managing the fish, forest, and wildlife resources of our state. They also serve the public in facilitating their participation in resource management activities. The MDC provides many opportunities for landowners and crop producers to learn how to manage the state's resources.

Summary

Most crop producers are very aware of the environmental concerns they face with their occupation. The protection of the air, water, soil, and the aesthetics of their land are important to them. Through educational efforts, producers must understand the causes of environmental problems and how they may guard against their effect on the producer's operation. Most problems with crop production are related to toxic chemicals and soil pollution or loss. There are several governmental agencies that help to oversee or regulate the use of the land to reduce or eliminate harmful activities that affect the crop producer's environment. These include the NRCS, the EPA, the DNR, and the MDC.

Credits

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Lesson 3: Knowing the Law

During a crop production cycle, the producer may face instances when certain aspects of the production of that crop will demand knowledge of laws governing the application of chemicals, possible property and fencing rights with neighbors, and the use of streams that are common to several producers. This lesson will deal with some of those issues and present some solutions to some possible problems that may arise.

Legal Requirements for Handling Chemicals, Wastes, and Equipment

Handling and applying pesticides correctly and safely require special knowledge and skills. Producers or individuals who apply and/or supervise other pesticide applicators must be sure pesticides are handled properly and safely. It is important to be familiar with all state and federal laws regulating the use, storage, transportation, application, and disposal of pesticides.

Federal laws and regulations set the standards for pesticide use. States have the right to be stricter than federal law but not more lax. The EPA regulates the use of pesticides. This regulation is mandated under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). FIFRA governs the registration of pesticides. No pesticides may be marketed in the United States until the EPA approves the registration request from the chemical company wishing to market it. Key provisions of FIFRA:

- Require the EPA to register all pesticides, each use of all pesticides, and approve the product label
- Require the classification of all registered pesticides as either general use or restricted use
- State that all pesticides must be used only as directed on the labeling
- Require users of restricted use pesticides to be certified applicators or work under the direct supervision of a certified applicator
- Provide penalties for actions contrary to its provisions
- Give the EPA authority to develop regulations, which are interpretations of the law and have the force of law

In Missouri, pesticides are registered under the provisions of the Missouri Pesticide Registration Act. Pesticide use is regulated under the provisions of the Missouri Pesticide Use Act. These two acts bring Missouri into compliance with FIFRA. The acts are administered by the Missouri Department of Agriculture, Division of Plant Industries, Bureau of Pesticide Control.

According to Missouri State Statutes (Chapter 281), persons working with restricted chemicals must be certified to do so under one or more of the following types of licensing procedures: as a certified commercial, a certified noncommercial, a certified public, or a certified private applicator. The Missouri Department of Agriculture establishes minimum criteria for these types of licenses. It also determines the curriculum and topics that must be included in the training program for applicator certification. These topics include:

1. Applicable State and Federal Pesticide Laws and Regulations
2. Pests
3. Pest Control (application techniques and IPM training)
4. Pesticides
5. Pesticide Waste
6. Applicator Safety and Worker Protection
7. Groundwater Protection
8. Endangered Species Protection
9. New Developments

Once the applicator has been through the training program and is certified, the training must be repeated every 5 years. If an employee has a valid, EPA-approved training card that has been issued during the last 5 years, no further training is required.

Legal Liabilities if Chemicals, Wastes, or Equipment Is Mishandled

If FIFRA or any regulation under it is not adhered to, individuals are subject to civil penalties. Fines can be as much as $5,000 for each offense ($1,000 for private applicators). Before the EPA issues the fine, a hearing can be held in the local city or county. Some violations of the law can be subject to criminal penalties. For commercial applicators, these penalties can be as much as $25,000 or 1 year in prison, or both. Private applicators can have penalties of $1,000 and/or 30 days in prison. States have the option of

establishing higher penalties. All major pesticide spills are required by law to be reported immediately to the U.S. Environmental Protection Agency, Region VII Office in Kansas City. The following information should be reported.

1. Name, address, and telephone number of person reporting
2. Exact location of a spill
3. Name of company involved and location
4. Specific pesticide spilled
5. Estimated quantity of pesticide spilled
6. Source of spill
7. Cause of spill
8. Name of body of water involved or nearest body of water to the spill area
9. Action taken for containment and cleanup

Many pesticide labels list an emergency telephone number that provides direct access to the manufacturer and people who know how to manage emergencies for a given product. If the spill occurs on a highway, call the highway patrol or highway department immediately. If the spill is on a county road or city street, call the sheriff, city police, or the local county or city fire department. These authorities are trained for such emergencies and will be able to assist in the cleanup.

Legal Land Description

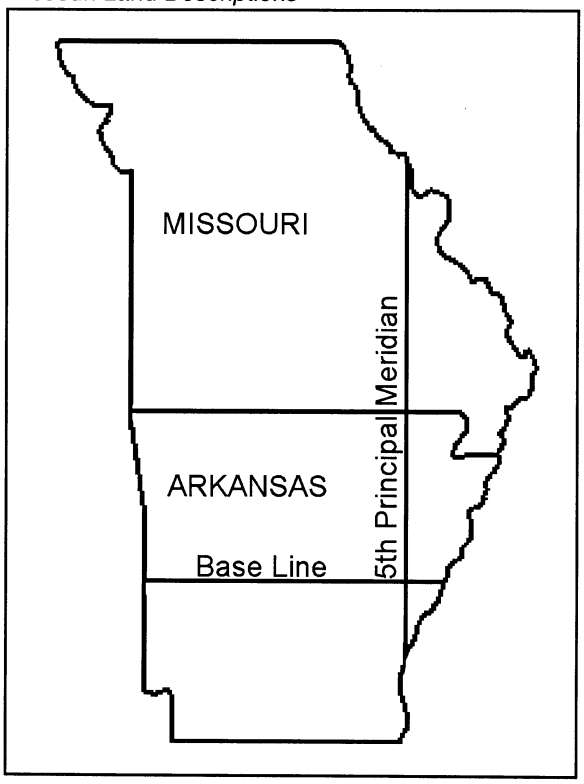
The location of a parcel of land in the United States may be described by one of two methods. In the 13 original states in the East and in some southern states, the land is surveyed in the "indiscriminate metes and bounds" system. This system uses natural land features, such as trees and streams, as well as neighboring land owners, along with distances, to describe plots of land.

Most states, including Missouri, uses the township-range system. To understand this system, common terms need to be defined.

Base line - The reference or beginning point for measuring north or south townships
Principal meridian - The reference or beginning point for measuring east or west ranges
Township lines - East to west lines that mark township boundaries
Range Lines - North to south lines that mark township boundaries
Range - Assigned to a township by measuring east or west of a principal meridian
Township - Thirty-six sections of land arranged in a 6 by 6 array, measuring 6 miles by 6 miles. Sections are numbered beginning with the northeast-most section, proceeding west to 6, then south along the west edge of the township and to the east.
Section - Basic unit of the system; a square tract of land - 1 mile by 1 mile, containing 640 acres

Figure 3.1 indicates that the 5th principal meridian runs north and south through eastern portions of the state of Missouri and that a base line is located running through the middle of Arkansas. These are used to locate parcels of land in Missouri.

Figure 3.1 - Base Line and Principal Meridian Affecting Missouri Land Descriptions



The land description generally starts with the smallest part of the description and proceeds to the largest definition. For example, if we located the northeast 1/4 of section 3 in township 2 north, range 2 west of the 5th principal meridian, we notice that piece of land encompasses 160 acres. Figure 3.2 indicates the location of township 2 north, range 2 west of the 5th principal meridian. Figure 3.3 gives the location of section 3 in that township, and the 160 acres of land in the northeast 1/4 of section 3 is indicated on Figure 3.4.

Figure 3.2 - Locating a Township

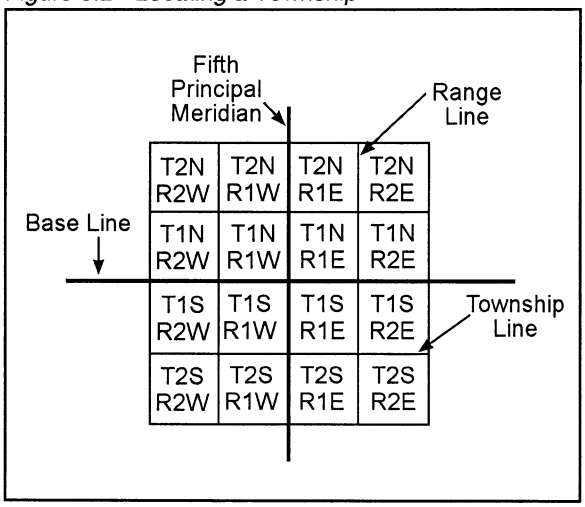
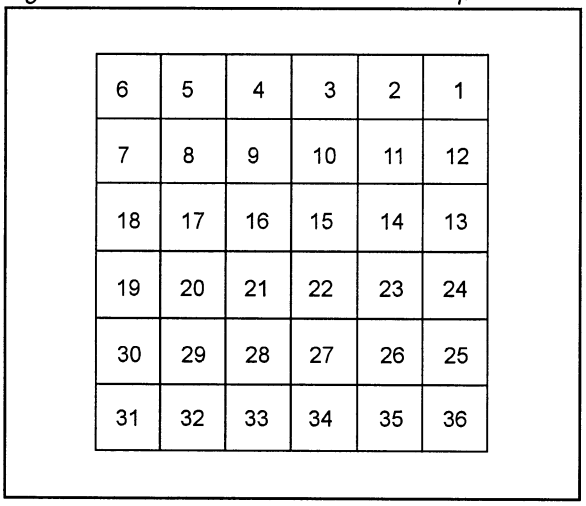
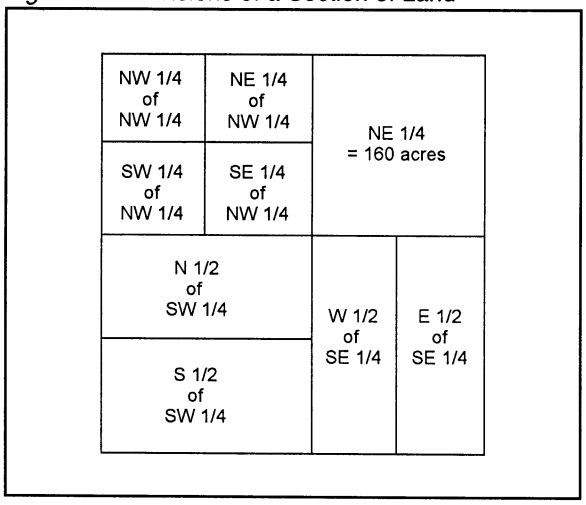


Figure 3.3 - Section Location in a Township



6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

Figure 3.4 - Divisions of a Section of Land



The use of the Township and Range method of legal land descriptions is required on land abstracts in Missouri to verify and indicate ownership.

Legal Liabilities for Crossing Property Lines, Fencing, or Other Damage

Fencing duties and boundary locations have been the subject of quarrels between neighbors for centuries. Sometimes there are many questions regarding those duties and rights. Answers are mostly supplied by Missouri state statutes and court decisions. They are supplemented by conjecture where the statutes and cases fail to provide clean answers.

Most disputes arise with animals crossing property lines and causing damage on adjoining property. Liability can sometimes be difficult to resolve. Crop producers as well as all agricultural property owners should acquire a copy of the University of Missouri Extension Guide G810 *Missouri Fencing and Boundary Laws* for reference. This guide gives information about general fencing laws; duties and liabilities of livestock owners; the definition, building, and maintenance of a "divisional" fence; and the use of streams as boundaries.

Solutions to most property line, fencing disputes, or questions of damage lies in a cooperative attitude with neighboring owners. When an honest difference of opinion exists, there is no substitute for an attorney's skill and advice. When a dispute arises or seem likely to arise, consult an attorney.

Nearly every year for the past 25 years in Missouri, there has been at least one fencing or property line "bill" introduced in the General Assembly, yet no bill has achieved passage in both houses to become enacted. Producers are encouraged to contact their state representatives and senators with fencing or boundary law recommendations.

Legal Liabilities of Polluting Streams and Groundwater

Recently, protection of both groundwater and surface water has received a great deal of attention as the scope of contamination has increased. The United States relies on ground and surface water for more than half of its drinking water and for more than a quarter of its total fresh

water needs. The Environmental Protection Agency (EPA) estimates that 1% of the nation's groundwater supply is already contaminated and is rapidly increasing.

A major source of ground and surface water contamination is the use and misuse of pesticides and fertilizers. Producers generally rely heavily on groundwater for their own consumption as well as for irrigating crops and watering livestock. Polluted groundwater causes contamination of wells and therefore affects the drinking water for producers, their families, and their livestock. Causes of pollution to streams and groundwater come from two sources, point and nonpoint. Point sources can be traced back to a specific source of the pollution such as a chemical spill. Nonpoint sources cannot be traced back to a specific source. An example of nonpoint pollution is chemical runoff from fields.

Misuse of chemicals can degrade groundwater in several ways. Irrigation backflow, where chemicals are mixed with the irrigation water, can cause serious groundwater pollution. Installation of backflow prevention equipment (valves) is an effective deterrent. Overapplication can cause excess chemicals to leach or percolate into the water table. Runoff can also pollute streams flowing from the producer's property, across neighbors' property, and into larger streams or rivers. Adherence to the pesticide's label, such as following proper dosage instructions, can greatly reduce the likelihood of groundwater and surface water contamination. Highly soluble nitrates can also leach into groundwater, which is an increasing problem in the Midwest.

Other potential sources of contamination occur when containers are improperly cleaned or disposed of and when pesticides are mixed and loaded in an area where residues are likely to reach ground or surface water. Some pesticide labels and some state statutes note the distances from wells for safe mixing and loading of pesticides. Again, close attention to instructions and ordinances can reduce or eliminate potential of ground and surface water pollution.

The attention given to this problem is reflected in the attitudes of the courts and state legislatures toward polluters. Violations of water protection laws and regulations lead to imposition of harsh legal judgments against polluters, especially for liability and negligence. This is not just a problem with high-level violators. Violations of small operators have a cumulative effect and contribute to the overall problem.

Violations are classified as civil and criminal violations. Civil violations may receive a judgment of up to $10,000 per day in fines and are based on the fact that the violation occurred and do not require the element of intent or negligence. If intent and negligence can be proven, then the violation may be criminal and the violator will receive a fine of up to $25,000 and possible imprisonment of 2 years. Chapter 644 of the Missouri State Statutes is a complete reference regarding stream and groundwater pollution.

Summary

Crop producers must be aware of the legal issues that may be associated with the use of agricultural chemicals. Regulation of chemical use is under the jurisdiction of the EPA and is mandated under the Federal Insecticide, Fungicide, and Rodenticide Act. Strict guidelines must be followed if a problem develops. Certain steps must be taken if a problem occurs, such as a chemical spill; there may be severe penalties imposed for that problem. Producers must also know how the locations of parcels of land are legally described in an abstract and that they have a responsibility to know and respect the location of the property boundaries. Ground and surface water pollution may be from a point source such as a chemical spill or a nonpoint source such as fertilizer or chemical runoff from a field. These problems may also carry a civil or criminal penalty.

Credits

Applying Pesticides Correctly-Missouri Core Manual. (MX328) University Extension. Columbia, MO: University of Missouri-Columbia, January 1997.

Clean Water Laws, Regulations, and Support Documents. Missouri Department of Natural Resources, Water Pollution Control Program <www.dnr.state.mo.us> 6 June 2000.

Missouri Fencing and Boundary Laws. (G810). University Extension, Columbia, MO: University of Missouri-Columbia, December 1999.

Missouri Guidelines for Pesticide Recertification Programs. Missouri Department of Agriculture, 2000.

Lesson 1: Planning the Crop

Successful corn and grain sorghum production requires an understanding of the various managment factors affecting crop performance. When planning for corn and grain sorghum crops, important management considerations are the environmental conditions, field history, and fertilizer requirements.

Environmental Conditions

Corn and grain sorghum are warm-season, annual crops. Obtaining an optimum yield will depend on the soil and climate of the particular site. Corn and sorghum are best adapted to well-drained, loamy soils. They can be successfully grown in soil with a pH range of 5.5 (mildly acidic) to 8.0 (moderately basic). Most commercial hybrids are adapted to mature in 130 to 150 days in the central Corn Belt.

Corn and grain sorghum are fast-growing crops that yield best with moderate temperatures and a plentiful supply of water. The ideal temperature is cooler than many think - 75 to 86°F. By this standard the central Corn Belt is often too hot, but overall its temperatures are the most favorable of any region in the United States and about as favorable as any large area in the world. In the Corn Belt, above normal temperatures are advantageous for planting until mid-June. The average planting date in Missouri is typically the average date of the last spring freeze. Refer to Figure 2.1 in Unit IV, Lesson 2 for these dates.

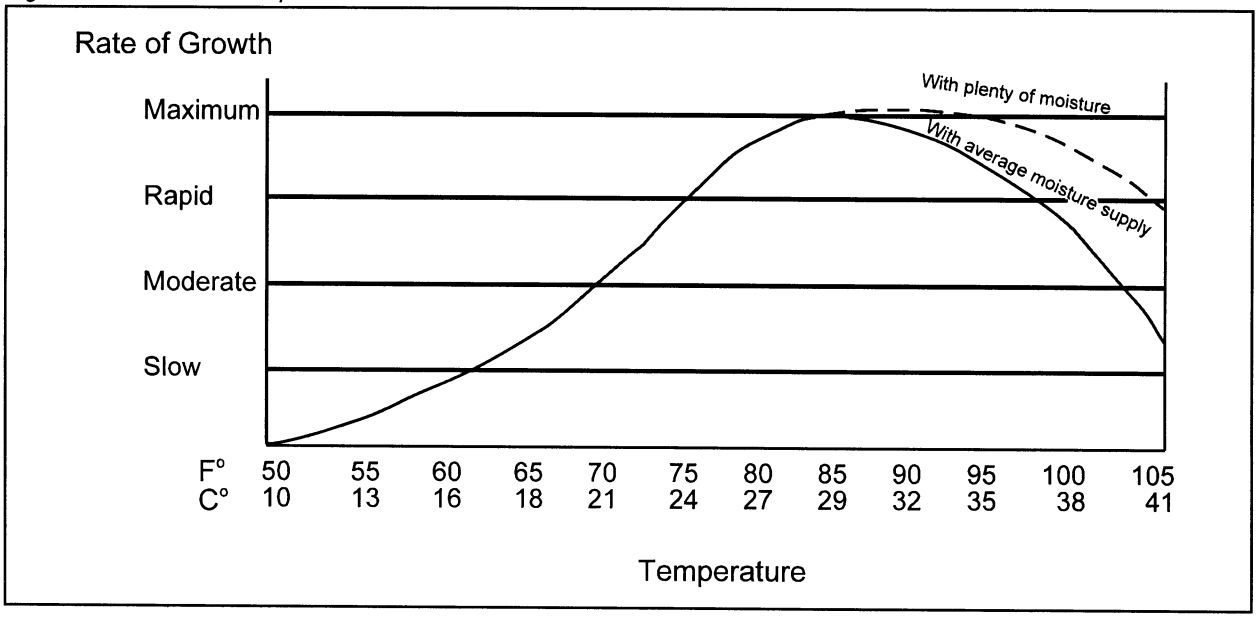
Cool temperatures at planting generally restrict nutrient absorption from soil and cause slow growth. Early planting dates and shallow planting take advantage of the more favorable soil temperatures near the soil surface, resulting in faster germination and emergence. At late planting dates, soil temperatures are generally adequate throughout all planting depths and soil moisture content becomes the limiting factor for rapid growth. Deeper planting depths usually have better moisture content at late spring plantings unless recent rains have occurred.

Slightly below-normal temperatures are better for corn growth from mid-June to early September. It is a misconception that corn and sorghum grow best when the nights are hot. The reverse is actually true. Corn burns up too much energy in cell respiration on warm nights. The ideal situation for maximum growth is cool nights, sunny days, and moderate temperatures.

When the temperatures reach 100°F, adequate moisture is difficult to maintain even with irrigation. Figure 1.1 shows the general effect of temperature for the season using 50°F as the starting point since corn hardly grows at all at lower temperatures.

As shown in Figure 1.1, when the temperature rises to the range of 80 to 86°F, corn and sorghum

Figure 1.1 - Effect of Temperature on Corn Growth



grow faster if moisture is adequate. When the temperature rises above 86°F, the roots have increased difficulty taking in water fast enough to keep the plant cells turgid (full of water). When soil moisture is limited, the optimum temperature is less than 80°F. With perfect moisture supply, the optimum temperature rises to about 90 to 95°F.

The "discomfort index" of corn and sorghum is due to an opposite set of conditions than that of humans and animals. Humans suffer in humid weather because they are not able to lose moisture and therefore cannot benefit from evaporative cooling. Plants suffer when they lose too much water. On clear, sunny days with temperatures of 70°F, plants show moisture stress.

These grains are also produced best in regions that have 25 to 40 inches of annual precipitation or are under irrigation to supplement natural rainfall. Moisture in the summer is critical. Corn and sorghum need 6 to 8 inches of rain (or irrigation) during the preflowering period. These plants use water efficiently. Large quantities are needed for high yields. Drought conditions lead to poor seed set and light test-weight gain, thus lower yields and lower-quality grain.

Sorghum will survive and produce satisfactorily under a wider range of conditions than corn. Sorghum plants are more drought resistant and can tolerate higher temperatures throughout their life cycle. They can also tolerate flood conditions better than corn.

Evaluating Field History

Before planting a stand of corn or grain sorghum on a particular field, there are several factors to consider: previous crops grown; the type, drainage, fertility, and slope of the soil; previous weed problems and herbicide applications; and previous pesticide problems.

There are advantages to planting corn and grain sorghum in a rotation with other crops. If the previous crop was a legume, the nitrogen needs of the corn will be lessened. This will save money in fertilization needs. There may be fewer disease and insect problems. A crop rotation breaks the cycle of some insect and diseases that thrive on corn and sorghum. Also, if a differnt crop was grown before the corn or sorghum, higher yields generally occur than with continuous corn or sorghum crops. Better control of weeds, especially annual weeds, may occur when rotating corn and sorghum with another crop.

There is no substitute for using soil tests when evaluating a field's history and determining its fertility needs. Properly administered soil tests can indicate organic matter and nutrient levels. For the majority of producers, the most important tests are those for lime, phosphorous, and potassium.

Examining the drainage history is more important for corn than for sorghum. Good drainage is indispensable for corn production. Small corn plants are readily killed when water stands on them. A soil that does not drain will interfere with the timing and completion of planting, cultivating, spraying, and harvesting. Well-drained soils are also warmer than wet soils. Warmer soils are important for quick germination and rapid growth of early planted corn and sorghum.

Erodibility of the soil is another important factor to consider in field history. Since corn and sorghum are row crops, the soil on the field will be more exposed to soil loss from wind and water. To determine if corn and sorghum will pose a problem with soil erosion, the producer needs to consider several factors: (1) the amount of rainfall in the area, (2) the length and steepness of the slope on the field, (3) the soil-erodibility factor, which is based on the texture and structure of the field's soil, (4) the different crops grown on the field, (5) and if any special erosion control practices have been performed on the field. These erosion control measures could include terracing, tiling, or contouring.

Disease and insect problems are not as serious as in the past. With today's corn and sorghum hybrids, resistance to diseases and insects are bred into the variety to lessen the damage. Seed treatments and early harvesting have also helped eliminate disease and insect problems.

Fertilizer Requirements

Fertilizer decisions have become more complex because of higher fertilizer prices, lower commodity prices, world food problems, environmental concerns, and more varieties and methods for application. Fertilizer will play an increasing role in feeding the world.

Choosing the right fertilizers and deciding when, where, and how to use them is not easy. However, it has an extremely important influence on profit at the end of the year. Therefore, it is important to follow certain steps in implementing a fertilization program to maximize corn and sorghum yields.

The first step is to understand fertilizers and how they behave in the soil. Though fertilizers come in many forms, brands, analyses, packages and colors, there is nothing very mysterious about them. The nutrient value is always guaranteed to the producer on the bag, tab, or invoice. The primary nutrients - nitrogen, phosphorus, and potassium - are listed in the same order throughout the United States. They are available in a gas, liquid, solid, slurry, and suspension form.

The producer should also understand soils and how to use them for maximum output. Soil samples should be accurately taken and analyzed with the recommendations followed to produce maximum yields. The producer must be able to estimate or determine the kinds and amounts of nutrients the soil will supply. This will be determined by what crop was previously grown on the field and the residual available nutrients in the soil.

The final step is applying the fertilizer when and where it counts.

Nitrogen (N) is the most limiting nutrient for corn production. Corn usually requires more nitrogen than can be supplied by soil or atmospheric sources. Nitrogen is very mobile in soils and undergoes rapid transformations compared with other nutrients. A producer's decision on a nitrogen source should be based on price, availability, ease of application, and potential for volatilization. All sources of nitrogen are equally efficient if they are properly applied in appropriate situations.

Split application of nitrogen fertilizer may substantially improve nitrogen use efficiency. Corn extracts less than 15% of its seasonal nitrogen uptake before rapid vegetative growth begins. The maximum nitrogen use rate occurs just before pollination. However, during early growth stages, considerable nitrogen may be lost due to denitrification and leaching. Apply 1/4 to 1/3 of the total nitrogen recommendation before corn emergence. In corn, the bulk of the split nitrogen application should be delayed until the V5 to V8 growth stages (five to eight emerged leaves with collars present), which occurs about 25 to 35 days after emergence.

Some nitrogen may be band-applied in combination with starter fertilizers but the rate should be less than 20 pounds of nitrogen per acre. Corn roots quickly grow into the soil between the rows. Side-dress nitrogen fertilizers early in the growing season to avoid root pruning. Nitrogen can be applied during early cultivation. Fall application of nitrogen is not recommended for most soils. For grain sorghum, side-dress about 10 to 25 days after planting, but before the five-leaf stage (growth stage 2). Nitrogen use by the sorghum plant increases very rapidly after this stage of growth with about 70% of the required nitrogen taken up by growth stage 5.

A recommended rate of nitrogen for corn is 1.3 pounds of actual nitrogen for each bushel of the yield goal up to 100 bushels per acre. Apply an additional 1.7 pounds of nitrogen for each extra bushel of a realistic yield goal above 100 bushels per acre. For example, the nitrogen recommendation for a goal of 160 bushels per acre is (1.3 lb. N x first 100 bu./A) + (1.7 lb. N x 60 additional bu./A) = 232 lb. N/A. Lower rates of nitrogen are needed for lower production levels because residual nitrogen from the soil and organic matter is used. Grain sorghum requires about 2 pounds of applied nitrogen to produce 100 pounds of grain.

Phosphorus and potassium fertilizers should be applied according to soil test results. Phosphorous nutrition is important to crop maturity, root and stalk development, and energy transfer and storage. Young corn or sorghum plants often turn purple as a result of a phosphorus deficiency. Phosphorus deficiency symptoms begin on lower leaf tips and progress along leaf margins until the entire leaf shows purpling. New leaves emerging from the whorl are usually green but may turn purple shortly after that. Symptoms often occur as young plants are exposed to good growing conditions following cool, wet conditions.

Many cultural or environmental factors may limit root growth, aggravating phosphorus-deficiency symptoms. Examples of such conditions include cool temperatures, too wet or too dry soil, low soil pH, compacted soil, herbicide damage, insect damage, and root pruning by side-dressing knives or cultivators. Fall application of phosphorus is generally recommended for an upcoming crop.

Tillage will help incorporate the fertilizer. Phosphorus injected preplant or with side-dressing equipment increases the availability to corn and sorghum roots.

Corn Belt growers commonly use coulter rigs that band apply starter fertilizer to the side and below the seed. These systems maximize placement efficiency, improve seedling safety, and permit higher fertilizer rates.

Corn and grain sorghum require as much potassium as nitrogen to produce good yields. Potassium is needed to build strong stalks, reduce lodging, fight diseases, and translocate water within the plant. The primary symptom of potassium deficiency is chlorosis (yellowing) followed by necrosis (tissue death) along lower leaf margins beginning at the leaf tip.

Fall application of potassium fertilizer is recommended because, like phosphorus, potassium is relatively immobile in most soils. However, potassium will leach on soils with CECs (cation exchange capacities) less than 8.0. Spring or side-dress application is recommended on sandy soils. Much of the potassium taken up by corn and sorghum is recycled to the soil through crop residue. Potassium recommendations should be increased following forage crop or silage harvest. A good corn or sorghum silage crop removes more than 200 pounds of potassium per acre. Potassium deficiency is common on corn and sorghum grown in a rotation with soybeans, especially in no-till systems.

Attention must also be paid to some minor nutrients such as sulfur, magnesium, and zinc needed for corn and sorghum production. High-yielding corn crops take up more than 30 pounds of sulfur and magnesium. Sulfur and magnesium deficiencies are most likely on sandy soils with less than 1% organic matter, especially during cool, wet conditions.

Zinc deficiencies are most common on sandy, low organic matter soil that has a high pH and phosphorus levels, especially under cool, wet conditions. Zinc deficiencies are evident on small plants as interveinal light striping or a whitish band beginning at the base of the leaf. Follow soil test recommendations to avoid zinc deficiencies.

Summary

With adequate moisture, corn and sorghum are rapidly growing, warm-season crops that do best in temperatures between 70 and 86°F. Conditions in the central Corn Belt present the most ideal conditions in the United States where planting takes place as soon as possible after the last spring freeze. Corn grows best in well-drained, loamy soils with pH level between 5.5 and 8.0. Adequate moisture is needed for corn and sorghum production provided by natural rainfall or irrigation, especially during the midsummer tasseling stage. There are several factors to consider with the history of a certain field before planting corn or sorghum. These include the previous crops grown; type, drainage, fertility, and slope of the soil; and previous problems with insects, weeds, and diseases. Nitrogen is probably the most important nutrient to consider for corn and sorghum fertilization. It is applied in split applications during the growing season and is not recommended for fall application. Phosphorus and potassium may be applied in the fall. Other nutrients such as sulfur, magnesium, and zinc should also be applied according to soil test results.

Credits

Aldrich, Scott, and Hoeft. *Modern Corn Production*. 3rd ed. Champaign, IL: A & L Publications, 1986.

Larson, Erick and Larry Oldham, *Corn Fertilization*, Mississippi State University Extension Service, <http://www.ext.msstate.edu/pubs/is864.htm> 30 Mar. 2000.

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Lesson 2: Selecting a Variety

The first lesson discussed planning the crop and determining fertilizer needs. Another major consideration the producer needs to determine is the seed variety to be planted. This lesson will review the classes of corn and grain sorghum, hybrids, maturity groups, and common diseases that affect these crops.

Classes of Corn and Grain Sorghum

Corn and grain sorghum are both grasses grown primarily for food and livestock fodder. Corn is classified as *Zea mays* and ranks as the largest crop produced in the United States. Grain sorghum is mostly produced as a livestock feed source in the United States but serves as a food staple for millions of people in China, India, and Africa.

Corn

Corn is divided into six main classifications determined by kernel characteristics. This includes dent, flint, popcorn, flour or soft, sweet, and pod or Indian corn. Some specialty corns have been developed but are generally genetic modifications of dent corn including waxy, high lysine, protein, and oil.

Dent corn is the most popular corn grown in the United States. It is characterized by the denting on the crowns of the kernel during ripening. Denting occurs when the soft starch of the endosperm shrinks as the grain dries out. Denting is more pronounced in some varieties with yellow, white, or red seeds. Yellow dent corn is predominantly grown for livestock with white dent corn preferred by cereal manufacturers.

Flint corn is made up of a small amount of soft starch and is covered by a hard starch. Because of this hard outer covering flint corn requires mechanical grinding before being fed to livestock. Flint corn is able to germinate at cooler temperatures and is grown in the northern plains. Because flint corn is resistant to weevils, it is also grown in tropical climates. Most flint corn is currently grown in Argentina.

Popcorn is very popular as a snack food. When the kernel is heated, the moisture in the kernel expands, causing the kernels to pop open. Popcorn is actually a variant of flint corn with small hard kernels. The best popping corn is dependent on the moisture in the kernel. The best results are on kernels with 13.5 to 15.5% moisture. Kernels can be various colors including red, blue, or calico but are generally yellow or white. Regardless of kernel color the popped flake is always yellow or white. Popcorn is divided into two classes depending on the shape of the kernel: pearl and rice. Pearl popcorn is rounder and smoother whereas rice popcorn is relatively long, flat, and slender.

Flour, or soft, corn is composed of a soft starch and a fine, thin layer of hard starch around the kernel next to the hull. Due to this large amount of soft starch, soft corn is easily ground into flour. Flour, or soft, corn is currently grown in the Andean regions of South America.

Sweet corn is chiefly grown for human consumption as a vegetable. The corn is referred to as sweet because the sugar produced by the plant is not converted into starch. The seed will appear wrinkled if the plant is allowed to mature. Sweet corn quality is dependent on harvesting before maturity. A lot of sweet corn is grown for the canning industry and also left on the cob and sold at grocery stores and farmers markets.

Pod and Indian corn are decorative corns and rarely used for human consumption. These varieties consist of multicolored varieties of flour and flint types. Indian corn is very popular as a fall decoration in the United States.

Specialty corns have been developed to meet specific markets including waxy corn, high lysine, high protein, and high oil corn. Waxy corn is used in manufacturing products such as puddings, adhesives, and sizing for paper and fabrics. High lysine, protein, and oil corns were developed to meet additional nutrient requirements needed by livestock but not found in most dent corn. New specialty type corn varieties are expected to be developed rapidly in the coming years as plant breeders everywhere are transferring genes to varieties and parent lines of hybrids. Developments in corn technology could be as important as the discovery of hybrid corn.

Sorghum

Grain sorghum is divided into four classes including grain, sweet, grassy, and broomcorn. Grain sorghum is the most popular sorghum

grown in the world. Grain sorghum is very drought tolerant and includes varieties such as milo, kafir, and feterita, which are grown all over the world. Crosses of different groups like milo and kafir are common in the United States and because of the extensive crossing are sometimes hard to classify. Grain sorghum plants can grow from 2 to 5 feet depending on the characteristics of the variety. However, most U.S. grain sorghum plants are dwarf type. Inflorescence of a grain sorghum plant can contain as many as 2,000 seeds.

Sweet sorghums are known as cane. They are generally grown for forage and only a small amount is produced for sugar or syrup. This sorghum type is generally taller than most grain sorghums, with heights as tall as 14 feet. In addition, the inflorescence and seeds are smaller.

Grass sorghum is most widely known as sudangrass. Sudangrass is grown for various forage uses including pasture, silage, or hay. Sudangrass grows rapidly and requires good management during harvest. Johnsongrass is also a grass type of sorghum. In most states, Johnsongrass is considered a weed with little nutritional value.

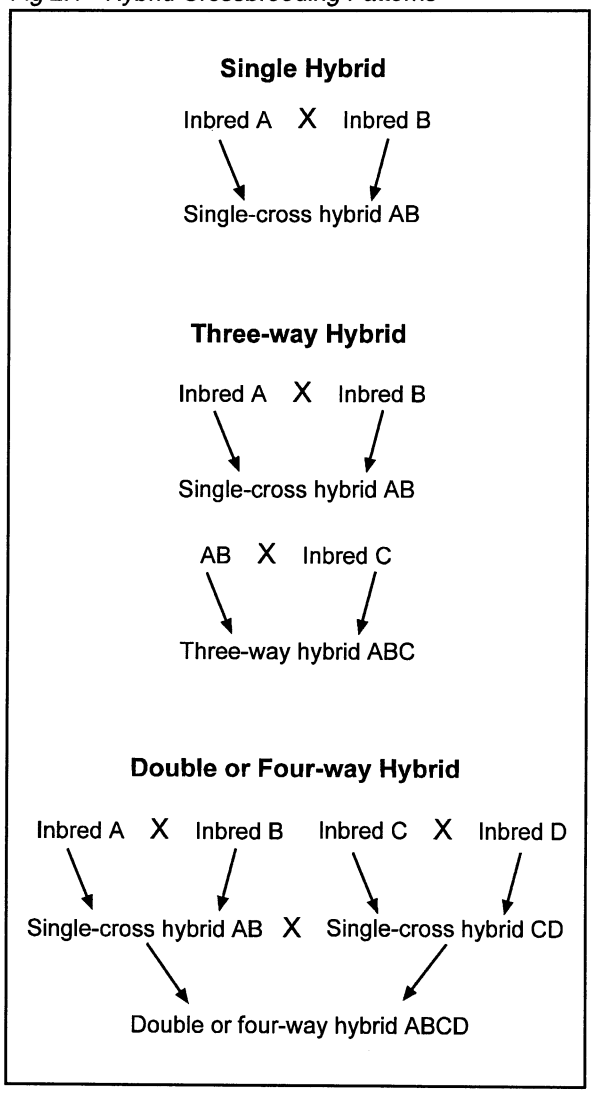
Broomcorn sorghum has long, stiff strawlike stalks with very durable inflorescence. Once used widely to make brooms, it is now second to plastic.

Hybrid Corn

Hybrid corn is the result of a cross between two parents that differ in one or more traits. A process of self-pollination over a period of 7 to 8 years can be developed. At the end of this period, plants will be almost genetically identical and are referred to as an inbred line. Desirable inherited qualities are selected from the inbred lines and crossed to produce hybrids. If the inbred lines were selected wisely, the hybrid seed will produce vigorous plants with desirable characteristics. Seeds harvested from the female parent plants are referred to as single-cross hybrid seed. Other hybrid crossing systems used to produce hybrid seed include three-way hybrids and double, or four-way, hybrids. Figure 2.1 shows the different crossbreeding patterns.

Hybrid corn developed to increase yields and was available to producers around 1933. The inbred lines were weak, but when the two lines were crossed the resulting seed was much more

Fig 2.1 - Hybrid Crossbreeding Patterns



productive than its parents. Hybridization of corn is considered the single most important advancement in the history of corn production. The higher-yielding hybrids received universal acceptance from producers and by 1960 were planted on over 96% of all U.S. corn acres. Currently, all corn acreage is planted to hybrids. Single-crossed corn hybrids are used for producing canned and frozen corn, whereas most double-crossed hybrids (the cross product of two single-cross hybrids) are used by producers. Some higher-yielding single-cross hybrids are making a comeback with producers.

Hybridization adds to the cost of corn seed, but the overall improvement in yields compensates for the additional expense. Hybrid corn can increase the yield by as much as 25 to 50%.

Selecting a Corn or Sorghum Seed Hybrid

Selecting the correct seed variety of corn or grain sorghum requires knowing the characteristics of the seed hybrid. This information is provided to the buyer on the certified seed tag. There are many considerations for the producer, but the primary items to consider are the maturity, yield, plant populations, seed cost, and replant policy.

Maturity date of the crop will vary throughout the state with some growing seasons being longer than others. In general, full-season hybrids have the greatest yield potential. The number of days from the last frost in the spring until the first frost in the fall affects the growing season. The growing season is also affected by the latitude and altitude, which can cause varying climatic changes in the temperature and moisture conditions.

Yield is another important characteristic to be considered when selecting a hybrid. A consistently high harvestable yield is desirable. Tolerance to stress, such as extremes in moisture or temperature, is extremely important in the yield of a crop. Other factors that will affect yield are resistance to corn borer, stalk rot, disease, and insects. Included with yield characteristics to consider for corn are plant and ear height and root lodging. Producers will need to measure yield under their own conditions over 3 or 4 years in order to reflect the hybrid's ability to produce. Yield potential is lost when varieties are not matched with local growing conditions.

Response to plant populations is another consideration when choosing a hybrid. Some hybrids must be planted at high populations to yield well while others do better at lower populations. In good crop years, high populations can increase profitability but the risk is higher if there should be a crop disaster.

A consideration for any crop is the seed cost. In recent years, cost has become one of the biggest factors as the more specific varieties like Bt corn, herbicide and pesticide tolerant corn, high oil corn, and high protein corn have been developed. The replant policy for the particular seed hybrid should also be a consideration.

Corn Maturity Groups

Several characteristics should be considered when choosing a corn hybrid. One of the most important is maturity. For example, if a corn producer wants to use the crop for silage or grain, the right maturity must be planted.

Full-season hybrids generally yield more than earlier-maturing hybrids. If a hybrid matures too early for the planting conditions, the yield will be less for grain or forage. In some years, the corn may lodge (fall over) more from stalk rot than a full-season hybrid. If the hybrid that is planted is too late in maturing, a yield loss may occur from an early frost. Producers should select a hybrid that will reach or be near physiological maturity 1 to 2 weeks before the average date of the first killing frost.

Hybrid maturity increases in importance as planting dates are delayed. Delays are usually attributed to weather problems. If a hybrid is purchased that matures properly when planted in early May, it may not mature if planted in late May. Seed companies supply the maturity grouping (days to mature) on their product.

In addition to maturity (days), many companies supply the average number of growing degree days (GDD) that are required for a hybrid to reach maturity. GDD are calculated for each 24-hour day and accumulated from the time the hybrid is planted until it reaches physiological maturity in the fall. Growing degree days are calculated as the average daily temperature minus 50. The following formula is used to calculate growing degree days.

$$\frac{\text{Max. Temp.} + \text{Min. Temp.}}{2} - 50 = \text{GDD}$$

For example, if the lowest temperature for that day was 55°F and the high temperature was 82°F, the number of GDD would be 18.5. If the maximum daily temperature is greater than 86°F, 86 is used to determine the daily average. If the minimum daily temperature is less than 50°F, 50 is used to determine the daily average. Producers can calculate their own GDD for their own farm if they keep a record of the minimum and maximum temperatures or use those reported by the local television or radio station. GDD is not a perfect guide to corn maturity but is a more precise description of relative maturity than the previous rough guide such as 100-day or 120-day maturity corn.

Seed corn dealers are the best source of information on the maturity of the hybrids they sell

and the recommended production area. Corn performance tests conducted by many state experiment stations are a source of information that can help compare maturity, lodging, and yield of hybrids from different seed companies.

Sorghum Maturity Groups

When selecting grain sorghum maturity groups, the same information and rationale presented on corn may be used for the selection of grain sorghum varieties. In addition, some seed companies rate their sorghum varieties by the number of days from planting to the 50% flowering stage. Most early-maturing varieties are rated at 60 days, whereas later maturing varieties range from 75 to 80 days. Some varieties are sold by a designated number representing the maturity of that particular variety. For example, a variety with a number of 600 would mean it reaches the mid-bloom stage about 60 days from planting.

Common Diseases of Corn and Grain Sorghum

Corn and grain sorghum diseases are managed by planting resistant varieties and adopting appropriate tillage and planting practices. However, diseases still attack these crops, causing lower yields and reduced profits. Some of the more common diseases affecting corn and grain sorghum grown in Missouri will be reviewed.

Corn Diseases in Missouri

More than 60 corn diseases have been reported in the United States, although many occur infrequently or are not prevalent enough to cause measurable loss. Some affect the plant or affect the kernel.

Common smut - This disease is caused by a fungus that is widely distributed over the world. Small to large galls (abnormal growth) form on an actively growing, aboveground plant part. The galls are covered by a glistening white membrane that later ruptures to release masses of black smut spores. Large galls on the ear and above are more destructive than galls below the ear. Initial infections to young plants come from spores in corn debris, soil, or manure. Secondary infections occur in the field.

Diplodia stalk rot - This disease is also caused by a fungus. The affected plants often die early with leaves suddenly turning a dull, grayish-green similar to frost injury. The lower parts of the green stalk turn tan to dark brown and the pith (spongy center) disintegrates. Diseased stalks are weakened and break easily. The fungus survives in corn debris and seed.

Gibberella stalk rot - This is another fungus-caused disease that is widely distributed in the northern half of the Corn Belt. External symptoms are much like those of diplodia stalk rot. A pink to reddish rot disintegrates the pith. Black specks that form on the dead stalks can easily be scraped off. This fungus survives in corn debris and rarely on the seed.

Fusarium kernel or ear rot - This is probably the most widespread disease attacking corn ears and is caused by a fungus. The caps of individual kernels or groups of kernels scattered over the ear develop a salmon-pink to reddish-brown discoloration. A powdery, cottony-pink mold forms later. Infection commonly follows some sort of injury. The same fungi may cause a stalk rot that is difficult to tell from gibberella stalk rot. The fungi survive in corn debris and seed.

Gibberella and diplodia ear rot - These ear rots are caused by the same fungi that cause the stalk rots. Gibberella is found most frequently in the cooler, more humid areas of the United States when the weather during the 4 to 6 weeks before harvest is unusually wet. A pink-reddish mold, often starting at the ear tip, grows on and between the kernels and tightly stuck husks. Infected ears are toxic to swine, dogs, and humans. Diplodia ear rot often begins at the base of the ear and progresses toward the tip. Part or all of the ear is rotted with a white mold growing between the kernels.

Aspergillus ear rot - This disease is caused by a number of species of fungi in the genus *Aspergillus*. The powdery mold growing on and between or within the kernels is usually black, greenish-yellow, or tan. The germ is discolored or dead. The disease is most common in the field when the weather is unusually wet for the month prior to harvest. Affected corn kernels may pack together in storage to form a crust, usually at the center and top of the bin. Some strains of this disease occasionally produce mycotoxins that are harmful if fed to poultry, swine, beef, and dairy cattle, or if consumed by humans.

Stewart's bacterial wilt - This disease Is caused by a bacterium and is most severe following mild

winters. Long, pale green to yellow or tan streaks with wavy margins form in the leaves. The streaks soon turn dry and brown starting at the feeding scratches made by the corn flea beatle. Dark brown cavities may form in the lower stalk pith. Infected plants sometimes produce premature, bleached, and dead tassels. The bacterium overwinters in the corn flea beetle.

Yellow leaf blight - This disease Is caused by a fungus and is most prevalent in the northern area of the United States after extended cool, moist weather. Rectangular to oval, yellow to tan spots, often surrounded by a red and purple margin and a broad yellowish area, form on the leaves. If the blight becomes severe early, the lower leaves turn yellow, wither, and die. The fungus winters in corn, oxtail, and sudangrass debris on the soil surface.

Northern and southern corn leaf blights - These diseases are caused by a fungus and affect the northern or southern portion of the corn-growing portions of the United States. Both are prevalent following warm, moist weather. The southern leaf blight has two races, Race O and Race T, which devastated the corn crop during 1970 but has been practically eliminated by planting resistant hybrids. Leaf lesions are tan with buff to brown borders, elongated between the veins, and generally parallel sided. The northern leaf blight is recognized by long, elliptical, grayish-green and tan lesions on the leaves. They usually appear first on the lower leaves. When severe, a plant may turn grayish-green and die early. The fungus for both diseases overwinters in corn debris on or close to the soil surface.

Common rust - This disease is caused by a fungus that often appears after silking following warm, moist weather. Small, round to elongate, golden to cinnamon-brown pustules form on both leaf surfaces and other aboveground plant parts. The pustules turn chocolate-brown to black as the plant matures. When severe, the leaves may turn yellow, wither, and die early. The fungus overwinter on living plants in southern states and spread northward by windborne spores.

Corn Stunting Virus Diseases

Stunting virus diseases were first reported in Missouri in 1963 beginning first in three southeastern counties. Since then, virus or virus-like diseases have been reported annually. Infections occur in more than 7,000 acres annually. Losses range from 5 to 95% in individual fields, with the most severe being in bottomland fields along the Gasconade and Missouri rivers. Most of these fields have been surrounded or infested by Johnsongrass, a common perennial weed grass proven to be a principal overwintering host for maize dwarf mosaic virus and maize chlorotic dwarf virus.

Maize dwarf mosaic virus (MDMV) - Symptoms of MDMV vary considerably, even in corn plants of the same hybrid in the same field. One plant may show symptoms early in the season, whereas another may not show symptoms until after pollination. Diseased plants are often found in spots or centers within a field. Symptoms first appear in younger leaves as indistinct light- and dark-green mottling between the veins, or as elongated pale green blotches and interrupted stripes. Sometimes the leaves become quite yellow. Corn plants that show this mosaic pattern are often dwarfed or stunted due to a shortening of the upper internodes. Some plants may only show moderate stunting. Some strains of corn may have reduced ear size, barrenness, and poor seed set. In general, ears remain poorly filled on plants infected early in the season.

Maize chlorotic dwarf virus (MCDV) - Rather than the typical mosaic patterns in the leaf tissues caused by MDMV, the MCDV causes vein clearing. When the leaves are held to the light, vein clearing is observed easily in the tertiary veins near the base of the leaf. Plants are also stunted as with MDMV and a reddening of the leaves may be present in some corn strains.

Wheat streak mosaic virus - Early symptoms of wheat streak mosaic virus appear as small chlorotic spots or broken streaks at the tips of young leaves. Streaks elongate and develop parallel to the veins. Older leaves may become chlorotic near the tips with green margins bordering the veins. General yellowing and stunting of the plant may occur as with MCDV or MDMV. Ears may develop poorly and have poor seed set.

Development of resistant or tolerant corn hybrids offers the best long-lasting method of controls of these stunting viruses. Johnsongrass has been recognized as a source of the stunting virus infestation. The eradication of Johnsongrass in corn and sorghum, and perhaps in other crops, is highly desirable.

Grain Sorghum Diseases in Missouri

Several different, normally harmless fungi in the soil can attack grain sorghum seed and seedlings. The organisms most commonly involved are *Fusarium*, *Pythium* and *Penicillium*. Fungi infection can be enhanced by low soil pH, certain herbicides, and cool temperatures.

Leaf diseases are caused by several organisms, both bacteria and fungi, that attack leaves in the summer and lie dormant in crop residue during the winter. Disease severity varies with the weather and the grain sorghum hybrid.

Bacterial leaf diseases in grain sorghum include bacterial stripe, bacterial streak, and bacterial spot. Bacteria causing these three diseases are believed to survive from one season to another in both seed and infected crop residue. They spread from plant to plant by the wind, splashing rain, and insects and are the most severe during warm, moist weather.

Leaf diseases caused by fungi include helminthosporium leaf blight, target spot, gray leaf spot, zonate leaf spot, rough spot, sooty stripe, and rust. Table 2.1 outlines the leaf symptoms of grain sorghum diseases caused by fungi.

Diseases affecting the leaves and stems of grain sorghum include anthracnose, sorghum downy mildew, crazy top, and maize dwarf mosaic virus. Anthracnose and sorghum downy mildew are generally more serious in the very humid Gulf Coast regions of the United States, but they can also be a problem in Missouri. Crazy top is caused by a fungus that winters in grasses and ditches. In the spring, it can spread in overflow water from ditches to fields. Crazy top is generally not a serious problem in Missouri. Maize dwarf mosaic virus does cause problems in Missouri where Johnsongrass is present. The virus overwinters in the rhizomes of Johnsongrass. The new shoots on the rhizomes are infected and the virus moves via insects to plants such as grain sorghum and corn.

Root and stalk diseases cause more damage to grain sorghum than any other disease in the state. Infected plants usually perform poorly and may lodge. Charcoal rot is the most common and damaging stalk rot. It can cause seedling root rot and stalk rot in grain sorghum with the stalk rot phase being the most common. Damage from this disease is generally worse in areas of a field where plants have been under drought stress.The lower stalk will appear shredded and dark gray. The fungus decomposes the pith within the stalk, leaving the plant weak and vulnerable to lodging. Fusarium stalk rot affects various grasses besides

Table 2.1 Leaf Symptoms of Grain Sorghum Diseases Caused by Fungi

Disease Name	Lesion Shape	Lesion Size	Lesion Color	Other Characteristics
Leaf blight (*Setosphaeria turcica*)	Irregular and long	1 inch long or longer	Gray with tan-red borders	—
Target spot (*Bipolaris cookei*)	Round, elliptical spots	1/8 inch to 1 inch	Tan with red borders	—
Gray leaf spot (*Cercospora sorghi*)	Elongate to rounded	1/4 inch or more	Dark purple	Old lesions may be gray
Zonate leaf spot (*Gloeocercospora sorghi*)	Bull's-eye appearance	1/4 inch to 2 inches	Alternating dark purple and tan bands	Lesions resemble a bull's-eye target
Rough spot (*Ascochyta sorghi*)	Broad elliptical	1/4 inch to 1/2 inch	Tan centers with purple borders	Center of the lesion is rough to the touch (feels like fine sandpaper)
Sooty stripe (*Ramulispora sorghi*)	Elongate elliptical	3 to 5 inches long, 3/4 inch wide	Tan center, purple margins	Centers of old lesions will appear sooty
Rust (*Puccinia purpurea*)	Round to elliptical raised pustules or blisters	1/16 inch to 1/8 inch	Light red-brown	Usually confined to older leaves

grain sorghum. Like charcoal rot, *Fusarium* targets weak, drought-stressed plants.

Diseases of the heads of grain sorghum are in the form of smut or mold. Covered kernel, loose kernel, and head smut are all forms of smut that affect the grain sorghum. All three smuts are not serious problems because of fungicide seed treatments. Head molds are more common in Missouri, especially during periods of rainy weather after the plants mature. These molds generally do not cause serious yield losses but can become a concern during storage.

Other plant disorders that may occur in grain sorghum production are not caused by bacteria or fungi. Nutrient deficiencies, extremes in soil pH and temperatures, air pollutants, insect and bird damage, and mechanical injuries can all influence yield potential. For more specific information on the management of grain sorghum diseases, review the University of Missouri Extension Guide G04356, *Management of Grain Sorghum Diseases in Missouri.*

Summary

Corn and grain sorghum are both grasses grown primarily for food and livestock fodder. Corn is divided into six main classifications: dent, flint, popcorn, flour or soft, sweet, and pod or Indian corn. Sorghum is divided into four classes including grain, sweet, grassy, and broomcorn sorghums. Hybridization does add to the cost of the seed, but the overall improvement in yields compensates for the additional expense.

Factors to be considered in selecting either a corn or grain sorghum variety include maturity, yield, and plant populations. Corn and grain sorghum diseases are typically managed by planting resistant varieties and adopting certain tillage practices.

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Lesson 3: Selecting a Tillage and Planting Method

Once the initial planning stages are complete and the variety has been selected, the producer must determine the best tillage and planting methods for the area. Seeding rates should be evaluated to obtain the recommended plant populations at harvest. Planting calendars are useful to help producers estimate the optimum planting time for the area.

Optional Tillage Methods

Tillage practices used in corn and grain sorghum production include conventional tillage, minimum tillage, and no-till. In Unit II, the specific definitions for each tillage practice were outlined. The tillage method chosen to plant corn and grain sorghum should be used to achieve the seedbed that will give satisfactory emergence. Tillage costs producers money in fuel, labor and wear and tear on equipment. By incorporating a tillage method that reduces the number of trips across a field and minimizes tillage depth, costs will be reduced. Added tillage may also increase potential for soil erosion. Producers should evaluate tillage by comparing what is currently needed and what methods were previously used for each field.

Optional Planting Methods

The number of optional planting methods in corn and grain sorghum production are limited. Corn and grain sorghum planted for grain are planted using either the row or drilled method. When using the row method, a producer uses a planter to plant evenly spaced seed in parallel rows. The drill method uses a drill for planting seed in narrow rows at high population counts. Much research has been done to determine the most ideal row width for a desired seed population. The width of the row is limited by the equipment being used. In the Midwest corn is most commonly planted in 28- or 30-inch rows. Grain sorghum may be planted in narrower rows, such as 18 inches. Recent trends in corn and grain sorghum production point toward narrow rows at higher population counts with yield increases of 3 to 5%. Key changes to consider for narrowing rows include tractor and combine rims and tires, combine heads, and planter modifications.

Recommended Seeding Rates

Most seed companies specify a range in seeding rates for the various hybrids they market. Final crop stands will vary depending on the production environment and growing conditions. Adjustments to the seeding rate should be made on a field-by-field basis using the yield potential of a site. Higher seeding rates are recommended for sites with high yield potential with high soil fertility levels and water-holding capacity. Lower seeding rates are preferable when droughty soils or late planting limit yield potential.

Recommended plant populations for corn at harvest range from 20,000 to 30,000+ plants per acre, depending on the hybrid and production environment. Genetically altered corn hybrids may require harvest populations greater than 24,000 plants per acre to achieve their yield potential.

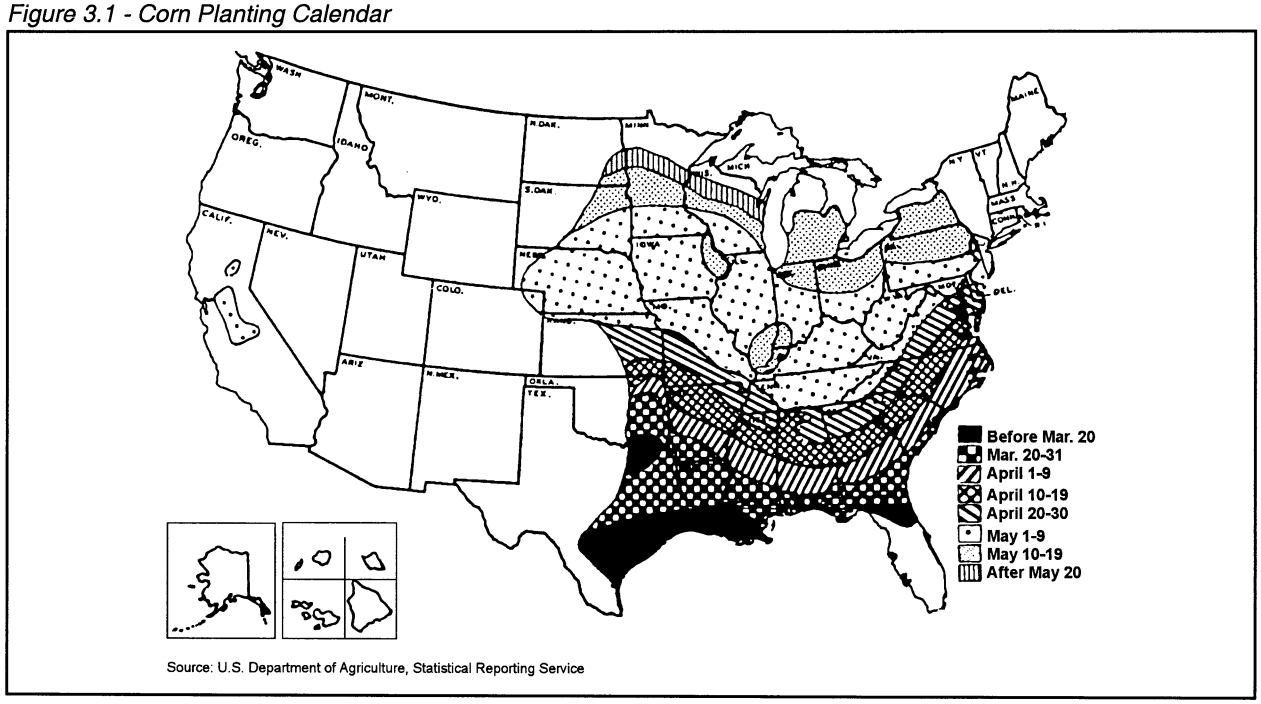
Grain sorghum may have plant populations at harvest as high as 100,000 or more plants per acre. A seeding rate of 5 to 7 pounds per acre is used in Missouri to get the desired plant population. Drier areas without irrigation may require 3 to 4 pounds of seed per acre, whereas irrigated sorghum does best if planted at 12 to 15 pounds of seed per acre.

Corn and Grain Sorghum Planting Calendar

Planting calendars are used to give producers an estimate of when corn and grain sorghum are planted in their local area and/or region. Frost and cool soil temperatures are the biggest limiting factors for planting corn or grain sorghum early in the spring. In Missouri, corn that is planted for grain is generally planted April 5 to June 10. The soil temperature for corn should be 50° to 55°F and 60° to 65°F for sorghum at a 2-inch depth from 8 a.m. to 9 a.m. constantly for 5 to 7 days before planting. In Missouri, soils warm up earlier than states to the north and many producers get "spring planting fever" at the immediate onset of warm weather. Early planting is not always a good strategy for increased yields. If warm weather continues, early planting can help alleviate late-season heat and moisture stress. However, if early planting is followed by cool, damp weather, seedling emergence will be delayed and the probability of seed and seedling injury will increase. Grain sorghum seed is likely to mold or rot in cold wet conditions.

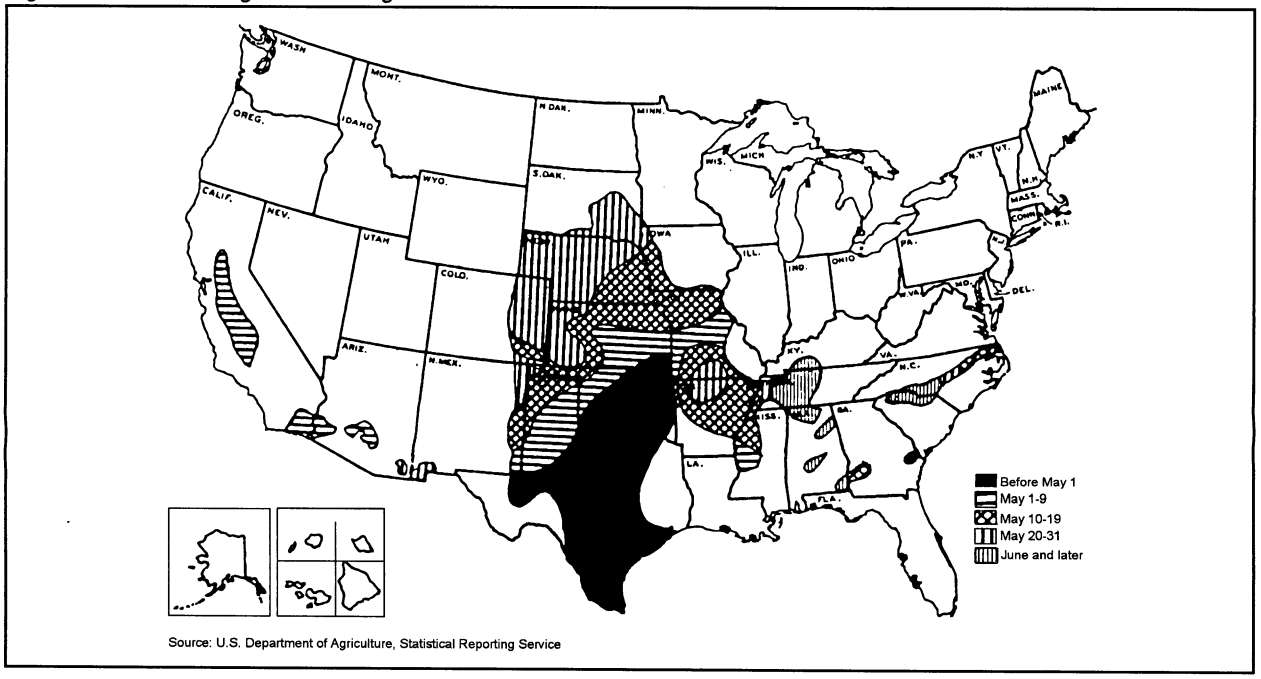
In Missouri, grain sorghum used for grain is planted April 25 to July 1. In the spring, untilled or residue-covered soils often dry and warm up more slowly. Soil temperatures should be checked at a 4-inch depth for fields with heavy residues. Plant conventional tilled acres first, if possible, to allow no-till acres time to dry and warm up. It is not wise to make assumptions about soil moisture or soil temperature. Various farm supply catalogs and stores offer special soil thermometers. Producers should use a thermometer or follow local planting calendars for their region. Figure 3.1 and Figure 3.2 outline the usual planting dates for corn and grain sorghum in the United States.

Figure 3.1 - Corn Planting Calendar



Source: U.S. Department of Agriculture, Statistical Reporting Service

Figure 3.2 - Grain Sorghum Planting Calendar



Source: U.S. Department of Agriculture, Statistical Reporting Service

Summary

Tillage methods used for corn and grain sorghum include conventional tillage, minimum tillage, and no-till. Corn and grain sorghum are planted by either the row or drilled method. Research is ongoing to determine the ideal row width for the most desirable seed population. Seeding rates for corn should have a plant population range from 20,000 to 30,000+ at harvest. Grain sorghum seeding rates have plant populations at harvest as high as 100,000 or more plants per acre. Planting calendars give producers an estimate of when corn and grain sorghum should be planted in their local area.

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Lesson 4: Selecting a Pest Control Program

Discussion in Lesson 2 dealt with diseases that are problems to corn and sorghum producers. This lesson will give information on the many insect, worm, bird, and rodent pests that plague producers in Missouri. This information will include a description of the pests, damage they may inflict to the crop, and control measures.

Types of Pest Control Programs

The objective of pest control measures is to reduce insect pest populations to acceptable levels. Specific control techniques include chemical, physical, and biological mechanisms.

Chemical agents called pesticides include insecticides and fungicides. Only about 9% of agricultural land in the United States is treated annually with insecticides and 1% with fungicides. About 67% of all insecticides used in agriculture are applied to two crops, cotton and corn. Most of the insecticides applied are long-lasting, synthetic compounds that affect the nervous system of insects on contact. Agricultural pesticides prevent a monetary loss of about $9 billion each year in the United States. For every $1 invested in pesticides, the American producer gets about $4 in return.

Nonchemical methods (using physical and biological mechanisms) include controlling pests by plowing them under in crop residues; introducing predators and parasites that feed on harmful pests; breeding plants that are pest resistant; releasing sterilized male insects into wild pest populations, causing females to bear infertile eggs; and using crop rotations.

Integrated pest management (IPM) is a more recently developed technology for pest control aimed at achieving the desired control while reducing the use of pesticides. Combinations of chemical, biological, and physical controls are used. If properly implemented, IPM can reduce pesticide use by as much as 50% while also improving pest control. Environmental problems can be reduced and producers and society as a whole will see significant benefits.

Despite the number of different pests that feed on corn, the average field of corn generally exhibits minimal pest problems. This is because the normal activity of most pest populations is too low to inflict significant injury to warrant attention. However, economic levels of pest injury do occur. Economic losses resulting from sudden outbreaks of pest activity can be prevented if the crop producer is aware of the biology of corn pests, monitors fluctuations in pest population activity, and implements timely corrective action.

The use of these corrective actions (chemical or nonchemical) will be determined by the producer. This determination will be based on the following factors.

Cost is probably the largest determining factor. Chemicals are very expensive and costs are rising continually. The amount and kind of chemical are based on the pest problem as observed by the producer when scouting the corn crop. Rising cost is one reason producers are looking for alternatives to pest control other than chemical use.

Many producers select their pest control action from previous experience or observing what other producers are using for control methods. This may not be the best rationale to use when making pest control decisions. Conditions change and so must pest control methods. Also, what one producer uses to solve a pest problem may not be successful for another producer.

Another factor in pest control selection would be considerations for the environment. More producers are becoming aware of harmful effects of overuse of pesticides. Educational efforts of groups and agencies responsible for land and water quality are making an impact on choices of pest control measures used by crop producers.

Other factors to consider when deciding pest control methods would involve the specific pest problem, soil types, and refuge requirements. Crop advisors from chemical suppliers, seed companies, and extension agronomy agents are very useful in recognizing specific pests and suggesting control methods. They can also help identify soil conditions and types that may affect chemical control success. Refuge requirements will provide insects with non-resistant varieties to survive on when resistant varieties are planted.

Pests Specific to Corn and Grain Sorghum

About 10,000 species of insects cause problems in food and fiber production or affect the well-being

of humans and domestic animals. Of these, fewer than 100 species cause most of the pest damage to corn production in the United States. This discussion will be limited to 20 of the most important insect pests affecting corn production in the Corn Belt area where Missouri is located.

Identifying and managing insect pests in the cornfield is difficult because there is great diversity among the insects themselves and the complex interaction of conditions that affect their movement and growth. Some insects are active only at night or may simply be difficult to find in the cornfield. Some pests are chronic problems and tend to be abundant almost every year. Others are sporadic and only occur every 5 to 10 years in numbers great enough to reach economic importance. Some pests are migratory and must have perfect timing to make a "successful" infestation. Weather must favor their migration or a host plant must be available for the insects to survive and reproduce.

Table 4.1 lists 20 corn pests that may present problems to corn and sorghum production in Missouri. They are grouped into four growth stages of corn when they are most likely to appear and damage the plant. Some pests may affect the plant in more than one stage of growth.

In addition to most of the pests listed in the table, there are three additional insects that are important to sorghum producers. These are the greenbug, sorghum midge and the sorghum webworm.

Greenbugs are aphids with a tiny, light green soft-body with a darker green stripe down their backs. They damage sorghum plants by sucking out plant juices. They also damage plants by injecting a toxin while feeding. They feed in colonies on the underside of leaves and leave behind a substance called honeydew. Sorghum in the seedling, boot, or heading stage will be most affected by greenbug feeding. Damaged leaves will turn from green to yellow to brown as they die. Larger plants are more tolerant of greenbugs, but the pests can reduce the crop's yield potential, especially during booting, flowering, and grain development.

The sorghum midge is an orange fly that lays its eggs on the spikelet of the sorghum plant. The newly hatched larva is colorless. As it feeds on the developing grain, it gradually becomes pale pink, then a deeper pink, finally turning into an orange-colored larva. Areas that are typically infested are areas where sorghum has been grown for several years and where Johnsongrass is prevalent. This pest overwinters in aborted sorghum spikelets and heads of Johnsongrass.

The sorghum webworm begins as a small, whitish moth. The egg of the moth is white with a pale green-yellow tinge when laid, but changes to a straw yellow over a 2-day period. The newly hatched, pale green caterpillar is thickly covered with spines and hairs and has four red-to-brown longitudinal stripes on its back.

Sorghum webworms are a major pest of grain sorghum in North America. They are most damaging during years of high moisture. Although grain sorghum with compact seed heads seem to be their preferred food source, the sorghum webworm will also feed on sweet sorghum, Sudangrass, Johnsongrass, corn, rye, and timothy. The caterpillars feed on the ripening grain, consuming the contents of the individual kernels and leaving the outside hull intact. Losses in individual fields may be as high as 30 to 80%. Extensive damage rarely occurs during periods of hot, dry weather.

Effect of Pests on Yields

Despite all the control efforts used, pests annually destroy about 35% of all crops worldwide. Even after harvest, insects, rodents, and birds inflict a further 10 to 20% loss. In the United States alone, corn borers cost producers and the food system more than $350 million annually in yield losses and crop protection costs. Effects of all pests on corn and sorghum in total losses have not been made available. Loss ranges vary extensively from region to region in Missouri. Some data shows that without soil and foliar-applied insecticides, increased production costs would range from about $1.00 to $6.25 per acre annually.

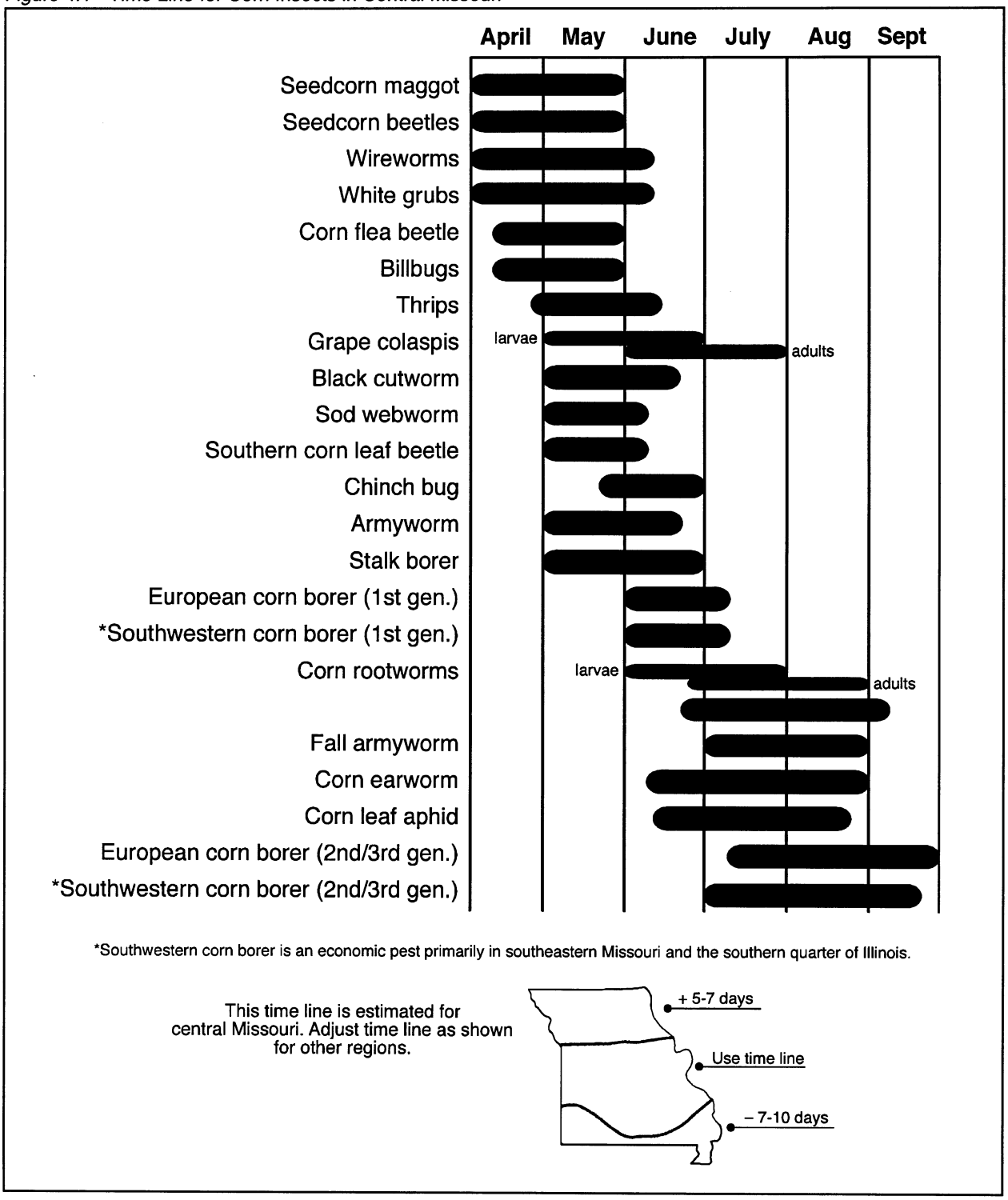
Available Pest Control Options

When planting corn or grain sorghum, there are four pest management options. They include (1) application of a granular or liquid soil insecticide at planting to prevent stand loss or reduce potential rootworm losses, (2) application of an insecticide in a herbicide tank mix applied as a preplant or preemergence treatment to prevent stand loss, (3) application of a seed treatment to prevent insect damage to seeds, (4) use of no treatment to prevent pest losses, and (5) planting pest-resistant hybrids.

Table 4.1 - Corn Pests

Growth Stage	Pest	Damage
Planting to Emergence (V2)	Birds, rodents	Seedlings pulled up and eaten
	Seedcorn maggot, seedcorn beetles, wireworms	Seeds bored into or hollowed out
Emergence to knee-high (VE-V8)	Wireworms, white grubs, grape colaspis larva, chinch bug	Stunting or wilting
	Wireworms, black cutworm, stalk borer	"Dead heart" (center leaves dying or dead)
	Stalk borer, billbugs, stink bugs	Unnatural growth (twisting, tillering)
	Thrips	Speckled or "sandblasted" leaves
	Corn flea beetle	Irregular narrow lines or "tracks" scratched from top layer of tissue
	Black cutworm, sod webworm	Plant cut off near base
	Cutworms, sod webworm, leafrollers, southern corn leaf beetle, stalk borer, armyworm	Chunks of leaf tissue or entire leaf eaten
	Billbugs	Small, symmetrical, rounded holes in leaves
	Southern corn rootworm beetle	Lacy, skeletonized leaves
Knee-high to tasseling (V8 to VT)	Stalk borer, armyworm, fall armyworm, grasshoppers, corn earworm	Chunks of plant tissue removed from leaf margins or ragged holes in leaves
	European corn borer, southwestern corn borer	Small, circular holes or elongated lesions in leaves
	Corn rootworm larvae	Stalks malformed: Lodging or growing upward in a gooseneck shape
	Stalk borer, European corn borer, southwestern corn borer	Holes bored in stalk
Tasseling to maturity (VT to R6)	Armyworm, fall armyworm, grasshoppers	Chunks of plant tissue removed from leaf margins, or ragged holes in leaves
	European corn borer, southwestern corn borer, corn rootworm beetle	Small, circular holes or elongated lesions in leaves
	Corn rootworm larvae	Lodging or growing upward in a gooseneck shape
	European corn borer, southwestern corn borer	Stalks broken
	European corn borer	Tassels broken
	Fall armyworm	Tassels eaten (in whorl)
	Corn leaf aphid	Tassels discolored
	Grasshoppers, corn rootworm adults, corn earworm, Japanese beetle, yellow woollybear	Silks clipped
	Grasshoppers	Large chunks of kernels removed, often at blister and milk stages
	Fall armyworm, European corn borer, corn earworm	Tunneling or chewing damage
	European corn borer	Ear drop

Figure 4.1 - Time Line for Corn Insects in Central Missouri



Applying a soil insecticide at planting may be warranted if pest populations threaten to cause stand loss or if rootworm threaten to attack corn root systems. Although the use of soil insecticides at corn planting time represents the leading use of insecticides in the Midwest and North America, a majority of the corn in Missouri is planted without the use of a soil insecticide because of limited pest pressure.

Soil insecticide treatments at planting time will aid in reducing stand losses from the following pests: seedcorn maggots, cutworms, grubs, and wireworm. Each of these pest problems is often associated with unique conditions and should not be considered a widespread problem applicable to all corn-growing habitats. Seedcorn maggots are more of a problem where organic matter levels are high and climatic conditions delay seed germination and seedling emergence. Cutworm problems will develop only if significant populations immigrate from the south or if a certain field is an attractive location to the immigrating populations. Fields with minimal weed problems are not attractive to cutworms.

Wireworms and grub infestations associated with stand loss are relatively uncommon. They may be more of a problem when corn follows either pasture, sod, forage, or fallow ground where specific grasses have aided development of wireworm or grub populations. In these cases, a soil insecticide with strength against wireworms and grubs is recommended. A seed treatment should be used to guard against damage to seeds.

After the corn stand is established, the frequency of severe pest problems tends to decline. However, periodic inspections should be conducted to detect pest problems. The primary pest problem during midstages of growth is infestation by corn borers. Less than 5% of corn stands exhibits significant infestations of European corn borer and few fields ever have infestations warranting corrective action. Corrective action involves spraying insecticides on the plant. This is usually more expensive and not warranted according to yield loss.

Another pest that may show up during midstages of growth is the corn rootworm. However, once it occurs, nothing can be done. If rootworm is significant, lodged plants will be evident.

Few pest problems occur as plants enter the tasseling and silk stages. Most of these pest problems are associated with the corn leaf aphid and various beetles. These are generally associated with dry conditions. Abundant corn leaf aphids on 70% or more of the stand may warrant rescue treatment, but the activity of beneficial predators usually takes care of such infestations when they occur.

As the ears mature, the second brood of European corn borer may become a problem. If detected early, rescue treatments (spraying) may be necessary to prevent excessive stalk injury and ear infestation. Fields with severe infestations should be flagged for early harvest. Significant lodging may occur if harvest is delayed.

Certainly one of the latest pest control options is that of planting insect-resistant hybrids. Corn growers and consumers already benefit greatly from biotechnology in the form of Bt corn that protects itself against the European corn borer by producing a larvae-killing chemical. A recent discovery by the Agricultural Research Service may help with this pest. Scientists have discovered a strain of corn from Argentina that possesses a chemical that female European corn borers find unacceptable for egg laying. Breeding this trait into corn could take several years. Other genetically improved hybrids, such as rootworm-resistant corn, are nearing commercialization.

Greenbugs will not be evenly distributed in a field, so it is wise to examine plants from all parts of a field. A control treatment should be used on greenbugs when 20% of the plants show yellowing leaves and insects are found on young plants from emergence to 6 inches tall. Treat larger plants up to the boot stage when greenbugs are causing red spotting or yellowing of leaves.

Several cultural practices have been recommended for control of the sorghum midge. These include preventing Johnsongrass or other hosts from producing heads in and around sorghum fields before the crop blooms, planting at the time of year best suited for the variety selected, and destroying crop residues that contain overwintering larvae. When a large adult population is detected at bloom, an insecticide treatment is warranted.

Control practices of the sorghum webworm include the destruction of crop residues to destroy overwintering larvae and early planting to escape the late-season buildup in webworm populations. Warm, dry weather also effectively deters damaging infestations.

Summary

Corn and sorghum producers have always been faced with the problem of pest control. Producers must consider the cost of control measures, previous experiences with pest controls, observing what other producers use, environmental

considerations, specific pest problem, time of the growing season, and soil types when determining what pest control methods they may use. Of the thousands of plant pests today, only about 20 are of importance to corn and sorghum producers. These pests may invade the crop during one or more of the plant's growth stages. Producers should know how to recognize the pest problem and understand what control options are available for their treatment. This may include planting insect-resistant hybrids.

Credits

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Lesson 5: Scouting and Maintaining the Crop

During the growing season, certain decisions are made that may affect the growing conditions of the corn and sorghum crop. These decisions may determine if the maximum production potential, bushels or pounds per acre, will be achieved.

Plant Condition Factors to Consider When Evaluating the Growing Crop

Evaluation of corn and sorghum crops should begin at the time of germination and continue through harvest. During this period, the producer should look for specific problems that may develop at the different stages of growth and development of the plant.

At germination, the producer should dig into the soil and evaluate the germination process. At different locations in the field, an evaluation should be made to determine possible germination problems and percentages. Problems affecting germination may be related to disease, insect, soil moisture, soil temperature, soil crusting, herbicide injury, or nutrient inefficiency.

Early stages and middle growth should be scouted to look for insect or disease problems. Most spring plantings have adequate moisture for growth. As the plant develops and grows, the moisture requirements increase until after pollination. As the crop nears harvest, moisture needs decline as the grain starts maturing and drying. Early stages of growth should also be evaluated for insecticide- or herbicide-related problems. Excessive herbicide usage could cause burning and plant loss.

The effectiveness of the producer's fertilization program may also be evaluated during the early and middle growth stages. Adjustments may need to be made next planting season to secure optimum yields. Crop nutrients may need to be increased for increased yields.

Determining When Replanting Is Appropriate

It is common that 10 to 15% of planted seeds fail to establish healthy plants. Additional stand losses resulting from insects, frost, hail, flooding, or poor seeding conditions may require a decision on whether or not to replant a field or part of a field.

The first rule is not to make a hasty decision. Corn plants can and often do outgrow leaf damage, especially when the growing point is protected beneath the soil surface (up to the six-leaf stage). If new leaf growth appears within a few days after the injury, then the plant is likely to survive and produce normal yields.

When deciding whether to replant a field, gather the following information: (1) original planting date and plant stand, (2) earliest possible replanting date and plant stand, and (3) input costs such as cost of seed and pest control for replanting and replant policy on the seed that was purchased. Table 5.1 and Table 5.2 may be used as a guide to assist in this decision.

Table 5.1 - Effect of Planting Date on Corn in Central and North Missouri

Corn Planting Date	Yield as % of Normal
May 11	100
May 16	99
May 21	97
May 26	94
May 31	90
June 5	85
June 10	80
June 15	75

Table 5.2 - Effect of Planting Date on Corn in Southeast and Southwest Missouri

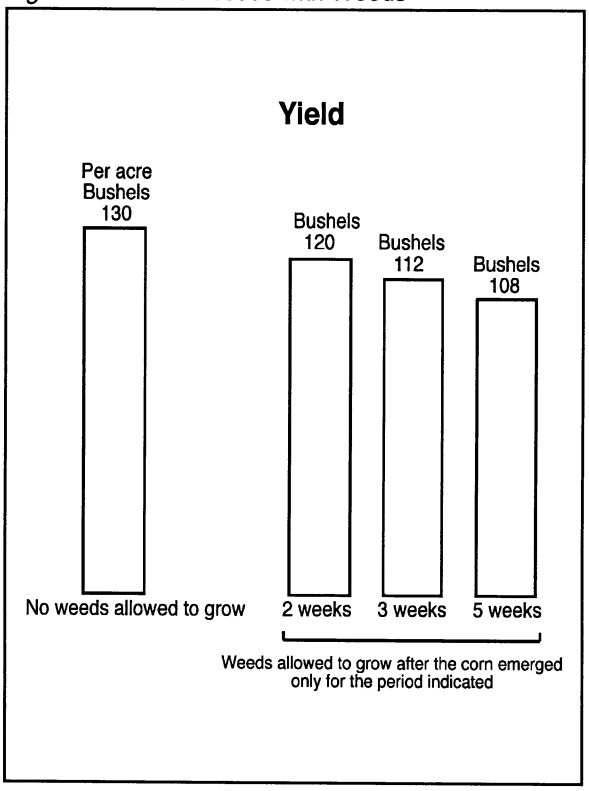
Corn Planting Date	Yield as % of Normal
April 1	100
April 10	99
April 30	92
May 10	87
May 20	83
May 30	79
June 10	72
June 20	59

To determine whether replanting is appropriate, compare the net income from replanting with the income from a sparse stand. Even if this comparison is positive, replanting may still be desirable. Other demands on the producer's time and competing crop management issues are important considerations. A spreadsheet program from the University of Missouri-Columbia is available on the Agricultural Electronic Bulletin Board (AgEBB) web site to help analyze the situation. The web site address is <http://agebb.missouri.edu>. This worksheet will figure seed cost, fuel, machinery, labor, loans for replanting, and possible increased dryer costs for late maturing corn.

Amount of Weed Pressure to Justify Herbicide Application or Mechanical Removal

The major objective of a weed control plan should be to control those weeds that emerge at or about the same time as the corn. Early planning should be followed by early action. Early action starts with good cultural practices such as seedbed preparation, adequate fertilization, crop rotation, optimum row width, and optimum population.

Figure 5.1 - Yield Losses with Weeds



The first 3 to 5 weeks are critical in controlling weeds in corn. Research shows that when weeds are only 6 to 8 inches tall, they have already cut corn yields. Figure 5.1 shows that allowing weeds to grow only 2 weeks after the corn came up caused a yield loss of 10 bushels per acre. Allowing weeds to grow 3 weeks and 5 weeks after the corn came up caused further losses.

Tables 5.3 and 5.4 show the effect on corn yields by two common weed problems in Missouri, infestations of pigweed and giant foxtail.

Many weed problems can be prevented with the application of preemergence herbicides or the use of mechanical or cultural practices. Seedbed preparation and the use of cultivators or rotary hoes would be examples of mechanical practices that are effective in controlling weeds. Selecting a planting rate for optimum stands would be an example of a cultural practice. Thin stands of corn favor a heavy population of weeds in the row.

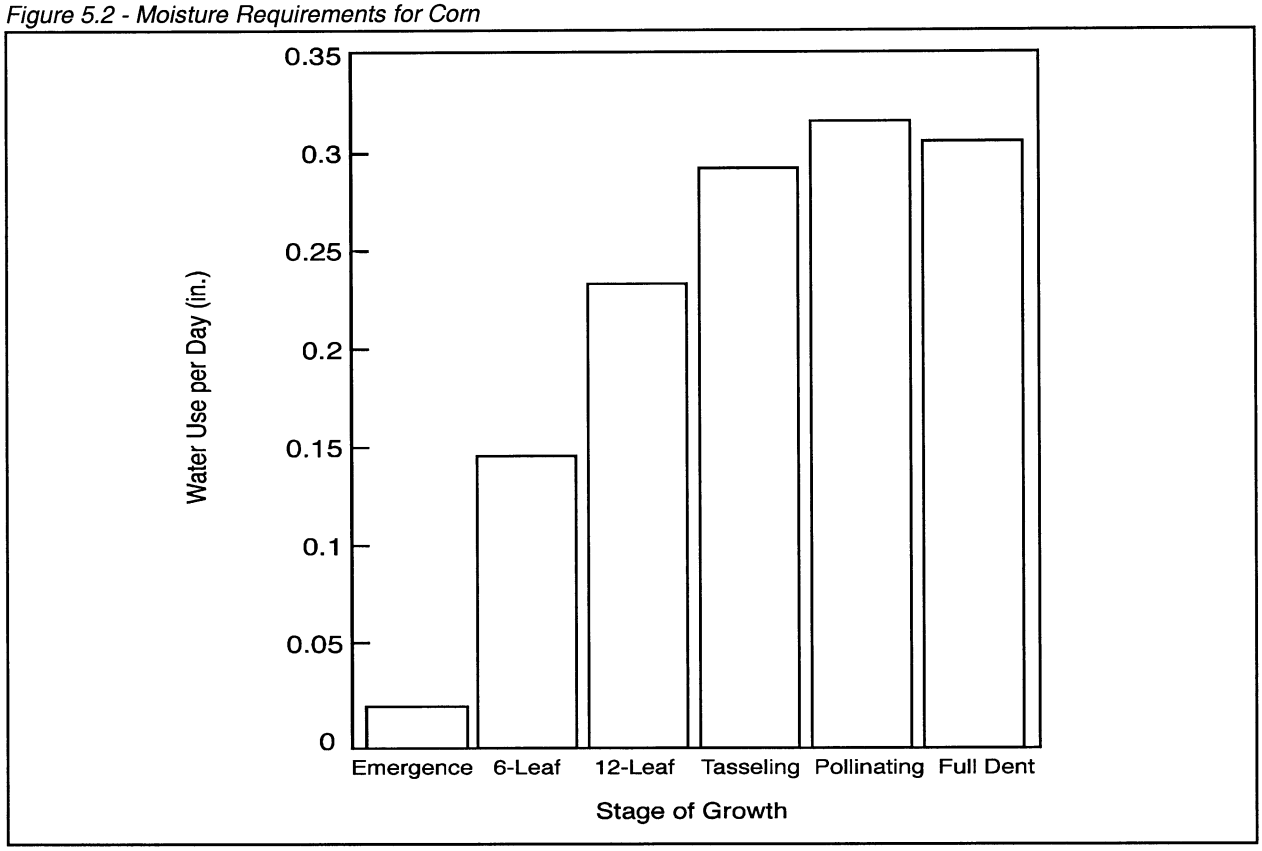
Table 5.3 - Effect of Pigweed Stand on Corn

Pigweed Stand in the Corn Row	Yield Per Acre (bushels)	Yield Loss (bushes/acre)
None	108	0
1 per 40 inches	101	7
1 per 20 inches	92	16
1 per 10 inches	91	17
1 per 5 inches	78	30
1 per inch	67	41
Band of weeds	64	44

Table 5.4 - Effect of Giant Foxtail on Corn Yield

Time Foxtail Emerged After Corn Planted	Average Bushels/Acre
Same day	115
3 weeks later	131
6 weeks later	132
12 weeks later	132
Weed Free	132

Figure 5.2 - Moisture Requirements for Corn



Amount of Insect Pressure to Justify an Insecticide Application

When trying to justify the application of an insecticide according to the amount of insect damage, there are several major factors to consider. These factors include identification of the pest or insect, stage of growth for the corn plant and/or grain sorghum plant when the problem develops, the severity of the damage to the individual plants, and the size of the damaged area in numbers of acres.

Scouting the corn and sorghum fields often at germination and during the plant growth stages will be important to recognize the development of a problem. Early evaluation and initiation of a treatment program could reduce the damage done by the pest. To aid in the decision of replanting from pest damage, follow the information given above.

Ask the pesticide dealer, an extension agronomy agent, or other crop experts for advice when monitoring pest populations and choosing the proper pesticide program and timing.

Environmental Conditions During Pollination That Affect Yields

Four environmental conditions or factors are of most concern to corn producers during pollination. These factors include moisture amounts, nutrient deficiencies, high temperatures, and weather factors, such as hail.

Larger seed yield reduction will result from water stress occurring from 2 weeks before silking to 2 weeks after silking than similar stress at any other period of growth. The largest yield reduction will result from stress at silking (early R1 stage) with smaller reductions resulting the further away from silking that the stress occurs. This is generally true with the other types of stress such as nutrient deficiencies, high temperatures and hail.

This 4-week period around silking is the most important time for the plant to have adequate moisture. Refer to Figure 5.2. If adequate rainfall is not present during this period, yields do not reach their full potential. If irrigation is available, this will be the most important time to monitor its use. The water needs for grain sorghum range

from about .05 inch daily at planting to a little more than .3 inch at day 50 of growth, and then tapers off gradually again to about .05 inch daily as it reaches maturity.

Planning for adequate nutrition for the corn plant should take place before planting. If soil tests are followed and nutrients added in sufficient amounts for the crops yield potential, this factor should not be a problem at this time.

Extreme high temperatures accompanied with hot winds during the day and at night are very stressful on the young plant during pollination. Stress at this time will cause a lag between ear development (beginning silking) and pollen shedding. Delaying the silking until after pollen shed will result in unfertilized ears.

During this stage the corn plant is more vulnerable to hail damage than at any other period because the tassel and all the leaves are completely exposed. Complete leaf removal by hail at this stage will result in essentially a complete loss of grain yield.

Some factors such as moisture and proper nutrient availability may be controlled by the producer. Weather problems such as hail cannot be controlled but their effects on the producer's income may be reduced with hail insurance.

Summary

From germination to harvest, the corn and sorghum producer needs to scout and evaluate the growing crop to look for possible problems and solutions to maximize yields. These may or may not be related to factors the producer may control. Producers need to know factors that must be considered to determine if replanting is justified and how to make those decisions. Evaluations of weed and pest pressures must be also used to determine appropriate corrective actions. Environmental factors such as moisture, temperatures, and weather damage must be considered to determine their effects on crop yields and goals.

Credits

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Lesson 6: Harvesting the Crop

Harvesting is one of the last steps a producer takes in preparing a crop for market. Before, during, and after the harvest, the producer must make a number of decisions to ensure the maximum return on his or her investment. As the grain is gathered, the producer is faced with several challenges. Crop losses, seed damage, and storage problems compound the efforts associated with harvesting. Once the grain is gathered, the producer must decide if drying grain is in his or her best interest and choose a method by which to dry. These issues will be covered in this lesson.

When to Harvest

Determining the optimum harvest time is critical for profitable grain production. The best time to harvest is when the producer can receive the highest yield with the highest quality. Factors that determine the proper time to harvest grain crops are divided into three categories: plant characteristics, weather conditions, and harvesting methods.

Plant characteristics refer to the plant's stage of maturity, tendency to lodge, and tendency to shatter. Lodging refers to breaking or bending the stalk below the ear. Shatter is the loss of grain from inflorescence. If the plant is not harvested at the appropriate maturity stage, it may cause a decrease in the yield and increase the possibility of loss due to lodging and shattering. A loss of grain nutrients for feed can also occur.

Corn harvested for grain is considered mature when the kernel moisture content is 20 to 28%. As a rule, corn with more than 15.5% moisture will need artificial drying if it is to be stored. High moisture corn can be used for feed if it is stored in an airtight container. Corn harvested for silage should be harvested after the ear is well dented but before the leaves turn brown and dry. Ears will be well dented between the 32 to 35% moisture stage. Grain sorghum should have a moisture content of no more than 20% and should be harvested after the heads have matured and the stalks begin to dry. Table 6.1 identifies the characteristics that indicate the proper harvest time. Moisture levels will vary depending on the storage system being used.

Weather is a consideration in harvesting because of the effect it has on mature crops. Rainfall, humidity, wind, and temperature affect crop moisture content. Harvesting crops with high moisture content may increase mold and cause overheating during storage. Adverse weather conditions such as heavy rains, hail, or strong winds can damage crops that are ready for harvesting. Also, harvesting equipment may not be usable in wet fields.

The harvesting method used will also influence the optimum harvest time. Corn or grain sorghum that is chopped for silage will have a much higher moisture level than for corn or grain sorghum that is being combined for grain.

Harvesting Methods

The two primary harvesting methods for corn and grain sorghum are combining and silage chopping.

Table 6.1 - Characteristics of Proper Harvest Time

Crop	Percent Moisture	Plant Maturity Stage	Physical Plant Signs for Harvest
Corn (Grain)	15.5%	50-60 days after pollination	Kernels are nearly all well glazed and dent corns, well-dented husks and bottom leaves dry, upper leaves 1/4 to 1/2 green
Corn Silage	65-70%	Medium to hard dent	Kernels fully dented and well glazed, husks begin to turn yellow although most leaves are green
Grain Sorghum	18-20%	Mature heads	Stalks begin to dry
Grain Sorghum Silage	60%	Dough stage	Before leaves begin to deteriorate

Corn is grown primarily for grain and is harvested with a combine equipped with a corn head known as a picker sheller. The ear is removed from the plant, the husks are removed from the ear, and the grain is shelled by removing the kernels from the cob. Corn that is used for silage is harvested by using a chopper that cuts the stalk into small particles. Generally, silage particles should be about 1/2 inch long, with 15 to 20% of the particles being 1 inch in length. The particle size has an effect on the ability to pack tightly to reduce air from the silage mass, which in turn allows for a more desirable type of fermentation. Manipulations in the particle size can be made through machine adjustments on the knives and shear bar.

Grain sorghum grown for grain is combined with a regular combine grain head. It should be cut as high as possible without skipping too many heads. Cutter bar guard extensions are helpful if heads droop. If lodging is a problem, a row-crop attachment is useful for pick up and intake of the crop. Threshing action should be only enough to detach the seed from the heads. Grain sorghum can also be harvested for silage by green chopping the standing crop in the field. As with corn silage, the particle size is important to obtain optimum conditions for desirable fermentation of the crop.

The estimated yield of a crop may be a determining factor as to which harvesting method will be used. Combining is generally used for a high-yielding crop that will be used for grain. Corn and grain sorghum that has a low yield will generally be used for silage. Corn yields can be estimated by counting the number of ears per acre and the number of kernels per ear. Multiple these two numbers to get an estimate of the number of kernels per acre. Divide by an average number of kernels in a normal bushel to get the yield in bushels per acre. Yield estimation can be done after the kernel number is fixed, about 2 weeks after the end of pollination.

Major Sources of Crop Loss During Harvest

Grain left behind when a field is harvested represents a loss of profits. Harvest loss cannot be reduced to zero but skilled equipment operators can reduce harvest losses to an acceptable level without affecting the rate of harvest. Before harvest losses can be identified and measured, the cause of harvest losses must be understood. The major sources of crop losses include preharvest losses, header ear loss, header kernel loss, combine cylinder loss, and combine separation loss.

Preharvest losses occur from plant lodging and appear as whole ear losses. Whole ear loss increases as the season progresses and is generally out of the producer's control at harvest. Average preharvest losses should be less than 1% of total crop yield. This loss can go much higher in adverse crop years or when harvest is delayed.

Header ear loss occurs when harvest equipment is driven at a ground speed that is too fast or too slow. Loss can also occur by driving off the row or operating the header too high, resulting in loss of whole or broken ears. Losses average 3 to 4% of the total crop yield. With proper machine operation and adjustments, losses can be held to 1%.

Header kernel loss occurs when kernels are shelled out and lost by the header at the gathering snouts or snapping bars and rolls. Losses generally average about 0.6%. Proper adjustments and machine operation along with good field conditions can hold kernel losses to about 0.4%.

Combine cylinder loss happens when unsatisfactory shelling action causes some kernels to remain on the cob or stalk as they pass through the machine. With correct cylinder or rotor speed and correct concave clearance adjustment, this loss should not exceed 0.3%. Correct adjustment results in few or no broken cobs with no kernels attached to them. Shelling action that is too vigorous will result in excessive kernel breakage.

Combine separation loss occurs when kernels pass over the sieves and out the combine. Correct sieve and wind adjustment can usually correct these losses, which should be held to 0.1% of the total crop yield.

Preventing Grain Damage at Harvest

To maintain high-quality grain, the percentage of damaged grain must be kept to a minimum. Major factors affecting the physical condition of the grain include improper combine or harvesting equipment settings, improper moisture at the time of harvest,

weather conditions, plant maturity, and excessive handling.

Improper settings on equipment can range from harvesting at the wrong speed to incorrect operational settings on the combine. Settings for cylinder speed, concave clearance, and the sieve should all be adjusted for the crop being harvested and the equipment ground speed. The equipment operator manual will give guidelines that should be followed for correct equipment operation.

Producers should also harvest grain at a moisture level conducive to maintaining the physical structure of the grain. Crop moisture and maturity at harvest should be inspected to avoid grain seed damage. Underdeveloped seeds and poor moisture both contribute possible seed damage. Once harvested, handling the grain seed should be kept to a minimum. The fewer times the grain is augured or dumped the less injury to the seed.

Local Storage Options

Producers generally have a number of possible storage options for their harvested crop. These include on-farm storage bins or silos, local county elevators, local processing facilities, and regional transport facilities.

On-farm storage is generally practiced by all producers if the total area available is significant enough to house the crops harvested. However, many producers who lack on-farm storage or who wish to market their grain early may opt to store grain in a local county elevator. Various processing facilities like ethanol plants, feed mills, or feedlots may be located near enough so producers can market their grain at higher profits and alleviate storage problems. Grain may also be trucked to a regional transport facility such as a railroad or river terminal to market or store harvested grain.

Storage Problems

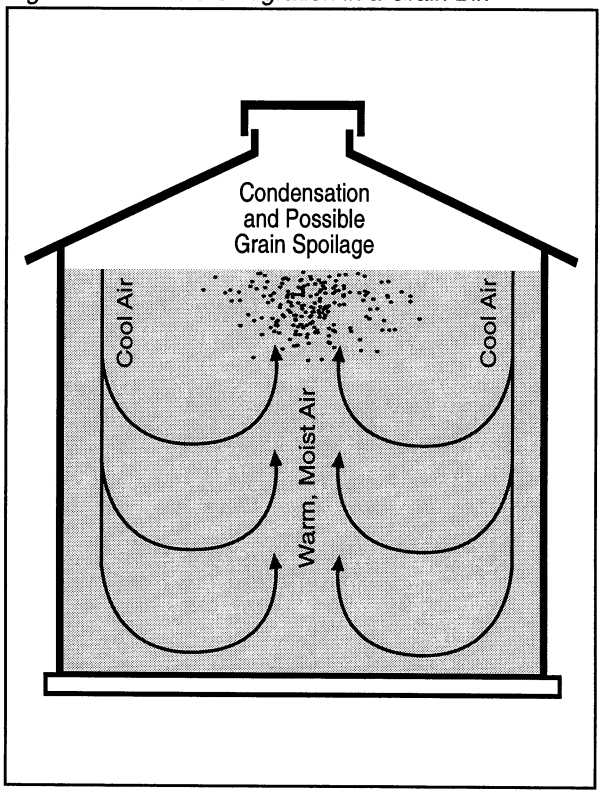
Improper storage can cut into the potential profits in corn and grain sorghum production. Economic loss to these grains during storage may be caused by high moisture content, improper drying, foreign material, and insect and rodent infestations. Mold can be a problem if grains are harvested and stored when the moisture content is too high. If moisture content is too high, the grain will heat up, encouraging rotting and spoilage. Improper drying can include both over- and underdrying, thus reducing quality. Foreign material in the grain such as weed seeds, plant parts, and insect parts can encourage grain spoilage. If adequate storage is not provided, insects and rodents can infest the grain and reduce the quality by contamination.

Figure 6.1 shows airflow in a grain bin and the possibility of grain spoilage from condensation. Grain near the outside walls will cool in the late fall and winter. The grain in the interior will remain warm. As the air is warmed during its upward movement, it releases moisture. Condensation forms on the surface of the grain, providing an ideal place for mold to grow.

Factors That Determine Whether to Dry Corn

The main goal of all grain producers is to limit harvest loss, and the ability to dry corn allows a producer to limit those losses. The factors that influence a producer's decision to dry corn are largely dependent on the weather, market price, grain quality, storage availability, drying equipment, and the cost of drying.

Figure 6.1 - Moisture Migration in a Grain Bin



Unfavorable weather conditions during harvest contribute to excessive harvest losses. A producer may harvest early and dry corn to prevent late harvest losses. In addition, the market price for corn may be higher early in the harvest season. By harvesting early at higher moisture content and then drying the corn to an acceptable merchandising moisture content, producers can capitalize on those higher market prices. Marketing options will be discussed in more detail in Lesson 7.

Grain quality is another factor influencing the decision to dry corn. Losses from molds, heat, and spoilage from higher moisture corn may be alleviated by the drying process.

The amount of storage available, dryer cost, and operational costs must all be considered before choosing to dry corn. Each of these will add to the cost of production and the individual producer must compare expected profit with the added costs to determine whether to dry the crop.

Methods of Drying Corn and Grain Sorghum

Methods for drying corn and grain sorghum include using heated or unheated air, as well as field drying. Drying methods are similar for corn and grain sorghum; however, an individual sorghum seed exposed to airflow will dry faster than when drying corn. The sorghum seed is smaller and the interior moisture can get out faster. But the greater flow resistance of a layer of sorghum in a bin reduces the quantity of airflow for a given static pressure. As a result, both the drying time and the cooling rates will be 2/3 to 3/4 that of corn for the same moisture content and drying equipment.

Unheated air may be used to dry harvested grain that contains no more than 15% moisture. To decrease the grain moisture content, unheated air must have a relative humidity of 70 to 75% or less. During the final drying stages, unheated air must contain less than 50 to 60% humidity to reduce the grain moisture content to 13%. Bins for drying must be equipped with perforated ducts or false floors to allow the air to be forced through all parts of the bin by a ventilating fan. Table 6.2 outlines the grain drying potential for corn given the relative humidity and temperature.

Table 6.2 - Humidity Chart for Drying Corn

Current Relative Humidity Reading	Current Temperature Reading					
	30°F	40°F	50°F	60°F	70°F	80°F
30%	10.3	10.0	9.6	9.2	8.4	7.5
35%	10.8	10.5	10.1	9.7	9.0	8.3
40%	11.3	11.0	10.6	10.2	9.7	9.1
45%	12.2	11.7	11.3	10.9	10.4	9.8
50%	13.1	12.5	12.0	11.6	11.1	10.5
55%	13.5	13.3	12.7	12.1	11.5	11.5
60%	14.6	14.0	13.3	12.7	12.0	11.2
65%	15.5	14.8	14.1	13.4	12.8	12.1
70%	16.4	15.5	14.8	14.2	13.5	13.0
75%	17.4	16.6	15.8	15.0	14.5	13.9
80%	18.7	17.8	16.9	16.0	15.4	14.8
85%	20.2	19.4	18.6	17.8	16.8	15.8
90%	22.5	21.5	20.5	19.5	18.5	17.4

Example: When temperature is 60°F and humidity is 60%, corn may be dried to 12.7% using unheated air.

The advantages of drying with unheated air include lower energy expense, decreased fire hazard, lower initial equipment costs, less management and supervision, less chance of overdrying, and a high-quality dried grain. Disadvantages arise because the unheated air uses outside air that is affected by natural weather conditions. Unheated air systems are not effective in cold, damp conditions. Other disadvantages are slower drying rates, more drying time required, bin fill limitations, and a greater possibility of damage from mold due to prolonged drying times.

Drying with heated air is accomplished by heating the air with natural gas or petroleum fuels and forcing the heated air throughout the storage bin. The heat from each gallon of fuel will evaporate 50 to 85 pounds of water from the grain if direct heat drying is used. If indirect heating is used, 35 to 60 pounds of water can be removed.

The advantages of using heated air include an increased ability to dry the wettest grain, no dependency on weather conditions, shorter and faster drying times, and high drying capacity. The disadvantages of using heated air drying include

higher initial cost, higher fuel expense, some fire hazard, potential to overdry grain (thus reducing quality), and more careful management and supervision are required.

In field drying, the crop is allowed to dry to the appropriate moisture content while standing. The standing crop is harvested with the appropriate combine head attachment to prevent kernel damage and pick up lodged corn.

Maintaining Grain Quality During Storage

The primary goal of a grain storage facility is to retain the quality of the stored grain. Factors that affect grain quality include the purity of the crop and variety, percentage of weeds and other mixtures, and percentage of diseased and damaged kernels.

Maintaining crop quality for corn is dependent on the following management steps: (1) store grain at a moisture content of 14% or less; (2) level the top surface to the grain; (3) aerate in the fall to cool the grain to 40°F; (4) do not allow the grain to freeze; (5) check and record the grain temperature every 21 days with aeration as soon as any increase in temperature is evident; (6) warm the grain to 65°F in the spring by running an aeration fan; and (7) try to maintain less than a 20-degree difference between average outdoor temperature and grain temperature.

Grain sorghum storage is essentially the same as shelled corn. Cooling is the first consideration with humidity and moisture control is secondary. Run the fan, regardless of weather conditions, whenever the grain is heating or over 22% moisture content. When the grain is below 22% moisture and not heating, run the fan whenever the outside air is 10 degrees cooler than the grain mass until the grain is cooled down to 40°F to 50°F. The increased airflow resistance of grain sorghum reduces aeration flow rates compared to corn. This may not be as critical as in drying, however, because of the low airflow rates and the greater latitude in aeration.

Silage Storage Problems

To maintain quality in corn or grain sorghum silage during storage, it is important to understand the ensiling process. The ensiling process occurs as chopped forages and grains are compressed and placed in the silo. The cells of the plants are still alive and breathing. Breathing plant cells and microorganisms form carbon dioxide and heat using the trapped air. As carbon dioxide increases, anaerobic bacteria form in the silo. These bacteria do not require the presence of free oxygen for metabolism. These desirable bacteria start the fermentation process when plant respiration stops. Therefore, it is important to control air exposure to silage. By limiting air during the ensiling process, carbon dioxide is maintained and the fermentation process can occur. If carbon dioxide levels are not maintained, mold will grow and nutrient losses will occur. In trench or bunker silos, the silage is immediately covered with a plastic cover after the last load has been included.

Silage is harvested at a recommended dry matter content of 30 to 40% and during storage, moisture contents are a concern. Silage high in moisture will seep or water will leak to the bottom of the silo or bunker taking vital nutrients with it. In addition, silage too low in moisture is hard to pack or store because of the extra air present. The extra air will also cause problems in fermentation and mold will grow. If silage contains over 50% dry matter, it is recommended that water be added in the ensiling process to obtain correct moisture content.

Temperature is critical in the fermentation process. The recommended temperature for desirable bacterial decomposition is between 80°F and 100°F. If the temperature becomes too hot, silage will appear to be black or brown with a caramel odor like burnt brown sugar. Freezing or low temperatures are of lesser concern in silage storage. If silage in bunkers or trenches becomes frozen, digestive problems can occur in livestock.

Silage should be properly packed or stored to prevent seepage, poor fermentation, and loss in storage capacity. Silage is kept fresh and spoilage is prevented on the feeding surface in upright silos if 2 inches of silage are removed daily in winter or 3 inches in summer. In trench or bunker silos, producers should remove 3 inches daily in winter and 4 inches in summer. If silage fails to have a light, pleasant smell with only a slight vinegar odor or a color other than slightly brown to dark green, the quality of the silage would be questionable.

Summary

Once a crop is grown and ready for harvesting, a producer's job is far from over. The producer

wants to receive the best possible price for his or her efforts, so different factors have to be considered before the crop is sold. Crop loss and seed damage must be minimized. Decisions need to be made whether it is more profitable to assume the burden of drying the grain or selling it with a moisture dock in the price. Storage of the crop must also be arranged. The decision to sell the crop immediately or hold onto it for a while is complex. A producer must be aware of economic conditions and decide which option is the most profitable. All of these decisions require careful consideration to achieve the best possible profit.

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Lesson 7: Marketing the Crop

Toward the end of the 20th century, the U.S. government was trying to have less influence on farm income. The Freedom to Farm Act and the NAFTA trade agreement had been enacted to allow producers to trade more freely in the global marketplace. However, no one had considered the impact of large grain importing countries like Japan falling into financial turmoil and responding by reducing imports. The American producer suddenly had much more freedom in a dwindling marketplace. With this knowledge of global market fluctuation, today's producer must place extreme emphasis upon making a profit. By studying the various options available, producers, grain buyers, and elevator managers can determine profitable levels at which to operate their enterprises.

Options for Marketing Corn and Grain Sorghum

Corn and grain sorghum producers have six basic choices when it comes to marketing their crops. They can (1) sell the crop when it is harvested, (2) store the crop and sell it later, (3) feed the crop to their own livestock, (4) forward price the crop through cash contracts, futures contracts, or options, (5) use a combination of these methods, or (6) participate in commodity price support programs from the government. What producers choose to do depends on the current cash price, the price of futures, and what they think is going to happen to corn and grain sorghum prices in between. To gain a better understanding of market price trends, producers can review average yield and price variations from previous years and current USDA or AgEBB crop reports.

Determining When to Sell, Feed, or Store Crop

If producers grow corn or grain sorghum for the market, they must decide whether the most profit will occur by selling directly from the field, feeding it to the livestock, or storing the crop for awhile. Factors that affect this decision are the cost of farm storage, the producer's prediction on trends in grain and livestock prices after harvest, and interest rates. Simply stated, if the price of corn is high and looks to drop in the future - sell. If the price of corn is low and looks to rise in the future - store. If the price of corn is low and livestock prices are looking up for the future - feed. However, the futures market can change drastically so a producer must pay close attention to global markets when making marketing decisions.

The corn market today differs in important aspects from the 1930s to the middle 1970s. The U.S. corn crop is now an important part of the world market for feed grains. Crop sizes in other parts of the world influence the U.S. price.

Corn is an important item in the balance of trade with other countries. Corn shipments overseas help the United States import needed materials such as fuel oil. The federal government is much less involved in support prices and does not provide grain storage bins. Corn prices are likely to have higher peaks and valleys today than when the government purchased large amounts of grain to raise the price in years of surplus and released feed grains from storage to dampen the price rise in years of short supply.

There has been some interest in establishing world grain reserves. A great increase has occurred in the amount of corn moved directly from the field to local elevators in cash grain areas. This has put a heavy strain on storage facilities and transportation. Railroad grain cars have often been inadequate to move all of the corn during the rush period. The situation is aggravated when the weather is ideal and the harvest is rapid.

In summary, based mainly upon the U.S. situation, (1) the odds favor regularly storing corn and grain sorghum for a short time after harvest, (2) storing until the next fall is risky, (3) success with corn and grain sorghum storage over a period of years depends upon selecting the right time to sell in individual years, and (4) feeding corn or grain sorghum is a good option when the cash price is low and livestock futures are trending steady to high.

Except for the period right after harvest, the average rise in price is little more than the cost of storage. Having storage capacity on the farm increases a producer's flexibility in deciding when to sell the crop. Some large local or regional elevators will accept delivery of a producer's crop and then let the producer decide when to declare it sold even though the buyer may already have moved it into the grain marketing channel.

If producers dry their grain and store it for an anticipated market increase, they must also

consider additional costs for that storage and figure a break-even cost to justify that storage. When doing so, producers must include the loss of interest on the money they would have received if the corn was sold on the cash market at the time of harvest. The following formula may be used to figure the cost of storage on a per month basis. Normal storage is 12¢ per bushel for the first 3 months of commercial storage (as a minimum charge) and 3¢ per bushel for each month after that.

(interest X current price ÷ 12) X 1 month + storage cost for that month =
Monthly storage cost

If corn is selling for $2.25 per bushel and interest is 9%, the first month's cost of storage would be as follows:

[9% (.09) X $2.25 ÷ 12] X 1 + 12¢ (.12) = 13.7¢ for that month

A spreadsheet may be found on the Internet at <http://agebb.missouri.edu/download/university> to figure storage costs for a given period. The file "cropstor.exe" can be downloaded to a hard drive for use. This spreadsheet was designed by the University of Missouri Extension Agronomy and Agricultural Economics staff.

Effect of Grain Quality on Market Price

In Lesson 6, the factors that affect seed damage at harvest or during storage were discussed. The efforts producers made to limit seed damage and thereby preserve grain quality will pay off when the grain is sold. The USDA has set standards by which all grain is tested and graded when it is purchased by licensed buyers. Factors used in grading include (1) test weight, (2) moisture content, (3) seed damage (cracked kernels), (4) foreign material present, and (5) special discounts such as musty, sour, heating, weathered, foreign odor, or discolored.

Producers need to be familiar with the grading levels because this will determine what price their grain will bring when it is sold. Corn is graded on a scale of 1 - 5, with 1 being the highest grade, or best quality. See Table 7.1. Likewise, grain sorghum is graded on a similar scale of 1 - 4, as shown in Table 7.2. Corn that falls below Grade 5 and sorghum that falls below Grade 4 is called "Sample" grade and is considered low quality. Corn's Sample grade will also have one or more of the following characteristics: contains stones, musty, sour, heating, and/or has a foreign odor. Sample grade for grain sorghum characteristics is the same as corn with the addition of badly weathered.

Comparing Moisture Docking to Drying Costs

Test weight of corn determines the weight of a bushel volume (1.244 cubic feet) of grain. Test weights determined on dry (15.5% moisture) corn indicate whether the grain crop reached full maturity. Low test weights indicate immaturity. If bushel test weight of mature corn is determined at harvest when grain moistures are greater than 15.5%, the test weights will be biased downward.

One of the biggest decisions a producer faces with marketing corn and grain sorghum is whether to sell the crop wet and take the moisture dock (reduced price) or spend the time and money to dry the grain to a moisture level that eliminates any dock. If cash grain prices are high enough or the producer has little or no available storage, the answer is easy—sell and take the dock. However, if grain prices are high and steady, or close to breakeven, then the producer should consider drying the crop.

High-moisture corn sells for less because it has less dry weight, costs more to dry, and discourages producers from selling it. The dock on high-moisture corn is often 3¢ per bushel for every 1/2% above 15% moisture. The cost for drying high-moisture corn is normally figured at 3¢ per bushel per 1% of moisture removed. Producers can use an on-farm moisture tester and figure their costs of drying or the amount of dock they would receive, compare this to the cash price of corn at that time, and determine their marketing strategy.

Shelled grain weights can be adjusted using a grain shrink table. Shrink represents both the moisture loss and 0.5% dry matter loss encountered during drying and grain handling. To estimate the amount a given wet weight of corn will lose during the drying process, multiply the wet weight by the shrink factor from the shrink table.

Table 7.1 - Grade Requirements for Corn

Grade	Minimum test weight per bushel (pounds)	Maximum limits of:		
		Damaged kernels		Broken corn and foreign material (%)
		Heat-damaged kernels (%)	Total (%)	
U.S. No.1	56.0	0.1	3.0	2.0
U.S. No.2	54.0	0.2	5.0	3.0
U.S. No.3	52.0	0.5	7.0	4.0
U.S. No.4	49.0	1.0	10.0	5.0
U.S. No. 5	46.0	3.0	15.0	7.0

U.S. Sample grade is corn that:
(a) Does not meet the requirements for the grades U.S. Nos. 1, 2, 3, 4, or 5; or
(b) Contains stones that have an aggregate weight in excess of 0.1% sample weight, 2 or more pieces of glass, 3 or more crotalaria seeds (*Crotalaria* spp.), 2 or more castor beans (*Ricinus communis* L.), 4 or more particles of an unknown foreign substance(s) or a commonly recognized harmful or toxic substance(s), 8 or more cockleburs (*Xanthium* spp.) or similar seeds singly or in combination, or animal filth in excess of 0.20% in 1,000 grams; or
(c) Has a musty, sour, or commercially objectionable foreign odor; or
(d) Is heating or otherwise of distinctly low quality.

Table 7.2 - Grade Requirements for Grain Sorghum

Grade	Minimum test weight per bushel (pounds)	Maximum limits of:		
		Damaged kernels		Broken kernels, foreign material, and other grains (%)
		Heat damaged (%)	Total (%)	
U.S. No. 1	57.0	0.2	2.0	4.0
U.S. No. 2	55.0	0.5	5.0	7.0
U.S. No. 3*	53.0	1.0	10.0	10.0
U.S. No. 4	51.0	3.0	15.0	13.0

U.S. Sample grade is sorghum that:
(a) Does not meet the requirements for the grades U.S. Nos. 1, 2, 3, or 4; or
(b) Contains stones that have an aggregate weight in excess of 0.2% of the sample weight, 1 or more pieces of glass, 2 or more crotalaria seeds (*Crotalaria* spp.), 1 or more castor beans (*Ricinus communis* L.), 3 or more particles of an unknown foreign substance(s), 7 or more cockleburs (*Xanthium* spp.) or similar seeds singly or in combination, 9 or more particles of animal filth per 1,000 grams of sorghum, or
(c) Has a musty, sour, or commercially objectionable foreign odor (except smut odor); or
(d) Is badly weathered, heating, or distinctly low quality
* Sorghum that is distinctly discolored shall not be graded higher than U.S. No. 3.

Corn Checkoff Dollars

For every bushel of corn sold in Missouri and 18 other states, a specified rate, or checkoff, is invested by the seller at the first point of sale. Since 1984, Missouri corn producers have been investing ½¢ per bushel of corn sold. Monies collected are sent to the Missouri Corn Growers Association, a state corn promotion board. The board is run by farmer-directors who invest checkoff monies in state programs of research, market development, and education to increase the demand for corn. Part of the fund is sent to the National Corn Growers Association (NCGA). Checkoff dollars are invested in the same areas as on the state level. These dollars along with the investment from NCGA members and state associations provide the funding base for new

the National Corn Growers Association (NCGA). Checkoff dollars are invested in the same areas as on the state level. These dollars along with the investment from NCGA members and state associations provide the funding base for new product development and help maintain traditional markets. Therefore, individual producers play an important role through checkoff dollar contributions by supporting the mission of NCGA "to enhance corn profitability and usage to improve the quality of life in a changing world."

Summary

By studying available market options, producers, grain buyers, and elevator managers can determine profitable levels at which to operate their enterprises. Corn and grain sorghum producers have five basic marketing options: (1) sell the crop when it is harvested, (2) store the crop and sell it later, (3) feed the crop to their own livestock, (4) forward price the crop through cash contracts, futures contracts, or options, or (5) use a combination of these methods. Producers must also decide when it is appropriate to sell direct from the field, feed, or store the crop. The main factors affecting these decisions are the cost of farm storage and predictions on future price trends in grain and livestock.

Several crop and noncrop factors influence prices in the United States. However, the odds favor storing corn and grain sorghum for a short time after harvest and feeding it when cash prices are low and livestock futures are high. Having storage capacity on the farm increases a producer's flexibility in deciding when to sell his or her crop.

The USDA has set standards by which all grain is graded for sale. Factors used in grading include (1) test weight, (2) moisture content, (3) seed damage (cracked kernels), (4) foreign material present, and (5) special discounts. Comparing moisture docking to drying costs is another important consideration for corn and grain sorghum producers.

Missouri corn producers play an important role through checkoff dollars to promote research, market development, and education to increase the demand for corn.

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Lesson 8: Figuring Crop Costs

The most important step in figuring crop costs is to keep an accurate and complete set of records of all costs incurred to produce the corn or grain sorghum crop. An approved accounting system must be adopted and understood by the producer for it to be worthwhile. Time must be planned during the season to record and enter costs. Plan time during the nongrowing season to analyze these costs to make changes to improve the net returns.

Variable Costs Associated with Corn and Grain Sorghum Production

To determine the break-even costs of a corn or grain sorghum crop, producers must be able to track all of their variable costs. Variable costs are also known as operating costs. Variable costs increase or decrease with the volume of output. For example, if a greater yield from the corn production is desired, an option is to increase the plant population. This will mean that additional seed must be purchased, therefore increasing the cost of production. Decreasing planting rates requires less seed, but the crop yield will also be less. Other types of variable costs include fertilizer, chemicals, and labor.

Detailed records are necessary to allocate costs correctly. For example, farm utilities include electricity expenses. These can be broken down into crop drying or ventilation and lighting for the farrowing facility. Applying the entire electric bill to crop production would be incorrect. Some form of monitoring must be done to appropriate costs to the proper enterprises.

Table 8.1 will give examples and amounts of possible variable costs that may be incurred with a corn or grain sorghum crop. These figures are from MIR (mail-in-records) enterprise records for the 1998 Missouri average crop costs from the University of Missouri Extension Service.

As can be seen from the information in Table 8.1, variable costs for the production of grain sorghum are less per acre than for corn. Comparable figures for the same year indicate the variable costs for grain sorghum production to be about 20 to 25% less than for an acre of corn; however, yield per acre and cash prices must also be evaluated when comparing the two crops.

Table 8.1 - Variable Costs per Acre for Corn and Grain Sorghum

	Corn	Grain Sorghum
Number of Farms Reporting	89	13
Average Number of Acres	332	119
Average Yield/Acre (bushels)	121	99.3
Average Variable Costs/Acre		
Seed	$27.89	$9.86
Plant food (fertilizer & lime)	50.50	45.33
Crop chemicals and materials	31.34	21.85
Machinery fuel, oil & repair	26.04	20.90
Machinery hire & services	6.30	4.18
Average labor cost/acre	26.56	4.16
Taxes and insurance	3.75	1.08
Miscellaneous	13.70	12.16
Operating interest	14.55	12.83
Total Variable Costs/Acre	$200.63	$152.35

Fixed Costs Associated with Corn and Grain Sorghum Production

As with variable costs, producers must also know their fixed costs of producing an acre of corn or grain sorghum to determine net returns. Fixed costs, also known as ownership costs, are costs that are unavoidable. Whether the farm operation produces at a record pace or nothing at all, fixed costs must be paid. They include such expenses as land costs, mortgage payments, insurance, and taxes. (Insurance costs include premiums directly related to the farm business, not personal health or life insurance.) Mortgage payments include interest and principal due in the coming year.

Table 8.2 shows examples and amounts of possible fixed costs that may be incurred with a

corn or grain sorghum crop. These figures are from the MIR enterprise records for 1998 Missouri average crop costs from by the University of Missouri Extension Service.

Table 8.2 Corn and Grain Sorghum Fixed Costs/Acre

	Corn	Grain Sorghum
Average Fixed Costs/Acre		
Machinery depreciation, taxes, and interest	$ 36.10	$24.87
Land costs, taxes, and interest	$ 93.45	$66.65
Total Fixed Costs/Acre	$129.55	$91.52

As shown with the variable costs, fixed costs per acre for the production of grain sorghum is lower than for the production of corn.

Determining an Acceptable Return on Investment

As with all crop enterprises, the net returns for the enterprise are determined by subtracting the total costs (variable and fixed costs) from the returns. This is most commonly done on a per-acre basis. From the examples from the tables, the total of all costs for corn production was an average of $330.18 per acre. With the production averages listed, this results in a cost of $2.74 per bushel of corn produced ($330.18 ÷ 121 = $2.74).

The corn crop must bring a return above $2.74 (in 1998) per bushel for a positive net return. However, in 1998 corn prices were suffering from a depressed market where there were surpluses, and prices were below average costs. Producers received a negative return per acre for that year. However, in 1996, 2 years earlier, producers received an average $141.44 net return per acre due to strong market prices.

As with all markets, yearly cycles exist. Producers must accept years where weaker markets cause lower prices in hopes there are more years where the net returns are higher. Total returns will depend on the total number of acres in production. A producer with a large number of acres will receive larger total returns. If a producer had 400 acres of corn and received $50 net return per acre, this would yield a total net return of $20,000 for the corn crop.

Calculating Cost Per Acre

As indicated previously, the total costs of production per acre is determined by adding the total variable (operating) costs with the total fixed (ownership) costs.

Summary

Only through complete and accurate records can a corn or grain sorghum producer determine crop costs. These costs are a total of the variable and fixed costs incurred in producing the crop. These are usually figured on a per-acre basis. Variable costs are those costs that will increase or decrease with production goals. These include seed, fertilizer, and chemicals. Fixed costs are those costs that must be paid and will be the same no matter what the level of production or yield. These include depreciation and taxes on the producer's equipment and real estate. Total costs are determined by adding all fixed and variable costs.

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Lesson 1: Planning the Crop

Soybeans have been grown for more than 5,000 years and primarily used for food or animal feed. China first introduced them to the United States in 1804. During the 1800s, farmers began using soybeans as cattle feed. Soybeans were used as coffee berries during the Civil War when real coffee was scarce. In 1904 at the Tuskegee Institute in Alabama, George Washington Carver, a Missouri native, began studying the soybean. As a result of his studies, other uses for the soybean were developed such as cosmetics, paints, and wood stains. For a review of the major and alternative uses of soybeans see Unit I, Lesson 1.

By the 1940s, the United States was growing as many as 78 million bushels per year, making soybeans a major export crop. Today, the United States produces more soybeans than any other country. Producers grow more than 2 billion bushels a year; Missouri farmers contribute 177 million bushels to this total.

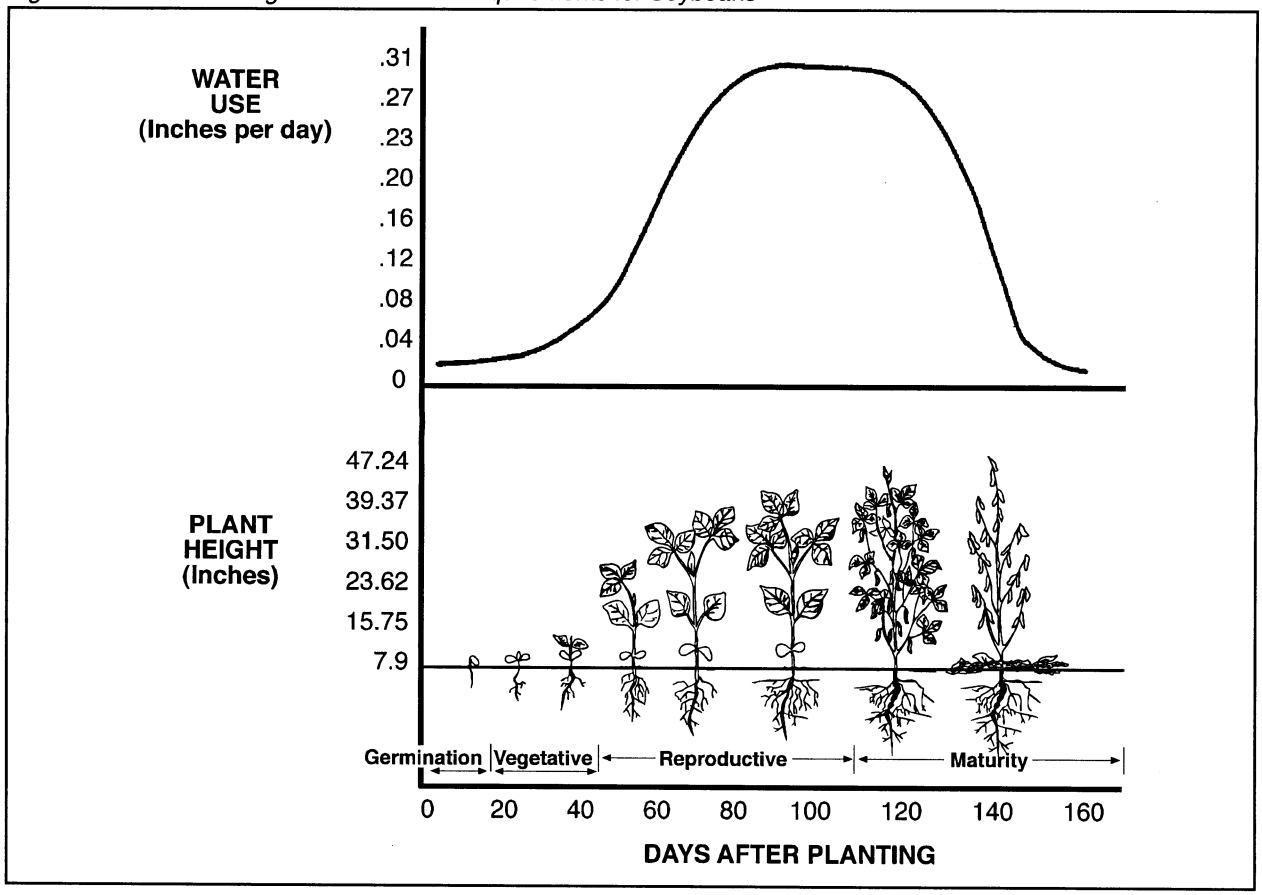
Environmental Conditions Necessary for Soybean Production

The soybean plant is highly responsive to its environment. Growing season, rainfall, topography, and soil type are crucial factors to raising a high-yielding soybean crop. A knowledge and understanding of these factors will help producers make more effective management decisions.

Growing Season

The state's growing season for soybeans averages about 175 days from mid-April (when temperatures rise above 28°F) to the end of October or the first frost. The optimum temperature for soybeans to germinate is 68°F. For the southwest, central, and northern regions of Missouri, these favorable conditions are usually reached between May 1 and June 10. The southeast Delta region reaches this temperature from late April to June 1. Planting later in June can result in yield reductions up to as much as 1 bushel per acre per week. Planting after July 1

Figure 1.1 – Growth Stages and Moisture Requirements for Soybeans



may reduce yields by as much as 3 bushels per acre per week.

Soybeans flower in the maturity stage in response to temperature and photoperiod (day length). To say that soybeans are photoperiod sensitive means they move from the vegetative to the flowering stage in direct response to day length. The key to their flowering mechanisms is the length of darkness during a 24-hour period because most soybean varieties begin flowering after day lengths become shorter. Cooler temperatures and longer day lengths cause delays in flowering, while warm and/or short days hasten flowering and maturity. This day length, or maturity factor, determines what soybean varieties Missouri producers can plant and when they can plant them. (Maturity groups are discussed further in Lesson 2, Selecting a Variety.)

Rainfall

Moisture, whether too much or too little, can affect soybean production. Soybeans require roughly 18 to 22 inches of water during the growing season for good development. Missouri's normal rainfall patterns provide adequate soil moisture during planting, but under normal conditions, soybeans require more than the average rainfall in late June, July, and August. In the fall, Missouri's rainfall normally increases, assisting late-maturing crops. Soybeans may need as much as 2.5 inches of rain per week during the reproductive growth stage. (See Figure 1.1.) This amount varies depending on the variety of seed used and the soil type of the field.

Soybeans are most sensitive to moisture deficiencies during flowering and pod development. A lack of water during these periods can reduce total yield or cause pods to abort. Irrigation relieves stressed soybeans during the middle of the growing season or when exceptionally dry weather occurs. Some southern and central Missouri producers have invested in irrigation systems to increase yields. However, these systems are expensive so producers should weigh potential costs against expected returns. The United Soybean Board reports that continuing research focuses on developing genetically altered soybeans resistant to drought and flooding to address soybean moisture problems. The United Soybean Board is a leading source for soybean data and marketing expertise, soy-related health news, and support soy product research and development.

Topography

The drainage of a field is another environmental condition that plays an important role in soybean production. Waterlogged soils can delay planting dates by delaying tillage and keeping down soil temperatures. They also create perfect environments for fungi and bacteria to grow that can lead to plant diseases. Nitrogen fixation and nutrient uptake may also be reduced. These problems can result in reduced yields. Poor drainage often occurs in fine-textured flatland soils with hardpans or claypans and unfortunately many of the soils in Missouri are of this type. Tillage methods and terracing systems can help prevent or remove excess water. To review these methods and systems see Unit III, Lessons 5 and 6.

Soil Type

Although soybeans are grown in various soil types throughout much of Missouri, the optimum soil type is a well-drained silty clay loam. This soil type has adequate water-holding capacity and releases water to the plants as needed. Soybeans can be grown in sandy clay or heavy clay soils when conditions are right, neither too wet or too dry. Due to moisture needs, they are better adapted for production in clay soils than either corn or cotton. Missouri counties with traditionally high yields have either silty clay loam soils or the producers are making up for less than adequate soil by utilizing current technology and making sound decisions.

Evaluating Field History

One factor to consider when evaluating a field's history is the previous crop grown in the field. Soybeans develop better when planted behind grass-type crops, such as corn or grains. These crops generally leave behind nutrients that can be utilized by soybeans and reduce the need for fertilizers. Considering the previous crop during planning can determine what type of fertilizers may be needed for the new crop.

Knowing the most recent type of tillage and/or planting method used can assist in projecting what pest problems need to be addressed. Soil should be tested if there is a concern about the possibility of a soybean cyst nematode (SCN) problem. This is the most destructive soybean pest in Missouri and can cause severe yield loss. A more thorough

discussion of SCN can be found in Lesson 2 of this unit.

In addition, knowing the previous tillage and/or planting method can determine what method(s) should be used for the new crop. An example of this is a field where only conventional tillage has been used and a producer chooses to use a minimum till or no-till method to reduce soil compaction. This should increase germination and crop yield. Another example is the use of no-till on land that has been in the Conservation Reserve Program (CRP) for 10 years. This program was designed to move highly erodible land out of continuous farming until it could become more stable. Therefore it is only beneficial to producers and the environment if this land is returned to production under a no-till method. This will maintain soil, water, and wildlife improvements.

Fertilizer Requirements for Soybeans

A soil test should be taken before planting to determine nutrient levels and soil pH. Soybeans typically do not respond well to directly applied fertilizer. They develop better on the nutrients left from the previous crop.

Soybeans are less tolerant of soil acidity than the other major row crops and require low soil acidity for nodulation, nitrogen fixation, and plant growth to take place. Soybeans generally develop better in soils with a pH of 6.2 - 7.0. Acidic subsoil (pH 4.0 - 6.0) must have the surface limed in order to maintain good yields. Liming a soil in this range can increase soybean yields by 15%. (Example: If soybean yields averaged 40 bushels per acre, this would mean an increase of about 6 bushels per acre.) Liming helps to release other nonbase plant nutrients and makes these nutrients more available to plants. After the nutrients have been used by plants, they have to be replenished by fertilization if a high productive level is to be maintained.

The three most important nutrients for soybeans, as for most crops, are the primary macronutrients nitrogen, phosphorus, and potassium. The secondary macronutrients and micronutrients are generally sufficient in most Missouri soils and are therefore not a problem in soybean production. For a better illustration of their importance, Table 1.1 shows the nutrients removed from the soil by a 50-bushel soybean yield. Information identifying specific needs or concerns of each of these nutrients follows.

Nitrogen

The soybean is a legume, which means it can extract an adequate supply of nitrogen from the atmosphere under normal conditions. Applying nitrogen fertilizer is generally not profitable. Research shows that if fertilizer is applied during planting, it delays nodulation and actually reduces the available nitrogen even further. However, small amounts of nitrogen can be applied at planting in sandy or cold soils to help stimulate plant growth until nodulation and nitrogen fixation begin.

Table 1.1 – Nutrients Removed by a 50-Bushel Soybean Yield

Nitrogen (N)	160 lb.
Phosphorus (P_2O_5)	40 lb.
Potassium (K_2O)	70 lb.
Calcium (Ca)	75 lb.
Magnesium (Mg)	32 lb.
Sulfur (S)	25 lb.
Zinc (Zn)	0.2 lb.
Iron (Fe)	1.7 lb.
Manganese (Mn)	0.6 lb.
Copper (Cu)	0.1 lb.
Boron (B)	0.1 lb.
Molybdenum (Mo)	0.01 lb.

Stressful environmental conditions such as wet, very hot and dry conditions, or very acidic soils can cause nitrogen deficiencies. Deficiencies may also occur if *Rhizobium japonicum*, bacterium necessary for nitrogen fixation, is not in adequate supply in the soil. Most soils contain adequate rhizobia if soybeans have been harvested recently. For fields that have been growing other crops for the past 3 or 4 years, the producer should plant soybeans inoculated with the bacterium.

Phosphorus

Soybean plants absorb relatively large amounts of phosphorus throughout the growing season. The greatest demand starts in the late reproductive stages just before the pods begin to form and

continues until about 10 days before the seeds are fully developed. A bushel of soybeans removes approximately 0.8 - 0.9 pound of phosphorus per acre. Recommendations on soil tests are based on building phosphorus levels over 8 years. Higher rates can be applied to current crops and carried over to the next crop. The amount needed varies from field to field based on crop history, seed variety, and soil type. Following soil test recommendations is the safest plan.

Soils deficient in phosphorus reduce the number of nodule bacteria needed for nitrogen fixation and good root development. The symptoms of phosphorus deficiency are a thin, dwarfed stem, lack of luster in the leaves, early defoliation, and poor or nonefficient nodulation.

Potassium

As with phosphorus, soybeans require relatively large amounts of potassium. A bushel of soybeans removes approximately 1.4 pounds of potassium from the soil. Uptake of potassium climbs to a peak during the period of rapid vegetative growth and then slows about the time the beans form. Generally, soybean producers can afford to raise the potassium content of their soils to a high level because it leaches very little (except in sandy soil), it is not used in excess by soybeans, and it is released every year in slowly available forms.

Soybeans grown in potassium-deficient soils have stunted growth with shortened internodes. The edges of leaves are generally scorched or yellow and curl downward, especially in the lower leaves. Severe deficiencies may have brown or black edges on the leaves.

Secondary Nutrients

Calcium, magnesium, and sulfur deficiencies are not as common as deficiencies of the major nutrients. Soybeans as a rule contain more secondary nutrients than other grain crops, except for corn's sulfur content. When limestone is used to adjust soil pH, adequate amounts of calcium and magnesium are provided for most field crops.

If a magnesium deficiency does occur it will begin in the plant's lower leaves and appear as a pale, green color between the leaves' main veins. Sulfur deficiencies become visible with the young leaves and veins appear pale. Plants lacking sulfur are very similar to ones with nitrogen deficiencies; however, these symptoms begin in the upper leaves wheras nitrogen deficiencies are visible in the lower leaves. Missouri has had very few cases of sulfur deficiencies reported except on sandy-textured, low-organic soils.

Micronutrients

Soil maintained at the proper pH level will generally contain adequate amounts of micronutrients for maximum soybean production potential. Only a few isolated river bottom soils in extreme northwest Missouri are affected by iron deficiencies, occurring in soils with a very high pH (7.5 or higher). The symptoms include yellowing of leaves between the veins, with leaves turning almost white in severe cases.

Manganese deficiencies may occur near old lake beds, glacial outwashes, and in peat soil. All of these are sandy soils high in organic matter or heavily textured acidic soils. Symptoms of manganese deficiencies are white or yellow leaves with green veins, a condition known as *Interveinal Chlorosis*.

Molybdenum deficiency occurs in very acid, sandy soils. Legumes need molybdenum for nitrogen fixation so symptoms of this deficiency, indicated by pale green or yellow plants, are actually from a nitrogen shortage.

Soybeans are much less sensitive to zinc deficiency than corn. If corn grows normally on the same soil, a producer can assume the soybeans have an adequate supply. Zinc has been found deficient in graded, severely eroded, or low organic soils. The symptoms of zinc deficiency are stunted plants with interveinal areas of the leaves becoming yellow. From a distance, zinc-deficient areas of a field will appear yellowish-brown.

Summary

First introduced in this country in the 1800s, soybeans have become a major crop for the United States and Missouri. Growing season, rainfall, topography, and soil type are crucial factors to raising a high-yielding soybean crop. Also, knowing the previous crops and tillage and/or planting methods of a field can help the producer plan fertilizer needs, pest management practices,

and current tillage and/or planting methods to be used.

Soybeans respond very well to fertilizer but are less tolerant of soil acidity than the other major row crops. A soil pH of 6.2 - 7.0 is the optimum level. The three most important nutrients for soybeans are the primary macronutrients: nitrogen, phosphorus, and potassium. Fertilizing with secondary macronutrients and micronutrients are generally not needed in Missouri soybean production.

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Lesson 2: Selecting a Variety

Once the local growing conditions have been evaluated (considering the field history and current fertility needs), the producer must select a soybean variety to plant. The variety selected must be adaptable to conditions in the field where it will be grown. High yields are much more likely if the strengths and weaknesses of the selected variety and field are similar. For example, if cool, wet soil is common to the field then an early maturing variety should be selected; if a disease is prevalent, a resistant variety should be grown.

Indeterminate and Determinate Soybean Varieties

Research is ongoing to develop new and improved varieties of soybeans. Crossing two soybean varieties combines desirable characteristics from both parents and selects against undesirable characteristics such as weak stem, shattering, and poor seed quality. These new and improved varieties are created for hardier crops with increased yields that are more adaptable to specific growing regions. They are more resistant to pests and changing environmental conditions (e.g., drought or flooding). As a result of continuing research, Missouri farmers currently have more than 300 soybean varieties from which to choose.

Soybean varieties differ in growth type by being either indeterminate or determinate. The indeterminate plant continues to grow along with flowering and podding stages. With the determinate variety, the main stem stops growing when flowering begins. Indeterminate soybeans frequently double in height after the first flowers appear. These varieties are commonly grown in northern Missouri and some have been developed into early-maturing varieties to use with southern double cropping.

Determinate varieties are shorter and have recently been modified into two classes that combine characteristics of indeterminate varieties, semi-dwarf and semi-determinate. Semi-dwarf varieties are true determinates and are only about half the height of normal varieties. Semi-determinate varieties have a shorter flowering period and grow 6 to 10 inches less than other determinate varieties. After flowering, only a small amount of vegetative growth occurs. Both types are more lodging resistant due to their shortened height and may have a higher yield than taller determinate types in highly productive areas.

Information on soybean varieties can be obtained from other producers, seed dealers, University and extension variety trials, or the producer's own strip trials. The University of Missouri conducts annual performance evaluations on new varieties at more than 10 locations throughout the state. Yield results and soybean quality differ from location to location, however, and producers should choose varieties based on trials in their area.

Factors to Consider When Selecting a Variety

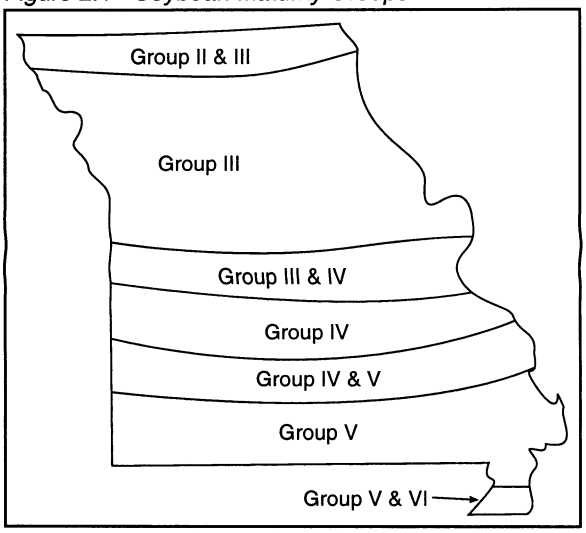
New soybean varieties from public and private sources are abundant. Yields have been steadily increasing due to genetic improvement, though not on all varieties. It is important for a producer to consider the following five factors when selecting a variety: (1) maturity; (2) standability; (3) pest resistance; (4) additional considerations - double cropping, shatter resistance, seed cost, seed quality, availability of seed and marketability of GMO crops, and intended use of the crop; and (5) yield.

Maturity

Soybean varieties are adapted to full-season growth in narrow bands from Canada to the tropics. This means that varieties are classified by their ability to mature and be harvested within the available growing season of a particular location. Varieties are specifically matched to the seasons by their reaction to the photoperiod (day length). All soybean varieties are classified within 13 maturity groups, 5 of which are successfully grown in Missouri. (See Figure 2.1.) The most predominantly grown variety in northern and central Missouri is maturity Group III. Some late-season Group II varieties are also grown in the extreme northern counties. Maturity Group IV varieties are adaptable to central Missouri and are grown throughout the south along with Group V. Group V extends into the Missouri Bootheel, with Group VI varieties also planted in the southernmost counties of Dunklin and Pemiscot. In rare instances, Group I varieties can also be planted in extreme northern Missouri counties.

When choosing a soybean maturity level, a producer should determine if a full-, early-, mid- or

Figure 2.1 - Soybean Maturity Groups



late-season variety is needed. Full-season varieties are generally more productive, but there are advantages and disadvantages to each of these depending on location and cropping system used. For example, in central and southern Missouri, mid- to full-season varieties will normally mature and be harvested in time to plant small grains. Producers who plan to rotate to winter wheat after the soybean crop will want to use an early maturing variety to avoid a delay in planting wheat. Likewise, if the soybean harvest is often delayed by wet weather, an early-season variety should be selected. Late-maturing varieties tend to flower longer and grow taller, which makes them more competitive with weeds and better producers on poorer soils. However, when soil fertility and moisture are high, these varieties may have excessive growth and lodge. These are just a few examples to illustrate why a producer must choose maturity levels that are suitable to their specific location and cropping system.

Standability

A variety must remain erect throughout a growing season to obtain maximum yields. Lodging before maturity can decrease yields 20 to 30%. Although the characteristics of lodging can be controlled genetically, the environment can alter this trait. High soil fertility, narrow row spacing, high plant population, and irrigation can increase lodging. As producers strive for high yields, use of semi-dwarf varieties can reduce lodging by controlling the height and width of individual plants.

Pest Resistance

The soybean has many pests - insects, weeds, disease, and nematodes - some of which are difficult to recognize. Many diseases go unnoticed but may reduce soybean yields as much as 15%. Scientists are working to breed varieties that can resist diseases, nematodes, and nutrient problems, but few insect-resistant varieties have been developed.

Two diseases that many varieties are resistance to are *Phytophthora* root rot and soybean cyst nematode (SCN). Although *Phytophthora* is less serious in Missouri than other states, it can still occur throughout the growing season on poorly drained soils. Nematodes, especially soybean cyst nematodes, are a serious problem in much of Missouri because of their ability to go undetected. Whenever a resistant and susceptible variety of equal yield potentials is available, the producer should select the most resistant variety. County extension centers and reputable seed dealers generally have information about pest-resistant varieties.

Additional Considerations

Other important considerations when selecting a variety include double cropping, shatter resistance, seed cost, seed quality, use of herbicide-resistant varieties, and intended use of the crop.

Many soybean varieties have similar performance when grown as a double crop or as a full-season crop. Good-performing, full-season varieties are the best when wheat follows soybeans, except in northern counties where wheat should be seeded by the end of October. When soybeans are planted after wheat or small grains in the same growing season, mid-season varieties are usually best. These varieties produce the necessary canopy (leaves) to shade out weeds but still mature fast enough to avoid frost losses. Determinate semi-dwarf varieties should not be used because of their low height and short flowering period. They mature too early and their pods are too close to the soil surface, making harvest difficult and low yielding.

Since soil moisture is the most critical environmental factor, a producer should double crop soybeans immediately after a small grain harvest only when there is sufficient soil moisture to ensure seed germination. Also, the fullest

season variety available should be used that will mature before frost. Seeding rate should be increased by 20% and rows should be narrow if possible. An effort to get good seed-to-soil contact should be made.

Some varieties have a tendency to shatter - pods break open before or during harvest and soybeans are lost. This is common during dry conditions, especially in western Missouri. Most new varieties are shatter resistant. Nonresistant varieties should only be used if they are exceptional in other aspects and an early harvest is expected.

Variety choice can be influenced by seed cost. Generally, a bushel or two of increased yield will cover any increase in seed cost, but a producer should be sure the potential yield difference is high enough to justify the expense. Producers should shop around to find the best price on the highest quality seed of a given variety. Also, keep in mind that smaller seed varieties need fewer pounds of seeds per acre, resulting in reduced cost.

Producers should not take chances on seed quality. There is very little difference in cost per acre of good seed versus poor seed or seed of unknown quality. The purchase of certified seed guarantees varietal purity, germination, and freedom from weed and other crop seeds. If a producer is using saved or bin-run seed, a germination and purity test can be obtained by sending a pint sample to the Seed Control Lab at the Missouri Department of Agriculture in Jefferson City. Several samples can be evaluated free of charge each year if the seed is for personal use.

The availability of herbicide-resistant varieties and marketability of genetically modified organisms (GMO) crops is also a consideration. In the worldwide debate on GMOs, producers are caught in the middle and they should stay current with developments in this market.

Producers should determine the intended use of the crop. Soybeans are developed into very diverse by-products and a producer can focus on planting soybeans for a variety of uses, e.g., edible soybeans, livestock feed, or oil protein.

Yield

The most economical and rewarding factor in selecting a soybean variety is high yields. However, producers should not choose the highest-yielding variety unless it also has other necessary characteristics (maturity, disease resistance, etc.) needed for the specific planting location. By considering other factors along with potential yield data, a producer has a better chance of obtaining consistent and optimum yields.

Yield information, along with lodging, height, maturity, and other characteristics are published in a special report titled *Missouri Crop Performance: Soybean* from the Agricultural Experiment Station. This report is available each January at county extension offices and producers can use it to evaluate varieties. (For a more detailed explanation of the yield information provided on this report refer to the University of Missouri Extension agricultural publication G04412 - *Soybean Variety Selection,* subhead *Yield.*)

For current soybean variety information, producers can access the Agricultural Electronic Bulletin Board (AgEBB) sponsored by the University of Missouri. This is a free computer information site that contains annually updated variety testing results on all major Missouri crops under the category "Crop Performance Testing" along with other valuable agricultural information. The web address is <http://www.ext.missouri.edu/agebb/index.htm>. Private companies can also provide information on soybean varieties suitable for cultivation in Missouri.

Determining Prevalent Diseases

Soybeans were considered a disease-free crop when they were introduced into the United States. That quickly changed and soybean diseases cause Missouri producers more than $100 million annually in losses and even more in wet years. Pathogenic fungi, bacteria, viruses, and nematodes cause soybean diseases. Producers must also recognize that crop injury can occur from improper use of herbicides or from environmental causes (excessive wind, rain, or temperatures) that may be mistaken as a disease.

Diseases are often classified in the following six categories: (1) seedling diseases, (2) root and stem diseases, (3) pod and stem diseases, (4) foliar (leaf) diseases, (5) virus diseases, and (6) nematodes.

Seedling Diseases

Disease	Causes	Symptoms	Control
Pythium Phytophthora Rhizoctonia Fusarium	Fungi acting independently or together. Favor cool, wet soils. Attack seeds before germination, as the seedling emerges, or after it is established.	Dark brown or reddish lesions on the root. Blackened and decayed lesions on the cotyledons. Shriveled cotyledons. Water-soaked primary leaves. Soft stems.	Plant high-quality seeds in warm, well-drained soil. Use fungicide-treated seeds in soils that hold water.

Root and Stem Diseases

Diseases	Causes	Symptoms	Control
Phytophtora Root and Stem Rot	Lives on crop debris in the soil. Attacks plant during periods of high soil moisture. Attacks plant at any growing stage. More prevalent in poorly drained clay soils.	Appear in young plants as a reduction in stand. Lesions on the stems and roots. Yellow leaves. Older leaves become yellow between the veins, wilt and die. Dark brown lesions on lower stems.	Plant-resistant varieties. Improve field drainage. Apply seed treatment that contains metalaxyl.
Fusarium Root Rot	Survive in soil and residues and are present in cultivated soils. Infect seeds, seedlings, roots, and lower stems.	Poor germination, late emergence. Stunted growth. Widespread wilting in young plants in low moisture soils. Older plants survive but wilt during low moisture.	Plant high-quality seeds in warm, well-drained soils. Ridge soil around plant base to promote root development.
Charcoal Rot	Fungus survives in crop residue. Enters roots of seedlings shortly after emergence. No outward symptoms until near harvest.	Wilt prematurely and defoliate under hot dry conditions after flowering. Tiny black specks on the roots.	Fertility program with strong plant growth. Rotate corn or cotton for 2 years to reduce fungus. Avoid high seeding rates.
Southern Blight	Found in clay soils of southern Missouri. Survives from year to year.	Seedling death before or stem rot shortly after emergence. White, cottony growth on lower stem.	Rotate crops less susceptible, such as grasses. Deep plowing.
Sudden Death Syndrome (SDS)	Soil-borne fungus attacking roots soon after emergence. Sporadic occurrence.	Yellow areas between veins that eventually become brown. Young pods and damaged leaves fall off. Upper root and lower stem may contain dark streaks. Root rot usually occurs.	Double cropping. Plant varieties that are resistant to leaf symptoms.

Pod and Stem Diseases

Diseases	Causes	Symptoms	Control
Pod and Stem Blight	Fungus spores developed in the tissues of the pod and stem are spread by the wind. Warm, humid weather helps fungus grow. Increase in severity if harvest is delayed.	Infection begins early but does not appear until plant matures. Small, black fruiting structures appear in linear rows on stems or scattered on pods. Seeds may have white mold growth. Seeds are often dull, cracked, or shriveled.	Plant bright, healthy seeds. Treat seeds and fields with approved fungicides. Plow under crop residue. Rotate crops.
Stern Canker	Usually affects plants intermittently rather than whole field.	Brown, slightly sunken lesions on leaf petioles or at the base of branches. Lesions or cankers eventually surround stem, choking the plant. Leaves remain attached to dead plants.	Plant disease-free seed. Use fungicide seed treatment prior to planting. Rotate with crops such as grain sorghum, cotton, or forages. Plant resistant varieties.
Anthracnose	First fungus infects plants at all ages. Second fungus only affects older plants. Spores infect healthy plants.	Produce reddish or dark brown areas on stems or pods. Later form into black structures resembling pin cushions with black spines that are difficult to see. May not show visible signs until weather conditions are more favorable for fungi growth.	Plant healthy fungicide-treated seeds. Apply foliar fungicides as needed. Rotate with nonhost crops.

Foliar (Leaf) Diseases

Diseases	Causes	Symptoms	Control
Brown Spot	Fungus hibernates in the tissues of fallen leaves and stems. Spores are spread to leaves and plants during warm, moist weather.	Small red-brown, angular spots on young leaves. Use crop rotation. Heavily infected leaves turn yellow, wither, and drop off.	Plant healthy, disease-free seeds. Treat seeds and fields with approved fungicides. No resistant varieties currently available.

Foliar (Leaf) Diseases

Diseases	Causes	Symptoms	Control
Downy Mildew	Fungus hibernates in infected leaf residues and survives on infected seeds. Prevalent during wet seasons, seldom causes severe damage.	Yellow-green areas on upper leaf surfaces. Spots later become enlarged and grayish-brown to dark brown with yellow-green margins. Grayish mold develops on underside of leaves with severe infections causing premature defoliation (leaf drop). Can spread to pods and infect the seed.	Plant healthy, disease-free seeds treated with a fungicide. Rotate crops. No varieties resistant to all but a few are moderately resistant.
Bacterial Blight	Survives in crop residue above soil surface and in seeds. Spread to seedlings during wet or rainy weather. Most severe during cool, moist weather.	Small, angular, yellow spots with water-soaked centers appearing on lower leaves. Spots turn dark, reddish-brown to black and surrounded with yellow halos. Centers of older lesions drop out or tear away leaving a ragged and shredded leaf. Often seen during midsummer and may appear about a week after a severe storm.	Plant healthy disease-free seeds. Rotate crops. Dry, hot weather often stops the spread of the disease.

Virus Diseases

Diseases	Causes	Symptoms	Control
Soybean Mosaic	Most common virus. Spread by seeds and from plant to plant by feeding aphids.	Stunted plants with crinkled and mottled leaves. Vary depending on the variety. Vary by the strain of the virus.	Plant disease-free seeds. Practice good weed control.
Bean Pod Mottle	Spread by the bean leaf beetle, farm machinery, wind-carried sand or soil, and infected seed.	Yellow-green mottling of young leaves during cool weather. Reduced pod formation if soybeans are water-stressed.	Use insecticides. Rotate crops with nonlegumes. Remove infected plants when first noticed. Plant disease-free seed.

Virus Diseases

Diseases	Causes	Symptoms	Control
Bud Blight	Wide range of hosts that serve as carriers. Transmission is by thrips and other insects. Tends to be sporadic. Highly susceptible areas include fields adjacent to fence rows with legumes and old stands of forage legumes. Infections usually begin on the outer edges of a field following insect patterns.	Vary depending on the time of infection. Before flowering: Terminal buds will turn brown, curve downward, and turn dry and brittle. Rusty flecking often develops on young leaves. Stems are discolored at the nodes. Plants are stunted. Produce little or no seed. During flowering: Small, undeveloped pods. Pods have dark blotches and poorly filled. Plants remain green after normal plants have matured.	Spray broadleaf weeds in nearby fields. Avoid planting next to other legumes. Plant a buffer strip of a nonhost crop between the fields.

Nematodes

Diseases	Causes	Symptoms	Control
Soybean Cyst Nematode (SCN)	Infection inhibits growth and functioning of the root system. Interferes with nutrient and water uptake. Reduces nodule formation. Affects the amount of available nitrogen.	Occurs without visible symptoms. Leaves may be yellow-green and wilt in midday more than healthy plant leaves. Usually occurs in small to large oval area of a field. Roots will be stunted and appear darker in color. Less nitrogen-fixing nodules. Females may be visible as shiny white or yellow round knots on roots. Mature cysts turn brown and fall off.	Avoid introducing it whenever possible. Work uninfected fields first to avoid spreading in soil. Rotate soybeans with crops that are not hosts. Use and rotate resistant varieties. Maintain good plant health. Weed control. Soil test in the fall to provide ample time to control before next crop.
Root-knot Nematode	Problem in sandy, light textured soils. Worms penetrate roots and feed on them.	Plants are stunted and yellow-green in color. Tendency to wilt under moisture stress during hot, dry weather. Reduced nodules and dark tumors appear on roots.	Plant resistant varieties. Rotate soybeans with grain sorghum and certain forages.

Nematodes are small, worm-shaped animals that move like snakes. Most are so small that they cannot be seen by the naked eye. They are found in water and soil everywhere in the world, feeding on microorganisms, plants, and animals. Most nematodes are beneficial organisms that help decompose organic matter, releasing nutrients for plant uptake. Several types of nematodes feed on soybean roots, but the soybean cyst nematode (SCN) is a plant-parasite and the only one that has been a severe problem in Missouri.

Young SCNs bore their way into the root and grow into either a sac-shaped female or a wormlike male. The females' bodies form a protective covering around their eggs resembling a cyst - where it gets its name. The females continue to swell and eventually break through the root surface. Several hundred young nematodes leave the sac and begin boring into the plant roots. The cycle begins again with each generation lasting up to 3 or 4 weeks depending on soil temperature. Eggs inside cysts can survive winter and other conditions such as floods and droughts. SCN infection inhibits the growth and functioning of the soybean root system, interfering with nutrient and water uptake. It also reduces nodule formation and affects the amount of available nitrogen.

SCN is difficult to identify because damage and yield loss occur without visible symptoms. Even when plants are under stress and SCN is present, symptoms can be mistaken for other problems such as low soil fertility, drought, and root rot. Leaves may be yellow-green and wilt in the midday more than those of healthy plants. SCN usually occurs in small to large oval areas of a field. Roots will be stunted and appear darker in color. They will also have less nitrogen-fixing nodules and females may be visible as shiny white or yellow round knots on roots. Producers should not rely on visual inspection of roots, however, because once cysts have matured they turn brown and fall off. SCN can also attack other legumes such as lespedeza, certain varieties of vetch, garden beans, and some clovers.

Although it can only move a few inches a year in the soil on its own, SCN moves every way that soil moves. It finds its way into bagged seeds through contaminated soil on farm and construction equipment, on workers, on birds, on root crops, in drainage or floodwater, or the wind - virtually by any means that soil particles travel. To control SCN, producers should avoid introducing it whenever possible because it cannot be eradicated from a field once it becomes established. Producers should work uninfected fields first to avoid spreading SCN in soil. Rotating soybeans with crops that are not SCN hosts (see Table 2.2), using and rotating resistant varieties, maintaining good plant health, and weed control are all preferred choices to nematicides. University Extension specialists recommend soil testing during the fall to determine if an infestation is present and to provide ample time to determine control methods to be used before the next crop.

Table 2.2 – SCN Nonhost Crops

Alfalfa	Forage grasses
Barley	Oats
Canola	Rye
Clover (red, white, ladino)	Sorghum
Corn	Tobacco
Cotton	Wheat

Root knot nematode is sometimes a problem in southeast Missouri fields that have sandy, light-textured soils. The worms penetrate roots and feed on them causing tumors that resemble root-rot infection. Female worms can lay up to 1,500 eggs in a root of a plant and the surrounding soil. Unhatched eggs can survive the winter. Plants showing symptoms may be stunted and yellow-green in color with a tendency to wilt under moisture stress during hot, dry weather. Reduced nodules and dark tumors appear on plant roots. Control of this nematode is similar to SCN measures: plant resistant varieties and rotate soybeans with grain sorghum and certain forages.

Summary

Scientists crossbreed different strains and varieties of soybeans to develop new and better varieties every day. Missouri producers currently have over 300 soybean varieties from which to choose. Soybean varieties are classified by two growth types: determinate (the main stem stops growing when flowering begins) and indeterminate (the plant continues to grow along with flowering and podding stages). Determinate varieties have been modified into two classes, semi-dwarf and semi-determinate, that combine characteristics of indeterminate varieties. Variety performance differs by location so producers should choose varieties based on trials in their area.

When selecting a variety there are five characteristics to consider: (1) maturity; (2) standability; (3) pest resistance; (4) additional considerations (double cropping, shatter resistance, seed cost, seed quality); and (5) yield. Of the 13 maturity groups, only 5 are grown in Missouri: Groups II, III, IV, V and VI. When looking at maturity, a producer should also determine if a full-, early-, mid- or late-season variety is needed. Full-season varieties are generally more productive, but there are advantages and disadvantages to each. Lodging before the crop is ready to harvest can decrease yields 20 to 30%, and many diseases that go unnoticed may reduce soybean yields as much as 15%. Scientists are working to breed varieties that can resist diseases, nematodes, and nutrient problems, but few insect-resistant varieties have been developed. All these factors, especially yield, play an important role in variety selection.

Several diseases prevalent in Missouri can drastically affect soybean production. They are generally divided into six different categories: (1) seedling, (2) root and stem, (3) pod and stem, (4) leaf, (5) viruses, and (6) nematodes. Although many of these can reduce yields drastically, the soybean cyst nematode (SCN) is considered one of the most severe disease problems in Missouri. An awareness of these diseases can help producers make decisions about selecting resistant varieties.

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Lesson 3: Selecting a Tillage and Planting Method

As stated in Unit III, Lesson 5, tillage is the act of moving soil particles or cultivating the land. Moving particles affects soil compaction, water intake, and microbial activity. The choice of tillage methods can limit planting options. The planting method used, or the means by which one places the seed into the ground, also has effects on the soil. Field history of soil erodibility, drainage, and fertility are all factors the producers should consider before selecting a tillage and planting method. Along with these issues, this lesson will discuss recommended seeding rates for producers to achieve optimum yields.

Optional Tillage Methods

Missouri soybean producers basically use four methods of tillage: conventional, minimum, no-till, and remedial. A discussion of the advantages and disadvantages for selecting a specific method follows.

Conventional tillage is any tillage system that attempts to cover crop residue, leaving less than 30% of the surface covered after planting. This method has maintained popularity with soybean producers over many years. Approximately 25% of Missouri farmers continue to use this method. Advantages of this system include (1) machinery is familiar and widely available, (2) system is adaptable to a wide range of soil and crop conditions, (3) it allows the use of cultivation for weed control throughout the growing season, and (4) soils warm faster when soil residues are incorporated into the soil. Disadvantages of conventional tillage are (1) higher fuel and labor costs, (2) greater field traffic that can lead to soil compaction, (3) high risk of erosion, and (4) reduction in organic matter.

Minimium tillage includes two methods: mulch-tillage and ridge-tillage. Use of the mulch-tillage method among Missouri soybean producers has increased over recent years. In this system, soil is disturbed only between harvesting and planting. More than 30% of the soil surface is covered with residue. Advantages of this method include (1) reduced soil erosion, (2) lower fuel and labor costs, and (3) maintaining conventional tillage method advantages. Disadvantages of mulch-till include (1) modifications to equipment required, (2) warming of soil slowed, (3) less effective under wet conditions, and (4) may require a larger tractor. Another minimum tillage system rarely used in Missouri is ridge-till. Seedbeds are raised In this tillage system. Advantages include (1) reduced erosion, (2) lower fuel and labor costs, (3) reduced compaction due to controlled traffic, and (4) weed control due to inter-row cultivation. Disadvantages include (1) inter-row cultivation is required to build ridges, (2) ridges must be level, and (3) wheels of machinery must be modified to avoid damaging ridges.

No-till, the most widely used tillage method among Missouri producers, is the system of planting narrow seedbeds without disturbing the soil. Herbicides are used to control weeds. Advantages include (1) lower cost and (2) greatly reduced erosion. Disadvantages include (1) high residues slow the warming of soils, (2) attachments must be added to equipment, (3) weed control is dependent on herbicides, and (4) high management by the producer is required.

Remedial tillage involves subsoiling and land leveling and is generally not used in Missouri. This system is used only under special conditions. Subsoiling involves loosening soil in severely compacted soils. Land leveling involves leveling off the top layer of soil. The controlled method uses a laser in an attempt to put a consistent slope on a flat field to move surface water. The uncontrolled method scraps the top layer of soil from high areas to fill in low areas. Both methods are very expensive and deplete organic matter.

Optional Planting Methods

Planting methods that can be considered for use by Missouri producers include row cropping, skip row, drilled or solid-seeding, broadcast, and aerial. Row cropping and drilled methods predominate in Missouri because of their consistency in producing good stands.

Row cropping is very popular because of its consistency in producing good stands. Crops are planted in straight rows. Row widths are based on environmental conditions and tillage method used. Row cropping does not require any special equipment; planters and drills used in conventional tillage and minimum tillage methods can be used easily. Convenience and familiarity make this method very favorable throughout Missouri.

Skip row planting is very similar to row cropping. The difference is that rows are left unplanted or skipped between rows. This skipped row is used for maneuvering equipment between rows for cultivating and easier sprayer applications. The width of the skipped row is based on the size of an individual's equipment. Skip rows can also be used in managing soil compaction or field traffic. This method is not typically used for soybeans in Missouri.

Drilled or solid-seeding is the method of using a drill to drive seeds into the ground with narrow spacing 10 inches or less apart. Drilling is primarily associated with no-till but can also be used in conventional or other minimum tillage methods. The wide use of no-till by Missouri producers makes drilled planting methods favorable throughout Missouri. Because of improvements in weed control, producers can use the drilling method to increase yields. Good early season weed control is essential until the canopy develops. Harvest loss is reduced because the combine can be operated closer to the ground. Seed depth control is usually less uniform with drilling equipment than with a conventional planter, resulting in poorer emergence. Use of a seeding rate slightly higher than that recommended for 30-inch rows is necessary.

Broadcasting and aerial are planting methods that distribute seeds uniformly over the surface of the field and are followed by light tillage. These methods require a firm, level seedbed to be effective in establishing a stand. The success rate is lower than when using row planters or drills because seeds are placed at random depths. Therefore, they are not typically used in Missouri for soybeans.

Recommended Seeding Rates

Optimum yields can be obtained with plant populations of 70,000 plants per acre. This would amount to approximately 4 plants per foot of 30-inch rows and 1 plant per foot in drilled rows. Populations less than 70,000 plants per acre may result in yield reductions due to insufficient plant numbers. Plant populations affect other characteristics such as low podding and excessive branching. However, low populations produce better lodging resistance wheras higher populations produce increased lodging. Populations above 150,000 plants per acre may result in yield reductions due to overcrowding. Other characteristics are higher podding, less branching, and increased lodging. Therefore, plant populations vary depending on the characteristics needed by the region. Table 3.1 gives recommendations and adjustments under average conditions.

The seeding rates shown in the table are designed to provide a starting point. Surveys show that many planters actually seed at different rates than suggested by most manufacturers' charts. Also, planters should be checked for proper adjustments. A planter that does not run level will cause uneven placement of seeds. Check the manufacturer's manual for specific adjustments.

For specific conditions, using the table, increase the seeding rate per acre according to the following guidelines:

5% for each rotary hoeing planned
10 - 15% for very early or very late planting
10 - 15% for short season varieties

Table 3.1 - Recommended Seeding Rates

Row Width (inches)	Approximate Lb/Acre*	Seeds to Plant Per Ft. of Row	Seeds/Acre	Expected Plants Per Ft. of Row**	Expected Plants Per Acre**
40	40	9	118,000	5.4 - 6.3	71 - 83,000
30	50	8.5	148,000	5.1 - 6.0	89 - 104,000
20	60	7	183,000	4.2 - 4.9	110 - 128,000
10	70	4	209,000	2.4 - 2.8	125 - 147,000
7	80	3	224,000	1.8 - 2.1	134 - 157,000

* Assuming 3,000 seeds per pound.
** Assuming from 60 to 70% emergence of planted seed, based on 80% germination seed and average to good conditions for establishment. If higher germination seed is used, planting rates may be reduced accordingly.

20% + for short season varieties planted very early or very late
35% for semi-dwarf determinate and semi-determinate varieties
10% for cold soils
50% for broadcasting
10% for no-till
10% for rough seedbeds
10% for thin line varieties
10% if a flexible or floating cutter bar or combine is not used or rough combing conditions are expected

Decrease the seeding rate per acre by:

5 - 10% if in the Bootheel
5% if lodging has been a problem
5% if planting under ideal conditions in rows
5% if using high-quality seed (higher than 85% germination)

Summary

Tillage systems used in Missouri soybean production are conventional, minimum, and no-till. The most widely used of these systems is no-till. Planting methods available to soybean producers in Missouri include row cropping, drilled or solid-seeding, skip row, broadcast, and aerial. Row cropping and drilled or solid-seeding are both very popular because of their consistency in producing good stands. Skiprow is similar to row cropping with the difference that rows are left unplanted or skipped between rows. Broadcasting and aerial seeding distribute seeds randomly across a field and are rarely used in Missouri. Optimum yields can be reached with plant populations of 70,000 plants per acre. Populations less than 70,000 may result in yield reductions due to insufficient plant numbers. Populations above 150,000 plants per acre may result in yield reductions due to overcrowding.

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Lesson 4: Selecting a Weed Control Program

Previous lessons have discussed the importance of evaluating local growing conditions when planning the crop, selecting a variety, and choosing a tillage and planting method. Choosing a weed control program that will reduce crop losses due to weeds will have an economic impact on the producer.

Factors That Determine a Weed Control Program

Weeds compete with soybeans for moisture, nutrients, and sunlight. Controlling weeds is one of the most important steps in successful soybean production. Statistics show that crop producers lose about 1 pound of soybean dry matter for each pound of weed produced on an area of land.

Good weed control requires early planning and good execution. This may involve mechanical or chemical control measures or a combination of the two. One or more herbicides are applied to most of the soybeans grown in the United States. Specific herbicides and rates will not be recommended in this lesson because the recommended chemicals, rates, and methods of application vary across the state and are likely to change through the years.

Weeds are responsible for as much as 15% of the annual losses in the state, thereby making a weed control program very important. Before choosing a weed control program there are several factors to consider.

- Knowledge of the annual recurrence of weeds in the field
- Knowledge of what type of weed control program was used previously in the field
- Crop rotations used and planned for the field - Continuous soybeans present more weed control challenges than if planted in a grass rotation.
- The variety of seed to be planted (herbicide-resistant varieties)
- Seed planting method - Narrower rows form a canopy earlier and shade out late season weed germination.
- Planting date - Delayed planting will allow early emerging weeds to be eliminated with tillage or a burn down herbicide before planting.
- Environmental conditions - Is the field close to a stream that is susceptible to runoff?

Start by scouting the fields after the crop is planted. Inventory the weed situation field by field and draw a map showing problem locations. This should be done within 2 weeks after the crop emerges. Include noncropped land such as fence rows, grass waterways, and drainage ditches. It is beneficial to include differences in soil types and textures, soil organic matter, and the pH on the weed map. These factors react differently with many soil-applied herbicides.

Weed Problems Specific to Soybeans

Proper weed identification is required to formulate the most effective herbicide program for each soybean field. Improper herbicide selection will result in poor weed control, which causes lower soybean yields. This often leads to another costly herbicide application for "salvage" weed control.

Broadleaf weeds, annual grasses, and perennial weeds plague Missouri farmers. Table 4.1 provides a list of common weeds that cause problems with soybeans in Missouri.

Table 4.1 - Common Weeds Occurring in Soybeans

Broadleaf Weeds	Annual Grasses and Perennial Weeds
Buckwheat, wild	Barnyardgrass
Cocklebur, common	Bindweed, field
Jimsonweed	Bindweed, hedge
Morningglory, ivyleaf	Cane, wild
Morningglory, pitted	Crabgrass, large
Lamb's quarters, common	Foxtail, giant
Mustard, wild	Foxtail, green
Nightshade, black	Foxtail, yellow
Pigweed	Hemp, dogbane
Ragweed, common	Horsenettle
Ragweed, giant	Johnsongrass
Smartweed, Pennsylvania	Milkweed
Sunflower, wild	Nutsedge, yellow
Velvetleaf	Panicum, fall
	Proso millet, wild

Weed Pressure's Effect on Yield

The toll on soybean yield may be heavy when there are uncontrolled weed problems. Many weeds emerge with soybeans as they germinate and increase in height at about the same rate as the crop. For this reason, and also because weeds are killed most easily in the early growth stages, early season control is most important. If weeds are controlled within 2 to 4 weeks after soybeans emerge, little damage is done to the yield. The longer the weed problem continues, the greater the yield reduction. Table 4.2 indicates how the yield of soybeans might be affected by the density and length of competition from a specific number of cocklebur plants per foot of row. When one cocklebur plant per foot of soybean row is left in the stand for the entire growing season, it can result in about 61% of yield reduction.

Table 4.2 - Effect of Cocklebur Density and Length of Competition on Soybean Yields

	Weeks That Cocklebuns Were Left Uncontrolled				
Density of Cocklebuns	4	6	10	12	Full season
	% reduction in soybean yield				
1 per 10 feet of row	2	5	10	13	13
1 per 5 feet of row	4	10	21	26	26
1 per 2.5 feet of row	5	14	31	39	40
1 per foot of row	10	15	38	60	61
3 per foot of row	10	36	60	80	80

Source: University of Arkansas

Table 4.3 shows the effect of foxtail weeds left in the soybean stand. If the stand was weed free, there was a yield of 30 bushels per acre. When the foxtail was left until the soybean plants were mature, the yield dropped to 12 bushels per acre.

The amount of damage caused by weed pressure varies depending on the growth stage of the soybean. If early weeds are controlled and a uniform stand of soybeans is allowed to become established, plants completely shade the ground and damage from weeds is minimized.

Weed Control Options

There is no simple cure for weed control in soybeans. There are a variety of possible approaches to weed control: cultivation, herbicide application, and herbicide tolerant system.

Table 4.3 - Effect of Removing Foxtail from Soybeans

Soybean Height When Foxtail Was Removed	**Average Yield**
Inches	Bushels per Acre
Weed-free check	30
8	30
12	30
16	29
22	29
Left until beans were mature	12

Source: University of Illinois

Cultivation involves removing weeds from rows manually or mechanically. There are several advantages to using cultivation as weed control. It is environmentally safer and more economic than chemical use, depending on acreage and amount of weed growth. The disadvantages are low effectiveness on weeds growing directly in the row, grass weeds, and increased cost of labor and fuel, particularly if cultivation needs to be repeated. Cultivation is also dependent on timing and severity of the problem.

The second method of weed control is the use of herbicides. This involves applying chemicals to fields or plants to either prevent or destroy weed growth. An advantage to this method is controlling weeds throughout the whole field with no need to reapply the chemical during the growing season. The roots are killed, slowing or preventing new growth. Disadvantages to using herbicides are the toxic effects on the environment, the cost of the chemicals, and the chance of plant injury. Chemical companies are working toward developing new herbicides that are environmentally safe and more affordable.

A third method of controlling weeds is the herbicide-tolerant system. This requires planting herbicide-resistant varieties. The advantages of this system are less trips across the field and reduced cultivation costs. There are several disadvantages of the herbicide-tolerant system: lack of residual control during the growing season, damage can occur to the plant if the herbicide is applied incorrectly, and no spraying can occur after the V-6 stage.

Summary

Weeds are responsible for as much as 15% of the annual losses in Missouri, thereby making a weed control program very important. When selecting a weed control program there are several factors to consider: (1) knowledge of annual reoccurrence of weeds, (2) knowledge of past herbicide treatments if any, (3) crop rotations used and planned, (4) variety of seed to be planted, (5) how the seed is to be planted, (6) planting date, and (7) environmental conditions. Each of these factors plays an important part in how the type of weed program will perform. A large number of broadleaf, perennial, and annual grasses cause problems for Missouri producers. Competition from weeds accounts for 30 to 80% of yield reductions and increases input cost of soybean production. Although there is no simple method to control weeds, methods fall into two categories: cultivation and herbicide control. Effectiveness of each depends on environmental conditions in the area.

Credits

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Lesson 5: Scouting and Maintaining the Crop

Evaluation of the soybean crop during the growing season, referred to as scouting, is one of the most important activities producers perform during the season. Scouting is the only way to determine when it is appropriate to begin management practices such as irrigation, IPM (integrated pest management), and herbicide practices.

Scouting the Growing Crop

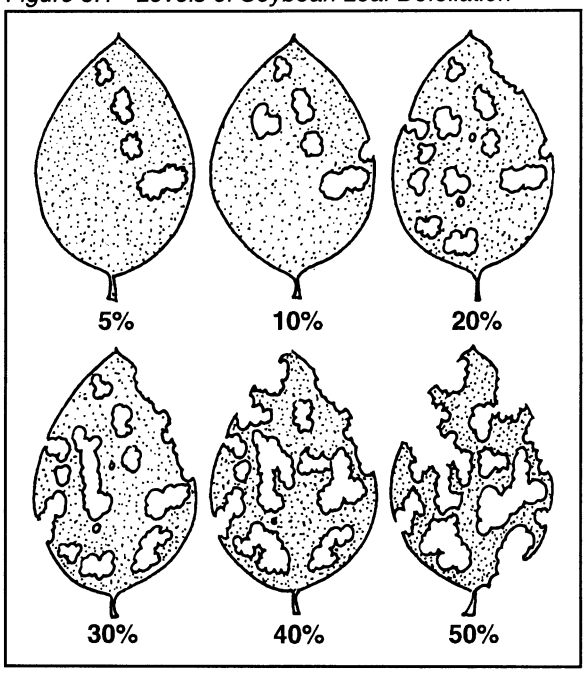
There are several reasons for crop producers to scout their fields on a regular basis. These reasons include evaluating the stand for replanting (as discussed below), checking for insect and disease presence and/or damage, evaluating plant nutrition practices and outcomes, checking weed presence, evaluating herbicide and insecticide effectiveness, moisture availability, and crop readiness for harvest.

Soybean growers are most concerned about how much yield or seed quality loss will result from the presence of pest insects. Loss of yield or seed quality will result only when the amount of injury exceeds the tolerance of the plant. This is known as the "injury threshold" of the plant. Defoliation is the most common and visible form of chewing insect damage to soybeans. Growers tend to overestimate defoliation. Defoliation damage can be estimated by removing 10 to 20 leaflets from the middle and upper portion of plants from several areas in the field. Compare these to the illustrations in Figure 5.1, average the percentage of defoliation, and the mean will reflect the level of damage for the field.

Herbicide and insecticide effectiveness may also be evaluated when scouting or surveying the field. If one or more of these problems still exist or become present, contact the chemical representative for adjustments and/or recommendations before proceeding. If additional weeds are a problem, this may be corrected early by a tillage method such as rotary hoeing.

Moisture management during the growing season can significantly affect soybean productivity. Soybeans require about 18 to 22 inches of water for good development and maturation. The objective of good moisture management is to provide water to the roots when needed by the plant to produce the most economical soybean yields. If the soils are overly wet, drainage practices may need to be employed. This may include tile drainage, tillage, or surface drainage. Ridge planting is another consideration before planting on traditionally wet fields. If moisture is deficient and a water source is available such as with a river, reservoir, or a deep well, irrigation may be a consideration. Without the optimum amount of moisture, the soybean plant may be stressed and maximum yield not obtained.

Figure 5.1 - Levels of Soybean Leaf Defoliation



Replanting Decisions

Deciding whether to replant is by far the most difficult decision to make when producing soybeans. This decision requires the producer to make an unemotional analysis of the field. In making this decision there are a few steps that should be followed. If crop insurance covers the damage, consult an insurance agent before taking action. When all of a stand is lost, it is realistic to replant if adequate growing season remains for beans to mature.

The first step is to determine the cause of damage. Causes can be the result of poor seed quality; planting too deep or too shallow; herbicide injury; insect or disease problems; cold, wet soils; hot, dry soils; or soil crusting.

Second, assess the damage by evaluating the stand density. If the stand loss is random or erratic, a stand count should be taken. If 40% (30% in southern Missouri) or less of the recommended stand remains, and it has been 3 weeks or less since the first planting date, it is probably economical to replant. A computer program (AG0031) at University Extension Centers is available for more assistance on replant decisions.

To estimate the amount of live plant populations remaining, count the number of live plants in the appropriate areas. For row planting, the easiest length of row in which to count plants is one equal to 1/1000th of an acre. For example, for 30-inch row width, use a row length of 17 feet, 5 inches; 20-inch row width, use 26 feet, 2 inches; and 15-inch row width, use 34 feet, 10 inches. (Refer to Table 3.1 in Lesson 3 of this unit, Recommended Seeding Rates, to determine expected plants per foot of row.)

The hula hoop method can help determine plant populations in drilled soybeans. Place a circular measuring device, such as a hula hoop, on the ground and count the number of plants contained within the circle. Refer to Table 5.1 for determining drilled soybean populations using the hula hoop method. Wait several days to determine if regrowth in these areas is possible. Do not count plants that have a potential for recovery. Again, if 40% or less of the stand remain, and it has been 3 weeks or less since planting, it may be necessary to replant.

Table 5.1 - Hula Hoop Method

	Inside Diameter of Hula Hoop				
# of Plants	30"	32"	34"	36"	38"
	Plants (1,000s) Per Acre				
4	35	31	28	25	22
6	53	47	41	37	33
8	71	62	55	49	44
10	89	78	69	62	55
12	107	94	83	74	66
14	124	109	97	86	77
16	142	125	110	99	89

After stand density has been established, yield potential must be predicted. Be sure not to overestimate normal yields for the area of the state. The entire field must be observed for amount of weed pressure, extent of plant defoliation, and large gaps in the stands. Refer to Table 5.2 for estimated yield potential of soybeans at various populations. Keep in mind that soybeans are most affected by weather conditions in July and August. When determining yield potential, assume normal weather patterns. Refer to Table 5.3 for effect of planting date on yield of soybeans.

Table 5.2 - Soybean Yield as % of Normal

Population	**30" Rows**	**7" Rows**
160,000	100	100
120,000	100	100
80,000	100	96
60,000	94	92
40,000	88	87
20,000	79	77
10,000	64	58

Table 5.3 - Effect of Planting Date on Soybean Yield

Planting Date	**Yield as % of "Normal"**
May 10	100
May 20	100
May 30	94
June 10	88
June 20	78
June 30	70
July 10	Not recommended in northern Missouri

Once the yield has been predicted, determine income by multiplying yield potential and predicted market price at harvest. Even if predicted replanting yield is greater than that of the damaged field, the cost of replanting may still be more than the additional replant yield.

There are cases when replanting is not the best option. When only parts of a stand are lost, the decision to replant is more difficult. If a total loss is suffered, it may be more profitable to file a crop insurance claim. A producer who double-crops may not have enough time for replanting. In such a case, filing an insurance claim may be the best option. Once the estimated yield and predicted market price are determined, a decision can be made about insurance.

Costs to consider when determining replanting cost are (1) the cost of the seed, (2) fuel and machinery costs, (3) additional pesticides and herbicides, (3) labor, (4) interest on loans, and (5) increased cost associated with late harvesting, such as increased dryer costs.

Decisions about Weed Removal

The decisions a soybean producer makes prior to planting will determine the method of weed removal. Cultural methods such as deep plowing in the fall or early spring will reduce most perennial weed problems. Producing soybeans in wide rows (greater than 20 inches) using conventional tillage methods allows for cultivation of weeds between the rows. However, grasses are not easily controlled by cultivation. Cultivation is also ineffective for controlling weeds growing directly in the row. Cultivator sweeps should be set to run as shallow as possible (1 to 2 inches).

Greater reliance is usually placed on herbicides for weed control in drilled soybeans because postemergence cultivation is more limited. A timely rotary hoeing early in the season can be effective. If rotary hoeing is used properly, less than 5 to 10% of a well-established soybean stand should be destroyed. Drilled or broadcast beans are also more competitive with weeds because of a more uniform crop distribution that forms a canopy earlier in the season.

Herbicides are the primary method of weed control in soybean production. Many new herbicides have been introduced in the last few years. However, no single herbicide is capable of controlling all of the common weed problems encountered in Missouri soybean fields. Many of the new herbicides are more species specific in activity than previous herbicides. A more complete treatment of weed control options and herbicide combinations is provided in the *Weed Control Guide for Missouri Field Crops* (MP575), which is updated annually and available at any county extension office.

Scouting for Insects

Soybeans are inhabited by many kinds of insects. Most do not pose a threat to profitable soybean production. A few kinds, however, can reduce yields significantly if their numbers are high. Scout fields regularly to stay abreast of insect infestations. Typically, insect problems are low early in the season, until late July or early August. From that time until the plants mature, soybeans may be invaded by large numbers of foliage feeders or pod feeders.

Thesholds have been established for most major insect pests and for several minor pests. Insecticides should be applied only when pest levels reach economic thresholds. Producers should become familiar with the threshold values for the major soybean pests in their area. A local University Extension Center will have current information available for producers.

Some of the more common soybean insects are the bean leaf beetle, stink bugs, corn earworm, and grasshoppers.

Bean leaf beetles overwinter under debris. They attack germinating soybeans by chewing on cotyledons, underground stems, and first sets of true leaves. Adults are about 1/4 inch long and vary in coloration (red, orange, tan, or gray) and markings (dots, strips, or both). All adults possess a black triangle at the base of their forewings. There are two generations per year in Missouri. As soon as soybean seedlings emerge, it is important to scout fields weekly for bean leaf beetle infestations. Scouting procedures are targeted at the adult stage because sampling for the larvae is expensive, labor intensive, and time-consuming.

Stink bugs overwinter as adults underneath leaf litter, tree bark, and other materials in areas not used for crops. Both the nymphal and adult stages attack primarily the seeds and pods of soybean plants. They also feed on plant stems, foliage, and blooms. Feeding punctures can be identified by the presence of small brown or black spots. In Missouri, insecticide treatments are recommended when adults or later-instar nymphs reach at least one insect per foot of row as soybean pods begin to fill with seeds.

Corn earworm larvae may attack soybean foliage and pods, especially in southern counties. Newly hatched larvae feed on terminal foliage for a few days before moving down to small pods and eventually to larger pods. Pod injury is most severe on mid-season and late-planted beans during late August and early September. There are three generations annually, but the last generation is the one most likely to damage soybeans.

Grasshoppers, both nymphs and adults of several species, may feed on soybean leaves and pods, especially during a dry summer. Damage is usually confined to rows adjacent to fences, ditch banks, and grassland. Grasshoppers overwinter as eggs in the soil, mate during May and June, and the partially grown to mature hoppers begin to move into crops during July and August when surrounding vegetation becomes scarce and matures.

Apply insecticides only when pest numbers reach or exceed threshold levels. Economic thresholds are always changing to include stage of development of the crop, stage of development of pest(s), weather, yield potential, market price of commodity, and cost of pesticide and its application.

Summary

Scouting the growing crop is a crucial step for the producer. Factors such as insect pest damage, weed and disease damage, and moisture availability help producers know when to implement management practices. If the crop is damaged, decisions regarding replanting need to be made. The cause of the damage needs to be determined and the damage needs to be assessed to determine if replanting is the best option. Cost factors for replanting will determine if yield potential can be increased. Methods of weed removal will be determined prior to planting resulting in either herbicide applications or cultural methods. Scouting for insect infestations should occur on a regular basis with economic thresholds determined for pesticide applications.

Credits

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Lesson 6: Harvesting the Crop

Harvest management is an important part of turning high-yielding soybeans into profit. Harvesting and storing the crop are the final steps that will determine if a producer will be profitable. This lesson will address challenges producers face and methods to reduce losses during harvesting and storage.

When to Harvest

Choosing the most favorable harvest time can be the difference between profit and loss for a producer. The factors that determine when to harvest soybeans are the maturity level and the climatic conditions. Harvesting should begin when the beans are mature, the leaves have fallen off the plant, and the stalks and pods are golden brown. Soybeans mature based on the variety; some are short-season varieties and some are long-season varieties. On average, they will mature 50 to 80 days after full bloom.

A determining factor in the maturity level of the soybean is the moisture content. A newly formed soybean seed contains nearly 90% moisture. The moisture content continues to decline throughout the growth and development of the soybean. At harvest, the ideal moisture level should be 13% or lower if short-term storage is used. For long-term storage, the moisture content should be 11 or 12%. Complete the harvest as quickly as possible after beans first reach combine maturity.

Climatic conditions affect the moisture levels of the soybean. Soybeans are hygroscopic, meaning they give up and reabsorb moisture more easily than other crops. Harvesting at moisture levels that are too low can cause high shattering losses. Shattering can be reduced when the relative humidity of the air is high. Avoid harvesting during hot, dry afternoons when pods and beans tend to be brittle. Early mornings or early evening hours when the dew is high will provide adequate moisture to reduce shatter. Typical moisture changes can vary from 16% at night to 9 to 10% during the hot, dry part of the days. Beans should be covered or stored immediately after harvest to reduce reabsorption of moisture from the air. Typically producers will wait until after the first frost to reduce problems with green weeds. Weeds can become tangled in the combine and cause drying problems when stored. The mature soybean normally remains highly viable after exposure to below-freezing temperatures.

Preventing Harvest Losses

There are two categories of soybean harvest loss. Soybeans lost during the maturation process are called preharvest losses. Losses that occur during the harvesting process are called harvest loss.

Preharvest Loss

Preharvest loss is loss that occurs before harvesting and is influenced by the soybean variety, weather, and timeliness of harvest. Preharvest loss is caused by lodging of plants and shattering of pods. To hold shattering to a minimum, plant shatter-resistant varieties. Beans that fall to the ground cannot be harvested. Harvest the bean as soon as the moisture is low enough. Starting early is important because the moisture content declines rapidly when the humidity is low. On average, total crop yield loss is 0.25% before harvesting begins.

Harvest Loss

Harvest loss during the harvesting process cannot be completely avoided but it can be reduced to an acceptable level. The most common causes of harvest loss are shatter loss at the combine header, stubble loss, lodged or loose stalk loss, cylinder loss, and separation loss.

Shatter loss at the combine header occurs when the header is operated improperly or when the crop tends to shatter easily. The soybeans are shelled in front of the combine and do not pass through the header. Shatter losses increase with crop dryness and a properly adjusted combine header will help to reduce losses. Adjustments to the combine header need to be made according to the guidelines in the operator's manual for that specific combine. Typically the reel speed is too fast or positioned too far forward. The forward speed of the combine and the reel speed need to be in proper proportions according to manual guidelines. On average, the reel speed should be 25% faster than ground speed.

Stubble loss occurs when pods are left on the stalk because they were missed by the cutter bar and not gathered into the combine. A cutter bar set too high will miss the lowest pods. This problem can be reduced by keeping the seedbed level when

cultivating and by operating the cutter bar as close to the ground as possible.

Lodged or loose stalk loss occurs when beans are left in the pods on downed stalks or those that are cut but do not pass through the combine. A pickup reel with pickup guards on the cutter bar will reduce these losses. In addition, the combine should be in top condition, the knife sharp, and the correct reel height used.

Cylinder loss occurs when beans are left in the pods after passing through the combine. This is a result of harvesting when the moisture content is too high and incorrect cylinder-concave settings. Cylinder speed should be set according to the operator manual. The settings may vary depending on moisture levels.

Separation loss occurs when loose beans pass out of the combine. This loss can be reduced with the correct blower and sieve settings. Set cleaning sieves and wind according to the operator manual.

Tips for Keeping Combine Losses Low

- Keep equipment in good working order.
- Keep the seedbed level.
- Operate the cutter bar as close to the ground as possible.
- Use a ground speed of 2.8 to 3.0 miles per hour.
- Use a reel speed about 25% faster than ground speed.
- Reel axle should be 6 to 12 inches ahead of the cutter bar.
- A six-bat reel will give more uniform feeding than a four-bat reel.
- Complete the harvest as quickly as possible after beans reach 13% moisture content.
- Cylinder speed and clearance should be set according to owner manual guidelines.

Harvesting Soybeans for Seed

Recent trends find producers returning to the practice of harvesting soybeans for reseeding. Soybeans genetically altered have not allowed producers to hold back seeds for future crops because of patents on the original product.

Soybeans that are being harvested for use as planting seed require special attention. The following list from the University of Missouri Extension publication G04410 provides guidelines for producing high-quality, good-germinating seed.

- Give special attention to genetic purity, freedom from weed seeds, and overall quality of the seed planted. Certified seed growers must use foundation or registered seed. Producers of noncertified seed can ensure varietal purity by planting certified seed.
- Plant seed fields on land that was not planted in soybeans the previous year unless the same variety was planted.
- Avoid early planting. Although yields may be higher, the quality of seed produced from early plantings is often poorer.
- Make every effort to control weeds. One or more cultivations are usually necessary even with good results from chemical weed control.
- Start harvest as soon as the bean reaches 13% moisture. Harvest as much of the crop as possible at 12% moisture or above to avoid cracked seed coats and splits. Stagger planting dates of the same variety so that they mature at different times.
- If heavy pathogen infection is predicted, consider using foliar-applied fungicides during the reproductive stages.
- Pay special attention to combine adjustments, keeping cylinder speed as low as possible while still doing a good job of threshing.
- Avoid harvesting during hot, dry afternoons when pods and beans tend to be brittle. Nights and mornings are the best time to harvest.
- When moving beans from the combine to storage and handling and conveying them while cleaning, drop the beans as few times and as short a distance as possible to reduce seed coat cracks.
- Avoid using auger elevators; they increase seed damage.

Storage Options

Soybean storage options are very similar to corn storage. Grain bins located on the farm can be used as well as local grain elevators. These local elevators store and condition the soybeans before selling and shipping them to a soybean processor or export elevator. Some areas may have grain buying stations or processing plants nearby that may purchase soybeans directly from the producer. Grain may also be transported by truck to a regional transport facility such as a railroad or river terminal to market or store harvested soybeans.

Storage Problems

Soybeans have a high oil content and absorb moisture from the air more easily than most other crops. High temperatures and humidity can lead to mold growth. Therefore, it is very important that beans are dried and humidity levels kept at equilibrium. Equilibrium describes the ratio between a relative humidity and the moisture content in soybeans. Drying can be achieved either with high temperature driers or with natural air. There are many types of driers available and each should be analyzed to determine the potential for causing cracks in the soybeans.

Storage bins should not be overloaded. Excessive depths of wet grain will increase drying costs and delay harvests. It is not good practice to add new grain on top of old grain in storage.

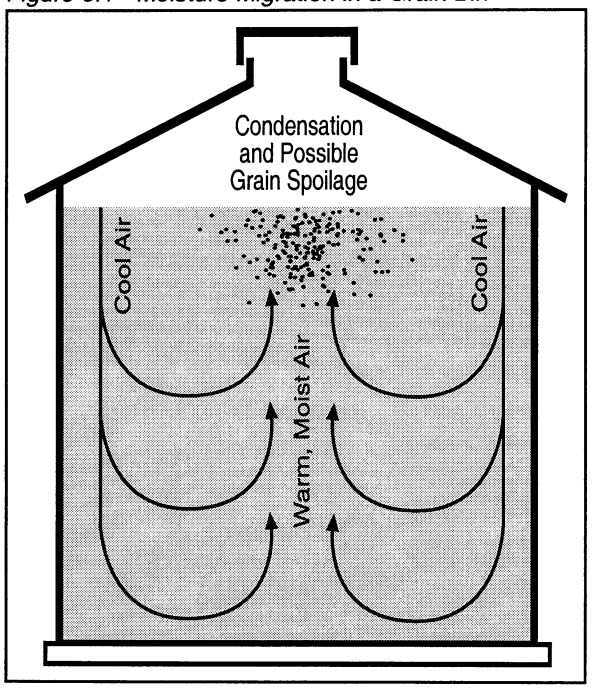
Avoid an accumulation of trash, such as weeds, in the soybeans. Trash will affect drying. Uneven moisture gradients in the trash and the soybeans can result in hot spots during later storage.

Insects are generally not a problem in soybeans if stored for less than 1 year. Special precautions should be taken if storage is going to be longer than one year.

Maintaining Crop Quality During Storage

Whether the soybeans are being stored for a short time or for longer periods, the temperature and moisture levels must be controlled. As outside temperatures decline, the soybeans cool near the surface and outside walls of a storage bin. The soybeans remain warm in the interior mass. Cool air moves down the inside walls, forcing warm air upward. When the warm air reaches the cool surface, condensation occurs. Figure 6.1 shows moisture movement through the grain bin.

Figure 6.1 - Moisture Migration in a Grain Bin



One of the most typical ways to control moisture in soybeans is by aeration. Aeration is a mechanical ventilation of grain in storage. The primary objectives of aeration are to (1) keep the soybeans at a seasonally cool temperature, within 10 degrees of the average monthly ambient air temperature and to (2) maintain a relatively uniform temperature within the soybean mass, preferably no more than a 10-degree difference from one part of the bin to another. Aeration prevents condensation that forms from warm, moist air by cooling the interior mass of soybeans.

Soybean mass temperature needs to be controlled throughout the year. Run the fan continuously if grain is above 16% moisture. Do not turn off the fan when it rains or there is bad weather. Beans should be cooled to 40°F in the fall and warmed to 60°F in the early spring. There should be no more than 15 degrees difference between the beans in storage and the average outdoor temperature. When warming beans in the spring, start fans for cooling when the outdoor temperatures are about 10 degrees warmer than grain temperatures. Forcing air warmer than 10 degrees above grain temperatures can cause moisture condensation within the grain mass. This condensed moisture can cause beans to go out of condition later.

Summary

The maturity level and climatic conditions determine when soybeans should be harvested. The moisture content determines the maturity level of the soybean. Soybeans should be at a 13% moisture level or lower at harvest. Climatic conditions also affect harvest time. Soybeans are hygroscopic and give up and reabsorb moisture easily. Harvesting after the first frost will typically provide ideal conditions.

Preharvest loss is caused by lodging of plants and shattering of pods before harvest. Shatter-resistant varieties should be planted and the bean should be harvested as soon as the moisture level is low enough.

Loss during harvest is caused by shatter loss at the combine header, stubble loss, lodged or loose stalk loss, cylinder loss, and separation loss. To reduce combine losses, keep the equipment in good working order and keep the seedbed level. The cutter bar should be close to the ground with a combine ground speed of 3.0 miles per hour. The reel speed should be 25% faster than ground speed with the reel axle 6 to 12 inches ahead of the cutter bar. Combine settings should be set according to the owner manual guidelines.

Proper storage of soybeans is very important because of their ability to absorb moisture easily. Beans need to be dried and humidity levels should be kept at equilibrium. One of the most typical ways to control moisture is by aeration. If condensed moisture is not controlled properly, it can cause the seed coat to crack or cause the beans to go out of condition later.

Credits

Management to Maintain Stored Grain Quality (G94-1199-A). Cooperative Extension, University of Nebraska-Lincoln. 1996.

Managing Grain for Year-Round Storage (AE-90). Cooperative Extension Service, Purdue University, West Lafayette, Indiana. 1997.

Measuring and Reducing Soybean Harvesting Losses (G01280). University Extension, Columbia, MO: University of Missouri-Columbia. 1993.

Missouri Soybean Handbook. (Manual 123). University Extension, Columbia, MO: University of Missouri-Columbia. 1982.

Lesson 7: Marketing the Crop

This unit discusses the process of producing soybeans for selling the crop. There are a number of marketing options available to producers. Crop prices are closely tied to national and world prices by a network of marketing tools. To be profitable, the producer must determine when to sell or store soybeans and understand how the quality of the grain affects the price. Soybean checkoff funds contributed by the producer enable soybean products to be marketed worldwide.

Marketing Options

There are many options available to producers when marketing their soybean crop. The most common methods are to sell for cash at harvest, store at harvest and sell for cash later, use forward pricing in the futures market, use delayed pricing, use grain pooling agreements, or a combination of these methods.

Probably the simplest method of marketing to practice and to understand would be the marketing option of selling the grain at harvest. This involves transporting the grain from the combine directly to the grain elevator, selling the grain upon delivery at that day's cash market price, and receiving payment from the elevator.

Some crop producers have storage facilities available to dry and store the grain when harvested and sell on the cash market later. This may be done if the cash market is unseasonably low at the time of harvest with the expectation and forecast of increased prices in the near future. The producer could transport the soybeans to the grain elevator when the cash price is expected to rise to a level of greatest profit.

Another option for producers is to use forward pricing in the futures market. Forward contracts can be established between grain elevators or on the futures market. The futures market adds a time dimension to the pricing process and helps smooth out price changes due to short harvest or bumper crops, shifts in government markets, and changes in foreign markets. Forward pricing is established in advance, sometimes as much as 12 months or more, and locks prices in place. The disadvantage is uncertainty of market prices that may rise above the price that was locked in. There is also a chance that a loss in yield or quality may occur.

To offset the risk associated with forward contracting on the futures market, producers use hedging. Hedging is using the futures market as a temporary substitute for a cash purchase or sale to be made at some later date. Hedging is a way of reducing some risk of holding investments.

The simplest but most expensive method is to use an alternative called put or call option contract. The put option gives the buyer the right, but not the obligation, to sell the commodity. The call option gives the buyer the right, but not the obligation, to buy the commodity. Option markets are like buying insurance against falling prices. If the market falls, a put option protects the producer. However if the market rises then a put option is worthless and a loss is suffered. A call option is more of a gamble. It requires the market to rise to be valuable. Used correctly both can offset risk and give the producer a profit. Before attempting to use the futures market, producers should seek the help of marketing specialists to gain a better understanding.

Delayed pricing, or cash contracts, is another option producers have available. Price is delayed until the delivery of the product. This delay allows the buyer to inspect the product and pay according to the quality after arrival. That reduces some risk involved with transporting.

Another marketing alternative would be to participate in a grain pooling agreement with other producers. This involves joining other soybean producers in an agreement to combine their harvest. This increases the volume of grain to such a size that would lend itself to bargain directly with a soybean exporter for the highest price per bushel.

Another option would be to use a combination of the above methods. A producer might sell some grain at harvest, store some and sell on the cash market during the winter, and also have some grain sold through a futures marketing option. This method of marketing would spread the risk associated with a marketing option over several marketing alternatives.

The federal government also offers price support programs that offer producers a loan in return for pledging some of their grain crop as loan collateral. Rather than repaying the loan,

producers can choose to default on the loan, keeping the loan money and forfeiting ownership of the grain to the government. If market prices were below the loan rate, producers will benefit from defaulting on the loan.

Determining When to Sell or Store Soybeans

The marketing of soybeans is a complicated issue. When to sell or store the grain is a decision a producer must make after becoming more informed of the soybean pricing structure. The primary pricing structure includes two segments: (1) the supply, demand, and governmental programs that affect and shape the pricing behavior of the market and (2) the market forces themselves that change and direct pricing behavior. The former is known as "price determination" and the latter as "price discovery."

There are many factors that interact over time to alter the supply and demand of soybeans, causing variations in price relationships between markets. A major decline of 2 to 3 million metric tons in Brazil's soybean crop can often result in a significant increase in U.S. export markets for soybeans and soybean products. This will ultimately increase soybean prices. Price is the hub of the system for the produce, regardless of whether soybeans are sold in the domestic or foreign markets.

Proper use and analysis of market information and a knowledge of the marketing options by the producer are the keys to increased profits. A successful producer will also become aware of the marketing information services offered through the media and with tools such as marketing newsletters. The decision concerning when to store or sell can only be made by the producer after becoming experienced with these factors.

Grain Quality

Soybeans are marketed on the basis of federally established classes and grades. Two classes of soybeans include Yellow soybeans and Mixed soybeans. There are five grades of soybeans: 1, 2, 3, 4, and "Sample grade." Price discounts or deductions from gross weight are imposed on soybeans that violate grading factors.

Yellow soybeans have yellow or green seed coats with cross sections of yellow or yellow tinge. Not more than 10.0% of other colors may be included with class Yellow soybeans. Mixed soybeans are those soybeans that do not meet the requirements of the class Yellow soybean.

The grade of a soybean is determined by several standards: the amount of damaged kernels due to heat or other means, amount of foreign material, amount of splits, and amount of soybeans of other colors. Table 7.1 shows the current standards for soybeans as set forth by the U.S. Department of Agriculture.

Table 7.1 - Soybean Grading Factors

	Grades U.S. Nos.			
Grading Factors	1	2	3	4
	Minimum pound limits			
TEST WEIGHT (lb./bu.)	56.0	54.0	52.0	49.0
	Maximum percent limits			
DAMAGED KERNELS				
Heat (part of total)	0.2	0.5	1.0	3.0
Total	2.0	3.0	5.0	8.0
FOREIGN MATERIAL	1.0	2.0	3.0	5.0
SPLITS	10.0	20.0	30.0	40.0
SOYBEANS OF OTHER COLORS*	1.0	2.0	5.0	10.0
	Maximum count limits			
OTHER MATERIALS				
Animal filth	9	9	9	9
Castor beans	1	1	1	1
Crotalaria seeds	2	2	2	2
Glass	0	0	0	0
Stones**	3	3	3	3
Unknown foreign substance	3	3	3	3
Total***	10	10	10	10

* Disregard for Mixed soybeans.
** In addition to the maximum count limit, stones must exceed 0.1% of the sample weight.
*** Includes any combination of animal filth, castor beans, crotalaria seeds, glass, stones, and unknown foreign substances. The weight of stones is not applicable for total other material.

U.S. Sample grade are soybeans that (a) do not meet the requirements for U.S. Nos. 1, 2, 3, or 4;

or (b) have a musty, sour, or commercially objectionable foreign odor (except garlic odor); or (c) are heating or otherwise of distinctly low quality.

Checkoff Dollars

Every producer who sells soybean crops participates in the national checkoff program. The checkoff dollars occur when the crop is first sold and is charged at a rate of 0.5% of the market price per bushel. Half of all checkoff funds remain in the state where the fund is collected and used as directed by producer-controlled boards. The other half of the checkoff funds are forwarded to the United Soybean Board (USB). The USB uses the funds on a national level to fund marketing and research projects designed to improve the demand for U.S. soybeans, both at home and overseas.

There are four main program areas where the national checkoff funds are used. International marketing works with other countries to increase soy exports. Domestic marketing focuses on increasing the demand for soy from food industry and industrial use. Production conducts research to look at ways to reduce production costs by the soybean producer. The New Uses area researches and develops new ways to use soy such as in wood adhesives, paints and coatings, lubricants, and solvents.

Summary

Common methods of marketing soybeans include selling for cash at harvest, storing at harvest and selling for cash later, use forward pricing in the futures market, delayed pricing, grain pooling agreements, or a combination of these methods. A producer must become informed about the soybean pricing structure to decide when to sell or store grain. Grain quality is based on classes and grades established by federal standards. Price discounts and deductions from gross weight are imposed on soybeans that violate grading factors. Checkoff funds are used to market and research soybeans to increase the demand both domestically and in foreign markets.

Credits

Missouri Soybean Handbook, Manual 123. University Extension. Columbia, MO: University of Missouri-Columbia, 1982.

Stasko, Gary F., *Marketing Grain and Livestock.* Ames, IA: Iowa State University Press, 1997.

United States Standards for Soybeans - Subpart J. U.S. Department of Agriculture. <http://www.usda.gov:80/gipsa/stru/reg/standard/soybean.htm> 28 Oct. 1999.

Lesson 8: Figuring Crop Costs

Raising a high-quality, high-yielding crop is the goal of every producer. Making a profit on that crop regardless of the quality is even more important to producers. Keeping good records is the best way for producers to plan and measure profitability. This lesson will address the costs associated with soybean production and how these costs are used to measure profitability. The total profit can only be figured after considering the variable costs, the fixed costs, and the labor costs of producing the crop.

Variable Costs

Variable costs are also spoken of as "operating costs." Variable costs per acre are those costs that vary with the level of production each year. These costs include seed, fertilizer, chemicals, machinery repairs, fuel, interest, and miscellaneous out-of-pocket costs. If the producer has a goal of increasing the production of soybeans from 40 bushels per acre to 60 bushels, the variable costs will also have to increase. More seed, fertilizer, and chemicals will need to be purchased. These costs represent about 38 to 40% of the total costs to produce an acre of soybeans. According to the Missouri Management Information Record (MIR) program, the average variable costs for an acre of soybeans in 1985 was $76.50. In 1997, the MIR program showed an average of $131.31 to produce an acre of soybeans. Variable costs have obviously increased over the years. The cost of seed, fertilizer, chemicals, along with machinery repairs have greatly increased.

Fixed Costs

Fixed costs are also known as "ownership" costs. Fixed costs are those costs that do not vary with the level of production each year. This includes depreciation and interest on machinery, interest, and taxes on land and other real estate, and possible labor costs. If a soybean producer decided to increase efforts to produce a higher yield, these costs would remain the same. These costs (including labor) represent about 62% of the total costs of producing an acre of soybeans. In 1985, the average fixed costs were $124.00 per acre. In 1997 these costs were $110.94 per acre. Producers have obviously reduced fixed costs in the last 12 years. Spreading the fixed costs per acre over more bushels by attaining higher yields offers the greatest opportunity for reducing per bushel costs and enhancing profits.

Table 8.1 shows average Missouri crop costs based on 1997 MIR summarized by University of Missouri Extension.

Table 8.1 - Missouri Average Crop Costs

Average Variable/Operating Costs /Acre	
Seed	$16.81
Fertilizer and Lime	7.00
Chemicals and Materials	33.00
Machinery Fuel, Oil, and Repair	23.00
Machinery Hire and Services	5.50
Average Labor Cost/Acre	22.00
Taxes and Insurance	3.00
Miscellaneous	9.00
Operating Interest	12.00
Total Operating Cost/Acre	$131.31
Average Fixed/Ownership Costs /Acre	
Machinery Depreciation and Interest	$28.44
Land Costs, Taxes, and Interest	82.50
Total Fixed/Ownership Costs/Acre	$110.94

Calculation of Cost Per Acre

Profitability of a crop is determined by looking at the cost of growing that crop less the returns received from sales. To calculate costs, first determine the total variable costs and the total fixed cost. Together these make up the total cost of production. Subtract total cost of production from total returns to calculate the return above variable cost.

Total (operating) variable cost
\+ Total (ownership) fixed cost
Total cost of production

Total returns
\- Total fixed cost
Return above variable cost (return on investment)

Acceptable Return on Investment

Unfortunately, crop producers are faced with decisions concerning levels of profitability each year of production. What is an acceptable return on their investment to produce a crop of soybeans? What factors must be considered to determine if their returns are worth their investment of labor and capital?

Producers must consider if the return is adequate for their labor. They must be able to make a living for themselves and their families. Returns to labor will determine their lifestyle and the quality of how their families will be able to live. The return to labor will be the result of subtracting the total costs of production (fixed and variable) from the total returns.

Producers must consider if the returns will allow expansion of the operation. Will it be enough to purchase larger and newer equipment to produce the soybean crop? Does the producer want to add or expand storage facilities?

There are several variables that must be considered to determine if the crop producers' profits are at an acceptable level. The final decision may involve consulting someone who knows the producers' finances, such as the banker or agricultural loan agent, but the ultimate decision should be made by the producers.

Summary

Variable costs are costs that change with the level of production each year. These costs include seed, fertilizer, fuel, and operating interest. Fixed costs do not vary with the level of production. Examples include depreciation on machinery, taxes, and interest on the land and equipment. Producers use the calculations of these costs to measure profitability and to plan and budget for the next year.

Credits

Massey, R.E. *1997 Missouri Crop Costs and 1999 Crop Cost of Production Estimates.* University Extension. Columbia, MO: University of Missouri-Columbia, 1999. <http://agebb.missouri.edu/mgt/fmcrop.htm> 13 Mar. 2000.

Missouri Soybean Handbook. Manual 123, 2nd ed. Columbia, MO: University of Missouri-Columbia, 1982.

Lesson 1: Planning the Crop

Cultivation of wheat and other small grains started some 9000 years ago in western Asia. Wheat and barley served as a primary food source for early civilization in the Middle East. The first wheat plants were derived from a wild variety that had grains that did not thresh out easily. Most of the wheat cultivated today is freely threshed and used in the production of bread. Oats were probably first noticed as weeds in wheat and barley crops and later cultivated as a food and feed crop.

Wheat is the world's leading cereal grain and most important food crop because of its unique bread making ability and diversity of uses in other products. This factor, along with its nutritional value and storage qualities, has made wheat a staple food for more than one-third of the world's population.

Although wheat and the other small grains of oats and barley are not produced as much as soybeans or corn in Missouri, they are considered important crops. In 1999, Missouri ranked 11th among all states in the production of wheat, producing about 57 million bushels per year. Figure 1.1 from the *1999 Missouri Farm Facts* shows the wheat production areas in Missouri by county.

The value of wheat and small grains is seen largely as livestock feed (grain or pasture forage). Wheat and small grains are also an important rotational crop for pest and nutrient management, and they can grow in the same growing season (double cropped) with other crops.

Environmental Conditions

All crops need certain environmental conditions to grow successfully and this is no different for wheat and small grains. Figure 1.2 from the USDA Economic Research Service shows regions of the

Figure 1.1 - Wheat Production in Missouri

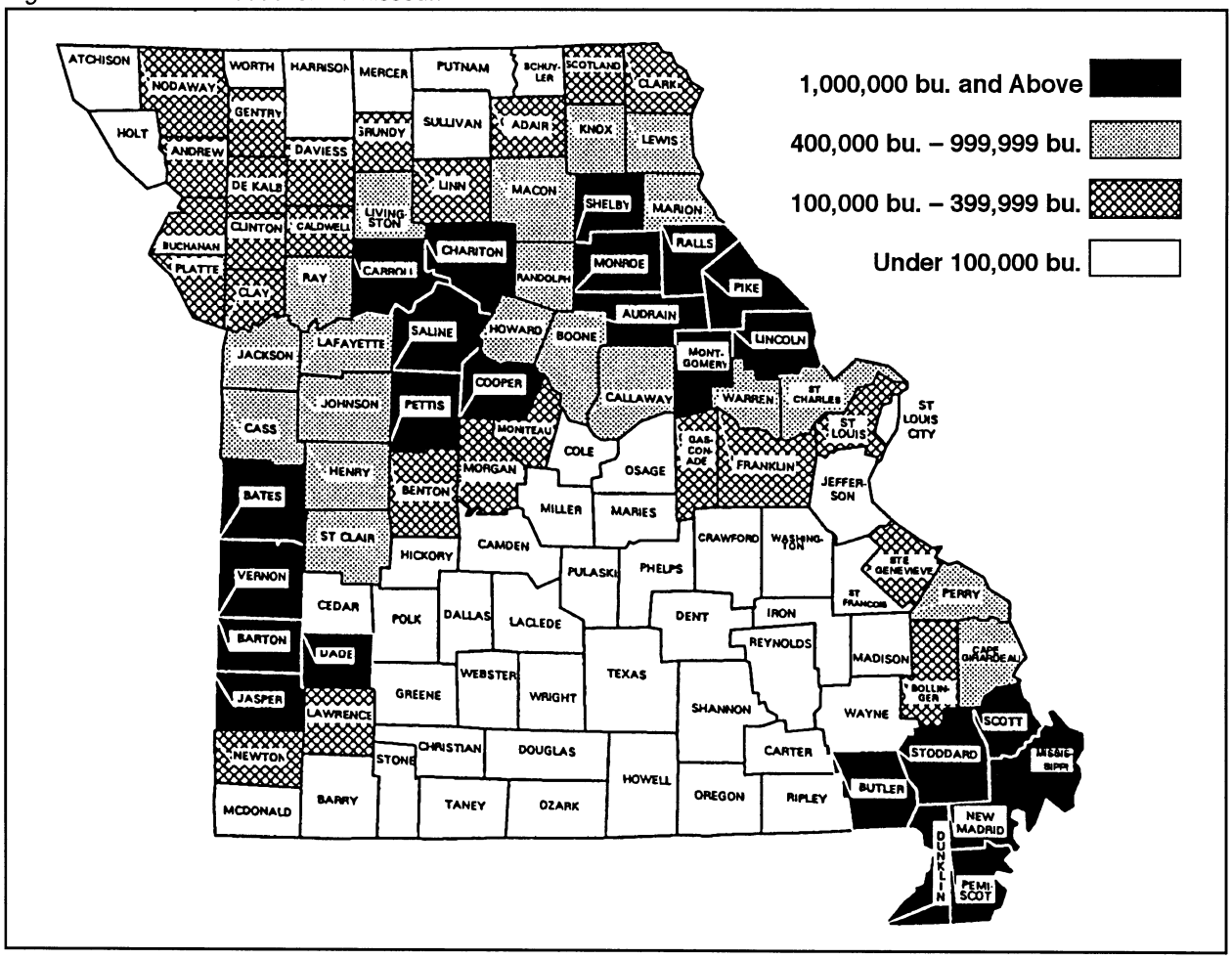
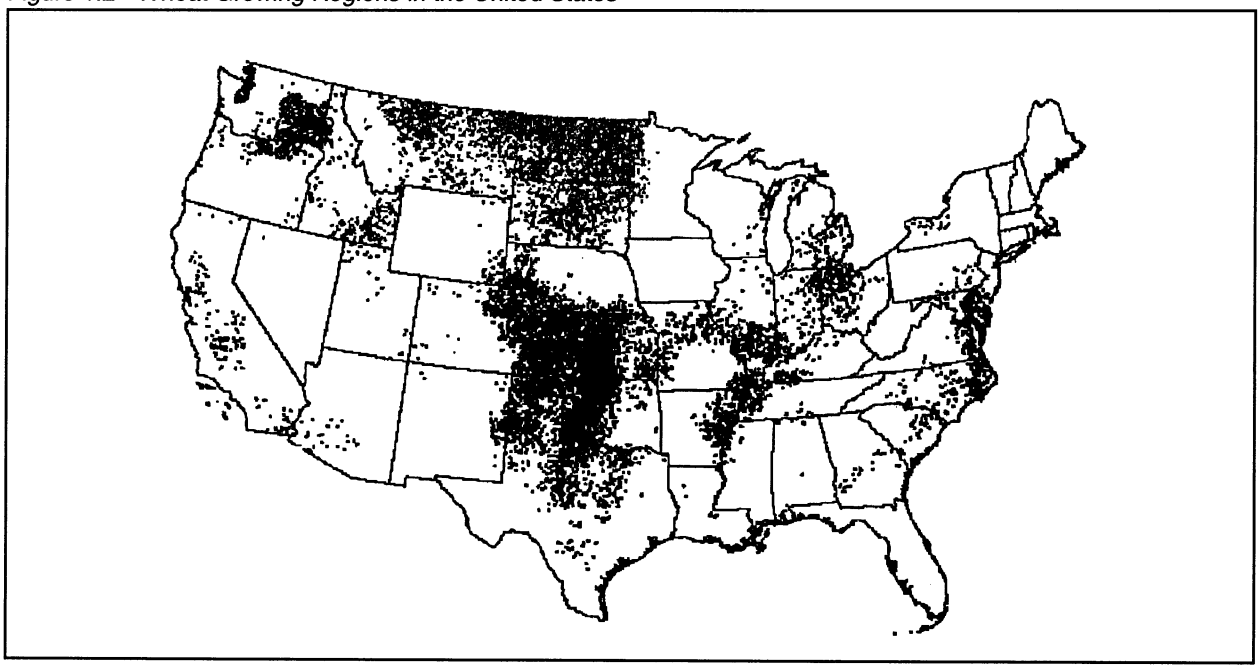


Figure 1.2 - Wheat Growing Regions in the United States



United States where wheat is planted. The following section lists the requirements of wheat and the small grains of barley and oats for growing season, rainfall, and soil type.

Growing season - Wheat and small grains are cool-season crops that grow best under moderate temperatures but can resist both cold and hot weather. This hardiness is essential for these crops to endure the freezing temperatures of winter, the late frosts of spring, the high temperatures of June, and the droughts that can occur anytime. Because of their winter growth habit, wheat and small grains are planted during the fall, become well established before winter, and "green-up" starting their growth quickly when conditions are favorable in spring. These crops not only resist freezing temperatures during winter but need the cold to joint and flower so they can set grain in the spring after the dangers of late frosts are usually past. Extended root systems of these winter crops enable individual plants to obtain moisture from deep in the soil during times of drought making them highly adaptable to Missouri conditions.

Some crops such as wheat have a unique character whereby the germinating embryo, or seedling plant, must undergo a hormonal-controlled conversion from its juvenile stage, or vegetative growth stage, to its reproductive stage. This process is called vernalization and ensures that the growing point remains underground until the arrival of warmer temperatures and is protected from freezing and death. Winter wheat has a prostrate growth habit whereby only leaves are produced aboveground during the fall, whereas the growing points and buds remain underground. This generalized growth habit is typical of grasses.

Winter wheat grows at temperatures as low as 37°F. Optimum growth is between 70 and 77°F with a maximum of about 90°F. Winter wheat crops can be planted from early September to mid-November. Planting wheat in late September or early October in northern Missouri is preferable and by mid-October in southern Missouri. Due to its susceptibility to the Hessian fly, planting should be delayed until after the "fly-free" date. The fly-free date ranges from September 28 at the Iowa line to October 17 at the Arkansas line. The best wheat yields often result from planting just after the fly-free date. Spring wheat is rarely used in Missouri due to the hardiness of winter varieties and the need for other row crops to be planted in the spring.

Oats have a very short growing season compared with other grains. They are very well adapted to grow in cooler temperature climates and therefore do much better than average in northern Missouri. Most oats in Missouri are planted in the spring as early in the year as soil conditions permit.

Barley has similar temperature requirements as wheat for growth; however, it is less winter-hardy than wheat and should be planted earlier. Producers in Missouri should not plant barley north of U.S. Highway 36 because winter injury could be severe in most years. Central and southern Missouri producers should plant early if they are using barley for pasture. If it is to be harvested for feed, producers should plant at later dates to help avoid barley yellow dwarf virus (BYDV) injury. Spring barley is rarely used in Missouri due to the hardiness of winter varieties and the need for other row crops to be planted in the spring.

Spring varieties of these grains are most often used to augment or increase the forage and nutrient value of existing pastures. They may also be used as a cover crop to prevent soil erosion on crop ground to be planted later.

Rainfall - Wheat and small grains combine drought escape and drought resistance to overcome moisture stress. Most of their growth occurs during fall and early spring, which are periods of highest rainfall. Winter varieties are harvested before the dry summer months and in that way escape drought. Nevertheless, times of low moisture and high temperature can limit production of wheat and small grains.

In some areas where available moisture is a concern, planting too early can cause excessive fall growth and soil moisture depletion for early spring growth, but this is not a problem for much of the state. Planting later than optimum often causes limited fall growth of both root and tiller formation, subjecting the crops to wind damage and the possibility of winter-kill damage (when plants are injured due to extreme weather conditions). However, producers may need to plant later when late rains allow grassy weeds to germinate. These weeds will be destroyed by tillage. Also, in areas where wheat and small grains are double cropped after row crops, they will be planted later than optimum.

Soil type and typography - Wheat and other small grains grow well on a wide range of soils but do not grow well on poorly drained soil, especially during wet periods. The major cause of loss is standing water and the formation of ice sheets where water accumulates. Adequate surface and subsurface drainage is absolutely necessary and more important for wheat than for other crops. Soil depressions caused by combines, grain carts, and tractors are major problems in some years. Wheat should not be planted in fields that were wet at the time a double crop of soybeans was harvested or where soil compaction is present. (More information on tillage and planting options will be presented in Lesson 3 of this unit.)

The best soils for wheat and small grains are well-drained loams and clay loams. Because these crops cannot stand "wet feet," producers should avoid flat sites with poor internal drainage, such as the claypan soils found in northeast Missouri.

Evaluating Field History

Two important factors to consider when evaluating the field where wheat and small grains are to be grown are knowing (1) the most recent crop and (2) what type of tillage and/or planting method was previously used.

Knowing what crop was most recently produced on the site allows producers to determine what type of fertilizer may be needed for the new crop. It will also provide insight as to nutrients that may be more available, such as additional nitrogen, following a soybean crop.

Knowing the history of tillage and/or planting methods used on the site can help producers in projecting what pest problems may need to be addressed. This will include the herbicide and pesticide use as well. Tillage and planting history can also determine what methods will be used for the new crop. For example, if erosion is a problem at the site, no-till methods can be used. Whatever the site's history, producers who have a good knowledge of previous crops and management operations will be better able to plan for successful current and future crop production.

Fertilizer Requirements

Adequate nutrients at each stage of development are essential for maximum economic yields of wheat and small grains. Nitrogen, phosphorus, and potassium are the primary nutrient needs for these crops. Most Missouri soils supply adequate amounts of the secondary macronutrients and micronutrients. Nutrient needs can be determined by several methods, including soil tests, field trials, nutrient removal and plant analysis, past experience, or a combination of these. However, the most reliable means of determining lime and nutrient needs is by soil testing regularly with support from the other methods listed. Producers

must keep in mind that a soil test is only as good as the sample collected in the field.

Lime - Liming should not be overlooked because wheat and small grains will respond to lime. Lime needs can be accurately determined by soil tests. The greatest need for lime is in the areas of high soil acidity (where pH levels are very low). Oats tolerate lower pH levels than either wheat or barley.

Nitrogen - Nitrogen is the element most frequently lacking for optimum wheat production. Needs will vary depending on the level of available soil nitrogen from existing organic matter, soil texture, and carryover from previous crops. Other factors that determine nitrogen needs are cropping system used and expected yield.

Soil tests measure the quantity of available nitrogen at the time samples are collected. Samples need to be taken after July 1 for applications before fall planting and again after November 1 for topdress applications to be done in the spring. In general, each 1% of organic matter supplies 8 to 12 pounds of nitrogen per acre through organic matter oxidation. Nitrogen available from a previous soybean crop ranges from 20 to 40 pounds per acre. Therefore, starter nitrogen is not usually necessary when wheat and small grains follow soybeans.

Producers should pay special attention to nitrogen fertilization. Too much nitrogen increases the possibility of lodging. If starter nitrogen is used, it should be limited because higher rates may cause excessive vegetative growth and delay the winter dormancy stage. Unless the crop is grazed, this can cause winter injury and reduce winter survival. In addition, small grains produced for hay and grown on droughty soils where nitrogen can accumulate may produce forage that is toxic to livestock.

Spring topdressing is the recommended time of nitrogen application for fall-seeded small grains. Applying anhydrous ammonia with tillage implements is an excellent method of cutting costs of preplant application by combining tillage and fertilizer operations.

Phosphorus - Wheat and small grains are known to respond well to application of phosphorus on soils testing low or very low in available phosphorus. These crops do not tiller well under severe phosphorus deficiency and are often more subject to winter kill. Adequate phosphorus is important in developing good, early root growth. Oats tolerate lower phosphorus levels than either wheat or barley. Unless a well-established root system has been developed, winter oats are extremely sensitive to frost heavage when plant roots are lifted up and out of the soil and exposed to weather and insect injury.

Phosphorus for wheat and small grains should be applied by broadcasting and then incorporation, injected in concentrated bands preplant, or banded at planting. Band applications of this plant nutrient with the seed at planting or injected preplant are recognized as generally more efficient than broadcast treatments, particularly when low rates are applied on acid soils that are low in available phosphorus. When phosphorus is incorporated into the soil, plants can continue to use it even when the surface is dry. Combining nitrogen and phosphorus applications at planting can save time and money.

Potassium - Wheat and small grain response to potassium application is less than that of phosphorus. Sandy soils are often found low in potassium and in need of fertilization. Potassium may either be applied as a planting time starter or broadcast and incorporated ahead of planting. Both methods should provide equal results. Applications of potassium in direct contact with the seed should be limited to avoid possible germination damage.

Research has shown all nitrogen, phosphorus, and potassium carriers to be essentially equal in supplying these nutrients to wheat and small grains when properly applied. Therefore, selection of these nutrient sources should be based on cost, availability, and adaptability to the overall farm operation.

Summary

Wheat is the world's leading cereal grain and most important food crop. It is also a staple food for more than one-third of the world's population. Although wheat and other small grains such as barley and oats are not produced as much as soybeans or corn in Missouri, they are still considered important crops valued mostly as livestock feed, rotational crops for pest and nutrient management, and in their ability to be double cropped.

Wheat and small grains are cool-season crops that grow best under moderate temperatures but can resist both cold and hot weather. These crops are planted during fall, become well established before winter, and "green up" in the spring. They resist freezing temperatures during the winter and can obtain moisture from deep in the soil during times of drought. Winter varieties can be planted September through November. Spring wheat, oats, and barley are rarely used in Missouri due to the need for other row crops to be planted in the spring. These crops are most often used to augment existing pastures or used as a cover crop.

These crops can tolerate a wide range of topography but perform best as grain crops on flat or gently rolling fields. The best soils for wheat and small grains are well-drained loams or clay loams and they do not grow well on poorly drained soils.

When evaluating field history, producers should know what crop was most recently produced on the site to determine fertilizer needs. Producers should also know what tillage and/or planting method was previously used to project pest problems and to determine current tillage and/or planting methods to employ.

Adequate nutrients are essential for maximum economic yields of wheat and small grains. Nitrogen, phosphorus, and potassium are the primary nutrients needs of these crops.

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Lesson 2: Selecting a Variety

Before planting, the producer must decide what type or class of wheat or other small grains will be selected. Before this selection is made, research information must be gathered on the types and varieties available. Consideration must be given to adaptations needed for the producer's area.

Classes of Wheat

There is great diversity with the wheat plant (genus *Triticum*). To classify this diversity, wheat differences are examined by growth habit, kernel color, and kernel hardness.

Growth habit refers to when the seed is planted and the stages of plant growth. Some wheat is planted in the fall with only the leaves aboveground and their growing point and buds remaining underground until spring. About 70 to 80% of U.S. wheat production is winter wheat. Other wheats are spring planted.

Kernel color is either red or white. Red predominates and the vast majority of crop improvement research in the United States is devoted to red-kernel wheat. The only advantage of white kernel color is the improvement of flour yield by allowing millers to be less stringent in removing seedcoat fragments from flour.

Kernel hardness of wheats in the United States is classified as "hard" or "soft" depending on endosperm granularity. Hard wheat has a protein-like material on the surface of the starch granules that causes the granules to adhere to the cell walls. Soft wheat does not have this strong starch granule-protein matrix. Therefore, soft wheat will yield large quantities of fine granulated flour when ground, whereas hard wheat yields a more coarse product. Soft wheats' fine granules are actually harder to control and will clog sifters in industrial bread-making equipment. Most bread is made from hard wheat because of the cohesive and elastic properties, which yield a bread with good volume and texture. Soft wheat flour is used mostly for cakes, cookies, and doughnuts.

Based on these differences, wheat grown in the United States is divided into five major classifications.

Hard red winter - This class is grown mostly in Nebraska, Kansas, Oklahoma, Texas, and parts of Missouri. In addition to bread making, another major use of this wheat is in livestock feeds.

Hard red spring - This class is grown primarily in the north central states, such as North Dakota and Minnesota, where the winters are too severe for winter wheat production.

Soft red winter - The main growing area for this class extends from Texas through parts of Missouri, northward to the Great Lakes and east to the Atlantic Coast but is mostly concentrated in Illinois, Indiana, and Ohio.

White - This class, which can be both a winter and spring variety, is produced in the Pacific Northwest and to a lesser extent in southern Michigan and western New York. White wheat is also a soft wheat used mostly for cereals.

Durum - Production is centered in North Dakota, with lesser amounts in Minnesota, Montana, South Dakota, and Arizona. Durum wheat contains more protein than any other classes of wheat and produces a dough that when mixed with water can be pressed through dies, making it desirable for products like spaghetti, noodles, and macaroni.

Wheat Varieties

Seed companies have many wheat varieties for producers to select from. Descriptions of these varieties can be obtained from the dealer or by using their Internet web site for information. The University of Missouri tests a number of varieties each year and publishes their results. These results may be obtained from University Extension centers around the state, or as with seed companies, from the Internet at the Agricultural Electronic Bulletin Board (AgEBB).

Since winter wheat is the predominant type of wheat raised in Missouri, performance tests were conducted on both hard red and soft red winter wheat. Results of the tests vary each year depending on the amounts of fall moisture for germination and early growth; mildness or severity of the winter weather, which determines winter survival; and spring moisture and temperatures, which affect tillering and stand development.

Environmental conditions and their effect on wheat yields during the test periods and at state testing

locations are also reported. Periods of excessive rainfall during grainfill may cause certain diseases and lodging. Delayed harvests, which may result in shattering and yield loss, are also reported. The University of Missouri test results reported under these conditions will list the varieties tested and their yields in all of the areas of testing across the state.

Figure 2.1 gives an example of how a wheat variety may be listed by a commercial seed company. The variety name or number is listed with its characteristics and a rating is given of how that variety performs in specific areas on a 1-10 scale with 10 being best. A short narrative describing the variety is also provided.

Producers should obtain information from seed companies as shown in the example and investigate University performance tests before making a wheat seed selection.

Class of Other Small Grains

Barley is one of the four major feed grains grown in the United States. It is a hearty plant, able to withstand many different growing conditions. However, barley is least tolerant of hot, humid conditions, which makes it unsuitable for the subtropical regions of the southeastern United States.

Figure 2.1 - Example of Information Provided by Commercial Seed Company

Characteristics	Rating	Description of Variety
		Variety X
Yield	9	Strong candidate for double cropping. Impressive yields and test weight. Superior standability. Strong drought tolerance. Best grown in areas not prone to winterkill.
Lodging resistance	7	
Test weight	8	
Drought tolerance	7	
Winter hardiness	4	
		Variety Y
Yield	9	Above average test weight and excellent yield. Superior winter hardiness and good standability. Excellent resistance to powdery mildew and stem rust.
Lodging resistance	6	
Test weight	6	
Drought tolerance	5	
Winter hardiness	7	
		Variety Z
Yield	9	Soft red wheat with superb yields and dependable winter hardiness. Adapted to a wide range of environments. Good test weight, and strong resistance to powdery mildew and stem rust. Superior resistance to soilborne viruses and moderate resistance to leaf rust.
Lodging Resistance	5	
Test weight	6	
Drought tolerance	4	
Winter hardiness	7	
		Variety X1
Yield	9	Broadly adapted variety that provides good overall disease resistance. Sound winter hardiness and top yields. Good standability. Resistant to soilborne viruses, scab and leaf rust.
Lodging resistance	6	
Test weight	4	
Drought tolerance	6	
Winter hardiness	7	

There are many different varieties of barley grown in the United States. But there are two basic types that are classified based on the number of rows of grain seen when the heads of the stalks are viewed from above. The two types are the two-row and the six-row. Most barley raised in Missouri is the six-row type because two-row barleys have not achieved the yield potential of six-row barleys. The two-row barley produces 15-30 kernels on each head of grain, and the six-row barley produces 25-60 kernels on each head of grain.

Oats are grown primarily in the north central states because the oat plant requires plenty of moisture and relatively cool weather. As with wheat and barley, oats may be planted in the fall or spring. In Missouri, most oats are planted in the spring.

Four varieties of oats are grown in the United States. White oats, which account for most U.S. production, are grown north of the Ohio River and east of the Rocky Mountains. This is the variety most likely to be planted in Missouri. Red oats are grown south of the Ohio River in Texas, Oklahoma, and Kansas. Gray oats are produced in the Pacific Northwest, and black oats are gown in small amounts in various parts of the country.

Selecting a Seed Variety

Although yield is often the key factor in variety selection, other characteristics can be important. Today's wheat and small grain varieties are quite similar in yield performance. Rarely do we find one variety that consistently out yields all others. What this means to producers is that factors other than yield should receive greater attention as varieties are selected for production.

Disease and stress resistance - Diseases can be a major problem across the state; however, the disease type and the disease pressure vary by location around the state of Missouri and from year to year. Select a variety with resistance and tolerance to the diseases and stresses commonly found in the producer's region of the state.

Height and lodging - Varieties differ in height and lodging resistance. Though generally correlated, taller varieties are not necessarily more prone to lodging. Lodging reduces both grain yield and grain quality. As soil fertility levels increase, stiffer-strawed varieties should be used. Careful attention must be given to both timing and rate of fertilizer applications and irrigation when used.

Maturity - As a group, barleys mature earlier than other grains, oats later. Wheat has early-, mid-, and late-season varieties. Differences among varieties with each grain type can be significant. Early-maturing varieties can avoid yield and quality reductions caused by heat or drought in mid-to-late summer. They can also be used for double cropping. Later-maturing varieties yield more when moderate temperatures and favorable moisture conditions persist into midsummer. Choose a variety that matches the environment and cropping needs of the region.

Winter hardiness - As a group, winter barleys are less winter tolerant than wheats; however, some winter barley varieties have better hardiness than most wheats. Winter hardiness is a complex characteristic determined not only by a variety's tolerance of cold, but also by its resistance to other stresses encountered during winter months. If winterkill is a problem in the region, select varieties with a higher winter-hardiness rating or consider using a mixed variety planting. Oats are the least hardy of the winter cereals.

Yield potential - Yield potentials vary from one area to another and from year to year. Yield potential is a genetic trait but is moderated by other factors such as disease and stress tolerance. To evaluate the yield potential of a variety, review data from test sites with an environment similar to that in the producer's area. Compare performance over several years if possible because a single year's data can be misleading.

Intended use - Barley varieties are classified as either feed or malting types. Feed types are generally classified as such because they did not meet malting barley quality requirements, not because they were bred specifically for feed use. When raising barley for feed, select varieties with consistently high test weight.

Grain quality - Test weight (bushel weight) is a price-determining factor in the marketplace. Choose varieties with good test weight records. Quality is a function of the bran-to-endosperm ratio. The endosperm (82-84% of the kernel) is the source of starch and protein. The bran is the covering or coating of the kernel. Higher test weights equal higher quality and command a higher market price.

Prevalent Diseases in the Area

Wheat diseases are major hazards in wheat production, causing losses through reduced yield and quality of grain. Wheat diseases are caused by parasitic bacteria, fungi, and viruses. Wheat is subject to attacks from about 50 different pathogens, but not all of the diseases will occur in a particular area or in a certain year.

Estimated annual losses vary from 10 to 25%, depending on many factors such as weather conditions, soil moisture, soil fertility, crop rotation, prevailing winds, and susceptibility of particular varieties to various diseases. Some disease losses cannot be prevented because no successful means have been devised for controlling some of the most destructive diseases. However, a considerable part of these losses can be prevented by using proven methods for disease prevention and control.

Recognition of the most common and destructive diseases is important to apply control measures whenever possible. Wheat diseases may be grouped in the following categories: (1) seedling blights, root rots, and crown rots, (2) leaf diseases, (3) diseases of heads, and (4) viral diseases.

Seedling blights and root rots are usually present every year in most wheat fields. Importance varies greatly with season, locality, and cropping practices. Wheat plants are subject to attacks from seed to maturity. Root decay, stunting, and premature death of older plants are characteristic of root rot infections. Root rots are caused by many species of fungi and are more severe in moist soils. Root rots cannot be completely prevented but they can be reduced. General control measures to reduce problems from seedling blights and root rots include buying sound seed of recommended varieties, cleaning and discarding shriveled seed, treating seed with a recommended fungicide to eliminate pathogens, sowing deep enough for adequate moisture for germination, planting in well-prepared seedbeds, and rotating crops.

Seedling Blights and Root Rots	
Helminthosporium crown and root rot	Circular patches of dwarfed, reddish-brown plants scattered throughout a field Dark brown lesions on the surface of the coleoptile of plant that progresses inward and may spread into the roots Infection of crowns, roots, and basal portions of the stem Distinct rotting of affected parts, typically a dry rot Widely distributed on wheat seedlings, causing failure to emerge
Fusarium root rot	
Gibberella root rot	
Pythium root rot	
Rhizoctonia root rot	
Wheat take-all	

Leaf Diseases	
Leaf rust	Found mainly on leaves but may occur on stems, especially between head and flag leaf First appears on older leaves and spreads up the plant to the flag leaf as the season advances Small, round or oblong, raised orange-red pustules on the surface of the leaf Most abundant on the upper leaf surface
Stripe rust	Pustules are light yellow and arranged in distinct straight-sided stripes about 1/16 inch wide and of irregular length Heavily invaded leaves may die Not common in Missouri wheat but it has been identified in some variety trials in the 1980s Like leaf rust, develops from spores blown in from southern wheat growing regions

Leaf Diseases	
Powdery mildew	Affected plants usually in parts of the field where growth is dense and the air moist, conditions ideal for infection Small, irregular or circular light gray spots on the upper surface of the leaves Spots enlarge as fungus grows and take on a floury appearance due to the production of an enormous number of spores Lower surface of the leaves beneath diseased spots turns yellow and older parts of the spots turn brownish Can develop on heads and stems under favorable conditions
Septoria leaf blotch	Appears first as light green to yellow spots between the veins of the leaves Lesions spread rapidly to form light brown irregular blotches with a speckled appearance Small submerged brown pycnidia in the blotches are the final diagnostic symptom Moves from lower leaves upward toward flag leaf Attacks leaf sheaths, stems, and flumes occasionally
Downy mildew (crazy top)	Infected plants are erect, yellowish green, somewhat dwarfed, and they tiller excessively - many tillers only a few inches tall Thickened leaves may be twisted, curled and stiff, and stand erect Stems may be thick and deformed, especially at the base of the head Heads may be distorted and open; chaff fleshy and green
Tan spot (yellow leaf spot)	Appears early in the season At first the spots are yellow-brown, bordered by yellow Round spots are oval to elongated, usually less than 1/16 inch long Found on both surfaces of leaves Spots increase in size as season advances Dead brown area of a spot may be 1/4 inch wide and 3/4 inch long and usually tapered
Cephalosporium stripe (fungal stripe, C-stripe)	This is a vascular disease Infected seedlings show yellowing, but most conspicuous symptoms appear after jointing Long, chlorotic stripes form on sides of the leaf midribs and run the entire length of the leaf Stripes extend down into leaf sheaths

Stem Diseases	
Stem rust	Wheat stem rust usually appears in Missouri every year, but severity of attack will vary Red spore stage is encountered during growing season and may occur on any aboveground parts Elongated ragged pustules on stem, leaf sheath, blade, or chaff usually begin to appear in mid-June Pustules rupture tissue, exposing powdery, brick-red mass of summer spores. As wheat nears maturity, black pustules filled with black spores appear
Leaf rust	See discussion under leaf diseases

Head Diseases	
Loose smut	Easily recognized by the characteristic dusty black appearance of diseased heads As a rule, glumes and grain are completely transformed to black powder, which shatters off, leaving a bare spike at harvest
Common bunt (covered smut, stinking smut)	Heads affected by bunt have a blue cast when they emerge from the boot Infected kernels are transformed into smut balls during growth Smut balls consist of masses of foul-smelling, dark brown powder, which are the spores of the fungus
Scab (head blight)	Premature ripening of one or more spikelets of a head any time after flowering When wheat is in the dough stage, light yellow color of diseased spikelets of the head shows in sharp contrast with healthy green of rest of head Light pink or salmon color may appear at bases of infected spikelets Kernels become grayish-white, badly shrunken and wrinkled, with rough, flaky seed coat called "tombstone"
Glume blotch	Causative fungus attacks heads most often Produces brownish blotches near the tip of the chaff Severely infected heads are chocolate brown and produce shriveled kernels May be found on leaves and joints Hard to distinguish from Septoria leaf blotch on leaves
Basal glume rot	Dull, brownish-black discolored area found at the base of each of the glumes covering a kernel Discoloration more pronounced on the inside than on outside of the diseased glume Some kernels are brown or black at germ ends
Black chaff	Attacks wheat (also barley, rye, and some grasses) Known as bacterial blight on barley and rye Occurs chiefly on the chaff of glumes Longitudinal, dark, more or less sunken stripes or spots, more abundant and noticeable as a rule on the upper than the lower halves of the glumes In moist weather, tiny yellow beads of bacteria ooze to the surface of black lesions and dry as minute, yellow scales Symptoms on leaves appear as water-soaked spots and streaks that eventually turn brown
Black point (kernel smudge)	Diseased kernels are discolored and appear weathered Black point describes the darkened and sometimes shriveled embryo end of the seed. Germinability is decreased
Black (sooty) head mold	Superficial head molds develop on the heads, especially if rainfall is high after senescence Infections progress to the seed, causing black point disease
Ergot	Empty florets occur in addition to kernels that are replaced by a plump, hard, purplish body larger than healthy kernels, usually two to five per head More common on barley but can be on wheat, oats, and some grasses

Viral Diseases	
Barley yellow dwarf virus (BYDV)	Most widespread virus disease of wheat in Missouri Stunting and yellowing are most the noticeable symptoms Symptoms are usually observed in late spring at about jointing Leaf yellowing begins at leaf tips and along midribs Flag leaves may have a reddish-purple tip Also causes "red leaf" in oats and "yellow dwarf" in barley
Soilborne wheat mosaic (SBWM)	Occurs on fall-sown wheat (also rye, barley, and some grasses) Detected in spring by presence of light green to yellow patches in the fields, from small areas to areas 50 feet or more in diameter Plants are dwarfed, tiller excessively, and have mottled leaves consisting of light green or pale yellowish stripes or blotches that tend to run parallel with the long axis of the leaves Occurrence of the disease depends on weather of fall and winter, which influences the growth and dormancy of the plants
Wheat yellow mosaic (WYM)	Soilborne virus common to Missouri More commonly seen in southeast Missouri, but can occur in other areas Tends to be more uniformly spread than soilborne mosaic Symptoms appear in early spring as yellow-green mottling dashes and streaks on leaves Streaks running parallel to veins taper to form chlorotic spindles Reddish streaking at the leaf tips often precede necrosis Some stunting and poor tillering.
Wheat streak mosaic virus (WSMV)	Most infections occur in the fall but symptoms are observed after the arrival of warm spring weather Yellowish streaking and mottling of leaves Plants may be stunted Leaf margins often rolled toward midrib As plants approach maturity, mottling disappears, leaves turn brown and die Heads that form may be totally or partially sterile

General control measures for wheat and small grain diseases include:

- Use sound seed of recommended varieties.
- Clean seed and discard shriveled seed.
- Use a recommended EPA-registered fungicide for a seed treatment.
- Use resistant varieties.
- Eradicate disease hosts (other plants).
- Use foliar application of fungicides.
- Practice crop rotation.
- Practice crop sanitation by plowing under crop residues.

Summary

Before producers begin to plant a crop of wheat or other small grains, they must secure and analyze information concerning what types and varieties of small grains are available and recommended for their location. Seed companies and University of Missouri recommendations should be considered when making these decisions. Producers should also be familiar with the many diseases they may encounter and be knowledgeable of prevention or control procedures to eliminate or reduce the risk of damage these diseases may inflict.

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Lesson 3: Selecting a Tillage and Planting Method

To optimize wheat and small grain yields, it is important for producers to have a good understanding of proper seedbed preparation, planting methods, and seeding rates. Producers have several choices when selecting which cultural method they want to use.

Tillage Methods

Seedbed preparation varies across the state depending on residue from the preceding crop, the need for moisture conservation, and the producer's personal preference toward tillage. The amount of tillage for seedbed preparation has been reduced during the past decade. Conventional tillage, which was prevalent in the 1970s and 1980s, is practiced only on a limited basis in the continuous wheat fields of the state.

Minimum tillage, including no-till, has several advantages. These include (1) reduced fuel costs, (2) reduced equipment costs, (3) decreased operator time, (4) less soil compaction, (5) less soil erosion, (6) improved soil moisture retention in many instances, and (7) maintenance of soil organic matter.

Factors to Consider When Choosing a Tillage Method

Producers should strive for a firm seedbed, which promotes good seed-to-soil contact and results in rapid germination and stand establishment at the lowest possible cost. Frequently, producers will till in an attempt to cover all their acres when the soils are too wet for tillage equipment. This contributes to compaction and tillage pans that can cause problems later in the growing season.

In continuous wheat fields, residue management is difficult. Most producers use one or two diskings or a chisel operation to incorporate residues. This is followed by another disking or the use of a field cultivator as planting time approaches. With more residues remaining on the soil surface, foliar diseases are increased. Resistant varieties are important in this cropping system. On the heavier, sloping soils, soil erosion by water is a major concern. Terraces, waterways, and crop residue management are required on many highly erodible acres.

Where crop rotations are used, the row crop residue after harvest is left untouched until late summer when one or two diskings or field cultivation is used before wheat seeding. Many producers have saved time and soil moisture by planting no-till wheat double cropped after harvest. Most drills are able to no-till into soybean residue in a wheat double-cropping system. No-till drills are also effective for planting into corn and sorghum residues. If the row crop is corn, some tillage may be performed to destroy the residue, which lowers the incidence of disease.

Residues reduce evaporation, soil erosion, runoff, and increase water infiltration and snow catch during the winter. After wheat harvest in the summer, a residual herbicide replaces several tillage operations to control summer weed growth. To maximize moisture savings, the wheat residue is left undisturbed until the summer crop (usually soybeans in Missouri) is planted no-till into the stubble. After the summer crop (soybean) harvest, the residue is left untouched until the following fall when wheat can be planted no-till, or if there is ample moisture in the soil profile in the spring producers may opt to plant a summer crop again.

Residue management, through conservation tillage, is an effective tool for reducing soil erosion. The percentage of the soil surface covered with residue is important in determining how much erosion will occur from rainfall runoff. Crop residue shields the soil surface from the rainfall impact, thus reducing the amount of particle detachment. Residue also reduces the amount of crusting, which allows more water to soak into the soil and creates numerous small dams, which reduce runoff velocities and capacity to carry sediment. As mentioned earlier, standing residue increases snow catch in the winter and increases moisture storage for the next crop.

If wheat diseases are a concern, moldboard plowing or deep disking buries residue containing the Hessian fly and other destructive insects. Control of volunteer wheat plants, either by mechanical or chemical means, can reduce the incidence of wheat streak mosaic virus by controlling the wheat leaf curl mite, particularly in the Plains states. Destruction of previous crop residue also helps control diseases such as *Rhizoctonia* root rot in areas of the state that may receive higher than normal amounts of rainfall.

Planting Methods

Most wheat or other small grains are planted with a drilling method. Planting wheat with a drill into a prepared seedbed will result in the optimum placement of seeds and number of seeds per unit area. Producers should strive for uniform stands to decrease lodging potential, to more uniformly extract soil moisture and nutrients from the soil, and to more efficiently intercept incoming light energy, all of which will optimize yield. Planting in rows as narrow as possible for expected moisture conditions helps accomplish these goals and will help control weeds.

Seeds that are broadcast and then disked or harrowed into the soil result in about 20% of the seed being either too deep or too shallow. Those seeds that are too shallow are subject to desiccation (drying up) after germination, and those planted too deep will leaf-out under the soil and die.

Planting equipment should be calibrated to place the appropriate number of seeds per linear foot of row to maximize yield. The number of seeds per pound varies from 12,000 to 20,000 depending on the type of wheat and the environment in which the planting seeds were produced. Planting too few seeds per acre could result in excessive tillering that may delay maturity and/or increase weed competition. Planting too many plants per acre is an unnecessary expense and may result in increased lodging and decreased yields due to lack of nutrient and moisture support.

Seeds should be planted into moisture if possible. Wheat and other small grain cultivars (varieties) that have long coleoptiles can be planted up to 3 inches deep, whereas semi-dwarf varieties should not be seeded more than 2 inches deep. In either case, deep placement of seeds can result in delayed emergence and erratic stands.

Recommended Seeding Rates

Seeding rates for wheat will vary across the state because of environmental conditions. In areas of lower rainfall, recommended seeding rates are lower. Recommended seeding rates for Missouri depend on whether the seed is broadcast and then incorporated or drilled. Recommended broadcasting rates range from 120 to 180 pounds per acre. This equates to 2 to 3 bushel per acre using wheat with a test weight of 60 pounds per bushel. When drilling, producers should use seeds per acre, not bushels per acre as shown in Table 3.1.

Table 3.1 - Wheat Seeding Chart

Plant Seeds Per Acre						
		Drill Row Spacing				
Desired Population Seeds/Acre	Seeds/sq. ft.	6 in.	8 in.	10 in.	12 in.	14 in.
(x 1,000)		Seeds per linear foot of row				
500	11	6	8	10	11	13
750	17	9	12	14	17	20
1,000	23	12	15	20	23	27
1,250	29	14	20	24	29	33
1,500	34	17	23	30	34	40
1,750	40	20	27	33	40	47
2,000	46	23	31	38	46	54

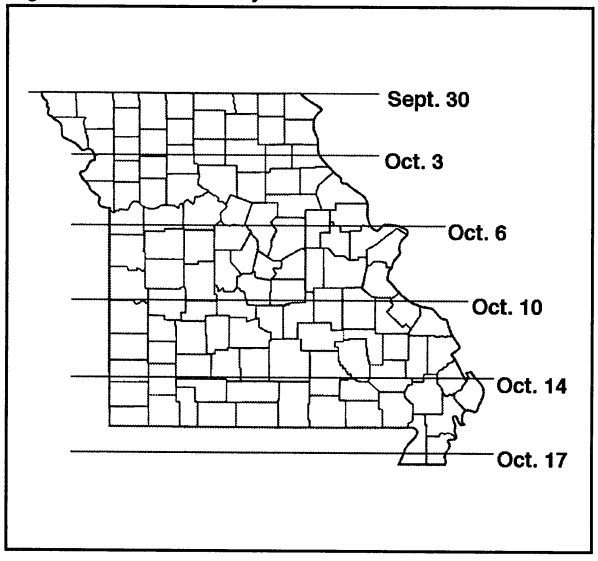
Actual rate = (seed per linear foot of row / % Germination) x 100
Example: (23 / 95) x 100 = 24 seeds per linear foot of row needed to seed 1.5 million seeds per acre drilled with an 8" row spacing
Source: Missouri Seed Improvement Association

The recommended seeding rates for barley are 96 to 120 pounds per acre if broadcast and 72 to 96 pounds when drilled. Barley has an average test weight of 48 pounds per bushel. The recommended seeding rates for oats are 96 to 120 pounds if broadcast and 48 to 96 pounds per acre if drilled. Oats have an average test weight of 32 pounds per bushel.

Using a Planting Calendar

Climatic conditions vary across the state causing the recommended planting dates to vary for different areas. Producers try to plant winter wheat at a time when seedlings have well-established crown roots and three to five tillers before winter dormancy. This enables the plants to reduce winterkill damage. Planting within a week of the Hessian fly-free date for an area will usually allow enough time for adequate fall growth. Figure 3.1 shows those dates for areas of Missouri. Planting too early increases the hazards of insects and diseases, such as the Hessian fly, leaf rust, and wheat streak mosaic virus. Planting later than optimum often causes limited fall growth, both root and tiller formation, and subjects the wheat or barley to increased potential for winterkill damage.

Figure 3.1 - Hessian Fly-free Dates



Winter barley is planted the same time as winter wheat. Barley is also attacked by essentially the same insects and diseases that attack wheat.

Spring oats are the first crop to be planted in the spring in Missouri. Selecting fields with well-drained soil to permit timely planting is essential. Spring oats should be seeded as early in the spring as soil conditions permit, preferably between March 1 and April 15. Grain yields will decrease rapidly because seeding is delayed past mid-April.

Summary

Most producers of wheat and small grains are practicing conservation tillage methods. Using these methods or no-till methods has several advantages. Seldom are fields prepared using the moldboard plow. Although crop residue could harbor some wheat and small grain diseases, there are also several benefits for leaving some residue in the field. These include conservation of soil and soil moisture. Most wheat in Missouri is planted with either a conventional drill or a no-till drill. Larger and more uniform plant populations are established using these methods. Planting dates for fall seeded grains usually follow the recommended Hessian fly-free date, whereas spring grains such as oats are planted as early as soil conditions would allow.

Credits

Agronomy Guide 2000. M.F.A., Inc. Columbia, MO, 2000.

Smith, C. Wayne. *Crop Production, Evolution, History, and Technology.* 1st ed., New York, NY: John Wiley & Sons, Inc., 1995.

Wheat Production Handbook, Kansas State University Cooperative Agricultural Extension Service, May 1997.

Lesson 4: Selecting a Pest Control Program

Lesson 2 discussed diseases that affect wheat and other small grains. This lesson will concentrate on insects in wheat and small grain. Information will be given on specific insects and pests that affect these small grains and how they may be controlled. Producers should become familiar with life cycles, appearance, and damage caused by insects that are recurring pests in their area.

Factors That Determine a Pest Control Program

The major objective of a pest control program is to reduce insect pest populations to an acceptable level. There are some factors to consider when selecting what type of control program is right for the area and for the level of production.

Many producers select their pest control action from previous experience or observing what other producers are using for control methods. This may not be the best rationale to use when making pest control decisions. Conditions change and so should pest control methods. Also, what one producer uses to solve a pest problem may not be successful for another producer.

Cost is probably the first factor to consider. Chemical control programs are very expensive and costs are rising continually. The amount and kind of chemical used will be based on the pest problem as observed by the producer when scouting the wheat or other small grain crop. Fields should be observed frequently during April, May, and June. Rising costs of chemical control measures are one reason producers look for alternatives to pest control other than chemical use.

Another factor to consider in pest control selection would be consideration for the environment. More producers are becoming aware of harmful effects when pesticides are overused. Educational efforts of groups and agencies responsible for land and water quality are making an impact on choices of pest control measures used by crop producers.

Some producers will consider nonchemical methods (using physical and biological mechanisms) for their pest control measures. These include controlling pests by plowing them under in crop residues, introducing predators and parasites that feed on harmful pests, using plant varieties that are pest resistant, and releasing sterilized male insects into the wild populations that cause females to bear infertile eggs.

Integrated pest management (IPM) is a more recently developed technology for pest control aimed at achieving the desired control while reducing the use of pesticides. Combinations of chemical, biological, and physical controls are used. If properly implemented, IPM can reduce pesticide use by as much as 50% while also improving pest control. Environmental problems can be reduced and producers and society as a whole will see significant benefits.

Other factors to consider when deciding pest control measures would involve the specific pest problem and the type of soil conditions where the small grains are being produced. Crop advisors from chemical suppliers and extension agronomy agents are very useful in recognizing specific pests and suggesting control methods. They can also help identify soil types and conditions that may affect chemical control success.

Pests Specific to Wheat and Small Grains

Wheat and other small grains are attacked by many insects. Fortunately, only a few insect species cause severe damage over large geographical areas that are very important. Most pests are only "occasional" pests and/or not geographically widespread. The status of many pest species is not always well documented.

Barley and oats are attacked by essentially the same insect complex that attacks wheat; therefore, the following list can apply to all cereal grains.

Aphids - Aphids are widespread pests on cereal grains. When feeding in sufficient numbers, they can cause significant damage. In addition to feeding damage, they may act as "vectors" (transmits, carries, or spreads) of barley yellow dwarf virus. Aphids are nearly transparent, soft-bodied, sucking insects. When present in sufficient numbers, they can cause yellowing and premature death of leaves. They exude drops of sugary liquid known as "honeydew," which may cause tiny scorch marks on the foliage and encourage the development of sooty molds.

Some aphid feeding may result in the development of necrotic (dead) areas, sometimes accompanied by purpling and rolling of the infested leaves. The life cycle of the aphids involve the winged, wingless, sexual, and asexual forms. When feeding on cereals such as wheat, barley and oats, the females of most aphid species reproduce asexually (without being fertilized), producing nymphs rather than eggs. Species of aphids commonly found on cereals include bird cherry-oat aphid, greenbug, corn leaf aphid, rose grass aphid, English grain aphid, and the Russian wheat aphid.

Stink bugs - Losses due to stink bugs are extremely variable and depend on the density of the insects, weather conditions, and duration of the crop-growing period. Mild winters and low rainfall encourage outbreaks of the insects. Stink bugs will feed on most cereals and grasses and a large range of weeds. Losses result primarily in reduced baking quality of the grain. Adult stink bugs feed on stem tissue or developing kernels. Saliva from this insect is toxic to the plant, and a single feeding puncture can kill a stem. Feeding on kernels during the milk dough stage will destroy the kernel, while feeding during later development stages will badly shrivel the grain. Feeding on the developing head may cause partial or total sterility. Adult stink bugs have a shield-shaped body and emit a disagreeable odor when crushed. Adult stink bugs hibernate under dead leaves and grass. In the spring they lay eggs on various parts of the plant. Their hatched nymphs feed on the plant.

Armyworms, cutworms, and stalk borers - These pests sporadically cause severe damage, and when they do, they can devastate large areas. The primary symptom of these insects is defoliation of the plant. Larvae feed on leaves, chewing from the edges to the midrib, or on the heads of cereal plants. Heavy infestations can be very destructive. Larvae may climb the plant and sever the neck just below the head. Some species may be found feeding at the soil surface, others underground feeding on roots, and still others feeding inside the stem. The adult worms lay eggs on the leaves and leaf sheaths near the ground. These eggs hatch within a few days and initially the larvae may feed where they hatch, feeding at night or early in the morning. In damp weather, they may feed all day.

Cereal leaf beetle - Significant yield losses can occur in winter wheat and fall-sown spring wheat. Yield losses of 15% to more than 25% have occurred with natural infestations. Adult beetles are 4-5 mm long, have a black head, light brown thorax, and a shiny blue-green wing covered with parallel lines of small dots. The most prominent symptoms of cereal leaf beetle infestations are the distinct, longitudinal stripes on leaves. These stripes are produced by the feeding of the adult beetles and of larvae. The insect produces one generation per year. Adults begin their feeding activity in the spring. They lay yellow eggs, either singly or in small chains, covered with a sticky film. The adults emerge in the summer. Adults overwinter in plant debris on the soil surface, in leaf sheaths, on ears of corn, or under the bark of trees. Wheats with hairy leaves are affected less.

Thrips - Thrips are small (1 mm), brown or black insects with a tapering, segmented abdomen. They have piercing and sucking mouthparts and usually have two pairs of narrow wings. They are usually found behind the sheath of the flag leaf, feeding on the stem. However, some leaves, stem, and heads may be attacked. Adults and nymphs both can cause damage and, if present in large numbers, may cause the tissue on which they are feeding to take on a silver coloration. Eggs are inserted into or attached to the host tissue. The generation time is very short and there may be 10 or more generations per year. Heavy rains will usually destroy most the population. Several thrips species live exclusively on cereals and on forage or weed grasses. Thrips rarely cause serious damage and it is unusual to find infestations at such a level as to warrant control measures.

Hessian fly - This is one of the most destructive insect pests on cereals. Widespread outbreaks have occurred, and in some locations the pest recurs annually. The Hessian fly is mainly a pest of wheat, but it may attack barley, rye, or other grasses. This pest has been reported in most wheat-growing areas of the world. Severe infestations of Hessian fly result in stunting of the plants, thin stands, lodging, and reduced yield. Injury is caused entirely by the larvae, which sucks juices from plant tissues. If infestations occur during jointing, infested stems will often break before maturity. The Hessian fly is 3-4 mm long, has a black head and thorax, and a pinkish or yellow-brown abdomen. Adult flies emerge in the spring from pupae that have overwintered in straw or stubble. The minute, oblong eggs are reddish in color and are laid in rows on the upper sides of leaves. The eggs hatch within 1 week. The legless larvae settle behind the leaf sheaths and

suck the sap of the plant. The larvae develop into translucent, pale-green, slug-like maggots.

Wheat stem maggot - In infested fields, 10-15% of the plants may be injured. Damage can be severe in some years, but the insect seldom causes widespread damage. Heavy infestations of individual wheat stands may kill a significant portion of the tillers. Wheat stem maggots attack young tillers in the fall or early spring. The tillers usually die and infected plants show the "white head" condition typically produced by stem-boring insects. Adults are about 6 mm long and pale green to yellow with dark stripes. Larvae overwinter in cereal plants or grasses. Females lay small white eggs, one per stem, near the sheath of the flag leaf. The larvae burrow into and consume the interior of the stem, killing the upper part of the stem and head. There are normally three generations per year; one in the spring, one in the summer, and a third in the fall that overwinters as larvae.

Sawfly - This insect can cause significant damage in some years, but infestations are usually not continuous. Nearly all cultivated cereals and native grasses act as hosts, although wheat is preferred. Fall-sown cereals are more commonly attacked. Wheat varieties having solid or partially solid stems are much less susceptible to attack. Damage by sawflies includes premature yellowing of the head and shriveling of the grain. The larvae girdle the stem and later in the crop cycle cause lodging. Sawflies produce one generation per year. Larvae overwinter in the straw. Adult sawflies are small, fly-like wasps and appear from late spring to midsummer. Females deposit small, white eggs in the upper nodes of stems just below the heads. Upon hatching, the larvae bore into the stem and tunnel downward, feeding on the pith of the stem.

White grubs - Many species of white grubs attack wheat and many other plant species. Cereal crops may suffer significant damage if seeded into heavily infested grasslands. White grubs are the larvae of May or June beetles. Eggs are deposited in the soil and the hatched larvae feed on roots. White grubs can partially or completely sever the roots of the host plants. This causes patches of wilting and dying wheat plants (especially in the seedling stage), symptoms that could be attributed to root rots. However, when stunted patches are observed, the surrounding soil should be examined for the larvae. When fully grown, the largest of these larvae may be several centimeters long and nearly 1 cm thick.

Wireworms - These insects are among the most damaging soil-infesting pests. Damage is usually most severe where wheat has been seeded after fallow or after of number of years of grass. Many species of wireworms are found throughout the world, all of which can attack wheat. Wireworm damage is similar to that caused by other soil-inhabiting chewing insects. The only sure way of identifying wireworm damage is to find them in association with the damaged seedlings. The name "wireworm" refers to the tough, wire-like appearance of the larvae. They are 20-30 mm long and are often smooth, hard, and highly polished. Larvae may attack wheat as soon as the crop is seeded, eating the endosperm of the kernels and leaving only the seed coat. A common sign of wireworm attack is the wilting and/or dying of many adjacent plants, either in a row or patch. Stems of affected seedlings will be chewed just above the seed. Wireworms are the larvae of click beetles, of which there are many species. The eggs are laid in the soil, usually in the spring, and the larvae take several years to develop. Generations overlap so all stages and sizes of larvae may be found in the soil at the same time.

Grasshoppers - Grasshoppers can severely damage full-seeded small grains, especially following a dry growing season. If grasshopper populations are high, treat fence rows and other areas before the grain germinates. Treating the margins of the fields after the grain emerges give adequate control. But if one or more grasshoppers per square yard are found throughout the field, apply chemical controls.

Pest Control Options

The measure or action taken for the prevention or control of wheat and other small grain insects will depend on the pest and the time of the year.

Some measures should be taken before planting. These would include plowing under residue to eliminate a place, or host, for some insects to winter. Some insects such as grasshoppers should also be scouted before planting. Three to five grasshoppers per square yard warrant control spraying. Also, when scouting before planting, if wireworms are noticed, a seed treatment would be in order.

During the growing season, foliar sprays should be used at the first sign of infestation of any of the insect problems discussed in this lesson. Most foliar sprays can be repeated if necessary after 14 days. Directions on the use of such sprays must be followed. As an example, foliar sprays must not be used a certain number of days before harvest. These may vary from 7 to 45 days.

Consideration should also be given to the control of insects and rodents that present a problem during storage. Storage bins should be cleaned thoroughly. Some control sprays must be used before filling with grain with a 24-36 hour waiting period before placing grain in the storage facility. Some sprays are placed on the grain as it enters the bin. Poisons may also be purchased for rodent control in stored grain.

Summary

It is very important that a producer of wheat or small grains such as barley or oats understands how to select a pest control program. The management and control of insects that may affect the yield potential of a crop will play a large role in the success of the crop. Producers must also be aware of the many pests that may invade the soil or growing plant, how to identify them, the damage they may cause, and methods of control.

Credits

Agronomy Guide 2000, MFA, Inc. Columbia, MO 2000.

A Guide to Wheat Diseases and Pests. Cornell University Extension. May 2000.

The Wheat Production Handbook. Kansas State University Cooperative Agricultural Extension Service. May 1997.

Lesson 5: Scouting and Maintaining the Crop

During the growing season, wheat and small grain producers must evaluate the crop to determine if and when problems may develop and know what corrective actions may be warranted. Examinations must also take place to evaluate cultural and mechanical practices the producer has used to plant and establish the crop.

Plant Condition Factors

During the growing season, the producer should know how the crop and individual plants are progressing. Are the plants being allowed to develop to reach their maximum yield potential? Several plant condition factors should be considered when evaluating the growing crop.

The first factor is to evaluate the crop regularly to determine if the fertility program is meeting expectations. The grower should be able to recognize problems that were caused by nutrient deficiencies. Sometimes corrective measures can be taken such as a nitrogen top-dressing in the spring.

Tillage and planting methods used by the producer should also be evaluated. The condition of the seedbed plays a large role in the successful establishment of the stand in the fall. Management of the previous crop residue should be evaluated to determine if a problem developed because of residue left on top of the ground. Did the conservation tillage or no-till planting procedure yield expected stand densities?

Another factor to consider would be the soil moisture level. The producer may dig into the soil to determine the soil moisture and its depth. If soil moisture is determined to be inadequate, the producer may be able to provide irrigation to the plants.

The type of weeds and the weed pressure (density) should also be examined. This should be done in the fall as the plants are starting to emerge and again in the spring when plants start to "green-up" after the winter. Decisions must be made whether a corrective action, such as spraying, is warranted.

Plants should be examined regularly for disease and insect damage. The success of any corrective treatment to counter pest and disease problems will be determined not only by what action is taken, but also the timeliness of that action or treatment.

Replanting Decisions

Replanting decisions are complicated by not knowing what future seasonal growing conditions will occur. Decisions should be based on historic trends plus current environmental and economic conditions. Two questions should be addressed when considering replanting: (1) Is there an economic advantage to replanting? (2) Should the same crop be replanted? The advisability of replanting must be carefully considered, keeping in mind that the cause and severity of injury, soil moisture, replanting costs, previous herbicide use, and replanting date all influence whether a crop should be replanted or if a different crop should be planted.

The cost of replanting must be recovered from a later maturing crop that typically has a lower yield potential than the original crop. Replanting also results in additional moisture loss.

While maximum wheat and small grain yields are obtained at plant populations of 28 to 30 plants per square foot, acceptable yields can be achieved with populations of 12-18 plants per square foot. A uniform stand, even at very low densities, will often produce above expected yields. Generally, replanting should be considered only for those fields with stands below 30% of intended plant densities or regions with 4- to 6-foot gaps.

Weed Pressure

Winter and summer annual broadleaf weeds have an important economic impact on winter wheat and other small grains. They compete with small grains for light, water, space, and nutrients, reducing some wheat yields by an estimated 10% each year. Weeds will also slow harvest and increase combine repair costs. Producers may be docked at the elevator for excessive grain moisture and/or weed seeds in their grain.

In 1982, only about 10% of the winter wheat acres in Missouri were sprayed with herbicides to control weeds. By 1998, however, approximately 60% were sprayed. Effective weed control in winter

wheat can eliminate or greatly reduce losses due to weeds and increase net returns.

Success with reduced and no-till programs is improved with weed-free winter wheat stubble after harvest. In addition, weed seed from the current crop will survive in the soil and cause problems in future crops. These potential problems underscore the importance of broadleaf weed control in small grains. An effective weed control program considers the entire cropping system. This approach involves the use of preventive, cultural, and chemical weed control methods.

Prevention, or stopping the advancement of weed infestations, is an important part of a total weed management program. It requires diligence from the producer but offers low-cost, effective control. Some rules for preventive weed control are (1) use crop seed that is weed free; (2) clean tractors, implement, and combines before moving them from infested to clean fields; (3) keep uncropped areas (fence lines and field borders) weed free; (4) do not allow livestock to move directly from infested to clean areas; and (5) spray or mow to prevent weed seed production in all areas.

Cultural weed control involves manipulating the crop/weed environment so conditions are favorable for crop plants but unfavorable for weeds. Crop competition and crop rotation are two important cultural control practices in small grain production.

Crop competition involves establishing a vigorous crop that can compete more effectively than weeds for water, light, space, and nutrients. Several factors contribute to competitive crops: proper seedbed preparation; adequate fertilization; high-quality crop seed; careful variety selection; and proper date, rate, and depth of seeding. These factors will also result in high-grain yields.

Crop rotations that include spring-seeded crops break the life cycle of problem weeds, particularly annual broadleaf weeds, and allow the use of tillage and herbicides that may not be feasible in a small grain monoculture. Adapted rotational crops include corn, grain sorghum, and soybeans.

Several herbicides provide excellent broadleaf weed control with minimal damage to small grain crops; however, some varieties are more sensitive to herbicides than others. Research has not been conducted on the herbicide sensitivity of many varieties presently planted. The following fundamentals should be considered before selecting a herbicide: (1) identify the weed problem, (2) spray when weeds are small and actively growing and at the proper stage of the small grain growth for the herbicide use, (3) use spray equipment that is in good condition and not contaminated with previously used herbicides, (4) calibrate the sprayer to ensure application accuracy, (5) read and follow directions on the herbicide label, and (6) know the rotational plans to avoid herbicide carryover problems to sensitive crops.

Timely weed control is important to reduce early season weed competition with the crop. Research has found that weeds that emerge at the same time as the small grain plant or within a week of emergence may cause as much as 35% reduction in yields. However, in stands where the weeds did not emerge until the third or fourth week after the grain emergence, the reduction in the grains yields was only about 8 to 12%.

Insect Pressure

Small grain fields provide an ideal habitat for many beneficial as well as harmful insect species. Some closely resemble each other so the producer has to be careful; accurate identification is important. Insects can be identified by visual appearance, location in the field, and seasonal occurrence.

After identification, it is necessary to carefully determine population numbers to decide when the insect levels have increased to the point of economic damage. This level is called the economic threshold and refers to the projected loss of a crop that is equivalent to the cost of treatment. Many factors influence how much damage occurs. Determining when an insect infestation caused economic damage is the basis of good pest management.

It is a good management practice to check grain fields for damaging infestations in the fall during the first 20 to 50 days after planting. This is when insect control with a foliar spray can provide greatest economic returns. Check fields as often as possible after this time, particularly before applying fertilizer, herbicides, or fungicides. If insect populations exceed thresholds, it may be possible to apply an insecticide as a tank mix with another chemical.

Check at least five spots in the field, examining at least 1 row-foot at each location. Include at least two samples near the field edges. Check closely because insects, particularly aphids and pupae of the Hessian fly, can sometimes be found at the base of the plant below ground level. It may be necessary to pull some plants out of the ground to sample for insect infestations at the root level. For larger plants, slap the plants to jar insects to the ground for counting.

If an infestation of a particular insect is light (i.e., 50 or fewer per linear foot), try to determine an exact count. If the population is heavy, making an estimate is acceptable. The following is a more in-depth discussion of how the insects discussed in the previous lesson impact wheat and other small grains in Missouri.

Aphids include several species of insects that are problems to wheat and other small grains. Aphids directly feed on the grain plant and indirectly transmitt viruses that cause disease. The four main aphids that infest wheat are the greenbug, English grain aphid, oat bird cherry aphid, and the corn leaf aphid.

The greenbug is particularly prevalent in the fall and it can cause economic losses due to direct feeding. The greenbug sucks plant juices and at the same time injects a toxin that can kill the plant. The English grain aphid is more common in the spring and can cause reduction in yield during heading. Mild, dry winters and cool, dry springs often favor aphid outbreaks. Setting threshold levels for aphids is difficult because of the influence of factors other than number of aphids per foot of row. The size and vigor of the plants, the temperature, time of year, moisture conditions, stage of growth, and presence of parasites and predators all need to be considered in deciding whether to apply insecticides. Refer to Table 5.1 for threshold levels for aphids in wheat.

The fall armyworm attacks wheat and other small grains from September to frost. They can destroy young plants, but most years the armyworm does not occur in sufficient number to cause damage. Fall armyworm damage is not likely after a dry summer.

Record the number of armyworm caterpillars per linear foot of drill row. Include even the small larvae. Be sure to take samples in the interior of the field because this pest is often heaviest near the field margins. Sometimes, only the field margins require treatments. Because armyworms attack grain in the fall in the seedling stage, a small number of larvae per linear foot or row can cause heavy damage. Threshold levels range from two to three larvae per linear row-foot for seedling wheat. For older plants, three to four larvae and obvious foliage loss justify control measures.

"True" armyworms feed on winter grains (wheat and barley) near the heading stage. They are referred to as true armyworms to separate them from fall armyworms and cutworm. On wheat, the larvae feed first on the leaves, next the beards, and then the kernel. The most severe damage in wheat is caused by cutting through the stem below the head and separating it from the plant. They mainly feed at night.

The heaviest infestation of the true armyworm is found near field margins and in low-lying areas of growing grain, especially where it is lodged. Check for pests in and under plant debris and in

Table 5.1 - Aphid Threshold in Wheat

Growth Stage	Treat If There Are More Than:
Seedling (0-30 days after planting)	3 aphids /row foot
Vegetative plants (30-60 days after planting)	6-8 aphids/row foot
Vegetative plants (60 days after planting to start of jointing)	10 aphids/row foot
Jointing	2 aphids/stem
Boot/flag leaf stage	5 aphids/stem
Head emergence to dough	10 aphids/head, including the flag leaf
Mid-dough to maturity	Do not treat

the heads. Shake or beat the heads and straw to dislodge the larvae. Check several locations in the field and average the count. Three to four armyworms per linear row-foot is a commonly accepted threshold. However, if the crop is nearly mature and there is no evidence of head clipping, control may be delayed. If the larvae are all mature, insecticidal control is not advised because these larvae will drop to the soil and pupate.

Cereal leaf beetles may infest late-planted winter grains but are most damaging to spring-planted oats. They may also feed on other wild and cultivated grass plants. The adults mate in the spring and lay their eggs on upper surfaces of the leaves from late March to late April. Closely examine plants and determine the average number of beetle larvae per tiller in several locations in the field. Population levels of one-half to one larva per tiller when 30% of the cereal leaf beetle eggs have hatched should be controlled in wheat. The threshold level in barley and oats is one and one-half adults or larvae per flag leaf.

The Hessian fly is the most damaging pest of wheat and barley. Oats are never infested by the Hessian fly. The adult fly lays eggs on the upper sides of the leaves and the small white maggots feed on the joints along the stem, discharging a toxic salivary secretion that stunts plant growth. Plants infested in the fall may die, and wheat infested in the spring often lodges and has smaller heads.

The best way to avoid Hessian fly is to plant resistant varieties and follow the planting calendar to observe the "fly-free" date. Planting fly-susceptible varieties after that date may help producers in some years, but it is not guaranteed. Growers who plant resistant varieties should inspect the wheat before making their customary nitrogen applications in the spring. If 20% of the tillers are infested with Hessian fly maggots or pupae at this time, significant yield losses can be expected and the nitrogen application may not produce the yield response to justify the additional cost. Before next planting season, producers should consider rotating wheat fields, turning under wheat stubble, and destroying volunteer wheat before planting.

Summary

Producers of wheat and other small grains should know what to look for when scouting their growing crop. Evaluations should be made to determine the effectiveness of their nutrient program, the tillage and planting methods used to prepare the crop, and weed pressure and control methods. Producers should also inspect for disease and insect damage and use appropriate controls. The small grain stands should be evaluated on an economic basis to determine if replanting is feasible. Generally, if the stand is 30% or more below the intended population, replanting may be justified. It is also important for producers to know how to control weed infestations by preventive measures, using cultural controls and knowing when chemical controls should be used. Producers should scout their fields often and be able to identify and know what pest pressure would also justify pest control measures.

Credits

Annual Broadleaf Weed Control in Winter Wheat. Nebraska Cooperative Extension Publication. January 1999.

Insect Pest Management. Integrated Pest Management. Alabama Cooperative Extension System. 1999.

Wheat Production Guide. North Dakota Extension Service Publication. May 2000.

Lesson 6: Harvesting the Crop

After all the work of tilling, planting, and caring for the crop during the growing season, the next important phase of wheat or other small grain production is the harvesting period. The objective at this time is to secure the most kernels of the grain at the proper moisture level and place them in a proper storage facility or deliver them to a local elevator for sale.

Factors Determining Harvest Time

Harvesting winter wheat may begin before June 1 in the southeast portions of the United States and as late as July 15 or later in Montana. Figure 6.1 illustrates the usual beginning times for winter wheat harvest.

As seen from the map, the usual beginning harvest times for Missouri would be June 16 to June 30. These times of course would vary with the condition of the crop. Harvesting barley and oats would take place during the same approximate period. Refer to Table 6.1 for harvesting information.

Grain should be harvested quickly and before shattering and sprouting of seeds in the head occur. Wheat harvested at less than 12.5% moisture is dry enough for storage. However, producers may harvest wheat at moisture levels as high as 20% if they can dry the grain quickly after it is placed in storage bins. High-moisture wheat delivered immediately to commercial buyers will be devalued (docked) according to the amount of water in the grain.

Figure 6.1 - Beginning Harvest Dates of Winter Wheat

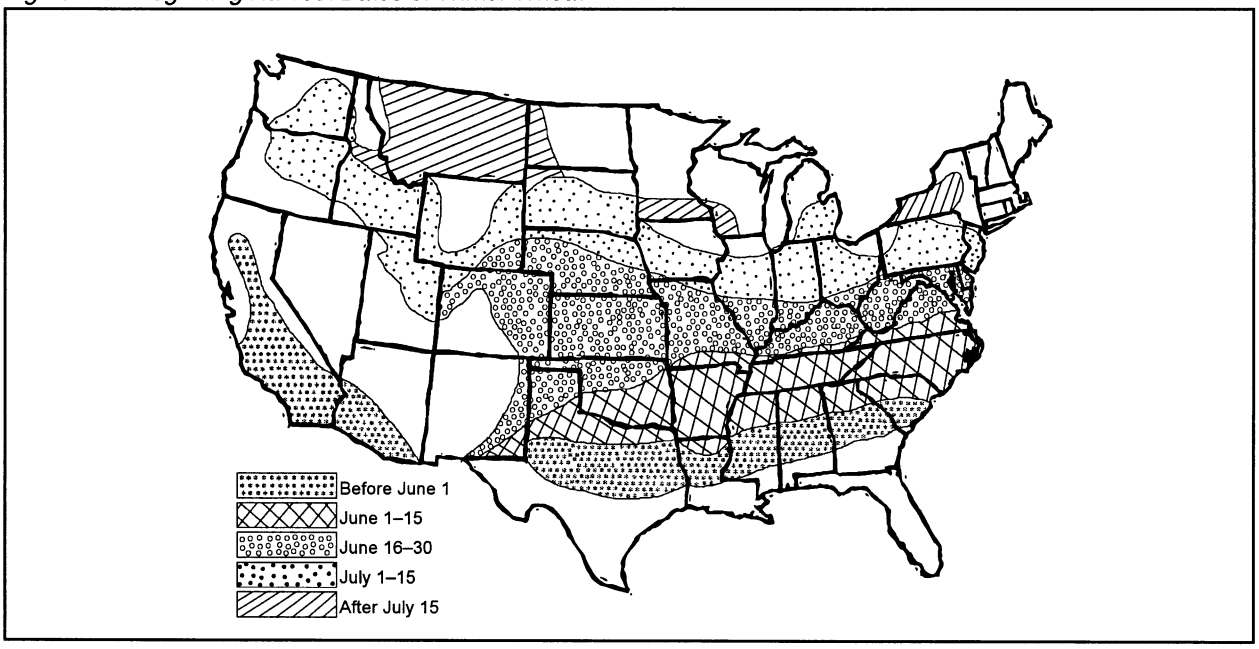


Table 6.1 - Harvesting Information

Crop	Percent Moisture	Plant Maturity Stage	Physical Plant Signs for Harvest	Method Used to Harvest
Wheat	below 14%	a little past hard dough stage	majority of kernels shell out when rubbed between hands	direct combine
Oats	no more than 13-14%	hard-dough or 2-3 days later	when the straw shows no greenness and the heads have turned a dull white	direct combine or windrow-pickup combine
Barley	below 14%	hard-dough stage	when heads have turned golden yellow but straw may be slightly green	direct combine or windrow pickup combine

Begin wheat harvest when the crop has field dried enough that it can be handled safely (not shatter from the head). A moisture meter is useful in giving a quick determination of crop condition. Most hand-held meters are calibrated for corn or soybeans and have charts for converting readings to other crops. If a meter is not available, weigh a 1/4- to 1/2-pound sample, dry it on a cookie sheet in a 260°F oven overnight (10 hours), and reweigh the sample. Calculate the moisture content by the following formula:

$$\text{Seed moisture (\%)} = \frac{\text{wet weight - dry weight}}{\text{wet weight}} \times 100$$

Some producers may choose to harvest wheat at moisture levels above 15% when growing grain in a double-cropping system. Significant profit potential exists for earlier wheat harvesting because of the increased yield of the second crop. For each 1-week delay in planting soybeans after the middle of June, decreased yields of 4 to 7 bushels per acre may occur. This potential yield loss alone provides enough incentive to offset the cost of drying high-moisture wheat. Other advantages of early harvesting would include increased yields owing to higher test weight and less shatter loss at the header during combining.

Seed Damage at Harvest

The major damage that may occur to the grain at harvest takes place from the threshing operation of the combine. Ideally, threshing removes all grain from the head of the plant without damaging the grain or the straw.

Threshing occurs at the cylinder or front portion of the rotor and is affected by concave clearance and cylinder/rotor speed. Cylinder/rotor speed determines how much grain damage will occur and the amount of seeds threshed from the head. Clearance will determine how many seeds are separated and drop through the concaves.

Symptoms of overthreshing are cracked grain and excessive amounts of return. The cracked grain is more likely to be blown over the shoe, and even if retained in the grain tank, it causes problems in handling and storage. To avoid overthreshing, set the cylinder no faster and not tighter than absolutely necessary to thresh the grain from the heads. Some operators prefer to leave an occasional kernel in the head as a sign of the best balance in threshing action. Table 6.2 shows the recommended initial settings for combines used to harvest wheat. Consult the operator's manual for barley and oat settings.

Crop Loss During Harvest

Today's modern, high-capacity combines are designed to do an excellent job of threshing and cleaning wheat and other small grains. All too often, however, part of the crop is left in the field or the quality of the grain harvested is less than desirable. Even in good harvesting conditions, combine losses as high as 8-10 bushels per acre of wheat can occur. Usually, a few minor adjustments can drastically reduce losses or improve grain quality. Since any additional grain saved is clear profit and clean samples are not docked, a little extra attention to combine adjustment can pay off.

As a rule, start with the machine adjusted according to the specifications in the operator's manual. Engine speed is often taken for granted, but it is one of the most important adjustments. If the engine speed is too slow, separator speed will also be too slow and performance will suffer. Be prepared to fine-tune the combine as required. To fine-tune a combine, the functions of the machine need to be considered.

Table 6.2 - Recommended Initial Combine Settings for Harvesting of Wheat

	Range	Recommended
Chaffer opening (inches)	1/4 to 3/4	5/8
Sieve opening (inches)	1/8 to 3/8	1/4
Fan setting (speed or choke)	medium to high	near high end
Cylinder/rotor speed (rpm)	750 to 1350	1000
Cylinder/rotor & concave spacing (inches)	1/8 to 1/2	1/4

The five basic functions are (1) cutting and feeding, (2) threshing, (3) separating, (4) cleaning, and (5) handling. The crop moves through the combine in this order.

Cutting and feeding take place at the header and feeder house. Adjustments include header or cutting height, reel speed and height, and reel position (fore/aft). The cutting height is controlled by the operator as conditions change. The goal should be to harvest all grain with the minimum amount of chaff and straw. The reel should be adjusted to gently move the wheat into the cutter-bar by positioning it slightly ahead of the cutter-bar. It should turn slightly faster than ground speed and be far enough down in the wheat to lay the heads onto the platform. The sickle should be sharp and in good condition. A dull sickle can limit ground speed and cause shatter loss.

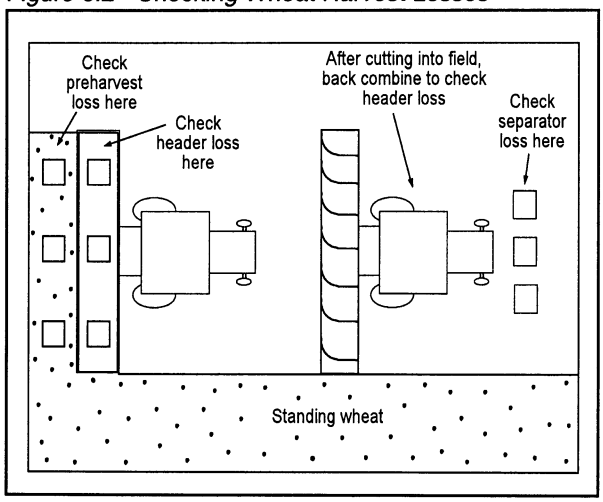
Threshing occurs at the cylinder or front position of the rotor and is affected by the concave clearance and cylinder/rotor speed. Cylinder adjustment is important and greatly affects the performance of the combine. Verify that the cylinder clearance indicator on the machine is accurate. The bars and concaves may be worn so that the clearance is greater than shown by the pointer. The concave and cylinder must be parallel from side to side. The operator's manual should provide adequate instructions on how to adjust these items. Since threshing plays an important role in grain cleaning, the cleaning shoe should not be adjusted until satisfactory threshing occurs.

The chaffer and shoe openings should be adjusted properly to allow the correct amount of airflow over the separators. Airflow should be adjusted so that the grain falls through the first 2/3 of the chaffer. If chaffer openings are too small, the passage of grain through them is limited, increasing losses and limiting the overall capacity of the combine. Sieve openings should be set large enough to let all grain through without allowing foreign material into the grain bin.

Combine capacity is the maximum rate at which a properly adjusted combine can harvest a crop while maintaining an acceptable loss level. A common limitation on conventional combines in wheat is the straw walker overload. If the combine is pushed beyond a reasonable rate, walker overloading will cause the losses to increase rapidly. Therefore, ground speed is very important. Reducing ground speed by 25% on an overloaded combine can easily cut harvesting losses in half.

Check the machine frequently to ensure efficient harvesting. During a single afternoon, conditions can change enough to require resetting some of the machine's components. A few simple ground counts will give an indication of combine performance. See Figure 6.2 for an example of how to check for wheat harvest losses.

Figure 6.2 - Checking Wheat Harvest Losses



Follow these steps, as indicated on the graphic, to determine losses.

1. Cut through a typical area at the usual speed, stop the combine and back up about 20 feet.
2. In the area behind the separator discharge, lay a 1-foot square frame down three times and take ground counts. Average the three counts. This is the separator count.
3. In the area between the cutter-bar and the standing wheat, take three more ground counts and average them. Do not forget to look for heads. This is the header count.
4. Take a final three ground count in the standingwheat and average them. This is the preharvest count.
5. Calculate header loss in bushels per acre with the following formula.

$$\text{Header loss} = \frac{\text{header count - preharvest count}}{20}$$

6. Calculate the separator loss in bushels/acre with the following formula.

$$\text{Separator Loss} = \frac{\text{separator count - header count}}{80}$$

Since the header width for most combines is about four times as wide as the separator, it takes about

80 kernels per square foot behind the separator discharge to equal 1 bushel per acre if no spreading devices are being used. If the combine has a bat-type spreader, use 65 kernels per square foot instead of 80. If a straw chopper is used, use 50 kernels per square foot, and if a chaff spreader is used, use 25 kernels per square foot.

What are acceptable losses? This depends on the condition of the crop and the attitude of the operator. However, for standing wheat under good harvesting conditions, machine losses can usually be held to 2% of the total yield. Higher losses will have to be tolerated in downed or damaged grain.

Since many factors can create combine losses, an organized approach to correcting the problem is needed. Figure 6.3 shows one method for pinpointing the cause of the lost grain. When fine-tuning a combine, try to change only one thing at a time so the effects can be seen. Keep referring to the operator manual; it seldom pays to deviate very far from suggested settings.

Local Storage Options

There are several important storage alternatives and substitutes for storage. Two important objectives of all of them are (1) higher net prices for the grain and (2) a more efficient use of labor, management, and machinery resources. Storage alternatives or substitutes include:

1. On-farm storage in grain bins
2. Commercial elevator storage
3. Price-later contracts
4. Buying futures positions to offset the cash sale of the grain at harvest

On-farm storage - Storage of grain on the farm for later cash sale is more popular with producers than are the off-farm storage alternatives and storage substitutes. Several primary advantages are:

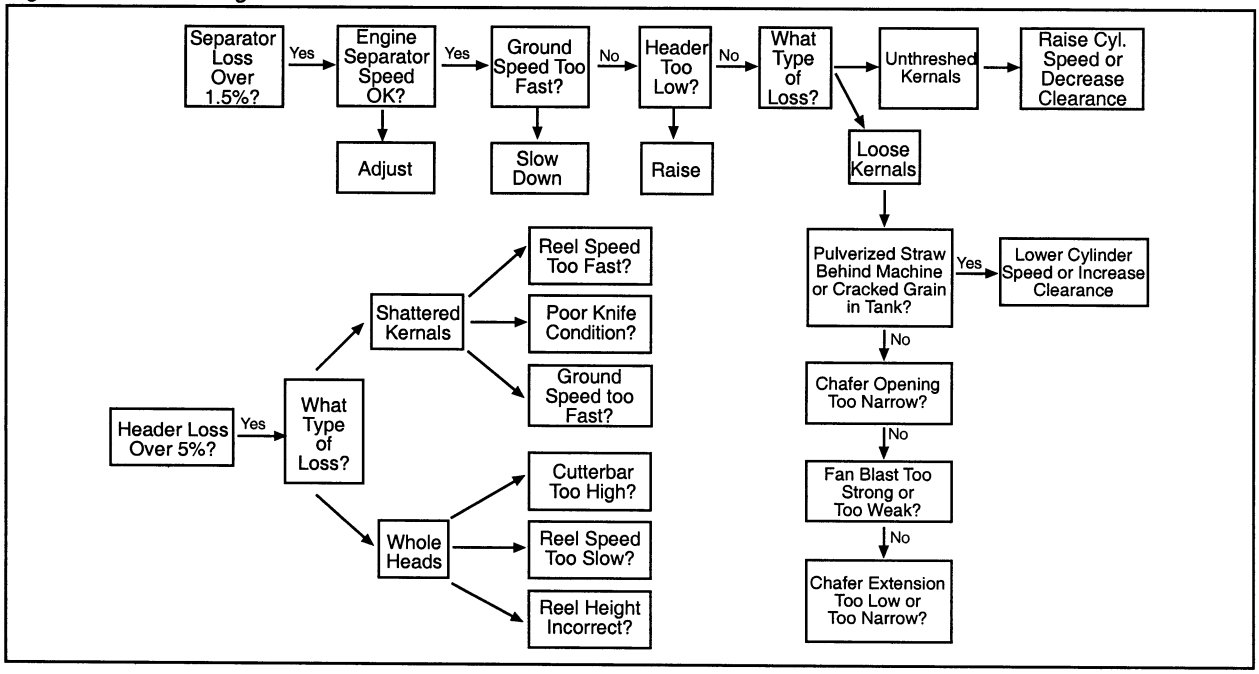
1. More efficient use of labor and equipment
2. Earlier harvest
3. Potential for grain drying returns
4. Additional marketing flexibility
5. Potential for higher net price
6. Provides tax management flexibility

Some on-farm storage limitations would include:

1. Costly on-farm storage of grain
2. Additional labor and management
3. Risk of grain quality loss
4. Potential for lower net prices
5. Risk of selling overdry grain

Commercial storage - Grain elevators seldom have excess capacity but those that do may be

Figure 6.3 - Correcting Wheat Harvest Losses



willing to rent this space to a producer for several months. The rental rate varies but it is typically about 3 to 4¢ per bushel per month with a minimum number of months guarantee. With commercial storage arrangements, the grain remains at the elevator location and can be retrieved by the producer. Because of combining grain at the elevator, the producers cannot recover the "exact" kernels of grain they delivered, but instead may withdraw the same "quality" as they delivered.

Price-later contracts - This type of contract is also known as deferred price agreements. With this type of arrangement, price is not established at the time of delivery but is deferred or delayed until a later time. This eventual pricing decision is made by the producer. Usually producers follow a "cash" plan whereby they retain the right to price at a later date, usually the same price being offered on the particular day on the cash grain market. The price-later (delayed pricing program) involves the delivery of the grain to the participating elevator at harvest. Ownership is transferred to the elevator and producers receive a "promise to pay" or "IOU" agreement from the elevator.

Futures market positioning - Another substitute for storage involves selling the cash grain at harvest and then taking a long (buy) position in the grain futures market. The advantage of this type of arrangement is that it is cheaper to "store on paper" than with the physical grain facilities. Producers who consider this method of "storage" should also realize there is substantial risk involved. Prices may decline after the futures position is taken and considered the same as a cash loss.

Storage Problems

Even if grain is dried to the correct moisture levels for the desired length of storage, storage problems may result.

Poor initial grain quality - Many kernels may be cracked during threshing and even in the field. Broken kernels and fragments are common to most grain going into storage. Kernel damage can be especially excessive when harvest conditions are unfavorable. The damaged kernels are very vulnerable to storage mold development and insect invasion.

Moisture migration - Moisture may shift from place to place in a bin of stored grain. The transfer of moisture is usually greatest in cool weather or during seasonal temperature changes when the grain is much warmer or cooler than its surroundings. When these changes in temperature occur, this may lead to convective air currents carrying moisture from one area of the bin to another. This creates pockets of wet grain that can spoil. This problem can be corrected with proper aeration.

Storage mold development - Storage molds can cause significant damage in stored grain. Storage fungi are always involved whenever spoilage occurs. This can happen both in the presence or absence of insects. Storage molds are caused by several species of fungi that grow on the grain and use it as a food source. If conditions are right (high moisture, high temperature), fungi can quickly cause serious grain quality losses. Fortunately, good engineering techniques can reduce losses from storage molds.

Insect and rodent invasion - Insects and rodents are a major cause of loss in stored grains, as well as in many other kinds of stored food products. They not only consume these materials but also contaminate them with fragments, feces, webbing, and bad smelling metabolic products. They therefore cause a major sanitation and quality control problem.

Several hundred species of insects are associated with stored grains and their products. Fortunately, only a few species cause serious damage. Some feed on the fungi growing on stored grain. Others feed on broken fragments, while others can attack the whole kernels. Insect invasion is usually associated with dirty facilities and inadequate control of moisture and temperatures in stored grain. Proper insect identification and control measures are important to prevent serious losses.

Maintaining Crop Quality During Storage

Many physical factors (moisture content, test weight, shrunken and broken kernel content, etc.) affect the market quality and therefore the price of wheat and other small grains. Only a few of these physical factors are normally affected by deterioration during storage. The economic impact of deterioration during storage depends on the type and severity of the damage.

Deteriorated grain - Damaged kernel count may increase if molds are allowed to discolor the germs of the grain. Discounts may range from 1¢ per bushel to 15¢ per bushel or more, depending on the percent of damaged kernels. The presence of live insects often causes the price to be discounted 5¢ per bushel to 10¢ per bushel.

Uncontrolled mold or insect deterioration may result in objectionable odors or increase the number of insect damaged kernels. This may cause the wheat to be designated "Sample grade," with discounts of 10¢ per bushel or complete rejection.

Insect-damaged kernels are a type of damage produced by lesser grain borers or weevils and contribute to the damaged kernel count, usually causing a discount of 3¢ per bushel or more. Certain preferred buyers, such as flour mills, usually reject grain with live insects or grain with more than five insect-damaged kernels per 100 grains.

Preventing discounts requires sanitation, monitoring, aeration, and proper use of chemicals. Grain damaged by mold is the simplest damage to prevent since it is caused by excess moisture somewhere in the grain mass.

High moisture grain must be dried to less than 12.5% moisture and preferably cooled within 4 days to ensure against the growth of molds and deprivation by insects. Heat must be added in areas of high humidity and airflow rate must be adjusted appropriately. At 85% relative humidity, wheat will equilibrate at about 18.5% moisture. Air alone at a relative humidity of 60% will dry wheat to 12-12.5% moisture over time. The higher the moisture of stored grain, the faster heated air should be moved through the storage bin.

Insect damage - Insect damage is the most difficult part of small grain storage because incoming grain must be held through the summer before cool weather arrives. There are more than 20 different species of insects adapted to survive in grain or grain products. Common stored grain insects have a life cycle of 4 to 12 months. Insect reproduction is definitely related to temperature through the life requirement ranges. Optimal feeding and reproduction of most storage insects typically occur from 70° to 90°F. The lesser grain borer is the most damaging grain insect in farm-stored grain. As grain temperature drops near 50°F, reproduction falls off rapidly as well as visible grain activity, including feeding.

Discounts related to insect presence can be reduced using integrated pest management (IPM) techniques. "What is the minimum insect density at which fumigation is cost-effective?" is a common question relative to insect control. The following guidelines are based on field research and surveys. The guidelines assume the grain will be moved to market in the winter and that the objective is to keep insect levels below detectable levels.

1. If more than two insects are found in samples, take a total of five samples in each bin.
2. If lesser grain borers or weevils (internal feeders) are found in more than one sample, or if more than one of these insects is found in a single sample, fumigation may be necessary unless the entire grain mass can be cooled to below 50°F within 3 weeks.
3. If only external-feeding insects (flat or rusty grain beetles, flour beetles, meal moths, sawtooth grain beetles, etc.) are found, an average of two per sample is usually acceptable if the grain can be cooled to below 50°F within 2 months.

Structures - The structure in which the grain is binned can help prevent loss and quality deterioration during storage. Structures used for grain storage should:

1. Hold the grain without loss from leaks or spills.
2. Prevent rain, snow, or soil moisture from reaching the grain.
3. Protect grain from rodents, birds, objectionable odors, and theft.
4. Provide safety from fire and wind damage.
5. Permit effective treatment to prevent or control insect infestation.
6. Provide headroom over the binned grain for sampling, inspecting, and ventilating.

Sanitation - Sanitation is critical to maintaining wheat or other small grain quality while in storage. The optimum time to clean a bin is immediately after emptying and again 4 to 6 weeks before refilling. Critical areas where infestation can normally be found include the floor area, unloading pits, sump pits, bin walls, ladder rungs, and openings if debris remains attached to them after unloading. Handling equipment and aeration ducts should also be cleaned. Crossover infestation may also occur if an unclean bin is close to bins

used for storage. New grain should not be stored on top of old grain.

After cleaning, bin walls may be treated with insecticides. Grain protectants (insecticides) may be placed on grain kernels entering storage. These may come in a spray form or as a dust for application. Apply chemicals according to the label recommendations. Fumigants may also be used after applying plastic to the top of the grain. Fumigation requires special training and is usually done by a commercial applicator.

Monitoring - Best management practices require monthly inspection throughout the storage period. Risk of major deterioration can effectively be eliminated by frequent monitoring. This requires a grain probe, moisture meter, temperature measuring device, and screening pans. Changes in moisture, temperature, insect activity, and odor can best be detected by inspections. Inspections should be made of more than just the surface of the grain. Insects may concentrate near the top of the grain and give false impressions of the infestation level.

Summary

Wheat and other small grain producers must be aware that harvesting is controlled by the calendar and the moisture content of the grain. Most winter grains are harvested between June 16 and June 30 in Missouri. The moisture content may vary, depending on the drying capabilities of the producer. Harvest losses can be reduced by the correct combine settings and adjustments. Threshing is when most grain is lost. Producers should know how to take harvest counts ahead of the combine and behind the machine to determine the cause of the grain loss. There are several storage options, but the most popular is on-farm storage maintained by the grower. This provides marketing flexibility and potential for higher net returns. Storage problems may be the result of poor initial grain quality, moisture migration, storage mold development, and/or insect invasion. Preventing storage losses requires proper sanitation, monitoring, aeration, and proper use of chemicals when treating grain problems.

Credits

A Comprehensive Guide to Wheat Management in Kentucky. Kentucky Cooperative Extension Service, 1997.

Grain Storage Management, A Guide for Keeping Your Grain in Top Condition. University Extension, Columbia, MO: University of Missouri-Columbia, 1989.

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Wheat Production Handbook. Kansas State University Cooperative Extension, May 1997.

Lesson 7: Marketing the Crop

To the grain producer, marketing means more than just selling. It encompasses setting financial goals, assessing risk, exploring pricing and delivery options, tracking market opportunities, and controlling one's ego.

No one can outguess the market and sell as prices peak with any assurance. Producers either sell too soon before the price peaks or too late because the price was never good enough. More often, grain producers sell with the bottom 50% of average prices offered during the crop year. Few producers sell within the top 1/3 of average prices. Those that do, however, spend considerable time and personal experience watching for the premium selling opportunities and following through on securing marketing contracts.

Marketing Options

The following facts related to common grains in Missouri will help in understanding how these grains are used or marketed.

Wheat

- More than 50% of wheat grown in the United States is exported as grain to foreign customers.
- About 33% of wheat is consumed domestically as a food product. Most wheat is sold to a nearby elevator that then markets the grain to a larger terminal market where it is then sold to flour and milling operations.
- About 8% of wheat is used as feed for livestock.
- About 4% of wheat is used as seed.

Barley

- About 57% of barley is used as feed for livestock and poultry.
- Food, alcohol (including malting), and industrial uses account for about 40% of the barley used.
- The remaining 3% is used for seed.

Oats

- About 55% of the oats grown in the United States are harvested for grain. Of this, about 50% is fed to livestock; 25% used for food, seed, and industrial uses; about 2% is exported to foreign customers; and the remainder is stored for future use.
- The remaining 45% of oat acreage is used for grazing cattle or sheep, as a cover crop to protect farmland from wind or water erosion, or as oat hay used as winter forage feed for livestock.

As indicated, wheat and small grain producers have three basic options, or choices, for marketing their crop: (1) harvest for grain only, (2) use for grazing and then harvest for grain, or (3) use in a forage system exclusively.

Most of the small grains produced in Missouri are harvested and marketed as grain. After harvest producers have two choices: (1) they must decide to price and sell the grain or (2) hold the grain. If they decide to price and sell the grain, they must then choose the most appropriate method of pricing - cash sale, forward contract, or hedging.

If producers decide to hold the grain (not to sell at harvest), they must choose the most appropriate method of retaining ownership. At least two methods of holding grain may be available to a producer. The first and most obvious method is to retain ownership through storage. For a period following harvest, the producer stores the grain and incurs the cost of that storage and the cost of the interest lost on the money not received from selling. For grain commodities traded on the futures market, such as wheat, producers can use an alternative method and buy a futures contract to replace cash grain sales. In this case the producer owns a futures contract rather than the actual stored grain. However, the idea is the same because the producer is speculating on higher cash grain prices. By owning futures contracts, the producer is speculating on higher futures prices.

Some grain buyers also offer producers the opportunity to price grain some time after delivery or some time after the title of the grain has passed to the buyer. These deferred pricing agreements are alternative methods of speculating on price changes. Although the ownership of the grain is transferred to the buyer, the producer retains the opportunity to benefit from higher prices. Producers also run the risk of lower prices, just as with ownership of grain in storage on their farms or owning a futures contract.

Deciding to use the crop for grazing and then harvesting is a second marketing option. If other forages (traditional pasture, hay stocks, etc.) are low or depleted, or if the planting date, growing conditions, and moisture levels have produced expected growth for the vegetative stage of the grain crop, producers may choose to harvest part of the crop through grazing. Therefore, one method, or option, of marketing the wheat or small grain crop could be through the extra weight produced through the livestock operation. Research has shown that if managed properly, there is almost no effect on grain yields of wheat grazed in the fall and some in the spring. This method of grazing requires removal of the livestock before the plant's jointing stage in the fall and application of fertilizer in the spring after grazing animals are removed.

Some grain crops, such as oats, may be used solely for forage use. Cattle producers may use the oat crop for some early spring pasture; remove the animals; and then cut, bale, and store the forage for use the following winter. Determining the value, or net returns, from marketing the entire crop or part of the crop through livestock feeding may be difficult to determine. Production costs are figured the same as with harvesting the grain and selling it on the cash or futures market; however, the value received would depend on livestock-related factors. The genetic potential of the animals, feed conversions, and setbacks to the animals through disease and/or parasites will affect the value received through the forage.

Determining When to Sell, Feed, or Store

Good marketing takes planning, selling discipline, and a clear picture of pricing and delivery alternatives. Marketing goals should aim to net higher returns than average prices for the entire crop, not just one truckload. Producers often sell for reasons not related to maximizing returns: bin space is limited, fertilizer payments are due, the end of the year is near, the weather is good with the promise of bumper future crops, or they are simply making room for the next year's crop.

Experienced marketers have two things in common - a market plan and a selling discipline. Planning to market means assessing costs of production and the appetite for risk at the individuals level. Keep in mind, accepting total risk runs the chance of not being in business next year.

One of the first things producers must consider before determining whether to sell, feed, or store the grain is the cost of production. Knowing exact breakevens using realistic yield expectations and assessing the producer's ability to control production risk must also be assessed. Establish a profit goal to arrive at a minimum selling target price.

Another option to consider is spreading sales over a 12- to 24-month period. Spreading sales allows the opportunity to price into three or four market rallies in an average crop year. Experienced marketers seldom incorporate all or nothing approaches to selling their grain. They will also try to avoid heavy delivery points during the year. Price slumps contribute seasonally to the price of grain. Some typical periods to avoid are during harvest, during 90-day storage expiration periods, and during cash flow selling periods such as in the spring.

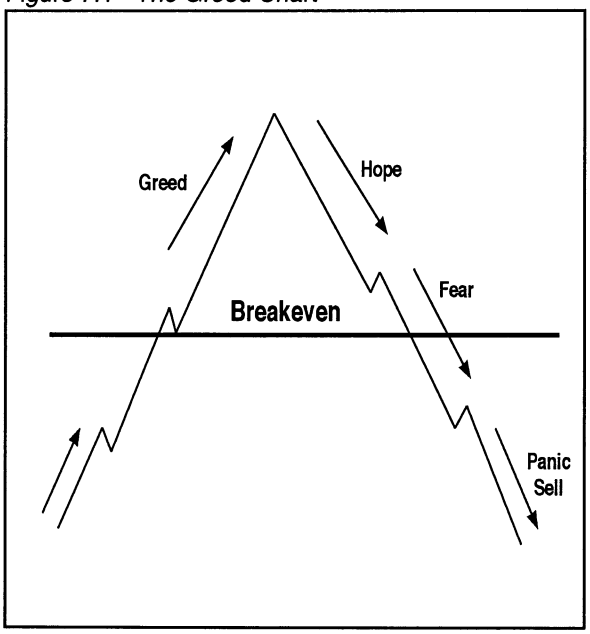
Another key to market determination is staying informed. Gather sources of information. Direct contact by telephone is still the most powerful marketing tool and information source. When deciding to sell, producers should contact a variety of sources. Maintaining regular contact with local buyers, grain dealers, millers, commodity brokers, and market analysts will provide well-rounded opinions required to make selling decisions. Additional information and market knowledge can be gained from the Internet, printed market reports, and television and radio market news services.

An experienced marketer will also have a thorough understanding of the terms and details of contracts used. Each grain dealer may have terms specific to the individual company.

The most common farm selling strategy is the "wait and see" approach. Often, producers store grain on a farm until cash flow needs dictate that they sell. Greed can distort sound marketing judgments. Marketing requires pricing discipline to control ego. See Figure 7.1.

The typical reaction to an upward (bullish) market is greed. Prices are rising, so grain marketers hold back deliveries in an attempt to sell at the top. Once the market peaks and starts to decline, greed turns to hope that prices recover, so producers do not sell. The market continues to fall and hope now turns to fear. Some producers are still reluctant to sell. Local cash bids are now too

Figure 7.1 - The Greed Chart



low to cover costs of production, so grain remains in farm storage. The market fails to recover. Now, fear has turned to panic, bills are due and cash grain is sold to cover payments.

Good marketing principles are just the beginning. To sell into the top 1/3 of the average yearly prices requires designing a personal marketing plan with discipline and market awareness.

Grain Quality and Effect on Price

The quality of small grains, such as wheat, is characterized by its protein content, strength of gluten, weight per bushel, amount of dockage, grades, milling data, and physical dough analysis. These qualities have an impact on the use of the grain for flour and therefore its price in the marketplace.

Information on grain quality indicated by its grade helps producers obtain the best prices. Grain traders (buyers) are also in a better position to know if the quality of the small grains meets their requirements and direct their purchases accordingly.

Tables 7.1, 7.2, and 7.3 describe the characteristics of wheat, barley, and oats to qualify for placement into a numerical grade.

An example of how these grades relate to prices received can be obtained from a description of a futures contract on the Chicago Board of Trade. A futures contract not only includes the size or number of bushels of the contract, the contract price, date of delivery, etc., it also states the "quality" or "grade" of grain contracted. For example, a wheat contract is priced on the delivery of U.S. No. 2 grain. If the producer delivers U.S. No. 1 grain, a 1 1/2¢ per bushel premium will be received. If the grain grades as U.S. No. 3, then a 3¢ per bushel discount, or dock, will be imposed.

Effect of International Markets

Markets for U.S. agricultural products have undergone an enormous change over the past few decades. World markets have replaced domestic markets in determining farm prices and income. Consequently, world markets dictate the state of rural agricultural economy in the United States. This transformation means U.S. agriculture and producers must compete and survive in a complicated global economic environment. This internationalization of U.S. agriculture creates many opportunities and challenges.

What does this mean to producers of wheat and other small grains in Missouri? First and most obviously, it means that markets exist where they would not have existed before. These markets must be identified and cultivated. Missouri, as well as other agricultural states, has developed International Marketing Specialists with offices in several foreign countries. They seek out markets and promote the sale of various agricultural products.

Wheat is the principal food grain in the United States and throughout the world. The United States is the third largest wheat producer in the world, accounting for about 11% of world production. Price determination for wheat is controlled by the interaction of the supply and demand factors, some of which are influenced by governmental policies. These price-determining factors are also influenced by growing (weather-related) and market (use-related) conditions in other countries.

Supply factors that affect price include beginning or carryover stocks of grain from the previous

Table 7.1 - Grades and Grade Requirements for Wheat

Grading Factors	Grades U.S. Nos.				
	1	2	3	4	5
Minimum pound limits of:					
Test weight per bushel					
Hard Red Spring or White Club wheat	58.0	57.0	55.0	53.0	50.0
All other classes and subclasses	60.0	58.0	56.0	54.0	51.0
Maximum % limits of:					
Defects:					
Damaged kernels					
Heat (part of total)	0.2	0.2	0.5	1.0	3.0
Total[1]	2.0	4.0	7.0	10.0	15.0
Foreign material	0.4	0.7	1.3	3.0	5.0
Shrunken and broken kernels	3.0	5.0	8.0	12.0	20.0
Total	3.0	5.0	8.0	12.0	20.0
Wheat of other classes[2]					
Contrasting classes	1.0	2.0	3.0	10.0	10.0
Total[3]	3.0	5.0	10.0	10.0	10.0
Stones	0.1	0.1	0.1	0.1	0.1
Maximum count limits of:					
Other material:					
Animal filth	1	1	1	1	1
Castor beans	1	1	1	1	1
Crotalaria seeds	2	2	2	2	2
Glass	0	0	0	0	0
Stones	3	3	3	3	3
Unknown foreign substances	3	3	3	3	3
Total[4]	4	4	4	4	4
Insect-damaged kernels in 100 grams	31	31	31	31	31

U.S. Sample grade is wheat that:
(a) Does not meet the requirements for U.S. Nos. 1, 2, 3, 4, or 5; or
(b) Has a musty, sour, or commercially objectionable foreign odor (except smut or garlic odor); or
(c) Is heating or of distinctly low quality

Table 7.2 - Grades and Grade Requirements for Barley

Grade	Minimum limits of		Maximum limits of				
	Test weight per bushel (pounds)	Sound barley (%)	Damaged kernels[5] (%)	Heat-damaged kernels (%)	Foreign material (%)	Broken kernels (%)	Thin barley (%)
U.S. No. 1	47.0	97.0	2.0	0.2	1.0	4.0	10.0
U.S. No. 2	45.0	94.0	4.0	0.3	2.0	8.0	15.0
U.S. No. 3	43.0	90.0	6.0	0.5	3.0	12.0	25.0
U.S.No. 4	40.0	85.0	8.0	1.0	4.0	18.0	35.0
U.S.No. 5	36.0	75.0	10.0	3.0	5.0	28.0	75.0

U.S. Sample grade is barley that:
(a) Does not meet the requirements for the grades U.S. Nos. 1, 2,3,4, or 5; or
(b) Contains 8 or more stones or any number of stones that have an aggregate weight in excess of 0.2% of the sample weight, 2 or more pieces of glass, 3 or more crotalaria seeds (*Crotalaria* spp.), 2 or more castor beans (*Ricinus communis* L.) 4 or more particles of an unknown foreign substance(s) or a commonly recognized harmful or toxic substance(s), 8 or more cocklebur (*Xanthium* spp.) or similar seeds singly or in combination, 10 or more rodent pellets, bird droppings, or equivalent quantity of other animal filth per 1 ⅛ to 1 ¼ quarts of barley; or
(c) Has a musty, sour, or commercially objectionable foreign odor (except smut or garlic odor); or
(d) Is heating or otherwise of distinctly low quality.

[1]Includes damaged kernels (total), foreign material, and shrunken and broken kernels.
[2]Unclassed wheat of any grade may contain not more than 10.0 % of wheat of other classes.
[3]Includes contrasting classes.
[4]Includes any combination of animal filth, castor beans, crotalaria seeds, glass, stones, or unknown foreign substance.
[5]Includes heat-damaged kernels. Injured-by-frost kernels and injured-by-mold kernels are not considered damaged kernels.

Table 7.3 - Grades and Grade Requirements for Oats

Grade	Minimum limits		Maximum limits		
	Test weight per bushel (pounds)	Sound oats (%)	Heat-damaged kernels (%)	Foreign material (%)	Wild oats (%)
U.S. No. 1	36.0	97.0	0.1	2.0	2.0
U.S. No. 2	33.0	94.0	0.3	3.0	3.0
U.S. No. 3[6]	30.0	90.0	1.0	4.0	5.0
U.S. No. 4[7]	27.0	80.0	3.0	5.0	10.0
U.S. Sample grade are oats that: (a) Do not meet the requirements for the grades U.S. Nos. 1, 2, 3, or 4; or (b) Contain 8 or more stones that have an aggregate weight in excess of 0.2% of the sample weight, 2 or more pieces of glass, 3 or more crotalaria seeds (*Crotalaria* spp.), 2 or more castor beans (*Ricinus communis* L.) , 4 or more particles of an unknown foreign substance(s) or a commonly recognized harmful or toxic substance(s), 8 or more cocklebur (*Xanthium* spp.) or similar seeds singly or in combination, 10 or more rodent pellets, bird droppings, or equivalent quantity of other animal filth per 1 ⅛ to 1 ¼ quarts of oats; or (c) Have a musty, sour, or commercially objectionable foreign odor (except smut or garlic odor); or (d) Are heating or otherwise of distinctly low quality.					

year's production, import amounts from other countries, and the amount of grain produced in the United States and other countries. Demand factors include food, seed, and industrial uses of wheat, the feed usage for livestock, and wheat exported to other countries.

Since wheat can be grown in more climates than some other major U.S. crops (corn and soybeans), the United States has a less dominant role in the international wheat market than with global corn and soybean markets. The major wheat competitors include the European Union (EU), Canada, Australia, and Argentina. A crop shortfall in one of these major wheat-producing countries can increase the demand for U.S. exports, strengthening U.S. prices. An abundant crop in one of these importing countries can reduce demand for U.S. wheat exports, lowering U.S. prices.

As stated, the major exporters of wheat are the United States, the European Union, Argentina, Australia, and Canada. The major importers of wheat include North African nations of Algeria, Morocco, and Egypt, the Middle Eastern nation of Iran, the Asian nations of China, Indonesia, Philippines, and Pakistan, and former Soviet Union countries of Kazakstan, Russia, and Ukraine.

Another factor related to international grain markets is government programs that contribute to carryover stocks of wheat. The Food Security Wheat Reserve (FSWR) was created in the 1980/81 marketing year to provide government-held reserves of wheat for emergency food needs in developing countries. This was replaced by the 1996 Farm Act with the Food Security Commodity Reserve (FSCR) that included other grains. In 1996, this amounted to 93 million bushels of wheat. These carryover stocks have an inverse relationship with wheat prices. If ending year stocks decline, farm prices for wheat tend to increase.

Global carryover of wheat stocks also affects the international wheat market. As global stocks decline, world wheat prices tend to increase. Their effect on global wheat prices also follows an inverse relationship. At the end of the last century (1999/2000), wheat stocks were approaching a 20-year low, causing a strengthening of wheat prices internationally.

Summary

To be successful in marketing a small grain crop, producers must understand their marketing options and have a thorough knowledge of the grain marketing process. The three basic options would include harvesting and marketing the entire grain crop, using part of the crop as forage for livestock and then harvesting and selling the grain, or harvesting the crop completely as a forage by pasturing or baling it for livestock use. Most of the small grain crops in Missouri are harvested as grain and either sold on the cash market or marketed with the purchase of a futures contract. Both involve some risk; however, if the producer is an informed marketer who develops a market plan, this risk may be reduced. The producer must also be aware of the factors that affect grain quality because grain quality has a direct effect on the price for grain when sold. In today's

[6]Oats that are slightly weathered shall be graded not higher than U.S. No. 3.

[7]Oats that are badly stained or materially weathered shall be graded not higher than U.S. No. 4.

agriculture, what happens with international grain production and markets greatly affect the prices of U.S. commodities such as wheat.

Credits

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Lesson 8: Figuring Crop Costs

The most important step in figuring crop costs is to keep an accurate and complete set of records of all costs incurred to produce the wheat or small grain crop. An approved accounting system must be adopted and understood by the producer to be worthwhile. Time must be planned during the season to record and enter costs. Time must be planned during the nongrowing season to analyze these costs and make changes to improve the net returns.

Variable Costs

To determine the break-even costs of wheat or small grain crops, producers must be able to determine all variable costs. Variable costs are also known as operating costs. These costs increase or decrease with the volume of output. For example, to obtain a greater yield from the small grain production, the plant population should be increased. This means that additional seed must be purchased and thereby increase the cost. Decreasing planting rates requires less seed, but the yield will also be less. Other types of variable costs include fertilizer, chemicals, and labor.

Detailed records are necessary to allot costs correctly. For example, farm utilities include electricity expenses. These can be from crop drying or ventilation and lighting for the farrowing facility. Applying the entire electric bill to crop production would be incorrect. Some form of monitoring must be done to appropriate costs to the proper enterprises.

Table 8.1 gives examples and amounts of possible variable costs that may be incurred with a wheat crop. These figures were received from the MIR (mail in records) enterprise records for the 1998 Missouri average crop costs publication assembled by the University of Missouri Extension Service.

Fixed Costs

As with variable costs, producers must also know their fixed costs of producing an acre of wheat or other small grain to determine net returns. Fixed costs, also known as ownership costs, are costs that are unavoidable. Whether the farm produces at a record pace or nothing at all, fixed costs must be paid. They include such expenses as land rent or mortgage payments, insurance, and taxes. Insurance costs include premiums directly related to the farm business, not personal health or life insurance. Cash rent/mortgage includes interest and principal due in the coming year.

Table 8.1 - Variable Costs for Wheat per Acre

Number of farms reporting	54
Average number of acres	157
Average yield/acre (bushels)	51
Average Variable Costs/Acre	
Seed	$ 15.26
Plant food (fertilizer and lime)	38.33
Crop chemicals and materials	1.70
Machinery fuel, oil, and repair	19.22
Machinery hire and services	5.36
Average labor cost/acre	16.06
Taxes and insurance	2.25
Miscellaneous	10.38
Operating interest	6.13
Total Variable Costs/Acre	$114.69

Table 8.2 gives examples and amounts of possible fixed costs that may be incurred with a wheat crop. These figures were received from the MIR (mail in record) enterprise records for 1998 Missouri average crop costs publication assembled by the University of Missouri Extension Service.

Table 8.2 - Wheat Fixed Costs per Acre

Average Fixed Costs/Acre	
Machinery depreciation and interest	$ 24.71
Land costs	82.82
Total Fixed Costs/Acre	$ 107.53

Determining an Acceptable Return on Investment

The decision to produce wheat or other small grains will depend primarily on the costs and expected returns for these crops in comparison with other crop alternatives. Type and amount of equipment, crop rotations, and farm size all affect the cost of producing crops. Tillage practices used and their timing also affect yields and production costs. Expected returns above costs for the farm operation must be computed to select the crops and the acreage of each crop to produce.

Returns above costs will depend on yields and prices received for that crop. Producers should use yields and prices (per bushel) that are reasonable for their location in the state. According to information from the University of Missouri Extension Service, the total cost of production (fixed and variable) in 1998 was $222.22. Using an average yield of 51 bushels per acre for that same year, the producer would need to receive $4.36 per bushel to break even.

Calculating Cost per Acre

As indicated above, the total cost of production per acre is determined by adding the total variable (operating) costs with the total fixed (ownership) costs.

Summary

Only through complete and accurate records can wheat or small grain producers determine crop costs. These costs are a total of the variable and fixed costs incurred in producing the crop. They are usually figured on a per-acre basis. Variable costs are those costs that will increase or decrease with production goals. These include seed, fertilizer, and chemicals. Fixed costs are those costs that must be paid and will be the same no matter what the level of production or yield. These include depreciation and taxes on the producer's equipment and land. Total costs are determined by adding all fixed and variable costs.

Credits

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Lesson 1: Planning the Crop

Use of forages for feeding livestock has been in place since humans first domesticated animals. Forages, especially native grasses, are very hardy and easily grow under any number of different conditions. The first farmers in Missouri profited from the abundant native plants to help feed their animals. Today, over half the feed given to Missouri livestock is produced in the state.

Forages are economically important in the production of animal and animal products. When planted on lower quality farmland, forages can increase the land's economic importance by producing a crop that can be converted into meat and milk products.

Forages, hay and pasture crops, are the most widely produced crops in the United States with 475 million acres of pasture and rangeland and 61 million acres of hay. As noted in the first lesson of Unit I, Missouri ranks second in the nation for hay production, excluding alfalfa, and fourth in all hay production. This and the fact that Missouri is second in the production of beef cows emphasize the importance of forage production within the state.

What Is a Forage?

Forage is the vegetative material (leaves and stems) of plants used as livestock feed. In Missouri, forages primarily consist of multiple varieties of grasses and/or legumes but can include grain crops such as corn and grain sorghum or stalks from harvested crops. Forages are used in three different forms, or forage productions systems: (1) fresh (pasture), (2) dried (hay), and (3) ensiled (silage or haylage). This lesson will focus primarily on the production of pasture and hay forages as silage is discussed in Unit VI, Corn and Grain Sorghum Production.

Differences of Forage Crops

Forage crops are typically grown for the intended purpose of being used as livestock feed. Producers must be aware of the differences in hay, pasture, and silage/haylage crops to make effective management decisions.

The hay crop is managed in much the same way as a grain crop. It requires knowledge in management skills, the necessary equipment for seedbed preparation and/or maintenance, fertilization, planting, harvesting, transporting, and short-term or long-term storage capabilities. Hay is primarily harvested by mechanical methods but can be grazed. Grazing is most often used in hay production to delay or eliminate a cutting (one complete harvest cycle). Hay crops require special attention when cutting, drying, and storing to maintain crop nutrients. Exposure to rainfall after cutting and before and after baling should be avoided because excessive moisture can rot hay. Also, the nutritional content and palatability of baled hay will gradually be depleted with long-term storage, so timely use or marketing is recommended.

Pasture production also requires specific knowledge and management skills. Equipment needs are generally less because harvesting is done primarily through livestock grazing. Due to this harvest method, permanent pasture crop areas must be fenced and maintained. There are existing perennial grasses and legumes that can be either improved or nonimproved. Improvements to pastures include fertilizer applications and seedings of additional grasses and/or legumes, especially varieties that extend the grazing season and improve nutritional value. Unimproved permanent pastures use natural grassland vegetation but still require good grazing management decisions to maintain a good crop.

Temporary or rotational pastures are seeded annually for summer and winter grazing needs or as needed in a crop rotation system. Wheat and small grains are commonly used for winter and early spring grazing, whereas millet and sorghum are seeded for summer grazing. The stalk fields remaining after grain harvest of these and other grain crops can be grazed as temporary forage pastures. These temporary pasture crops will generally require the installation of temporary fencing.

Silage is preserved in moist, succulent conditions by partial fermentation in a tight container. The moisture content at harvest is generally greater than 50%. A forage harvester is used to chop the crop for easier handling and better packing in a silo. There is little to no loss from shattering, leaching, or bleaching. Weather conditions are less dependent on extended periods of favorable weather. Plants used as silage must contain sufficient carbohydrates for fermentation and low

amounts of calcium and protein. A relatively new method of harvesting is round bale silage. This method uses forage of a relatively high moisture content. It is baled with a round baler and then stored in a sealed container, usually a plastic bag. Baled silage is more likely to spoil than silage in traditional silos.

Haylage is forage that could have been cut for hay but is stored with a higher moisture content than hay, but with less moisture than silage. The moisture content at harvest is generally below 50%. The lower moisture limits bacterial action. High levels of carbon dioxide from respiration create good preservation conditions. Livestock find haylage more palatable than high moisture silage.

Evaluating a Forage Site

Introduction of forages into an agricultural system can be a very complex undertaking. There is a large variety of forages available to producers. The types of forage systems that can be in operation (pasture, hay, silage, or a combination system) are important to evaluate current site characteristics to determine what forage system can be started. When evaluating a site, a producer must consider the following questions:

- What is the intended use of the forage crop from the site?
- What are the existing forages on the site or what was the previous crop?
- Does the site's topography limit forage species and/or intended use of a crop?
- Does the site's soil (type and fertility) limit forage species and/or intended use of a crop?

Intended Use of Forage

Site evaluations must first consider the intended use of the forage to be produced, whether for hay, pasture, or silage/haylage. By considering the intended use, specific characteristics of existing or planned forage varieties can be evaluated.

Producers must keep in mind that forages used in hay and silage/haylage sites are to be harvested for later feed use or sale. Therefore, these crops need to have higher yield characteristics to offset harvesting and marketing costs. Hay and silage/haylage crops must also be able to withstand harvesting pressure or the repeated cutting or harvesting of a crop. The ability to withstand this pressure will affect the quickness of regrowth, amount of forage developed between cuttings, future season cuttings, and the longevity of the forage stand.

Pasture forages should be evaluated knowing they are to be consumed directly by animals. This intended use requires forage varieties adapted for rapid growth and tolerant of hoof traffic and soil compaction. If current forage varieties do not have these characteristics, the site will need to be improved. These forages should be able to use the poorer soils and topography that are typically associated with pasture sites.

Existing Forages or Previous Crop

Producers must consider any existing forages or what crop was previously planted when evaluating the selected forage site. If new forages are to be introduced into an existing forage stand, the producer should introduce forage species that complement the existing crop and will enhance the overall forage quality. When dealing with previous crops, producers must be aware of any carryover herbicides, pesticides, insecticides, and fertilizer applications that could affect new forage growth. Producers must know the regrowth ability of the previous crop, especially in new forage stands. These stands are developed as pure quality stands, and any regrowth of the previous crop would reduce the quality and may become a weed problem.

Topography

Topography deals with the visual surface of the land. Elevation is one consideration. Because some plant species tend to be elevation specific, they may grow better at some elevations. The elevation in Missouri is fairly consistent so this is not a major concern in this area. Another consideration is slope of the land. Slope will determine the erosion hazard and the amount of available topsoil. Other considerations, such as stoniness, weeds, amount of brush, and the amount of boggy or marshy soils are all considerations that may limit available existing forage and possible improvements. This will be a determining factor for forages planted for harvest or pasture and will affect the amount of time and money needed to establish a forage crop.

Soil

The condition of the soil or soil quality is an additional factor to be considered in forage establishment and production. This includes soil type and texture, drainage, and fertility. Soil type and texture will determine the types of forages that will be most productive. For example, most legumes prefer deep loams, but there have been acceptable results with any well-drained soils. Grasses tend to be less particular about soil conditions; some are better suited to wet soils and others are adaptable to dry, unirrigated soils.

Soil drainage is another important factor. Many forages can tolerate a short duration of flooding. However, long-term, poorly drained soils will affect the forage species to be planted. Legumes, such as alfalfa, require well-drained soils, while birdsfoot trefoil is tolerant of wet, moderately well-drained soils and alsike clover is very tolerant of wet locations. With grasses, tall fescue is tolerant of wet soils where reed canarygrass is best adapted to wet, marshy areas.

Soil fertility is another consideration. Recommendations for planting can be based upon soil tests. Legumes typically require 6.5 to 7.5 pH with alfalfa being the most sensitive. Grasses are more tolerant and prefer 5.5 to 7.0 pH with some species accepting pH ranges as low as 4.0 or as high as 9.0. Nitrogen (N) is used as a starter to aid in forage establishment. Legumes require 10 to 20 pounds per acre and grasses need 20 to 40 pounds per acre. The incorporation of phosphorous and potassium before planting is needed because these minerals are not mobile in the soil. Optimum P for grasses and legumes is 140 pounds per acre and optimum K is 200 pounds per acre.

Summary

Forage production is a major industry in relation to the use of forages in livestock production. Forages, especially native grasses, are very hardy and easily grow under many different conditions. The decision to establish a forage crop and the factors in determining the types of forages to establish are all major considerations in this decision. Management decisions include the intended use of the forage, existing forages, previous crops, topography, and soil.

Credits

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Lesson 2: Selecting a Variety

Forage plants are suitable for specific production situations. Each has distinct advantages and disadvantages. The selection of forage crops to be produced should be based upon certain characteristics along with their adaptation to the soil, climatic conditions, and intended use. The following lesson will discuss various forages and how they can be used in hay and pasture production.

Cool-season Grasses

Cool-season grasses are plants exhibiting vigorous growth habits in the spring and fall months. These plants turn green and initiate new growth as temperatures warm in the early spring, typically in late February or early March, or when soil temperatures reach 40°F. As soil and air temperatures rise and spring rains occur, cool-season grasses begin a period of rapid growth. Optimum growth occurs when air temperatures reach 59°F to 77°F in late spring and then when they fall to this same temperature in early to mid-fall months.

During summer months, cool-season plant growth slows and plants become brown and dormant. This occurs due to their inefficient use of water and sunlight energy during hot and dry weather conditions. The temperature at which summer dormancy occurs varies by grass species. Irrigation can prolong cool-season grass growth in the summer months; however, growth potential will not reach that of early spring and fall production. Some cool-season grasses may remain green during mild winters, extending grazing use in fall and spring.

Table 2.1 lists the most common cool-season perennial and annual grasses grown in Missouri along with the advantages and disadvantages of each.

Table 2.1 - Cool-season Grasses

Name	Advantages	Disadvantages
Kentucky Bluegrass *Poa pratenis* Perennial	▸ Well adapted to the glacial and loessal (windblown) soils ▸ Most productive during cool, moist spring and early summer ▸ Palatable to all livestock ▸ Nutritious, rich in minerals and vitamins ▸ Ideal companion for common white clover ▸ Spreads by underground rhizomes, maintains dense stand on suitable soil ▸ Best used for pastures	▸ Dormant and unproductive during late summer ▸ Requires high phosphorus and lime soils ▸ Consistently low yields ▸ Unsatisfactory yields for hay
Orchardgrass *Dactylis glomerata* Perennial	▸ Adapted best to rich soils; relatively well adapted to light, medium fertility and moist, heavy soils ▸ More tolerant to heat, drought, and low fertility than bromegrass ▸ Shade tolerant ▸ Rapid establishment ▸ Rapid regrowth after cutting or grazing ▸ Good second and third growth ▸ Used primarily for pasture with legumes	▸ Moderately winter hardy ▸ Coarse and unpalatable at maturity ▸ Less nutritious than bromegrass or timothy ▸ Very competitive with legumes ▸ High nitrogen requirement for good production in pure stands
Reed Canarygrass *Phalaris arundinacea* Perennial	▸ Long lived, sod-forming, leafy perennial ▸ Flood tolerant and high yielding ▸ Good growth during summer ▸ Drought resistant ▸ Palatable to most livestock	▸ Requires heavy nitrogen applications ▸ Germinates slowly and competes poorly ▸ Expensive ▸ Must be carefully managed to maintain palatability (mow before seed heads emerge)

Name	Advantages	Disadvantages
Smooth Bromegrass *Bromus inermis* Perennial	▸ Best adapted to high to moderate rainfall and cool summer temperatures ▸ Best adapted to deeper, better soils ▸ Very winter hardy and drought resistant ▸ Palatable to all livestock ▸ Fits well into grass-legume mixtures ▸ Used for pasture or hay	▸ Seed fluffy and difficult to sow ▸ Slow establishment ▸ Cannot stand extended periods of hot, dry weather ▸ Weakened by heavy grazing ▸ Low productivity when grown along with nitrogen ▸ Low productivity in second and third growth
Tall Fescue *Festuca arundinacea* Perennial	▸ Adapted to a wide range of soil and climatic conditions ▸ Well adapted to shallow, droughty ridge soil due to high drought resistance ▸ Survives on wet, poorly drained soil ▸ Easy to establish satisfactory stand ▸ Can be grazed closely ▸ Combines well with legumes ▸ Good regrowth after harvesting ▸ Resists trampling damage in low, wet areas ▸ Best used for pasture	▸ Lack of palatability, especially for hay and silage ▸ Fescue toxicity ▸ Possibility of physiological disorders in livestock, e.g., "fescue foot" ▸ Very competitive with associated legumes ▸ Dormant during periods of high temperatures
Timothy *Phleum pratense* Perennial	▸ Winter hardy, well adapted to cool humid climate ▸ Adapted to a wide range of soil conditions - best growth on clay or silt loam soils that are moderately well drained ▸ Seed usually plentiful and low priced ▸ Rapid stand establishment ▸ Good yields starting in first hay year ▸ Little competition with legumes in mixtures ▸ An ideal companion for birdsfoot trefoil ▸ Easy to harvest and cure ▸ Widely used for pasture, hay, and silage	▸ Less productive than orchardgrass or tall fescue ▸ Susceptible to heat and low moisture conditions ▸ Low palatability and feed value at mature stages ▸ Easily weakened by heavy grazing or frequent cutting ▸ Produces an open sod
Small Grains (Barley, Oats, Rye, Triticale, Wheat) Annuals	▸ Easy stand establishment ▸ Provides early spring, late fall, and winter grazing ▸ Well adapted for double crop	▸ Must be planted annually ▸ Costly ground preparation ▸ Soil erosion

Warm-season Grasses

Warm-season grasses are plants that exhibit vigorous growth in the early spring and summer months. These grasses begin to turn green and initiate new growth as the soil temperatures reach 60°F in the spring. Optimum growth of these grasses occurs when air temperatures reach and maintain a 77°F to 104°F range.

Annual warm-season grasses are often used as pasture, hay, or silage crops throughout Missouri. Their rapid production of high-quality forage during late spring and summer makes them potentially important in summer grazing systems. They work well in rotation with row crops; however, the costs to establish them annually make these crops an expensive source for animal gain compared to perennial forage crops. For the advantages and disadvantages of the most common warm-season perennial and annual grasses grown in Missouri see Table 2.2.

Cool-season and Warm-season Grasses Complement Each Other

A combination of cool- and warm-season grasses will provide a continuous supply of available forage for grazing due to their different growth habits. Warm-season grasses begin their most vigorous growth in the summer whereas cool-season grasses grow best in spring and fall. Ideally, one-third of grass pasture mixtures should be made up of warm-season varieties. The growth periods of these two grasses complement each other and extend the length of crop production in the state of Missouri.

Table 2.2 - Warm-season Grasses

Name	Advantages	Disadvantages
Bermudagrass *Cynodon dactylon* Perennial	▸ Adapted to deep, sandy loam and medium-textured soils. ▸ Prefers pH of 5.5 or above. ▸ Drought resistant	▸ Intrusive into crop fields. ▸ Marked decrease in quality in late summer and fall ▸ Requires more irrigation than other warm-season grasses ▸ Not as winter hardy as other types
Big Bluestem *Andropogon gerardi* Perennial	▸ Adapted to moist, well-drained loams of relatively high fertility ▸ Good summer forage production ▸ Highly palatable to all classes of livestock ▸ Makes good quality hay if mowed before seed heads emerge ▸ Tolerant of close grazing with good recovery if protected during first part of season	▸ Slow establishment ▸ Warm-season producer only
Caucasian Bluestem *Bothriochloa caucasica* Perennial	▸ Suited to marginal cropland ▸ Used in land reclamation ▸ High crop yields ▸ Excellent stand persistence ▸ Withstands heavy stocking rates	▸ Not adapted to extremely sandy, loose soils ▸ Not tolerant of wetland soils ▸ Lacks winter hardiness, not adaptable to northern Missouri
Eastern Gama Grass *Tripsacum dactyloides* Perennial	▸ Prefers loamy soils with adequate moisture ▸ Tall perennial grass ▸ "Ice Cream" grass - high nutrition and palatability ▸ High production	▸ Doesn't grow as well in upland soils ▸ Because of early growth and palatability, best grown in well-managed pure stand instead of mixture
Indiangrass *Sorghastrum nutans* Perennial	▸ Provides quick ground cover after seeding ▸ Productive hay crop	▸ Not widely grown ▸ Excessive nitrogen or untimely application will stimulate weedy grasses detrimental to stands ▸ Should not be grazed until it reaches 8 to 10 inches in height ▸ Avoid overgrazing
Little Bluestem *Schizachyrium scoparium* Perennial	▸ Adapted to a wide range of soils ▸ Valuable in watershed protection ▸ Good hay and pasture qualities	▸ Does not do well in wet soils ▸ Requires precise grazing/haying management
Sideoats Gramagrass *Bouteloua curtipendula* Perennial	▸ Grows in shallow soils ▸ Good pasture source for livestock and wildlife ▸ Stand should be well established before use ▸ Good nutrient quality	▸ Not adapted to wet, sandy, or saline soils ▸ Harvest should not be over one-half the growing leaf material
Switchgrass *Panicum virgatum* Perennial	▸ Adapted to soils that are medium textured to sandy ▸ High yield late spring/ early summer ▸ Easy to seed ▸ Abundance of high-quality seed ▸ Easy to establish satisfactory stand	▸ Warm-season producer only ▸ Less palatable at maturity ▸ Poor competition with other grasses ▸ Poor regrowth potential

Name	Advantages	Disadvantages
Pearl Millet *Digitaria sanguinalis* Annual	▸ Tolerant of acidic sites. ▸ Drought tolerant	▸ Needs well-drained soils
Sorghum-Sudan grass & Hybrids *S. bicolor* Annuals	▸ Provides abundant grazing during warm summer months ▸ Best adapted to deep, moderately to highly fertile soils ▸ Drought resistant ▸ Can be used as warm-season emergency or supplemental pasture, hay, green chop, or silage	▸ Has to be established annually ▸ Warm growing season required for best results ▸ Susceptible to low temperatures ▸ Heavy nitrogen user ▸ Prussic acid poisoning of livestock ▸ Difficult to cure as hay ▸ Nitrate poisoning in dry seasons

When cool- and warm-season grasses are combined in pasture situations, they provide other benefits as well. Combining complementary varieties provides a good balance of nutritional quality throughout the grazing season and reduces the risks of crop losses from changes in weather conditions, plant-specific diseases, insect outbreaks, and various factors that may affect pure crop stands.

Forage Legumes

Another plant type commonly used in forage production are forage legumes. Legumes are broad-leafed plants capable of "fixing" their own nitrogen. These plants tend to be higher in digestible proteins than grasses and typically are a higher-producing forage when compared to grasses.

Alfalfa is the most productive legume, with potential yields of up to 6 tons per acre on good soils. Alfalfa is productive into the midsummer under nondrought conditions. This legume establishes a deep taproot and can be productive for 5 or more years under proper management conditions. When selecting alfalfa, use productive, disease-resistant varieties that are adapted to Missouri conditions. Good management practices for alfalfa include timely harvesting at the proper growth stage; control of insects, diseases, and weeds; and nutrient replacement.

Although the other major legumes are not as productive as alfalfa, each has potential benefits in forage systems. Depending upon soil conditions, erosion hazards, climate, and use, each legume has specific characteristics that fit into diverse growing conditions. Refer to Table 2.3 for the advantages and disadvantages of growing some of the most common forage legumes in Missouri.

Forage Legumes That Complement Various Grasses

Just as a combination of cool- and warm-season grasses can be beneficial to the forage producer, utilizing legumes with grasses can improve forage stands. Legumes can lengthen the growing season of cool-season grasses because they often grow longer into the summer months. Legumes also enhance the soil quality by increasing nitrogen levels in the soil and provide added nutrients for the growth of grass species.

When combined with grasses, legumes provide more available nutritional components for livestock in both pastures and harvested forages. With a higher protein yield per acre, the added nutrition can lead to increases in average animal gain and weaning weights. Also, better nutritional forage can increase animal conception rates and decrease herd health problems.

Forage improvement with legumes is never final. Even under the best weather and management conditions, legumes will not last indefinitely. Drought is very damaging, especially to ladino, alsike, and red clover. Legumes can be reduced or lost in pastures that are overgrazed, lack fertility, are improperly fertilized, or are plagued with diseases or insects. Pastures and fields that receive too much or too little rainfall can severely affect legume growth.

Using Small Grains in a Pasture Management System

A variety of small grains can be used in forage systems, both during forage establishment and to augment existing pasture quality. One grain most commonly used is wheat. Another small grain used, especially in areas with a colder climate, is

Table 2.3 - Forage Legumes

Name	Advantages	Disadvantages
Alfalfa *Medicago sativa* WS Perennial	▸ Adapted to wide range of climatic conditions ▸ Grows best on deep, well-drained, fertile soils ▸ Provides abundance of nutritious feed ▸ Long-lived stands, if properly managed ▸ Drought resistant ▸ Can be grown alone or in grass mixtures	▸ Does not thrive on acid or nonfertile soils ▸ Relatively expensive seed ▸ Problem of bloat if pastured ▸ Stands reduced or destroyed by winter killing
Birdsfoot Trefoil *Lotus corniculatus* CS Perennial	▸ Adapted to a wide range of soil conditions (moisture, pH, and fertility) ▸ Feeding value comparable to alfalfa ▸ Can reseed itself under favorable conditions ▸ Good growth in summer due to deep root system ▸ Can persist better under heavier grazing than alfalfa or red clover ▸ No bloat problem	▸ Difficult to establish good stands ▸ Slow establishment ▸ Slow recovery after grazing ▸ Weak-stemmed when grown alone and lodges easily ▸ Seed shatters easily
Clover, Alsike *Trifolium hybridum* CS Perennial	▸ Can use as specialty legume for wet, poorly drained soils ▸ Cheaper than topdressing w/nitrogen on grass pastures ▸ Highly palatable ▸ Winter hardy	▸ One cut, does not produce in summer except under very moist conditions ▸ Short-lived on droughty, upland soils
Clover, Ladino *Trifolium repens f. Giganteum* CS Perennial	▸ Hardy, less injured by winter heaving ▸ Tolerates wetter soils than alfalfa ▸ Very productive ▸ High in minerals, rich in protein and vitamins, and low in fiber ▸ Reestablishes by natural seeding ▸ Ideal legume in many grass-legume pasture mixtures	▸ Susceptible to long periods of severe drought ▸ Possibility of bloat problems ▸ Poor germination if planted too deep ▸ Continuous grazing will kill out the stand ▸ May have laxative effect on animals
Clover, Red *Trifolium pratense* CS Perennial	▸ More winter hardy than alfalfa ▸ Grows better than alfalfa or sweet clover on slightly acidic or poorly drained soils ▸ High nutritious yields after first year ▸ Rapid stand establishment	▸ Short-lived in pasture mixtures (most red clovers are biennial) ▸ Reduced production during drought ▸ Expensive seed
Clover, Sweet *White - Melilotus alba* *Yellow - Melilotus officinalis* CS Biennial	▸ Adapted to a wide range of soil and climatic conditions ▸ Winter hardy ▸ More resistant to heat and drought than alfalfa ▸ High yielding and excellent for pasture when many pasture plants are present ▸ Low-priced seed	▸ Less palatable due to coumarin content ▸ Spoiled hay or silage may cause "bleeding disease" in cattle ▸ Makes poor hay ▸ Poor recovery after cutting ▸ Very susceptible to black stem, root rot, and virus diseases
Clover, White *Trifolium repens* CS Perennial	▸ Excellent pasture, combines well with grasses ▸ Can be grown on a variety of soils ▸ Reestablishes itself by natural seeding ▸ Will stand close grazing	▸ Sensitive to drought ▸ Lower yields than ladino ▸ Can cause bloat ▸ Difficult to establish
Lespedeza, Korean *Kummerowia stipulacea or K. striata* WS Annual	▸ Productive warm-weather annual ▸ Especially suitable for use on pasture soil of low fertility ▸ Resistant to drought ▸ Fast to obtain good stands ▸ Relatively low seed price ▸ Good quality hay, easy to cure ▸ Excellent source of livestock pasture	▸ Slow growth in spring ▸ Not tolerant to cold weather ▸ High summer temperatures and high humidity necessary for best growth ▸ Slow development (best stands develop after third year)

winter rye because it is the most winter hardy of the small grains. Winter barley and oats are also used with forages; however, rye, barley, and oats are less desirable than wheat as a companion crop because their heavy, early growth competes with young forage seedlings. Pearl millet and winter vetch can also be used.

There are a number of benefits to including small grains in existing pasture systems. Because of the winter growth patterns of small grains, they can provide high-quality pasture forages in winter and spring months. Small grains will also increase pasture yields and can extend the pasture grazing periods.

Using small grains as cover crops for new pastures also provides benefits. Most studies show that cover crops such as wheat reduce weeds, control erosion, and furnish winter protection to young forage seedlings.

Forages Used for Silage or Haylage

Basically, any crop that can be fed green as pasture or harvested for hay can be used for silage or haylage. The difference between these two types of stored feeds is the moisture levels at which they are stored; silage is stored at 60 to 65% moisture and haylage is stored at 40 to 50% moisture.

Some grasses typically grown for silage and haylage are smooth bromegrass, timothy, ryegrass, millets, orchardgrass, sudangrass, and reed canary grass. Legumes used include alfalfa, sweet clover, red clover, ladino clover, alsike clover, soybeans, field peas, vetch, lespedeza, and birdsfoot trefoil. Common grains used are corn, grain sorghum, wheat, oats, barley, rye, and triticale.

Summary

Understanding the growth habits of cool- and warm-season grasses allows a producer to choose pure varieties or mixtures that best fit individual production needs. Each grass type has its advantages and disadvantages and a producer should be knowledgeable of these in order to raise a successful crop. The same applies to forage legumes. By combining legumes and grasses, producers can gain many benefits from pastures and harvested forages. Likewise, small grains can provide added nutrition to existing pastures or protection for new forage crops. Basically, any crop that can be fed green as pasture or harvested for hay can be used for silage or haylage.

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Lesson 3: Selecting a Tillage and Planting Method

Proper seedbed preparation is essential for young plants. There are several types of tillage and planting systems used to establish a forage stand. Pasture improvements should be made to maintain the crop. Soil tests must be done to determine nutritional needs.

Establishing a Forage Stand

Establishing a good stand is critical for profitable forage production. There are three basic types of tillage systems used to prepare the seedbed for forage planting. These types include some type of complete tillage method, reduced tillage, and no-till methods.

When using a complete tillage system, it is usually necessary to deep plow first with an implement such as a moldboard plow to make a mellow, compact, weed- and grass-free seedbed. If limestone and basic applications of mineral fertilizers are needed, they should be applied before plowing and then turned under. Plowing several weeks before seeding will allow time for rain as well as disking, harrowing, and rolling to compact the soil. It will also allow weed seeds to germinate for killing. Starter fertilizers should be applied just before or at the time of seeding. Seeding may then be accomplished by using a drill to apply the seed or broadcasting the seed using a fertilizer type applicator.

Using a reduced tillage method to establish a forage stand may involve the use of a field chisel, followed by drilling or broadcasting the seed. If seeds are broadcast, some type of roller should be used to compress the seed into the soil for better germination.

The no-till method is useful in new plantings on areas that are prone to wind erosion and on steep slopes. This method injects the seed into the soil using some type of "no-till" seeder without any previous tillage. The advantage of this method is the reduced number of trips across the field, which saves costs and reduces the occurrence of soil erosion. Existing vegetation must be effectively killed with postemergence herbicide before planting.

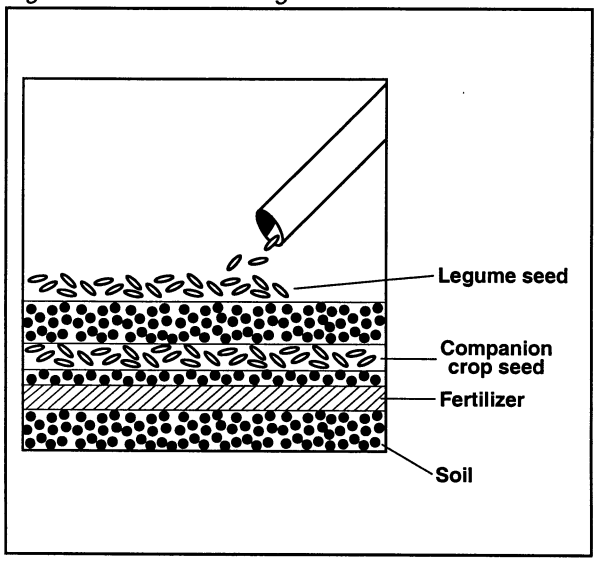
There are four general planting methods used to seed forages: (1) broadcasting, (2) conventional grain drill usage, (3) use of a specialized type of roller, such as a Brillion seeder, and (4) the no-till seeding.

Broadcasting is the least desirable seeding method, especially for late summer seedings, but it is probably the most widely used. Efficiency of broadcast seeding can be greatly increased by rolling or cultipacking the seedbed before planting the seed. Broadcasting can be a satisfactory method of sowing some grasses and legumes on fall-seeded grains in midwinter. A midwinter seeding made when the soil is honeycombed with frost will soon be covered with sufficient soil for germination.

A conventional grain drill equipped with a grass seeding attachment may be used for forages. These are usually short metal tubes that scatter the seed in front of furrow openers. Seeds of similar sizes and weights can be mixed and seeded together. It is difficult to use lighter seed such as orchardgrass mixed with a legume and obtain a uniform distribution with frequent mixing or stirring. The practice of banding, placing the seed directly over the fertilizer, aids in making a stronger and more vigorous forage stand while reducing the seeding rate about one-fourth. Refer to Figure 3.1 for an example of band seeding.

Seeders that will seed and pack in one operation, such as the Brillion seeder, consist of two sets of corrugated rollers with a seed box mounted on top

Figure 3.1 - Band Seeding



of the frame directly between the two rollers. Seed is dropped between the corrugated rollers that pack the soil below the seed and then around it. These seeders do an excellent job of seeding primarily because they ensure a firm seedbed and even distribution of seed that is not sown too deeply in the soil.

The fourth method is no-till seeding, which was discussed earlier as a tillage method. A no-till seeder is used without any previous tillage.

Renovating a Forage Stand

Most Missouri pastures have adequate grass stands but they need legumes added or reestablished. If the soil is capable of growing legumes, they can easily be established in grass stands. Adding a legume to a grass is cheaper than topdressing the grass with nitrogen.

Pasture improvement with legumes is never final. Even under the best weather and management conditions, legumes will not last indefinitely. Legumes are lost from forages by overgrazing, disease, insects, lack of fertility, excess moisture, drought, or any combination of these.

Legumes can be established in grass sods with plowing and without completely losing 1 year's production. Before renovation, check for a broadleaf weed problem. Spray before beginning the renovation, usually in the spring or early summer, before legume establishment is started. There are three general methods of reestablishing legumes in grass sods with a minimum of production loss. However, with any of these methods, success of the new seedlings will depend on adequate moisture, light, and fertility.

Method 1 - Overgraze grass during fall and early winter. Apply lime, phosphorous, and potassium as recommended by soil tests before or during this period. Do not use nitrogen in the fertilizer mix because it stimulates the older grass and decreases the young legume's chances of becoming established.

Broadcast the legume early enough in winter so that freezing or thawing will cover the seed. February seedings have a 50% chance of success than April seedings. Early grass growth should be immediately removed by grazing to allow the legume to establish roots. This step is very necessary for success. Repeat this procedure as needed throughout late March (in southern Missouri) and in April and early May. Clipping will seldom substitute for grazing.

Method 2 - Till the sod in late fall or early winter so that 40 to 50% of the sod is disturbed. During the winter, the legume seed is either broadcast or drilled into the partially opened sod. Do not apply nitrogen fertilizer. Remove the early grass growth by clipping or grazing.

Method 3 - Use a chemical to retard the grass growth. Chemical expenses can be partially offset by not having to till. Seeding is done with no-till equipment.

In most cases, a nonselective herbicide is used. This is a contact killer, so seeding must occur during the growing season - early spring or late summer. Apply the herbicide according to label directions. Too heavy a chemical rate is costly and retards the grass too much, allowing summer weeds to invade. This can be as detrimental to new seedlings as competition of the existing grass sod.

Fertilizer Application Needs for Forage Establishment

Proper soil pH and fertility are essential for optimum economic forage production. Take a soil test to determine soil pH and nutrient status at least 6 months before seeding. This allows time to correct deficiencies in the topsoil zone. The topsoil in fields with acidic subsoils should be maintained at higher pH values than fields with neutral or alkaline soils. Producers maintain topsoil pH at levels of 6.0 to 6.8 depending on whether it is a legume or grass being seeded and depending on the soil type.

Adequate lime is necessary for forage establishment and production. It serves to correct soil acidity and supplies calcium and magnesium. Lime also affects the availability of most of the other essential elements needed for forage production. Phosphorous availability, in particular, increases as the pH is increased. If the soil is extremely acid, it is best to apply part of the lime at least 6 months before seeding.

Seeds can germinate with or without fertilizer but young plants will soon use the small amounts of nutrients in the seed. They are then dependent on the level of fertility around them for development.

Most research shows that available phosphorous applied at seeding time and proper placement are the key elements in establishing legumes and grasses. A small amount of banded nitrogen and potassium may also be beneficial at seeding time but do not include more than 50 to 60 pounds of a combination of nitrogen and potash in a starter fertilizer.

Nitrogen encourages aboveground vegetative growth. Phosphorous encourages root development, particularly the lateral and fibrous rootlets. Quick root development is especially important in fall-sown forages. A sturdy root will counteract winter injury and prepare the plant for rapid spring growth.

A starter fertilizer should consist primarily of phosphorous (40 to 80 pounds) and a small amount of nitrogen (20 to 30 pounds). It may contain some potash but excessive amounts at seeding may damage legume and grass seedlings. Established stands of legumes and grasses need a liberal supply of potash.

After forage stands are established, use soil tests to determine the amount of phosphorous and potassium to use for topdressing. It is best to take a new soil test every 3 to 4 years.

Summary

Establishing or re-establishing forages does not necessarily have to be a complicated process. If recommended practices are followed and adequate moisture, light, and fertility are available for the young plants, excellent stands may be produced. Seeding methods must involve proper seedbed preparation. This may be done with conventional tillage equipment or equipment that involves little or no tillage. Seeds may be broadcast or drilled. Soil tests must be done prior to seeding to establish proper nutrient levels and repeated every 3 to 4 years to maintain a good stand of forage.

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Lesson 4: Scouting and Maintaining the Crop

Once the forage crop is established, the producer cannot think of it as a "leave-alone" crop. Proper maintenance of the forage crop is essential to maintain a high-quality product that efficiently uses economic inputs for economic gain. A regular scouting and maintenance program will promote positive production while decreasing the amount of inputs required. Systems allowed to run down will require more money for repair than a system that is continually maintained.

Pests Associated with Forage Production

Biennial and perennial weeds are probably the biggest weed problems for grass hay and pasture producers. Both biennials and perennials produce seed each year, potentially starting new infestations. Perennial weeds reproduce from underground roots, or rhizomes. The rooting structure can survive for several years in the soil and are often unaffected by occasional mowing or livestock grazing.

A good insect management program requires proper identification of the insect species causing the damage. Two major pests of alfalfa in Missouri are the alfalfa weevil and potato leafhopper. Alfalfa weevil adults lay eggs in the older alfalfa stems in late fall and early spring, and the larva damage mainly the first cutting. Potato leafhoppers migrate to Missouri in June from southern states. The immature or nymph stage stunts plants and yellows leaves. It also lowers yield and protein content by sucking juices from young upper stems. Grasshopper infestations in Missouri are sporadic and generally cause more damage in dry years. They can do considerable damage in a very short time. The two most common species in Missouri are the differential grasshopper and the redlegged grasshopper. Their damage consists of large, irregular holes extending from the margin to the center of the leaf. The tips of alfalfa and other plants may also be injured. Another infrequent pest of alfalfa is the blister beetle. These insects cause only limited plant damage to alfalfa but when ingested by livestock, the animals become sick and even die. In Missouri, few if any blister beetles are present in the first cutting of alfalfa but may be common in alfalfa harvested during July or August.

Pest Control Options

Healthy, properly maintained forage systems are less likely to be susceptible to the encroachment of weeds, and they are better able to withstand minor insect damage with little effects to the overall plant population. Without proper management, broadleaved weeds can directly compete with forage grasses and pasture to reduce their nutritional value and longevity. Weeds can replace desirable grass species, filling gaps or voids and reducing yield and overall quality of the hay or pasture. In addition, some plants have toxic properties that can cause livestock injury or loss under certain circumstances.

Several pest control options exist for the producer. Forage monitoring is the regular inspection of forage areas subjected to insect infestations in the past. Areas such as fencerows and areas near waterways should concern a producer because these sites typically attract insects. A monitoring program helps to determine the economic injury level and the economic/action threshold. Economic injury level is the term used to describe the lowest pest population density at which an economic impact is felt. The economic/action threshold describes the pest population density at which control measures should be enacted. To conduct a monitoring program, a producer does a walk-through inspection of forage systems and sets insect traps throughout it.

If an insect infestation is too big to handle with a simple monitoring method, use more advanced technology. Mechanical means such as tilling, mowing, or weed pulling can be used. This technique works best on small infestations that can be easily controlled. For larger infestations, cultural control, and pesticide methods can be applied. Cultural control is the manipulation of the environment to reduce a favorable climate for pests. Examples of cultural control include crop rotation, trap crops, and controlled burn. A more drastic solution is the use of pesticides as a means of controlling pests. Pesticides can be a chemical or an organic mixture.

Brush Control

The use of brush control management strategies is meant to restore the balance of the forage species used in either a pasture or a harvest situation. Brush plants use three to five times

more water and nutrients than forage plants for growth and production. Brush plants also compete for sunlight energy with forages and tend to choke out slower-growing forage species. Regulating their growth, therefore, is essential to crop maintenance.

Brush can be controlled in pasture and forage crop situations in many ways. Mechanical methods such as mowing, chain sawing, root plowing, and bulldozing are effective, but some can be costly in equipment needs or labor hours. Prescribed burning is also an option; however, weather, safety factors, and local regulations must be considered if this method is chosen.

The use of chemical methods is another possibility. The effectiveness of this technique will vary depending on the application of the herbicide at the correct rate under favorable weather conditions and during the time that the brush species is at its weakest stage of growth. Because different plants react differently to herbicides, using chemical methods may not ensure the results that a producer needs.

Another option to consider is grazing management. By using this method, healthy forage ecosystems choke out encroaching brush plants. If this method is chosen, rotational grazing restricts the animals from overgrazing. Stressed forage systems are more susceptible to brush and weed infestations.

Perhaps the best method is a combination of the ones listed above. A producer should tailor a brush control program based on the extent of the problem and then plan and expect long-term results. System recovery from brush encroachment will take time, and expecting instantaneous results is impractical.

Maintaining or Renovating a Forage System

To improve forage yield and animal performance, the pasture or field needs to have ongoing maintenance and periodic renovation. Pasture or field renovation means renewing the area with the introduction of desired forage species into present plant stands. This may involve fertilizing and liming according to soil tests, partially destroying the sod by disking, controlling weeds and brush, reseeding, and prescribed burning.

Spreading fertilizer is based on soil tests and prescribed nutrient requirements for those forage species present. Liming amends and adjusts the pH of the soil. Soil tests should be done early so any needed lime can be applied well ahead of seeding. The benefits of lime move downward very slowly, perhaps no more than 1 inch per year. Disking incorporates organic material into the soil and breaks up the surface area for better water and air penetration. Renovation is more successful if tillage can be done in the late fall.

Suppressing and/or destroying unwanted plants can be accomplished in a variety of ways. A producer can use mechanical means such as mowing, pulling, cutting, and tilling. Cultural methods such as rotational grazing allows livestock to overgraze in the fall and tillage will be more effective at tearing the sod. Chemical means, such as herbicides, will destroy unwanted plant species.

To introduce other forage species into an existing ecosystem a producer can use the techniques of overseeding and no-till planting. Overseeding involves broadcasting grass or legumes into a forage stand that may be thinned or overgrazed. This is typically done in late winter or early fall. No-till planting involves the use of a no-till drill, a device that places seed into the soil at the optimal depth without tilling the soil surface. This allows for lower seeding rates, the precise placement of seed, a reduction in the loss of organic material, *a* reduction in water loss experience during tillage, and a reduction in erosion from tillage. Seeding in January and February on frozen ground will obtain excellent stands. New seedlings are occasionally injured by a late freeze, but this is usually less of a threat than seeding too late. Late seedings lack soil contact for good germination, and summer stress kills many undeveloped seedlings.

Prescribed burning to renovate forages is commonly reserved for warm-season grasses. This practice removes previous years' growth, keeps invading woody plants in check, and reduces competition from invading cool season grasses. Usually conducted in the spring, prescribed burning encourages fast and vigorous growth right after the burn by releasing nutrients locked up from previous years' growth. If a producer decides to use this technique, safety must always be kept in mind. Select conditions and procedures that will cool the fire. Wind, relative humidity, and air temperature must be considered; cool, damp conditions work best for

prescribed burns. Fire barriers to stop the path of a blaze must be established beforehand. Always seek the advice of persons experienced in planning and conducting prescribed burns.

Fertilizer Requirements for an Established Stand

Plant nutrition is an important consideration in maintaining a forage stand. Many factors come into play when planning for the nutrition of a forage. To determine a forage's nutrient status and nutritional needs, a number of tests must be conducted. Plant and soil analyses are used to optimize plant yields based upon nutrients available and to maximize economic and nutrient inputs. A soil analysis typically samples just the surface, though deeper subsoil samples are taken for deep-rooted perennials. A plant analysis looks at samples of plant tissue to determine the plant's current nutrient status. Because it will look at more nutrients than soil tests, plant deficiencies can be detected.

Phosphorus is especially critical when legumes are established. Unless the soil tests medium to high, better stands are usually obtained if some phosphorus is applied just before or at the time of seeding. Potassium is not as critical as phosphorus at the time of establishment, but legume persistence is greater if adequate potassium is used in a topdressing program. Nitrogen should not be used when establishing legumes in a grass sod. It increases the growth and vigor of the grass and increases the competition for the new legume seedling. Boron is important to alfalfa and should be applied in the topdress fertilizer at a rate of 1 pound per acre per year. However, boron is toxic to alfalfa seedlings and should not be applied at seeding.

One part of keeping plants healthy once the proper nutrients have been applied involves keeping the nutrients in the plants. Protecting soil and water resources is important because nutrients such as nitrogen and potassium are very soluble and tend to move readily into the water table, and/or streams, ponds, etc. Therefore, it is important to apply correct amounts of these nutrients at the proper stage of plant growth to minimize losses to water movement.

Summary

Maintaining the forage crop is essential to the productivity of the forage system. Pests, which include weeds and insects, must be identified and controlled by the most economic and effective means possible. Control options may include mechanical, cultural, biological, or chemical means. Regulating the growth of brush is also essential to crop maintenance. Methods for maintaining and renovating forage systems include tillage, fertilization, reseeding, and controlling weeds, insects, and brush. Fertilization to improve the nutrition of the forage is essential for maintenance of the forage stand.

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Lesson 5: Selecting a Grazing System

When choosing grazing systems, the producer should consider the best options for maximum production. Considerations should include water resources and stocking rate of livestock on the grazing operation. The number of "cow-calf" days for a specific pasture needs to be determined as well as any variables that may affect grazing patterns.

Grazing Systems Used to Maintain Optimum Production

There are basically three types of grazing systems: (1) continuous, (2) rotational, (3) and management intensive. Each grazing system has advantages and disadvantages.

Continuous grazing is the most traditional method used for animals. This method uses a single or few pastures for full-season grazing. Cattle may be left on these pastures year-round and fed hay in those pastures when grass or other forages are not available. The advantages of continuous grazing are lower setup costs (water and fence), less required management (labor), and animals can eat their choice of plants if the pasture is not overstocked. Disadvantages include less beef produced per acre, poor forage utilization (animals only use about 30 to 35% of the available grass), less desirable plants begin to dominate, and difficulty in maintaining legumes and reestablishing weakened areas.

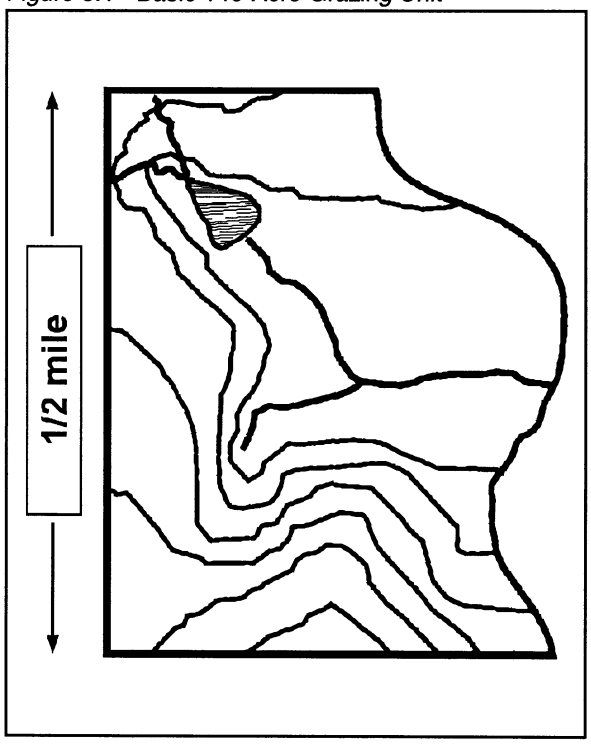
Rotational grazing involves moving a herd of animals from between two to seven smaller pastures. The advantages of this system allow the producer to match grazing to plant growth, provide rest periods for desirable plants, increase forage and animal production, reduce brush invasion, and set aside fields for haying or fall stockpiling. Disadvantages include more time and labor to manage the operation and additional expenses in fencing, waterers, and maintenance.

Management intensive grazing (MIG) involves the use of eight or more pastures. Animals are rotated as with the rotational grazing system only more separate pastures or paddocks are used. Animals are moved more frequently using a shorter duration of time for grazing per pasture, typically about 5 days. Advantages include maintenance of a desired pasture composition of plants, less damage to the soil with compaction, increased production per acre over the other two systems of grazing, longer periods of regrowth for each pasture, and more contact with the animals by the operator allowing for the identification and correction of potential problems with the herd.

Influence of Water Resource Locations on Grazing Patterns

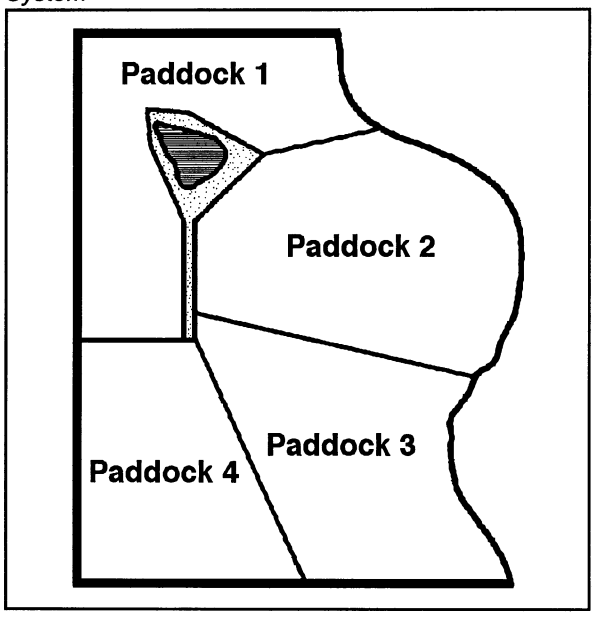
The first step in planning a grazing system is to evaluate the resource base available to the producer. One of the most basic resources would be the water supply. In a continuous grazing system using one pasture, the water source may be a stock tank fed by a deep well or a body of water such as a pond. Animals would have access to the water at all times and crowding is not much of a consideration with herd size. Refer to Figure 5.1. This drawing represents a 140-acre pasture with a water source in the upper corner and seeded with mixed cool and warm season grasses.

Figure 5.1 - Basic 140-Acre Grazing Unit



The same pasture could be used for a rotational grazing program; however, some modifications must be made. Individual pastures must be fenced and the water supply must be made available to each pasture. Figure 5.2 shows this

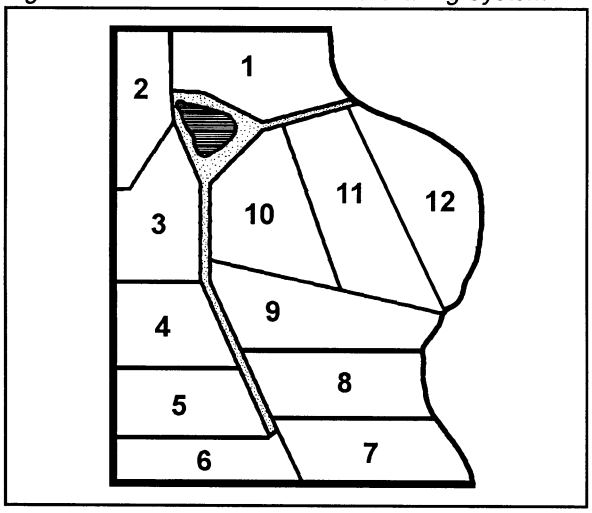
Figure 5.2 - Simple 4-Paddock Rotational Grazing System



modification. Animals are allowed to leave each pasture and follow an alleyway to the water supply, which is the same pond used with a single pasture, conventional grazing system. All of the gates to unused pastures simply remain closed. Transferring animals from pasture to pasture is relatively easy.

Further subdivision to make the shift from rotational grazing to management intensive grazing can be made with or without additional water development. Figure 5.3 shows an additional alleyway design and fencing, decreased pasture size, increased pasture number, and the animals still have access to the water supply.

Figure 5.3 - 12-Paddock Intensive Grazing System



Although many producers make the initial subdivisions without making additional water source development, they often find that later steps in subdividing would have been easier if water supply improvement had been done in the first stages of development. Improving water distribution with the addition of water lines and water tanks in individual pastures greatly increases the flexibility the manager has in fence placement and keeping paddocks similar in shape and size.

If the decision is made to use alleyways, certain effects must be accepted. Alleyways are likely spots for erosion to occur and for weeds such as thistles or nettles to take hold. Both are the result of bare ground created by continual animal traffic. Livestock will likely deposit manure in an alleyway when they travel to water rather than depositing it on the productive part of the pasture. Also, beef cows grazing in a paddock system that have water available in every paddock will drink 15 to 20% more water on a daily basis than cattle that have to use an alleyway for water access.

Determining Livestock Carrying Capacity of a Grazing System

Determining the appropriate stocking rate for a particular grazing unit is a key decision affecting the profitability and viability of a grazing operation. Livestock intake and performance are very dependent upon forage available to the animal on a daily basis. Setting the stock rate too low results in wasted forage and lost profit potential. Setting the stocking rate too high results in lowered intake and animal output and diminished profits.

Carrying capacity is the stock rate that is economically and environmentally sustainable for a particular grazing unit throughout the grazing season. Carrying capacity is largely determined by four factors: (1) annual forage production, (2) seasonal utilization rate, (3) average daily intake, and (4) length of the grazing season. These terms can be expressed in the mathematical formula below.

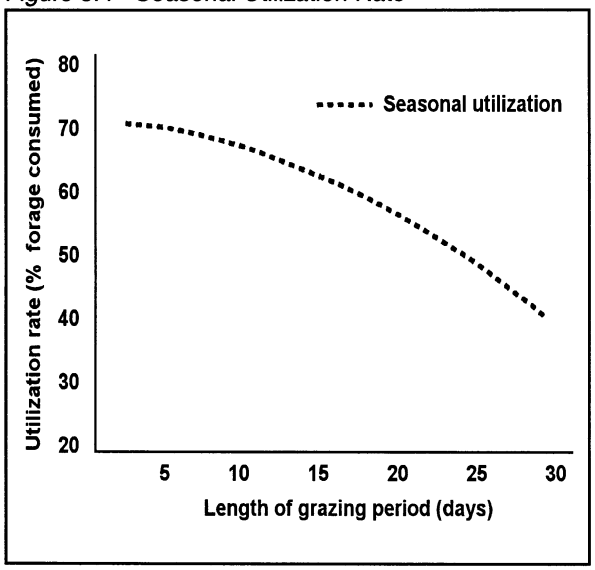
$$\text{Carrying capacity} = \frac{\text{Annual forage production} \times \text{Seasonal utilization rate}}{\text{Average daily intake} \times \text{length of growing season}}$$

Annual forage production is the total amount of forage dry matter produced per acre annually. This would include both hay and pasture harvested

from grazed animals. This term in the formula would be expressed as pounds of forage per acre.

Seasonal utilization rate is the percentage of the annual forage production that will actually be harvested by the grazing livestock. This is dependent upon rotation frequency and level of animal performance. Figure 5.4 should be used to estimate approximate seasonal utilization rate based on average grazing period length. For example, on a 3-day rotation a seasonal utilization rate would be about 68%. Utilization rate is unitless decimal fraction in the formula.

Figure 5.4 - Seasonal Utilization Rate



Animal daily intake should be set at the level that will be required to yield the desired animal performance level. This may be the most difficult part of the entire process. To determine the appropriate intake value accurately, some estimate of forage digestibility and energy is required. These values cannot be reliably determined without careful forage sampling and laboratory analysis. Average forage intake values for high, medium, and low performance of steers or cow-calf pairs would be 3.5, 3.0, or 2.5%, as a percentage of the animal's body weight. For example, a 1200-pound cow of medium milking ability would consume about 36 pounds of forage dry matter per day. In the formula, the intake is expressed as pounds of forage/pound of liveweight.

Length of the grazing period depends on how many paddocks are available and the required rest period. The rest periods are going to vary for different species and changing environmental conditions.

As an example, assume that an average acre will produce 7600 pounds of forage annually. If an average 3-day grazing period is used, Figure 5.4 shows that the corresponding seasonal utilization rate is approximately 68%. The livestock will be steers with a gain of 1.5 - 2 pounds per day per head. This would be a moderate performance level so intake is entered at 3% of body weight, which is .03 pounds of forage per pound of body weight. It is important to enter intake in the formula as .03, not as 3% so that units cancel out. Anticipate grazing the steers from April 20 to October 1 for a total of 164 days.

Make the following calculations.

$$\frac{\text{7600 lb. forage/acre X .68}}{\text{.03 lb. forage/lb. live weight X 164}} = \text{1050 lb. live weight/acre}$$

The 1050 pounds of live weight/acre is an indication of the carrying capacity of this unit. If 525-pound steers are purchased, can two steers be stocked on 1 acre? Only on the first day of the grazing season. It is hoped that the steers are gaining weight each day and the forage availability in August is lower than that in May. If expected average daily gain is 1 3/4 lb./head/day, the average weight of steers at mid-season will be 668 pounds (525 + [82 days x 1 3/4 lb./day]). Initial stocking rate could be set at 1.6 steers/acre (1050 lb. live weight/acre divided by 668 lb. live weight/steer).

Remember, this is a guideline to help make initial stocking decisions, not a magical recipe for universal financial success.

Calculating Cow-calf Days for Warm- and Cool-season Grasses

When determining "cow-days" for a specific pasture there is also a formula. However for those who prefer not to work with equations, forage allocation can be made even simpler. An average for each forage stand density is 215 pounds/acre-inch for thin pasture, 333 pounds/acre-inch for average pasture, and 450 pounds/acre-inch for thick pasture. Assume that a 1000-pound lactating cow will consume about 3% of her body weight, a cow-day can be figured to be equal to 30 pounds of forage consumed. By dividing 30 pounds of

forage per cow-day into the pounds of forage per acre-inch, the cow-day yield of thin, average, and thick pasture is about 7, 10, and 15 cow-days/inch, respectively, of pasture consumed.

This becomes a simple method of allocating pasture by following these steps.

1. Look at the pasture and determine it to be thin, average, or thick.
2. Measure or estimate the height of the pasture to be allocated.
3. Subtract from the total height the height of stubble you want the animals to leave.
4. Multiply the difference between starting height and ending height by the cow-days/inch to figure available cow-days/acre.
5. Divide the number of cows in the herd by cow-days/acre to determine how much area should be allocated.

Here is an example. Look at the pasture and determine if it is thin, average, or thick. For this example, we will use average grass, which gives us a cow-day/inch factor of 10. Next, measure the height of the forage to be 8 inches. It has been decided to leave a 3-inch residual. So from that subtraction, the result will leave 5 inches to be grazed. Five inches grazed times 10 cow-days/acre-inch would equal 50 cow-days/acre. If there are 100 cows, 2 acres/day would need to be allocated.

This works well for 1,000-pound cows, but what about other classes of livestock? Grazing management is an imprecise science because of ever-changing conditions, so these figures will always be an approximation, not perfection. When there is livestock of different weights, divide the estimated total weight of all the livestock in the herd by 1,000 and the result will be fairly close to cow-day equivalents.

Influence of Different Grazing Patterns on Cow-Calf Days

As can be seen from the previous discussion, there are several variables that may affect cow-days of grazing. Certainly the size of the pastured area will depend on the number of animals in the herd. If paddocks or pastures in an intensive grazing system are small, the herd size should be decreased from that of a conventional large pasture system, for example.

The amount of forage or stand density would play a major role in how long the herd may be left on a given pasture. If the forage was thin due to lack of moisture during the growing season, the cow-days would be shortened. Animal size (weight) also influences how may pounds of forage would be consumed per day.

Summary

When choosing a grazing system, a producer may employ a continuous system, a rotational grazing program, or an intensive grazing system. The size of the individual pastures determines the system used. An important consideration that must be given to each of these systems is the water resource available. Arrangements must be made for the herd to have free access to water in each of the grazing methods. How long the herd may be allowed to graze would be determined by the annual forage production of the pasture unit, the seasonal utilization rate or each pasture, the average daily intake of the animals, and the length of the grazing season. There are some simple steps that may be used to determine cow-days on a pasture, but differences such as size of the animal, forage density, and size of the pastured area must be taken into consideration.

Credits

Missouri Grazing Manual (M157). University Extension, Columbia, MO: University of Missouri-Columbia, 1999.

Lesson 6: Harvesting for Seed

Forages used in pasture and feed systems originate through the production of forage seed. Most forage seed is produced in the western United States, although native grasses tend to be produced in local areas. Forage seed production is a precise science that requires specific management practices. This lesson will discuss unique factors that must be considered and management practices used when producing forage for seed as opposed to producing forage for hay and pasture.

Producing Forage Seed

The goal of forage seed production is a consistent high-quality product. This goal is dependent upon the environmental conditions existing in the production location, the cultivar physiology (physical makeup of a variety), and market availability.

When considering environmental conditions, it must be noted that most seed crops are grown in regions other than where they are to be used. Therefore, producers must know the existing conditions in the production location to raise a successful crop. Conditions that have the greatest effect on forage seed production are photoperiod (the daily amount of time plants are exposed to light), seasonal temperatures, and the average amount and occurrence of rainfall. Optimum seed production occurs in areas with warm summer temperatures and low humidity. Rainfall during seed maturation and harvest will decrease quality and yield.

Cultivar physiology plays an important part in forage seed production because producers must be aware of the selected variety's reproduction needs. In selecting cultivars, care must be taken to match them to the region of production. For example, forage cultivars developed in the Midwest are best adapted to Midwest conditions.

Once the desirable environmental conditions for one or more forage cultivars has been determined, then the final consideration needs to be if there is an available market for the crop. Most markets for forage seeds are determined by the location of seed processing mills. If a seed processing mill is nearby creating a local market for forage seeds, the producer may choose to raise a forage seed crop. However, if the nearest mill and market are some distance away, transportation and other costs incurred to sell the crop may be too high to gain an acceptable profit.

Additional considerations producers should consider when producing forage seed is the intended use of the forage after harvest and the value of the forage crop versus the seed crop.

Additional Costs Incurred

Since the object of crop production is to make a profit, then all costs must be considered to determine if an acceptable return will be received on the investment. Forage seed production incurs more costs than hay and pasture production due to additional management, inputs, machinery, storage, and transportation needs.

Management costs for seed crops are higher due to more intensive management of pests and crop conditions to produce a high-yielding and quality crop. Likewise, input costs are higher because more expenses are incurred from fertilizers, irrigation, herbicides, insecticides, and labor than are usually associated with hay and pasture production. Machinery costs are also increased due to the need for specialized harvesting equipment that is not used in typical forage crop production. Specialized storage in silos or bins, necessary to keep seed at the proper humidity, can also increase production costs. As mentioned previously, transportation can be more costly depending upon the location of the nearest market. Expenses can include fuel costs and maintenance of owned or leased trucks and/or trailers to haul seed, or the cost to contract services.

Additional Management Factors

A key element to healthy plant growth is fertilizer. Grasses and legumes have different fertilizer requirements. Nitrogen (N) is extremely important to grass growth. The time of nitrogen application depends upon the growth habit of the plant. Grasses that grow and develop flower buds during summer respond to one application of nitrogen in early summer. Cool-season grasses need split applications of nitrogen, both in the spring and in the fall, because initial flower growth begins in the fall. Timing of nitrogen is highly dependent upon the growth habits of individual species and cultivars. The amount of nitrogen that a grass

requires is influenced by current soil fertility. As the crop ages, more nitrogen is required to keep seed production high. Legumes also require nitrogen, but their needs differ from those of grasses. Legumes need to be inoculated with nitrogen-fixing rhizobia to aid in plant growth. Legumes need phosphorus (P), potassium (K), calcium (Ca), and other nutrients for proper growth. Depending on the species, the legume may require less of these nutrients for plant growth than for harvest.

As an area is prepared for planting, it will become evident that a pest management strategy should be started. Pests can plague a field in the form of weeds, insects, and disease. Each brings with it different problems that must be effectively controlled to cultivate a crop from seeding to harvest.

Weeds compete with forage plants for soil and water resources. Because of open areas from row planting, weeds are able to become established in seed production fields. Weed seeds decrease overall seed quality grade and reduce the price gained at market. It is necessary to practice some sort of weed control system. Control methods include roguing, mechanical control, chemical control, and biological control.

Insects also pose a threat and tend to cause more problems in legumes than in grasses. Some insects attack foliage and others attack the flowers of the forage, greatly affecting the yield. Several control options are available. A producer can manipulate the environment by rotating crops and planting varieties that are selected against the pests. Also, insecticide/chemical control agents and biological control agents offer other solutions.

Plants are susceptible to diseases in their environment. To avoid any problems, it is best to select cultivars that are resistant to diseases. Grasses tend to be more prone to disease than legumes, particularly foliar rusts. Treatment usually consists of fungicides; however, close monitoring of the crop is necessary to detect any potential problems before they become established in the plant.

Harvesting Forage Seed

Harvesting forage seeds is similar to harvesting grain crops, but some specialized equipment and methods are required to optimize yields. When combining forage seed, it can either be directly combined or swathed.

Direct combining requires seed to be at or near maturity. This method tends to have higher losses due to "shattering" of the ripened seed. Shattering occurs when the seed breaks away easily from the floral attachments and is lost. This method is lower cost because it only requires one trip across the field. There is also less chance of seed sprouting.

Swathing is done when seed heads are light green to yellow because they are at a less mature stage. Swathing forages while still green, then allowing them to cure in the field before combining, increases seed yields. The forage should be cut high off the ground with a windrow on top of the stubble to promote good air circulation. Combine the windrows when the crop is thoroughly dry. This method is higher costs because it requires more trips across the field. There is also a chance of sprouting damage.

Summary

Raising and harvesting forage seed is a precise science. The producer must consider environmental factors, forage species and specific cultivars, and available market. Additional costs include management, input, machinery, specialized storage, and transportation. Management factors to consider are a crop establishment plan, fertilizer, soil and water management, pollination management, and pest management. Harvesting the seed can be done by direct combining or swathing, cutting, and combining.

Credits

Biondo, R.J. and J.S. Lee. *Introduction to Plant and Soil Science and Technology.* Danville, IL: Interstate Publishers, Inc., 1997.

Stewart, B.R. , M.J. McCaskey, and M.K. Mullinix. *Forages Unit for the Advanced Crop Production and Marketing Course* (Instructor's Guide). Columbia, MO: University of Missouri-Columbia: Instructional Materials Laboratory, 1985.

Suits, S. *Introductions to Grassland Management* (Student Reference). Columbia, MO: University of Missouri-Columbia: Instructional Materials Laboratory, 1997.

Lesson 7: Harvesting for Feed

The goal of most forage programs is to maximize economic yields of nutrients while ensuring stand persistence. Frequent cutting produces high-quality forage whereas less frequent cutting generally results in increased stand longevity. Therefore, harvesting requires a compromise between quality and persistence. Decisions on when to cut have to be made based on a sound understanding of how a plant grows and survives.

Determining Harvest Timing

Several factors can determine harvest timing. One of the most important aspects is the stage of maturity of the plant. The harvest of feed is generally based upon vegetative and seed productive stages of the plant. Harvest should occur at the onset of the reproductive stage. The plant should be actively growing vegetatively and not be expending energy toward reproductive growth. Table 7.1 gives the recommended stages of maturity for the harvesting of several grasses and legumes. The description of a stage of maturity refers to the whole field, not to an individual plant. An accurate method to determine the stage of development is to count 100 stems randomly selected from the field and determine the average stage of development. Legumes are higher in nutrient value, so a grass/legume mixture should be harvested when the legume is at the proper stage of maturity, regardless of the species of grass.

Table 7.1 - Recommended Stage of Maturity

Plant	Recommended Stage of Maturity for Harvest
Alfalfa	Bud to 1/10th bloom*
Red Clover	¼ to ½ bloom
Timothy	Late boot stage
Bromegrass	Seed heads emerge
Orchardgrass	Blooms emerge
Reed Canarygrass	Seed heads emerged
Tall Fescue	Boot stage

*1 in every 10 buds is in bloom

Weather patterns also affect the time of harvest. For optimum forage harvest, weather during harvest should be dry and warm. To ensure top quality hay, there should be a minimum of 3 days of dry weather during the actual harvest from cutting to baling. Excess humidity in the air will increase the length of drying time. Warm breezes and sunshine will shorten the days required to dry. Silage and haylage will not require as long to dry down to storable moisture content.

Forage Quality at or During Harvest

Though a producer's job is mostly finished by harvesting time, there are still several factors that affect the quality of a harvest. Factors include the prime growth stage, mechanical damage, climatic losses, and moisture content. To harvest the best possible crop and to maximize the investment return, avoid any negative factors affecting forage quality.

Harvests that occur after the prescribed growth stage will have several negative characteristics. The total digestible nutrients (TDN) in the plant will decrease, as will the protein content. Other available nutrients will also decrease. Harvesting before the prime growth stage will reduce the quantity of forage harvested and the nutrients stored in leaves and stems will not be maximized to the fullest.

Mechanical damage is a major cause of dry matter loss that occurs during raking and baling. This primarily affects the leaves, the highest quality part of the plant.

Climatic losses, attributed to rain and sun, can also affect crop quality. Downed hay (cut hay that has not been baled and stored) is susceptible to losses from leaching caused by rain. Hay left down and exposed to the sun for too long can experience significant losses from blanching. Blanching is the bleaching away of nutrients from the leaf and stem of the plant.

Plants that are harvested can still lose up to 60% of their moisture through respiration, so keeping the moisture content of plants in mind after harvest is important. Dry matter loss averages 5 to 6% but can go as high as 15%. The losses are nonrecoverable. Hay should be baled between 18 and 22% moisture content and is safe for inside storage at 15 to 18%. Moisture levels higher than 22% in the bale lead to dry matter and quality loss

due to heating and molding of the hay. Therefore, losing as little amount of moisture as possible is important.

Moisture is especially important for the forage ensiling process. Haylage is forage stored at moisture levels of 40 to 50%. Silage is forage stored at moisture levels of 60 to 65% moisture. Most green chop forages (grasses and legumes) are typically stored as haylage.

Harvesting Methods

Harvesting methods vary depending on the needs and resources of the individual producer. Each method needs to be evaluated for profitability to the operations.

Mowing is the process of removing the top part of a plant from its root system, about 3 to 6 inches above the ground level. If a plant is harvested below 3 inches, the plant is weakened by removing valuable leaf tissue necessary for regrowth. Plants cut more than 6 inches will not maximize the amount of forage harvested.

Conditioning is a method of speeding up the forage drying process. There are two types of conditioning - mechanical and chemical. Mechanical conditioning is a system of rollers that crush the plant stems, allowing for more surface area to be exposed to evaporation and drying. This is particularly effective on coarse plant stems by opening more surface area to moisture loss. The drying rate can increase by up to 80% in first cuttings. A disadvantage of mechanical conditioning is that a slight loss in dry matter may occur and finer stemmed plants may slide through the rollers without being crushed, voiding the effects of conditioning. Chemical conditioning is applied at the time of mowing and removes the plant's waxy coating so moisture can easily escape. This method is used primarily with alfalfa but is also efficient on legume crops. The drying rates in second and third cuttings are increased. However, additional equipment is needed to apply the chemical during cutting and this method does not work well with grasses.

A mower conditioner combines the mowing and conditioning process in one machine. This method causes less damage to forage due to a single cutting/crimping process and fewer trips across the field, providing savings on fuel, maintenance, and labor costs. However, if the rollers are adjusted incorrectly, increased losses in dry matter may occur. This equipment is also more costly than a mower.

Swath manipulation is the mechanical method of turning or spreading forage to enhance even drying. There are three types of swath manipulation: raking, swath inversion, and tedding. Raking is a method of mechanically inverting forage into tight windrows. The windrows are efficiently inverted and fluffed for drying and the rolls provide better pickup for the baler. If the hay crop is thick, wet sections in the middle may not dry completely and dry matter may be lost, especially leaves in legumes. Inversion, a process similar to raking, involves inverting the mowed swath on belts, the bottom moving to the top and the top to the bottom. This method is gentler as it inverts and fluffs the windrows and does not toss the hay during pickup, which can knock leaves off the legumes. This method is not as efficient as tedding. Tedding uses a machine with rotating tines that stirs, spreads, and fluffs the hay. This method allows for uniform drying by spreading out the hay and may decrease drying time by up to 2 days. However, it is more damaging to legumes with fragile leaf structures, leading to nutritional loss.

A popular harvest method for hay is baling. Rectangular bales are commonly baled at 14 x 18 x 36 inches in size and weigh between 50 to 80 pounds. They provide ease in stacking and feeding and are easier in transportation and marketing operations. However, rectangular bales are more labor intensive in hauling and stacking, and indoor storage is needed to maintain highest quality. Large, high-density bales are becoming popular with sizes ranging from 24 to 50 inches wide and tall, 48 to 98 inches long, and weighing between 440 and 2000 pounds. These higher-capacity bales are more efficient to harvest and transport. However, specialized equipment is needed for harvesting and feeding, which increases the cost. Wind damage can also occur if the bales are not covered.

Round bales are typically reserved for on-farm use. They range in size from 36 to 72 inches in diameter, 48 to 64 inches in length, and weigh between 440 and 2000 pounds. These bales are less labor intensive than small rectangular bales and can be stored outside. The bales can be placed in convenient locations around the farm to provide small feeding units for planned consumption time. However, they are not easily

transported or stored indoors. Additionally, these bales can lose nutritional value with outside storage unless they are wrapped or bagged. Disposal of the used plastic wrap or bag is also an environmental concern.

Silage chopping is done with a forage harvester that is used to chop the crop. A pickup or cutting mechanism carries the forage into the machine where rotating knives cut the forage into small pieces. The chopped forage is then blown through a spout to a trailing wagon or truck. Chopped forage is stored in tower silos, bunker silos, or silage bags. Labor requirements are usually less than for hay harvest. Losses can occur from drift between the blower and the trailing vehicle. Forage harvesters require more power to operate.

Forage Quality During Storage

Moisture content in baled hay of more than 22% can lead to dry matter and quality loss from heating and molding. Most green chop forages (grasses and legumes) are typically stored as haylage. Moisture levels below 40% in haylage decrease the anaerobic fermentation process. Moisture levels more than 50% can lead to spoilage in the stored forage.

Nutritional value of properly stored forages will be maintained for approximately 1 year without noticeable losses. As more drying occurs, dry matter will decrease, thus reducing some nutritional value. Forages stored outside or without protection from the elements will be subject to greater losses from leaching of nutrients from rain, mold, and spoilage.

Storage Methods

Baled hay is typically stored inside livestock barns or specialized pole hay barns at 18 to 20% moisture levels. Storing hay inside will cause less exposure to weather and the hay will maintain higher quality longer. In addition, the hay is more accessible for feeding when stored in barns. Hay stored inside is, however, more labor intensive and costs may be increased for buildings, labor, and maintenance. Wet hay will experience loss from microbial activity, spoilage, and mold. The internal heating of wet bales could cause a fire.

Outside storage is another option. Round bales are typically stored outside due to size and handling needs. Sometimes, rectangular bales are also stored outside. This method is less labor intensive and does not require the capital outlay of barns. However, additional protection is needed that can require specialized equipment. Round bales should be wrapped with a protective plastic covering. All bales should be covered with a tarp to provide protection from the weather. A protective layer, such as gravel or old tires, must be placed on the ground to protect the hay from spoilage and loss due to contact with the soil. Additionally, large bales are more difficult to move and require specialized equipment. This is especially true for transporting bales long distances, which can make this an expensive option. Nutritional value is lost quicker in hay stored outside due to continued exposure to weather.

Methods of storage for silage and haylage include tower silos, silage bunkers, and silage bags. Tower silos are constructed of concrete or steel and range in capacity from 50 to 4000 tons. They maintain the quality of the forage, provide protection from the weather, and take up less ground space than the other options. Crops can be stored between 50 and 65% moisture. The weight of the silage packs the forage to reduce trapped air. They are easily adaptable for automated feeding equipment. Some loss to spoilage may occur at the top of the silo. Additional labor is required to unload the silage by hand or move the chute if automated equipment is used. There are dangers of gas buildup in tower silos and they have an initial higher cost to build.

Silage bunkers are usually made of concrete, with a concrete floor and concrete sidewalls. The sidewalls vary from 10 to 20 feet high. They are economical and easy to store and remove forage for feeding. Crops can be stored between 50 and 75% moisture. Packing of the forage is usually done by a tractor to reduce trapped air. They are not typically protected from the environment unless a plastic covering is used, which will add additional costs. Fermentation does not occur as well as when other storage methods are used. Unloading is typically done with a front-end loader or tractor.

Silage bags are made of plastic and enclose the forage. The average bag size is 150 to 200 feet long and approximately 9 feet in diameter. Bags are often used as a short-term method of storage. They take up more storage space than a tower silo. Bags must be maintained to minimize damage to the plastic to avoid spoilage, which can

reach as high as 50%. Additional labor is required to dispose of bags and plastic remnants. A tractor with a front-end loader is needed for unloading.

Methods to Enhance Poor Quality Forage

Forage quality is defined in different ways. For our purposes, forage quality will be defined in a practical sense to address grazing systems in Missouri and surrounding states. Forage quality is considered as the value of pasture grasses and legumes as nutrients for grazing animals. Forage quality can also be described in terms of protein, fiber, and other components important to the nutrition of animals. Most ruminant nutritionists would consider high-quality forage to be one with high protein and low fiber.

In a pasture, there are three major factors that affect forage quality. The first factor is plant species. Legume species tend to have higher quality than grass species. In keeping with our definition of high-quality forage, adding legumes to a pasture would increase the protein and lower the fiber.

In Missouri, it is possible to maintain at least 20 to 50% legumes in a pasture, keeping much of the forage in a leafy, vegetative stage of growth. To keep legumes in a pasture, the pasture (or paddock in an intensive grazing system) must be rested for reseeding and restoring carbohydrates. In addition, the pastures or paddocks should not receive high rates of nitrogen fertilizer unless the forage will be cut for hay or "mob grazed." High rates of nitrogen cause grasses to form a canopy over the legumes.

The second major factor affecting quality is plant maturity. As a plant matures from the leafy, vegetative stage into the steamy, reproductive stage, protein decreases and fiber increases. Under proper management, maturity is controlled as pastures or paddocks are more uniformly grazed; the result is higher-quality pasture. Some legumes such as birdsfoot trefoil, annual lespedeza, and red clover should be allowed to mature for natural reseeding and for stand persistence. Fortunately, these species retain relatively good forage quality even at advanced stages of maturity.

The third factor affecting forage quality is the plant part. Leaves contain more protein and less fiber than stems and are therefore of higher quality. Plant part is important to consider in legume hay production because leaves can be shattered during raking and baling, thereby lowering the quality. Plant part is perhaps more important to consider in a grazing pasture. As cattle graze plants such as vegetative alfalfa, their first bite contains a high proportion of intact leaves. Their second bite contains large amounts of stem, which is lower-quality forage. When they graze vegetative tall fescue however, their first and second bite both contain leaves.

Some of the other factors that affect forage quality, but to a lesser degree, include climate and biological stress. Temperature affects fiber concentration. As a rule, cooler temperatures cause lower fiber concentrations, and therefore, higher digestability. Biological stress includes plant diseases and insects. Diseases and insects usually lower forage quality by reducing the number of leaves or cause the plant to produce lignin and antiquality components. Examples of antiquality components include alkaloids in reed canarygrass that cause animals to be sensitive to the sun, resulting in skin disorders, and the tall fescue endophyte that results in fescue foot conditions.

When considering how to improve the quality of forage in storage, two factors should be examined. The first factor involves the method of storage. This factor is probably the most overlooked. Too often, bales of hay are left in the field or grouped at the edge of the pasture and left unprotected. Nutrients are rapidly depleted by the effects of sun and moisture to these uncovered bales. Providing a covering or a wrap as well as placing them in some type of storage facility would greatly enhance their quality.

The second practice that may be used to enhance quality of stored forages would be the practice of injecting anhydrous ammonia into the bale. There are two excellent reasons to ammoniate low-quality forage. First, ammonia breaks cell wall linkages and increases digestibility. Second, ammoniation requires hay to be covered and indirectly provides protection from the elements. In case of tall fescue, there is a third reason to ammoniate. Ammonia neutralizes the toxic effect of some compounds in fescue and results in an increase in daily gains by at least 50%.

Summary

Profitability of the forage crop is highly dependent on harvesting at the appropriate time. Maturity level and weather conditions are the primary factors to consider. Forage quality at the time of harvest can be affected by the growth stage of the plant, mechanical damage, climatic losses, and moisture content. There are a variety of harvesting methods; each should be weighed for the economic yield of nutrients and maintenance of the crop. After harvest, the moisture content and nutritional value must be monitored for quality. The storage method chosen will also affect the nutritional value of the forage. Forage quality can also be enhanced by choosing a legume to include in the forage, harvesting the forage at the proper stage of maturity, and using measures to maximize leaf retention. Stored forage can also be improved through proper storage techniques and ammoniation.

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Lesson 8: Marketing the Crop and Figuring Crop Costs

The final step after planting, growing, and harvesting a forage crop is to develop a successful marketing strategy. The producer's goal is to receive the maximum return per acre of forage production for that year's production.

Local Forage Marketing Options

There are two basic ways to market forages. One method is to market it through feeding the forage to animals such as beef or dairy cows. The animals convert the nutritive value of the forage into meat or milk for later sale. The other method that will be discussed in more detail is marketing the forage to sell to buyers.

Hay can be used as a cash crop. Options for marketing grass or legume hay include quality-tested hay auctions, tele-auctions, computer posting, sale to hay dealers, and neighbor-to-neighbor sales.

There are few quality-tested hay auctions in Missouri. Most are in states where forages play a more major role in their agriculture's economy. Wisconsin and California would be good examples. These two states are major dairy or milk-producing states. More high-quality forages are sold and fed to cattle in these two states than almost all other states combined. Many tons of forages are marketed through this method in these states.

Tele-auction is the method of selling hay over the telephone using conference calling. Bidders know the quality and the amount of hay they are bidding on and therefore can buy it without having to see the forage. Shipment is then made from the seller to the buyer.

Some producers in Missouri are familiar with computer posting. The Missouri Department of Agriculture is involved in a joint venture with the University of Missouri-Columbia to market hay through an Agriculture Electronic Bulletin Board (AgEBB) computer web site. This site may be accessed through <www.agebb.missouri.edu>. This listing includes seller names, cities, counties, and phone numbers. Sellers can be listed by either region or forage type. Bale type is included as small square, large square, small round, large round, baleage, or some other form. The number of bales and approximate weight of each bale of forage are listed. Additional information includes whether the hay has been analyzed, its crude protein, acid detergent fiber (ADF), relative feed value, and percent total digestible nutrients. An area for notes may list such information as "first cutting" or "do not call before 6 p.m." Hay listings will be left on the system for 60 days unless updated.

Some forages are sold to hay dealers who then transport the forage to another area for resale. These dealers are called entrepreneurs, or speculators. Their goal is to buy at a lower price and then resell at a higher price to cover their input costs and make a profit.

The most popular method in Missouri to market hay or forages is the neighbor-to-neighbor (private treaty) method of sale. This may also be known as word-of-mouth advertising and sales. Most of the forage sold by this method stays in the local area. The buyers can view the quality and amount of hay before buying. Transportation costs are lower with this method. A large amount of forages sold through this method goes directly from the field to the buyer immediately after cutting and baling.

Effect Forage Quality Has on Price

Forage quality plays a major role in the pricing structure of hay sales. A large amount of hay and other forages are bought and sold around the state. Quality factors are as important when purchasing hay as when producing it. When buying hay, visual appraisals of quality can be deceiving. High-quality hay tends to sell at a premium. Market hay grades are based on forage quality and reflect forage species, composition, and maturity. Legumes tend to grade highest, followed by legume/grasses, grasses, and finally heavily weathered forages.

To get the best price, the forage should be quality tested to provide comprehensive information to buyers. Description characteristics include color, odor, mold, heating, mixture, dust, and foreign material. The seller should also provide a chemical description. The producer must know how to take an accurate forage sample from the center of the hay bale.

Forages differ greatly in chemical composition and digestibility. Forages used to be evaluated strictly on the proximate analysis or crude fiber system. More recently, detergent analysis systems, which include acid detergent fiber (ADF) and neutral detergent fiber (NDF), provide better estimates of fiber and digestibility. The detergent system measures basic components of the plant and relates them to the animal's digestion and production. Mobile near infrared reflective spectroscopy (NIRS) vans used for determining forage digestibility permit on-site testing of hay. Hay samples can also be sent to laboratories for thorough analysis for nutritional ration balancing. One such laboratory is the Livestock Nutrition Laboratory, P.O. Box 1655, Columbia, Missouri, 65201.

Variable and Fixed Costs Associated with Forage Production

As defined in an earlier lesson, variable costs are those costs that may change each year depending on the level of production. These costs are also known as operating costs. Fixed costs are expenses that are not affected by the level of production and will remain the same no matter how much production is planned or achieved per acre. These costs are known as ownership costs.

Table 8.1 gives some examples of fixed and variable costs for certain types of forage production operations. These figures were obtained from the MIR (mail-in-record) enterprise records from 1996-98.

Table 8.1 - Missouri Average Forage Costs 1996-98

	Alfalfa Hay	**Mixed Hay**	**Clover Hay**	**Fescue Seed**	**Corn Silage**	**Grass Hay**
Average Operating Costs/Acre						
Seed	$ 1.31	$ 5.97	$ 2.51	$ .22	$22.30	$ 1.75
Plant food (fertilizer and lime)	21.47	16.96	8.21	11.74	40.94	10.67
Crop chemicals	6.77	1.95	6.71	6.48	21.72	2.21
Labor	18.00	26.19	12.72	8.85	36.17	14.40
Machinery, fuel, oil & repair	22.24	22.75	20.43	6.78	37.26	11.79
Machinery hire and services	7.06	7.25	.92	2.26	12.23	5.00
Miscellaneous	11.56	11.68	4.40	1.39	14.76	2.40
Operating interest	2.44	2.55	2.07	2.11	4.16	2.59
Total Operating Cost/Acre	$90.85	$95.30	$57.97	$39.83	$189.54	$50.81
Average Ownership Costs/Acre						
Machinery depreciation & interest	$ 34.34	$18.33	$21.40	$6.62	$35.62	$13.39
Land costs, taxes & interest	65.60	49.22	50.01	28.06	69.00	41.63
Total Ownership Costs/Acre	$99.94	67.55	$71.41	$34.68	$104.81	$55.02
Average Total Costs/Acre	$190.79	$162.85	$131.13	$78.18	$293.61	$107.13
Average Cost/Ton	$79.17	$83.94	$66.90	$ .34	$25.56	$52.26
Average Machinery Investment/Acre	$74.00	$41.00	$41.76	$11.86	$41.11	$49.04
Average Real Estate Investment/Acre	$788.00	$536.00	$600.00	$336.02	$880.56	$690.14

Calculation of Cost Per Acre

Refer to the examples of cost calculation earlier in this lesson in the three tables for 1996, 1997, and 1998 economic information received from the Missouri mail-in-record analysis.

Summary

There are several methods of marketing forages. Some are more common in Missouri than others. Some of these methods include quality auctions, tele-auctions, computer posting, sale to hay dealer, and private treaty sales. Most hay in Missouri is marketed through the private treaty, or word-of-mouth sales. The quality of the forage is the major factor that would determine the price or value of the forage. If the forage was tested, the chemical description should be included when advertising for sale. Examples of fixed and variable costs for forage production for cost calculation and figuring returns per acre may be obtained from extension offices MIR analysis.

Credits

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Lesson 1: Planning the Crop

The cotton plant is unique among the commonly grown row crops in the United States. Originating as a semi-tropical, perennial plant, cotton has been bred and cultivated for production as an annual that can grow in a wide range of temperate environments. By understanding the necessary environmental conditions, evaluating field history, and determining fertilizer needs, producers will be better prepared to make good management decisions concerning cotton production.

Environmental Conditions Necessary for Cotton Production

Cotton, like any other plant, requires specific conditions to grow well. Before a producer plants cotton for the first time, environmental conditions need to be examined to determine if cotton will grow under the existing conditions. The environmental conditions that have the greatest effect on cotton production include growing season, rainfall, and soil type.

Growing Season

Cotton is considered a warm-season crop, growing best during summer months in warm climates. Cotton requires a frost-free period (the number of days from the last frost in the spring until the first frost in the fall). This necessary frost-free period is the main reason that cotton will not grow in northern climates. Instead, it is mostly grown in southern regions of the United States including southeast Missouri. Some newer varieties, however, are able to produce in climates with shorter growing seasons. In Missouri, the growing season falls between early May and late October.

Cotton needs specific temperatures during the planting and germination stages. It should only be planted in the spring when the average soil temperature is at least 65°F for 3 consecutive days. Once the cotton is planted, the seeds will not germinate unless the average air temperature is at least 75°F, with 85°F being optimum. Both soil and air temperatures determine spring planting dates. In Missouri, cotton is typically planted between May 5 and May 15. Cotton planted before May 5 will risk cool soil temperatures but may be able to establish a stand in some years. Cotton planted after May 15 and before May 20 will probably not have significantly lower yields but can delay plant maturity and harvest. Planting after May 20 usually results in reduced yields and is not recommended.

The development of the cotton plant is directly tied to the temperatures it encounters. It develops very predictably at temperatures between 65 and 85°F. In other words, a cotton plant grows above a base temperature of 60°F with little or no development occurring below this threshold. To manage and monitor the crop, producers use a method of temperature measurement in heat units, called DD-60s. Heat units are calculated by averaging the maximum and minimum temperatures for a day and subtracting the base temperature. The equation for determining heat units is listed below:

[(max. temp. + min. temp.) ÷ 2] - 60 = heat units

For example, if today's high and low temperatures were 80°F and 60°F, respectively, then the formula would arrive at [(80°F + 60°F)÷2]-60 = 10 heat units, or DD-60s. Table 1.1 provides an outline of the DD-60s requirements for a cotton crop.

Table 1.1 - Average DD-60s Required for Missouri Cotton

Growth Stage	Heat Units DD-60s	Average Date[1]
Planting	0	May 1
Seedling Emergence	55	May 12
Add Nodes to Main Stem	45-65/node	3 days/node
First Square	500	June 17
First Bloom	850	July 6
Cutout[2]	1300-1400	July 28 - Aug 6
First Open Boll	1700	Aug 20
Harvest	2150-2300	Sept 21+

[1]Based on average DD-60 accumulation for Portageville, MO
[2]Assuming 20 main stem nodes and 10 to 12 effective fruiting branches

Studying DD-60s can be helpful in accessing and managing the crop's rate of development throughout the season. This is especially important in the Missouri Bootheel region because 2,250 DD-60s on average are accumulated from May 1 to October 1. Additional information and

listings of DD-60s can be found in some weekly farm magazines or in the monthly *Missouri Cotton News*, distributed by University Extension at the University of Missouri Delta Center.

Rainfall

Rainfall and moisture can affect the soil temperature. A good rainfall of more than 1 inch can drop soil temperature at least 5 degrees. Moisture in the soil may delay warming of the soil for 4 to 5 days. Therefore, cotton seeding should be done with weather forecasts in mind. The producer should strive for several clear days after planting to enhance germination.

Before first bloom, cotton needs ¾ to 1 inch of water weekly. During peak bloom, the water requirement is 1 to 1 ½ inch per weed. During late bloom to early maturity, no water is required. Careful monitoring of the crop will reveal times when the cotton needs water. This is evident by wilting, when the plant starts to lose strength, or turgor (cell wall strength that keeps the plant upright). If available, cotton responds well to irrigation. However, excessive water can lead to increased vegetative (stem and leaf) growth instead of reproductive (flower or boll) growth. Rain gauges should be used to monitor rainfall and irrigation.

Soil Type

Irrigation needs should be based on the soil type. Sandy soils will not hold water as well as other soil types and may need to be irrigated more often. Clay soils have better water-holding capacity, restricting drainage, and seldom need irrigation. However, excessive clay soils will resist root growth through the clay layer and can stunt cotton plants. Silty soils are the compromise between the clay and sand.

Evaluating Field History

Field history refers to the previous crop that was on that particular field. Knowing the previous crop can aid the producer in making management decisions. If the previous crop was not cotton, the weeds found on the field may pose a problem to cotton. The correct herbicide to kill the weeds found may affect the cotton plant. If weed problems are severe, germination and growth may be affected.

If the previous crop was not cotton, a soil test should be done to determine soil fertility and soil nutrients, especially if the plant was a legume, such as clover and alfalfa. Legumes naturally take nitrogen out of the air and put it in the soil through nodes on the roots. Excessive nitrogen may cause problems in vegetative and reproductive growth.

Previous crops may have also had particular insect problems that may impact the cotton crop. The correct insecticide to kill the infestation may also have affected the cotton. Many insects lay eggs in the ground and removing the previous crop will not necessarily kill the insects.

Fertilizer Requirements for Cotton

Like many other plants, cotton has certain fertilizer requirements for varying levels of production. Determining the correct rate of fertilization for cotton is difficult because many variables affect its growth.

Cotton does not respond well to stress because stress affects the amount of nutrients absorbed by the plant from the soil. Some items that may cause stress in the cotton plant include soil texture, drainage, field preparation, weather, variety of crop selected, planting date, planting and germination rate, emergence rate (the number of seeds that produce plants that come up from the soil), previous crop, and nutrients and chemicals in the soil. A current soil test will provide the best option for a balanced fertility program.

The amount of nutrients needed by the cotton plant varies throughout the plant's growing cycle. During spring and early summer when the temperature is low, the cotton plant requires relatively small amounts of nutrients. As temperatures and plant size increase, the amount of nutrients needed by the plant also increases. Peak nutrient amounts are typically needed in late June and throughout July.

The most important nutrients needed by cotton are nitrogen, phosphorous, potassium, and boron. These nutrients are normally found in the soil in varying amounts. To obtain maximum cotton yield and production, optimal levels of these soil nutrients are needed. Cotton prefers a soil pH of 6.0 to 6.5.

Nitrogen is commonly found in the soil in two main forms: ammonium nitrogen (NH_{4+}) and nitrate (NO_{3-}). Ammonium nitrogen is commonly found more often in clay soils, which will hold less of the nitrate form. Nitrogen is used in chlorophyll (the process of making new tissues in the plant). A process in the soil called nitrification (the conversion of ammonium nitrogen to nitrate by bacteria in the soil) changes the levels of each type of nitrogen in the soil. If excessive water is found in the soil, nitrification will be slowed or stopped. This will allow the nitrogen to be given off in the form of gas, which then escapes into the atmosphere and will not help the plant.

For optimal production, cotton must have the correct level of nitrogen throughout its growth cycle. Excessive nitrogen in the soil can delay plant maturity, slow flowering, cause excessive vegetative growth, increase insect infestations, reduce the plant's resistance to diseases, and increase the risk of boll rot disease and lint (boll fiber) quality. When the plant is young, very little nitrogen is needed. When the plant is flowering and forming the boll, large amounts of nitrogen are needed. A common rate of fertilization for nitrogen is 80 pounds per acre.

Fertilizer can be applied at seeding and just before blooming. Thirty pounds per acre is typically applied at planting. Fifty pounds can be side-dressed just before blooming. If the previous crop was corn or soybeans, there will probably be nitrogen left in the soil from previous fertilizations. The amount of nitrogen applied to the field should be reduced.

Phosphorous is another important plant nutrient. Unlike nitrogen, phosphorous does not move very well through the soil. Because of this, the plant needs help to get enough phosphorous. Mycorrhizal fungi associated with the roots of cotton plants take food from the plant but in return helps absorb phosphorous from areas around the roots. Cold soils inhibit phosphorous intake by the plant because the roots grow slowly. Typically winter crops like wheat need larger amounts of phosphorous. If the field was previously planted for wheat, the field will probably not need to be fertilized with phosphorous.

Potassium is also an important nutrient. Potassium is needed in larger amounts in the plant, especially during the period while the bolls are being set on the plant. Potassium is important in the pH balance of the plant's cells and for enzyme production. Potassium is taken directly into the roots without the assistance of fungi or other organisms. Desired potassium levels in soil for cotton vary according to the soil's CEC. These charged particles are important near the roots because the roots will be attracted to some particles and repel other particles.

Another group of soil nutrients needed by plants are secondary macronutrients: calcium, magnesium, and sulfur. Secondary nutrients are typically applied in the fertilizer but a soil test should be done to determine if sufficient amounts of each element are present in the soil.

Calcium helps strengthen cell walls, increase plant growth, produce proteins, move carbohydrates, and balance cell acidity. A calcium deficiency makes the plant more susceptible to diseases and leads to weaker plant stalks. Magnesium is used in making chlorophyll in the plant. Chlorophyll is needed in photosynthesis, the conversion of sunlight into plant food. Sulfur is used in producing certain amino acids, which are the smaller particles that make up protein.

A third classification of soil nutrients is micronutrients. These nutrients are needed in the plant in very small amounts. Micronutrients are rarely applied as fertilizer because the soil generally has a sufficient amount naturally. Common micronutrients are boron, molybdenum, zinc, iron, manganese, copper, and chlorine.

Boron is important in cell formation and in the production of fruit by the plant. Boron is usually plentiful in southern soils but found less in soils in northern cotton producing areas like Missouri. Soil moisture has a direct influence on boron availability to plants. As soils become drier, boron becomes less available to the plant.

Summary

Careful consideration should be given to the field conditions when considering growing cotton. Previous crops, moisture, irrigation, and other factors should be considered. A soil test can reveal information about soil nutrients. Macronutrients such as nitrogen, phosphorous, and potassium are very important to the plant, as is the micronutrient boron. Secondary nutrients are nutrients needed in smaller amounts, including calcium, magnesium, and sulfur. A third group of nutrients, called micronutrients, are needed by the

plants in very small amounts. Micronutrients in soil include boron, molybdenum, zinc, iron, manganese, copper, and chlorine.

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Lesson 2: Selecting a Variety

Once the decision has been made to plant cotton, a producer must choose which variety to plant. Due to research in cotton production and cotton growing conditions, many cotton seed varieties are available. With the help of cotton consultants, producers can make decisions about cotton varieties and disease management.

Cotton Consultants

To produce a high-quality cotton crop, many factors need to be controlled and/or managed. Finding the answer to these questions and finding the pertinent information may require more time than the producer has available. For this reason, many cotton producers employ cotton consultants.

Cotton consultants are hired professionals who aid producers in making correct management decisions based on local conditions. Cotton consultants are asked to perform a variety of tasks, including recommendations for variety selection, pest control, irrigation and water management, soil fertility determination, cotton classification, gin selection, and product marketing. They are often contacted during the growing season to evaluate growing fields for insect infestations, soil fertility problems, irrigation scheduling, and other problems. The consultant offers solutions to problems including alternative methods of solving the problem.

Selecting a Cotton Variety

Many factors are involved in selecting a cotton variety, including yield ability, maturity, plant size, hairiness, transgenes, fiber properties, seed size, herbicide program, tolerance, cost, and insects. Many producers select more than one variety of seed and use different varieties in different fields according to the conditions of each particular field. The variety selected should come from consultant recommendations and local production data.

Yield ability is perhaps the most important consideration in selecting a cotton variety. Yield ability is the total production of a variety of saleable cotton, which in turn determines crop income. How much cotton a variety produces varies from state to state, county to county, depending on local growing conditions.

Plant maturity is determined by the average number of growing days needed from seeding to harvest for the variety. Local climate information is important in deciding when the crop will mature. If the average planting date is known, the harvesting date can be determined by knowing how long a variety takes to mature. Cotton bolls need to open during hot, dry days, not during rain; rain will stain cotton. If August is normally a rainy month, a variety that will open its bolls in September is preferred.

Plant size is a measure of how tall the cotton plant will grow upon maturity. Cotton varieties differ in total plant height. Too much vegetative growth (plant height) will reduce boll production and cause harvesting problems. Growth regulators are sometimes used to limit plant height but is a cost that can be reduced or eliminated by selecting a shorter variety.

Some cotton varieties have hairs growing on the leaves. These hairs can pose a problem in harvesting by getting into the cotton fibers or lint and decreasing the cotton's value. Some varieties have smooth or semi-smooth leaves that reduce the amount of trash in the lint. Missouri does not typically grow varieties that have hair.

Transgenes refer to the varieties of cotton that have been developed that are resistant to particular herbicides like Roundup, Bromoxynil, and Buctril 4EC. These transgenic varieties enable producers to kill weeds with the herbicides without affecting the health of the cotton plant. These varieties are more expensive, however, and not as readily available. Varieties resistant to particular insects have also been developed and reduce the cost of insect control.

Fiber properties include staple length (fiber length), color, cleanliness, uniformity, fiber strength, elongation (how much a fiber will stretch before breaking), and fiber diameter.

Seed size is important in the ginning process because very small seeds are difficult to separate from the lint. Seed size also determines the number of seeds per pound, which is important in purchasing seed.

The herbicide program used to kill weeds should also be considered when selecting cotton variety. As mentioned, transgenic varieties are resistant to certain herbicides. Additionally, some varieties do

not compete as well with weeds as others. Knowing the weed history of the field is important.

Tolerance is another important factor to consider. Certain varieties seem to withstand damage from insects better. Tolerance also relates to how well the plant is able to withstand stress during the growth stages.

One of the biggest concerns for producers is the cost of the seed. Although some older varieties are less expensive, many new varieties are more productive and offset the cost. In addition, transgenic seeds cost more but allow for different management practices in pest control that may be more cost effective.

Insect resistance is an important factor in selecting a cotton variety. There are many insects that may infest cotton. Spraying for harmful insects unfortunately can kill beneficial insects. Also, harmful insects return sooner after spraying than beneficial insects, making the problem even worse.

Cotton Diseases

Cotton diseases are commonly caused by fungi, nematodes, and bacteria. The most common diseases found in cotton grown in Missouri include seedling disease, boll rots, bacterial blight, leaf spots, *Cercospora gossypina*, *Alternaria*, Fusarium wilt, Verticillium wilt, root knot nematode, Reniform nematode, and Lance nematode. Symptoms include stunted growth, poor color, reduced vigor, lower yields, and death. So far there are no varieties immune to all or even most cotton diseases. There are, however, varieties that have limited levels of resistance to certain cotton diseases, like root knot nematode, Fusarium wilt, and Verticillium wilt.

Seedlings are especially susceptible to diseases and usually die. Older plants are able to survive some diseases but with reduced production. Chemicals applied to the seed before planting aid in managing seedling diseases. Most cotton seed is treated with a fungicide.

A plant's ability to withstand disease is also relative to the amount of stress on the plant. Plants stressed from weather (drought or too much rain), too little fertilizer, air pollution, or chemical injury are more susceptible to disease.

There are several methods for managing cotton diseases. The three most common include rotating crops and crop varieties, planting resistant varieties, and planting in warm, well-drained soil. Integrating all three is the most effective method of reducing and controlling cotton diseases.

Fungicide can be applied to the seed, sprayed onto the plant, or injected into the ground after the plant is growing to fight several common cotton diseases.

Summary

Selecting the variety of cotton to plant is based on a number of factors. Utilizing a cotton consultant can make decisions much simpler. The variety selected should be based upon the cotton's yield ability, maturity, plant size, hairiness, transgenes, fiber properties, seed size, herbicide program, tolerance, cost, and insect problems. There are also many diseases that can affect cotton in Missouri: seedling disease, boll rots, bacterial blight, leaf spots, *Cercospora gossypina*, *Alternaria*, Fusarium wilt, Verticillium wilt, root knot nematode, Reniform nematode, and Lance nematode. Careful management can reduce these disease problems.

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Lesson 3: Tilling and Planting the Crop

Preparing the soil for seeding is an important task in producing any crop, and cotton is no exception. Many factors need to be considered when preparing the field for cotton seeding.

Seedbed Preparation

Correct cotton seedbed preparation means preparing a seedbed that is firm, well drained, free of vegetative growth like weeds, and provides a proper environment for the cotton seed to grow. For the cotton seed to germinate properly, the seedbed needs to be prepared for optimal growth. There are two main types of seedbed bed cultivation and seeding - conventional tillage with seeding and conservation tillage.

Conventional tillage for cotton involves plowing fields after fall harvest to shred stalks from the previous crop and mix them into the soil for use as fertilizer. Spring tillage may involve deep subsoil chiseling to break up hardpan clay. Disk and chisel plows follow these operations in the spring to mix any remaining residue and to incorporate herbicides into the soil. Next, beds are formed using a "hipper," a specialized tillage implement that mounds soil in rows leaving an irrigation trough between the mounded rows. Cotton seed is planted in the peak of the mounded rows, which restricts the root growth of the growing plants. Raised beds allow the soil to receive more sunshine, warming the soil and increasing germination. This procedure should be done 2 to 3 weeks before planting to allow rainfall to settle the soil. Table 3.1 outlines the advantages and disadvantages of conventional tillage operations.

Conservation, or reduced, tillage is also used to prepare cotton fields for seeding. The two methods, reduced tillage and no-till cotton, have met with mixed results. The advantages of conservation tillage methods include labor and fuel savings with fewer trips needed over the field. In reduced tillage and no-till, the crop is seeded directly into the mounds from the previous season. Fertilizer and herbicides are generally applied at the same time, along with insecticides and fungicides if needed.

A special planter is used for no-till seeding. The planter cuts through the crop residue, places the seed, covers the seed, and firms the soil over the seed. Stubble left from crop residue protects the seedlings from wind and sand.

Table 3.1 - Conventional Tillage Operations for Cotton

Tillage	Purpose	Advantages	Disadvantages
Shred stalks in fall	Allows stalk to decompose and reduce insect overwintering sites	Can reduce insect pressure the following season	None
Disk in fall	Mixes residue into top layer of soil	Hastens decomposition of residue	Less residue on soil surface can allow blowing soil in spring
Deep subsoil	Break traffic pan layer	Can improve rooting and water infiltration	Costly operation and pan traffic may reform if soil is tilled while wet after subsoiling
Disk/chisel in spring	Mixes residue in top layer of soil and/or herbicide incorporation	Removes any winter weed growth	Less residue on soil surface can permit blowing soil; traffic pan can reform if disking occurs while soil is wet
Form beds with "hipper"	Provides a fresh bed to plant on	Allows the soil to warm up before planting	May reduce surface drainage and require water furrows in some poorly drained fields

Row and Seed Spacing

Once the seedbed has been prepared, the producer is ready to begin seeding. To seed the crop, the proper seeding rate and row spacing should be determined. Row spacing for cotton ranges from 30 to 38 inches apart. Some research has been done on rows narrower than 30 inches but with diminished yields resulting. Row spacing is set by adjusting the planter units on the row crop planter. Seed spacing is generally set to place the seeds from 2 to 4 inches apart, or 3 to 4 plants per foot.

Another factor affecting seeding rate is seed germination, or the percentage of seeds that will actually grow. Typical cotton germination is about 80%. Most producers drop one extra seed per foot to make up for the germination percentage. Seeding rates need to be adjusted higher if the germination percentage of the seed is lower because fewer seeds will actually grow.

Typical seeding rates leave a plant population of 50,000 to 60,000 plants per acre. Overseeding of cotton can cause too many plants to grow, competing for limited water, nutrients, and sunlight. This will result in lower cotton production. Lodging may also occur. In extreme cases, the crop needs to be thinned to allow for maximum production.

Proper seeding depth for cotton is only about ¾ inch deep. The plant will begin to emerge from the soil 7 to 9 days after planting. A problem with cotton is that the seed cannot penetrate a heavy soil crust. This is a result of rain occurring just after seeding, leaving a harder crust on top of the soil. Some producers will increase seeding rate in anticipation of a packing rain.

If low germination occurs, some producers may opt for reseeding, or seeding again directly over the first crop seedlings. Planting rates on the second seeding will be adjusted to a lower rate.

Cotton Planting Calendars

Keeping accurate records is an important management tool in any area of agriculture. Cotton producers use many records. One important record is the cotton planting calendar. The planting calendar allows the producer to base the planting date on expected rainfall, temperatures, and other climate conditions when the cotton bolls are opening and later when the cotton is ready to be harvested.

By using a cotton planting calendar, the producer can maximize the cotton production. Generally, the earlier a cotton crop is planted, the more frost-free days are available for the cotton plant to grow, resulting in increased production. However, as mentioned in previous lessons, cotton should not be planted until soil temperature has reached at least 65°F. Therefore, a balance of early planting with soil temperature considerations should provide maximum production.

Most cotton is planted in Missouri between May 5 and May 15. Cotton planted after May 20 generally shows diminished production due to the shorter growing season.

Summary

Several very important decisions need to be made at or before cotton seeding. The seedbed must be properly prepared for the cotton to grow, and producers must decide whether to use conventional or conservation tillage. Once seeding begins, the planter should be set to provide proper row spacing, and proper seed placement in the soil. Cotton seeds are normally set 3 to 4 inches apart and only about ¾ inch deep in the soil. Cotton planting calendars allow the producer to compare records from prior years and to make more accurate management decisions to optimize growth for the current growing season.

Credits

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Lesson 4: Selecting a Weed Control Program

When producing any crop, a producer's major concern is weeds. Weeds can be present in any growing crop and every effort must be made to control weed growth.

Because cotton is a relatively slow-growing plant, weeds can become easily established without much competition. Weeds grow faster than cotton and can quickly overtake the field. Estimates indicate that chemical weed control can cost producers $5 to $25 per acre beyond crop yield loss.

Factors Influencing a Weed Control Program

Weed control in cotton is not a simple process. When planning a weed control program for cotton, the following factors should be considered: field history, soil type and structure, use of herbicides, and method of application of herbicides.

A field history is needed to evaluate what crops have been planted before, including known weed problems and previous applications of herbicides. The carryover residue of some herbicides can affect the growth and health of the cotton plant. Research in cotton varieties has resulted in the development of transgenic varieties that are resistant to weeds. Prior use of these varieties may have an impact on the weed control method used for the current crop.

Soil type and structure may affect the weed control program selected. Soil type will determine how well the herbicide moves through the soil if injected into the ground, as does soil structure.

Only a limited number of herbicides have been developed specifically for cotton. Most herbicide research is conducted on crops for which millions of acres are planted annually, such as corn, soybeans, and wheat. Cotton accounts for a relatively small acreage compared with those crops. Cotton is a slow-growing broadleaf plant. Therefore, any herbicide designed to kill broadleaf weeds can injure or kill cotton plants. Weeds should not be allowed to grow taller than cotton because spraying the weeds then becomes more difficult and results in damage to the cotton plant. Because cotton is a broadleaf plant, many producers will opt for preplant and pre-emergence herbicides. These herbicides provide effective weed control on the soil surface before cotton germination. Currently, no selective, over-the-top sprayed broadleaf herbicides are effective in controlling weeds without harming the cotton plant. Herbicides designed to control grass-type weeds in cotton are very useful because they do not affect cotton plants.

Method of application for individual types of herbicides should be considered. Some herbicides work well only with certain application methods. For instance, not all herbicides work well in a hooded type sprayer, where a hood directs the chemical onto a specific area on the ground. The directions for application will be shown on the herbicide label; these directions should always be followed.

Weeds Specific to Cotton

Certain weeds are more problematic in cotton fields because they are difficult to control and steal valuable nutrients from the cotton. These common weeds include signalgrass, barnyardgrass, bermudagrass, fall panicum, foxtails, goosegrass, jimsonweed, hemp sesbania, hophornbean copperleaf, lambsquarters, pigweed, crabgrass, nutsedge, Johnsongrass, cockleburs, morningglory, velvetleaf, spurred anoda, and prickly sida.

Grass-type weeds can be controlled with any herbicide containing floumeturon that is applied directly onto the soil. Broadleaf weeds are more difficult to control, especially velvetleaf, prickly sida, and spurred anoda. The herbicide, Command, is especially effective in controlling these weeds.

Effect of Weeds on Cotton Yields

Weeds growing in a cotton field compete with the cotton for the available nutrients, including fertilizer and water. This competition can reduce cotton yield and ultimately producers' income.

The amount of crop loss due to weeds varies according to moisture levels, the soil fertility, and cotton's vegetative growth. If the weeds have more vegetative growth (leaves) than the cotton plant, more sunlight will be absorbed by the weeds instead of the cotton. The growth of the weeds will increase more, while cotton growth slows.

Keeping the weeds out of cotton is especially important just before harvesting, as the weeds will leave seeds and other plant parts in the harvested cotton, further reducing the crop's value.

Weed Control Options

Controlling weeds in cotton involves many different strategies and techniques. Most producers have found that preplant herbicide application will reduce problem weeds as seedlings begin to grow. Application before planting does not impact the cotton plant. Using herbicides to kill growing weeds before planting is sometimes called burn-down because weeds are killed quickly, and fields are left barren.

Most producers also apply herbicides just after planting, before the seedling emerges from the soil. Because cotton is a slow-growing plant, the weeds will generally emerge from the soil first and applying herbicide after planting reduces or kills the growing weeds.

As the cotton plant grows, weed control becomes even more difficult. If the herbicide used is for grass-type weeds, it can be sprayed on the cotton plant without any impact to the cotton. If a broadleaf weed herbicide is being used, care must be exercised to avoid spraying the cotton plant or it will also be injured or die. For this reason, producers will sometimes use a hooded sprayer, which sprays herbicide under a cover and only in the space between rows, not over the top of the crop.

During the growing season, it is important to scout the field for weeds. Scouting involves walking through the crop, looking for growing weeds, and marking on a field map where the weed infestations are located. These areas should be monitored, and when weed infestations become serious, they should be sprayed, not the entire field. Scouting will be discussed in more depth in the next lesson.

Some producers will use between-row cultivation to control weeds. This will kill the weeds growing between the cotton rows. Unfortunately, this does not remove weeds growing very close to plants or directly in the rows.

Research in cotton varieties has resulted in the development of transgenic varieties that are resistant to weeds. Use of herbicides developed for transgenic varieties more effectively control weeds without concern of damage to the cotton plant.

Summary

Careful consideration should be given when developing a weed control program for cotton. Weeds can dramatically decrease cotton production and require careful control strategies. Three common methods of weed control are preplanting, pre-emergence, and spraying between rows of growing cotton.

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Lesson 5: Scouting and Maintaining the Crop

After a producer has planted his or her crop, its growth and development are not guaranteed. The cotton plant requires continual maintenance to keep it free of pests. Sometimes it may be necessary to completely replant the cotton crop. A producer should continually scout the cotton crop and look for pests. If a pest problem is evident, the producer has several options. He or she can implement pest control strategies such as herbicide or pesticide applications. It may also be necessary for a producer to apply a growth regulator if the cotton is unable to adequately control its own growth cycle.

Evaluating the Growing Crop

Once the crop starts growing, several factors need close monitoring. Cotton is not a crop that can be ignored after planting and before harvest. Careful monitoring of the growing crop throughout the season is crucial to its overall health and production. Moisture, plant density, weeds, insects, plant health/soil fertility, and plant growth are all items that should be monitored.

Moisture level is important to a cotton plant. Moisture should be monitored in relation to irrigation and plant needs. If the plant appears to be wilting, more water is needed. Too much water, however, can limit the overall growth of the plant due to a lack of oxygen to the plant roots.

Plant density (spacing) can also affect the health and yield of the crop. If plants are too closely spaced, they will compete for limited water and nutrients. If plants are too widely spaced apart, replanting should be considered. Cotton seedlings should emerge in about 5 days. A crop that emerges in 5 days has a better chance of survival than a crop that takes longer, even as little as 3 days more. A crop that takes 10 days to emerge is more likely to produce only about one-third of the crop that emerges in 5 days.

The stage of growth and development of existing weeds should be considered when evaluating a cotton field. If weed populations are light, control and treatment are probably not immediately necessary. However, weed populations vary throughout the growing season. What may not be a problem now can become a problem in as little as a few days. If weed populations are heavy, control programs should be implemented.

Insect population resulting in plant damage should be carefully monitored. If insect populations are light, keep monitoring the crop. If insect populations are heavy, consider implementing an insect control program.

The overall health of the plant should be monitored throughout the growing season. The health of the plant is an indication of any soil fertility issues. If plants appear to be green and healthy, soil fertility is probably not a concern. If overall plant health begins to diminish, consider soil testing to determine what plants are lacking.

How the plant uses extra nutrients is another factor to monitor. Early in the plant's life, vegetative green growth is more common, while reproductive growth occurs later in the plant's life. Too much vegetative growth will limit the production of cotton lint. Too little vegetative growth may indicate plant stress.

To determine these factors, a scouting program should be used. Scouting is a systematic and regular inspection of the cotton field for insects and their damage. Scouting can also include determining levels of weeds, plant vigor, water needs, and other factors. Further discussion of scouting will follow later in this lesson when discussing insect pressure.

Plant mapping is an effective technique that growers can use to ensure that they keep their crop on schedule. By quantifying several growth parameters of the cotton plant, growers and consultants can identify potential problems or opportunities for managing their cotton. This requires the time and effort to collect and interpret simple plant maps. Sampling a cotton field involves going to four areas of a field and measuring five plants in each area. Three sampling periods are important: prebloom, bloom, and postbloom. (Detailed guidelines for plant mapping is available in the University of Missouri Extension publication, *Cotton Plant Development and Plant Mapping*, G4268.)

Replanting Considerations

The main concern of producers once the plant has begun to emerge from the ground is the quality of the stand. All cotton seeds planted will not grow

into plants. Although seed germination percentage is used in variety selection and to determine seeding rate, the field may still appear to have uneven stands.

To determine if replanting is appropriate, remember that the ideal seeding for cotton is three to four plants growing per foot. If the average of the field is slightly less than that, replanting is probably not appropriate. If the field appears to have much less than three to four plants per foot, serious consideration should be given to replanting.

Replanting decisions should be based mostly on economic and financial factors. Just because a field looks uneven does not justify replanting.

The most important factor to consider is timing. If the decision to replant is made too late, the crop will not have enough growing days to produce, making the second seeding a waste of seed, time, and money.

The producer must realize that the added cost of replanting may exceed the projected income from the harvested crop. Replanting also causes minor damage to the existing plants. Many plants will recover, but some will not, impacting the seeding rate on the second seeding. No matter how heavy or light the crop appears at seedling time, the field will always look better later in the season as plants continue to grow. Thin spots in the field will not look as thin later.

Weed Considerations

Good weed control is more difficult to achieve in cotton than in corn or soybeans because cotton grows more slowly and herbicide options are limited. Determining whether to use herbicide or mechanical removal of weeds during the plant's vegetative and reproductive growth stages is a difficult decision. Weeds compete with the plant for nutrients and water. Weeds can be especially harmful during the reproductive stage because the cotton plant needs even more nutrients when the cotton bolls begin filling. Once the bolls begin to open, the amount of nutrients the plant needs begins to diminish; weeds have less of an effect on the plant at this time.

A producer should take several steps in making the decision to use herbicides or mechanical removal of weeds.

- Analyze the height of the weeds in relation to the height of the cotton plant. Will the herbicide make more contact with the cotton than with the weeds and damage the cotton plant?

- Determine the density of weeds in relation to the density of the cotton. If there are more weed plants per square foot than cotton, treatment is highly recommended.

- Determine the impact on the crop if mechanical removal methods are used. Can enough plants withstand the stress of cultivation to maintain a profitable crop?

- If vegetative growth appears to be stunted or diminished, consider a weed control treatment. Vegetative growth leads to reproductive growth and overall plant health.

Insect Considerations

As a crop, cotton can be damaged by a number of insects. If insects are not properly controlled during the growth season, overall yield or production can be reduced 25 to 85%. In addition, insects can diminish crop quality by feeding on the lint and seeds or by delaying crop maturity.

To determine the amount of pest damage in a crop, fields should be scouted at least once a week and more often during the flowering stage when the plant is most susceptible to insect damage. As stated earlier in this lesson, scouting is a systematic and regular inspection of the cotton field for insects and their damage. The purpose of scouting is to get an accurate estimate of the types and numbers of insects in the field by checking a limited number of plants.

By knowing the type, number, and location of insects and damage within a field, a producer can make sound decisions about insect management and justify the time and expense of scouting.

There are some general guidelines to follow when scouting a field.

1. At planting, place boll weevil traps. Place a minimum of one trap per 50 acres.

2. From emergence of the plant until the plant makes the third true leaf
   a. Check for thrips, cutworms, mites, and aphids.
   b. Make initial stand counts.
   c. Check boll weevil traps weekly.
3. From the third true leaf until the fifth node stage
   a. Check terminals (end of plant stems) for eggs, larvae, and weevils.
   b. Check for damage on plants by plant bugs and weevils.
   c. Sweep the borders of the field for plant bugs.
   d. Record node height and position of pinhead squares (square-shaped part of the stem at the fifth stage).
4. From fifth node to first bloom
   a. Remove and store boll weevil traps.
   b. Check terminals for eggs and larvae (minimum of 25 plants per field).
   c. Calculate percent square set (check minimum of 25 plants per field). The square is the unopened flower bud on the cotton plant. Count the squares on the top five fruiting nodes and assess percent set.
   d. Begin sampling 100 green squares per field when 15% of squares reach one-third grown or larger. Check these squares for boll weevil, bollworm or plant bug damage.
   e. Assess weekly mean node height and mean number of squares per acre.
   f. Count number of plant bugs and beneficials per 100 sweeps per field using a sweep net.
5. Post first bloom
   a. Pull one-third grown or larger squares (100 per field minimum) for worm and weevil damage counts.
   b. Check top 6 inches of plant for eggs and larvae.
   c. Check whole plants (10 to 20 per field) for eggs, egg masses, and boll damage.
   d. Check blooms for weevils, worms, and clouded plant bugs.
   e. Assess weekly number of squares and bolls per acre.

Correct identification of the insects that can cause damage to the cotton plant is essential. Once the insects have been identified, knowing a threshold level for each insect is important.

- Cutworms - if the cotton plant stand is reduced to fewer than three plants per row foot
- Thrips - one or more thrips per plant are found on seedling cotton (Thrips are extremely hard to find due to size and mobility. Large numbers of damaged plants are an indicator of thrip presence.)
- Fleahoppers - one plant bug found per 10 feet of row (not usually a problem in cotton in Missouri)
- Boll weevils
  With traps: one trap per 10 acres, clustered with other traps (four traps for 40 acres clustered together) Threshold is two per trap per week prior to emergence.
  Without traps: threshold level is 10% of squares damaged the first 2 weeks in July, 15% of squares damaged in the last 2 weeks in July, and 20% of the squares damaged in August
- Bollworms - 10% of bolls damaged by moth flight
- Aphids - low populations start to increase
- Spider mites - if 50% of leaves are infested
- Clouded plant bugs and Lygus Plant Bug
  1st week of squaring, 6 to 8 plant bugs per hundred squares
  2nd week of squaring, 8 to 10 plant bugs per hundred squares
  3rd week of squaring, 10 to 12 plant bugs per hundred squares
  4th week of squaring, 15 to 18 plant bugs per hundred squares
  After 4th week squaring, not ususally a problem
- Armyworms - 5 egg masses and live larvae per 100 plants, or 4 or more worms in 100 blooms and bolls
- Whiteflies - when 50% or more of the plants are infested (not a problem in Missouri)
- Root worm nematodes - found in the soil, testing of the soil is necessary

An important component of insect control is the use of integrated pest management (IPM). Integrated pest management is the use of natural predators of harmful insects to control pests. The use of IPM can reduce the cost of pesticides to the producer. Beneficial insects unfortunately tend to be specific to a particular insect pest. Multiple beneficial insects may be needed and can be purchased; however, this is not practical in most cases. IPM's major advantage over chemical use is that the insects are specifically targeted. However, if chemical control is used, many of the beneficial insects will also be killed.

Growth Regulators

There are times in the life cycle of a cotton plant when the producer may want to control the growth of the cotton. Cotton's growth is managed using compounds called growth regulators. By nature, cotton has its own built-in growth control mechanism that is usually adequate in unstressed plants. Growth regulators are generally necessary because cotton is naturally a semi-tropical plant, preferring climates not found in cotton producing areas. The farther north cotton is produced, the more crucial the supply of boron becomes. Boron, a micronutrient, performs a key function in the growth and fruiting process. This is why it is so important to the plant. Boron allows the plant to transfer sugars from leaves to the fruit.

If the plant is under insect stress, growth regulators are needed. The most effective plant growth regulator is used when the plant begins to produce fruit. This regulator naturally slows vegetative growth and encourages reproductive growth. Growth regulators are generally used during early bloom to speed up the flowering process. This provides for more a more uniform flowering and harvesting. Common growth regulators used in cotton production today are PIX (Mepiquat Chloride), which is used to shorten plants, and PGR IV, Maxxon, and Cytokin, which are used to help roots develop and bolls set.

Summary

Cotton is a crop that requires intense management during the growing season. The crop must be regularly scouted and evaluated for moisture, plant density, weeds, insects, plant health/fertility, and plant growth. Replanting decisions should be based primarily on economic and financial factors. Replanting may exceed the projected income. Management decisions regarding weed and insect infestations have to consider the pressure that the cotton plant can withstand. Growth regulators may be necessary in the northern portion of the growing region to encourage reproductive growth.

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Lesson 6: Harvesting the Crop

After spending the entire season monitoring and managing a crop, every producer is eager to harvest. Harvesting any crop is a stressful time due to the crucial management decisions to be made. Deciding when to harvest is just one of the many management decisions a producer needs to make. Cotton is generally harvested when a high percentage of the bolls are open and the leaves have fallen off the plant.

Factors Determining Harvest Timing

Cotton harvesting generally starts in October and can sometimes last through mid-winter. Cool weather and frost can speed up cotton harvesting because cool weather causes leaves to fall off the plant, referred to as defoliation. Leaves can cause problems by clogging mechanical harvesting equipment, which is the most common cotton harvesting method. Defoliation reduces trash and green leaf stain in the harvested lint. This trash is generally from chopped up leaves and other vegetative plant parts harvested with the lint.

To manage harvest time properly, cotton producers use chemicals to defoliate plants. These chemicals are referred to as crop harvest aids. In addition to defoliation, these chemicals suppress further growth and encourage the cotton bolls to open.

Timing of defoliation is crucial to ensure ideal lint quality and optimum yields. Defoliation applications should be timed so that harvesting can keep up with defoliation. Defoliating too early reduces the oil content of the seed and reduces viability and total yield. Defoliating too late may result in diminished results, since the defoliating compounds rely on warmer temperatures to be effective.

Defoliation is typically done when at least 60% of the bolls are open. Defoliants are sprayed directly onto the plants. Correct timing of defoliation can be determined by several different methods. One method involves plant mapping. Plant mapping is analyzing and recording the various growth stages of the plant. Using this method, producers apply defoliants when plants have at least four nodes above the lowest cracked boll (a boll showing visible lint). In fields where there are less than two plants per foot per row, the number of necessary nodes decreases to only three. The plants have reached the end of the effective boll loading period or "cutout" at this time.

Another method of determining defoliant timing is to count the number of nodes above the white flower. Commonly called NAWF (nodes above white flower), Missouri producers find this method to be very reliable. The NAWF occurs at or near the eight or ninth node. An NAWF of five usually occurs around August 10 to 12 and indicates correct timing for defoliation.

After defoliation, it normally takes the boll approximately 4 to 6 weeks or 750 to 850 heat units to mature. Cool temperatures increase this time frame. Other factors that determine timing of defoliation include boll firmness, percent of open bolls, seed coat coloration, heat unit accumulation (a weather measurement), and visual assessment. Generally, the 60% open bolls rule is followed for determining defoliation, and later, harvesting.

The timing of the harvest also affects the harvest method used. Harvesting the cotton crop can be accomplished using two different methods. Some producers prefer the once-over method of harvesting; all cotton bolls are harvested at the same time. Usually this method reduces time, fuel, labor, and other harvesting costs. The two-harvest approach has an early harvest of those bolls ready for harvest and then a later harvest of the rest of the bolls. A second harvest operation is more expensive but the potential return may justify the cost.

Harvesting the Cotton

Historically, much of the cotton grown in our country was harvested by hand, a laborious, painstaking task. The most common method of harvesting cotton today in much of the United States is with a mechanical cotton picker.

Cotton pickers are a product of advanced engineering. The cotton picker has spindles that pull the fiber from the boll, remove the trash and lint, and cut the fibers away from the seeds. Later in the ginning process, the seeds are removed and processed.

The cotton picker is a row-crop harvester and harvests each row separately. Generally, cotton pickers are limited in width due to the complexity

than one row picker is used at the same time in the a field.

A cotton stripper is used in some areas of Texas and Oklahoma where the stalks do not grow very tall. The cotton stripper plucks the entire boll from the stalk rather than picking the fiber from the boll like a cotton picker. When a cotton stripper is used, all bolls should be open. The stem is destroyed as the bolls are striped from the plant. Multiple harvests of the same plant are not possible and unopened bolls are lost. The ginning process cleans the stems and other plant debris from the lint.

Cotton should be harvested when the dew leaves the field and stopped when the dew returns in the evening. Cotton with a moisture content lower than 12% can be harvested and stored without mold damage. Many cotton pickers have moisture monitors on the machine to detect the moisture level in the cotton. If a moisture meter is not used, moisture level can be determined by biting the cotton seed. If the seed cracks, the moisture is low enough for the crop to be harvested.

Crop Losses During Harvest

As with harvesting any crop, reducing crop loss is an important consideration. Most crop losses are due to the improper condition of the cotton picker. Worn or damaged spindles can result in crop loss.

Misalignment and misadjustment of the spindles to moisture pads and doffers reduce the efficiency of the picker, also resulting in crop loss. Improperly adjusted spindles will leave some cotton on the spindle, twisting and damaging the fibers.

Excessive trash in the lint can reduce its value. Trash in the lint can be caused by incomplete defoliation where leaves are taken into the picker with the lint. Picking units and basket grates should be cleaned regularly with the trash and low-quality fibers discarded.

Storing Cotton

Once the cotton is harvested, the lint is usually stored for a short time prior to ginning. A common method of storing lint for short periods is in a unit called a module. Modules are bundled lint, covered with water-resistant tarps, stored in the field.

Modules should be monitored for moisture content during the first 5 to 7 days. If moisture levels are too high, the internal temperature of the module will begin to rise. A rapid and continuous rise in temperature of 15 to 20 degrees indicates too much moisture, and the module will need to be ginned as soon as possible. If the internal temperature of the module exceeds 110°F, the module must be ginned immediately.

Place modules in a field location that is relatively free of gravel, stalks, and other debris to prevent these items from working into the lint and reducing the quality. Modules should be placed on well-drained sites that are accessible during wet weather by module trucks or the producer.

Summary

If proper management decisions are made during cotton harvest, a high-quality crop will be the result. Harvesting not only involves the actual picking of the cotton, but also the planned defoliation. The use of defoliants will increase the value of the crop by reducing the amount of trash from chopped-up leaves. Once the cotton is harvested, modules are used for short-term storage. These tarp-covered cotton bundles are stored in the field.

Credits

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Lesson 7: Marketing the Crop

The final step in the harvesting of the cotton crop is marketing. Cotton is unique in the various methods used in marketing the crop. A producer has various options to consider and often these decisions must be made well in advance of the harvest.

Marketing Cotton

The first step in marketing the cotton is to schedule a gin. Ginning is the process of separating the lint and seed. It also includes drying the cotton and cleaning the lint to remove trash. After the cotton was harvested, the raw cotton was probably placed into modules and stored in the field. Depending on the moisture level and the temperature rise in the module, the gin should be scheduled as quickly as possible.

It will be necessary to call the local cotton processor to schedule a time to process the crop. It may be necessary to negotiate times, price, and transportation of the modules. Once the gin is scheduled, the cotton is delivered and processed.

The price received by the producer for the ginned cotton and cottonseed oil can be determined using two different markets - the cash market or forward pricing, using cash contracting or hedging.

Cash market pricing relies strictly on the current market price. Generally, like most crops, the price of cotton is at the lowest price of the year during harvest due to the excess supply compared to the demand.

Some producers will opt to contract their crop. The crop is contracted with an established price at a prior date to the actual processing and delivery. With cash contracting, a sale price is firmly established and does not reflect fluctuations in the cash market at harvest time. Cash contracting has disadvantages. If the market moves upward to higher prices at harvest, the producer will receive only the negotiated price. Also, if the producer experiences crop disasters or failures, the negotiated amount of the crop is expected to be sold, and the producer may be required to purchase cotton to meet the contract.

Some producers will pursue hedging, or using the futures market. Hedging is a complex procedure where the producer first sells contracts, or a set quality and quantity of cotton. As the season progresses, the producer must later buy the same number of contracts back, hopefully at a lower price, to get out of the futures market. Hedging allows the producer to use basis, or the difference between futures and cash price, to strive for a profit. Unfortunately, for every person making money in the futures market someone loses money, so there is great risk. The futures market should not be used by the inexperienced person due to the great risk.

Cotton Quality Factors

The price the producer received for cotton is especially dependent upon quality. Standards have been established by the U.S. Department of Agriculture to ensure uniformity in grading, resulting in standard quality and pricing that are consistent throughout the world. Cotton quality is measured by many different factors.

One factor that determines cotton quality is color grade. Color refers to the degree of whiteness and yellow in the lint. Ideally, lint would be pure white, but it can be discolored due to improper defoliation and wet weather damage to the crop. Color grades include white, light-spotted, spotted, tinged, and yellow-stained.

Another important factor in cotton quality is fiber length. Fiber length is typically measured by computerized machines and is given in lengths of thirty-seconds and hundredths of an inch. Longer fibers are more desirable, making the spinning process more efficient with stronger, more uniform yarn.

Measurements are taken on the cotton with an instrument called a micronaire to determine the diameter or fineness of the cotton fiber. Fiber diameter affects yarn appearance, uniformity, and strength. Finer diameters are preferable.

Strength of the fiber is a factor in cotton pricing and is relative to the variety of cotton raised. Cotton fibers are clamped between two jaws 1/8 inch apart, and the fiber is stretched until breaking. Measurements of cotton strength are reported in grams per tex. A tex is equal to the weight in grams of 1,000 meters of fiber. Fiber strength directly relates to yarn and fabric strength, and spinning efficiency.

Length uniformity measures the uniformity of the length of the fibers in a sample. Fiber length uniformity is related to uniformity of the yarn, spinning efficiency, and overall yarn strength.

As mentioned in the last lesson, having trash in the cotton is not desirable. When cotton is graded, a trash measurement is taken using a machine called a video trashmeter, which measures the percentage of trash on a cotton sample's surface. This sample measurement will provide an estimate of the total amount of waste in the cotton bale.

Cotton Checkoff Program

Much like other crops, cotton is supported by money from the federal Farm Bill. Cotton checkoff dollars originated in the U.S. Farm Bill, with the first inclusion in the Farm Bill of 1967.

Cotton checkoff dollars are funds raised from the sale of cotton in the United States. Each time cotton is sold, a set amount of money is charged against the sale, with the funds collected by a controlling agency. With cotton, the money is sent to the U. S. Cotton Board and is administered from that office. Typically, the amount charged to the sale amounts to about ½¢ for a man's cotton shirt. Foreign imports contribute more to the fund, sometimes twice as much.

Cotton checkoff funds are used for advertising and marketing to help cotton compete with artificial fibers and to maintain and expand domestic and foreign markets for U.S. cotton. Funds are also used for research to develop new seed varieties, herbicides and pesticides, and methods of processing.

Although there is some opposition to the checkoff program, millions of dollars are raised each year to help the cotton industry. As a result, cotton consumption has steadily increased each year since the inception of the program.

Summary

The marketing process used in the cotton industry is very complex. Unlike many other crops, cotton is often contracted for price well in advance of harvest. Producers can also choose the local cash price or can opt to use the futures market but must be aware of the risk of the futures market changing. Cotton pricing reflects the quality of the cotton, and cotton is graded on color, fiber length, fiber diameter, fiber strength, trash, and uniformity of the fiber length. The cotton checkoff program provides funds for research and to promote the cotton industry.

Credits

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Lesson 8: Figuring Crop Costs

Once the crop has been harvested, the producer must determine his or her profit from the crop. To determine profit, an accurate listing of costs must be assembled. Costs can be broken down into two categories: variable and fixed.

Variable Costs

Variable costs of cotton are those costs associated with inputs necessary to produce a specific crop yield calculated on a cost-per-acre basis. By figuring the cost per acre, the producer realizes a profit or loss for each field. By knowing the profit or loss of each field, the producer can decide if another crop should be considered for that particular field. Seed, fertilizer, chemicals, fuel and oil, labor, harvesting, and interest on borrowed capital are all variable costs associated with cotton production.

Seed costs can vary depending on seeding rate, the number of times the field was seeded, and the variety of seed purchased. Seed from varieties used for a number of years will tend to be less expensive. Newer, transgenic varieties will be more expensive due to the company's need to recover research costs in developing these varieties. However, the added cost of the seed may be offset in the reduced cost of weed control. Another factor to consider in seed cost is the quality of cotton produced by a particular variety. Varieties producing higher-quality lint will generally be more expensive but result in higher profits.

Fertilizer costs vary since the condition of each field is different. To determine fertilizer requirements accurately a soil test should be taken. Recommendations from the test results can be used to estimate costs.

Chemicals are used extensively in crop production. These variable costs are often recorded separately so producers can realize where the most or least dollars are being spent. Common types of chemicals used in cotton production are insecticides, fungicide, growth regulators, and defoliants.

Insecticides can dramatically add to the total variable costs if insect problems are significant. A thorough scouting program can accurately monitor insect populations. Timely applications of insecticides before insects become a severe problem will reduce costs.

Herbicide costs also vary from field to field, because different fields will not have the same level of weed problems. Significant weed problems can be determined at the same time as insect scouting and appropriate measures can be taken. Cotton herbicides are fairly expensive; applications should be timed to gain the most value in production but limited to control costs.

Fungicides are generally only applied before or at seeding time. Occasionally, fungal problems are severe enough to warrant a second application on growing crops and added costs will result.

Growth regulators are used to control vegetative growth, speed up plant blooming, and help retain bolls. The number of applications of these chemicals depends on crop management plans and the weather. These costs should be figured into the variable costs of the crop.

Harvest aids (defoliants and boll openers) are used to chemically remove the leaves from the plant and force bolls to open in a uniform manner. This causes the plant to focus on blooming, thus decreasing the time until harvest. Defoliants are usually only applied once but are considered a critical harvest aid for Missouri's cotton production. Using a combination of these harvest aid chemicals can reduce variable costs by as much as $30 per acre as only once-over harvest is needed.

Other variable costs that must be closely monitored are fuel and oil. A record should be kept of all fuel and oil used in cotton crop operations. To determine the cost per acre for fuel and oil, total costs are divided by the total cotton acres. Any other regular maintenance of machinery should also be figured.

One commonly omitted factor in agricultural operations is the cost of labor. Many producers include the cost of hired labor, including crop consultants, scouting services, and other hired services but fail to include their own time into the costs. Producers must recognize that their own time is worth as much, or more, than any of the hired services and should be included in the variable costs of the operation.

Harvesting costs should be included in the variable costs, whether one is using the producer's machinery or hiring someone else to harvest the crop. If the producer's own machinery is used, the wear and tear costs should be included because they will cost the owner/producer money to fix and maintain them.

Ginning the cotton is considered a variable cost. If the crop were not produced, obviously this cost would not be needed. Ginning costs are generally charged to the producer by weight, not acreage, so an average yield needs to be determined (production per acre) to establish the cost per acre on an individual lot of ginned cotton. This allows the producer to determine the costs on each individual field. Although not as accurate, most producers just divide the total cost of ginning by the number of acres to determine the cost per acre of all fields. This method does not give the costs per each field. Transporting the modules of cotton from the field to the gin is included in the ginning fee.

If the cotton has to be stored, and the storage facility is rented, a variable cost will result. Many producers will store the raw or ginned cotton until later dates to maximize profits, since the price of cotton is generally lowest at harvest time. However, the crop may diminish in value due to storage.

In production agriculture, income from a crop is usually received only once or a few times a year. Some producers may need to borrow money in the form of an operating loan to pay expenses during the growing season and repay the loan when the crop is sold. Any interest on this borrowed money would be considered a variable cost, since the interest would not be there if the crop were not produced, and the money had not been borrowed.

Any other costs that occur during the growing season due to producing the crop are considered variable costs.

Fixed Costs

Fixed costs are costs that do not vary with the level of production. They are generally regarded as whole farm, or whole enterprise costs. Fixed costs are not normally charged on a per-acre basis but should be divided by the number of acres to make profit and loss calculations easier to perform. In some cases fixed costs can amount to more cost per acre than variable costs. Examples of fixes costs include taxes, insurance, loan payments, rental fees, utilities, and depreciation.

Taxes are considered a fixed cost because tax payments must be made regardless of production. The most common type of fixed cost tax would be property taxes, which are charged in many states including Missouri.

Another type of fixed cost is insurance. Producers should carry insurance on the entire operation, especially if hired labor is present. Insurance costs include liability insurance, fire insurance, hail/disaster, and even earthquake or hurricane insurance in certain areas of the country.

Any time money is borrowed to purchase land or machinery, the loan payments would be considered fixed costs. These payments must be made on both land and machinery, regardless of production.

If equipment or land is rented, the payments would be considered a fixed cost, again for the same reason: purchased equipment payments are a fixed cost. Even if the crop is not produced, the rental charges still must be paid.

Farmstead utilities are a fixed expense. Utilities include electricity, sewer, water, and other services used on the farmstead. Caution should be observed when considering utilities, because at times utilities would be considered a variable expense. An example of this would be an electric charge for operating an irrigation pump. If the pump were not used, there would not be a charge. If the pump was used, this expense would be a variable cost and should be figured into that category.

One fixed cost often overlooked is depreciation expense. Depreciation is the decline in value of a piece of machinery or other equipment due to wear, tear, usage, and aging. Although a producer does not pay anyone money for depreciation, money should be set aside in a bank account yearly so that the machine can eventually be replaced with a new model from the money saved in the account from accumulated depreciation expenses. Producers who do not include depreciation expenses in fixed costs are not providing for later equipment replacement. Unfortunately, if the producer is "trying to make ends meet," this is the first expense ignored and not figured into the profit calculations. By not

including replacement equipment costs, the enterprise or operation might show a false, or inflated, profit.

Cost per Acre

Once the fixed and variable costs have been figured, calculating total costs is very important, yet relatively simple. After total fixed and variable costs are calculated, the two costs should be added to get a total cost value.

A total cost value is useful to the producer because it gives the total amount of money spent on the crop. However, if a producer wants to compare with other years, total cost is not that useful, since the number of acres planted in that crop may have changed or inflation may have caused prices to increase substantially.

Total cost is also not very useful when determining the price needed to break even for the crop, because the crop is sold in pounds, which is easily converted to pounds per acre. For these reasons, most producers will divide the total cost by the number of acres planted to get cost per acre.

By knowing cost per acre, the producer can more readily determine a break-even price (divide the cost per acre by total pounds produced per acre). Knowing the break-even price can help the producer determine an acceptable return on investment.

Return on Investment

Once the income and expenses are known, the producer is then able to calculate a profit or loss from the crop or the whole farm. Obviously, producers like to maximize profits. With agricultural prices lower than most producers would like, a determination must be made of what is the acceptable level of profit.

Return on investment can be defined as money received by the producer above costs, which can be used for farmstead improvements or investments. Return on investment is also commonly called "profit," or what supports the farm family through the coming year. If the overall return on investment for the entire farm is not enough to support the family and its lifestyle, decisions and changes must be made.

To determine an acceptable return on investment, several factors should be considered. If the producer needed to borrow money to produce the crop, the return on investment should be sufficient to cover the cost of borrowing the money. In addition, the producer should consider alternative uses for the money compared to investing in a growing crop. As an example, if bank interest rates on certificates of deposit are higher than the return on investment from the crop, raising the crop was probably not a sound financial decision, especially when figuring the stress and decisions of raising the crop compared to investing in certificates of deposits.

Another factor to consider would be whether an alternative crop would raise the return on investment. If another crop had lower costs, and higher income from higher prices, a switch to that commodity might need to be considered.

Like everything else, there are exceptions to the above rules. If the land has never been used to plant cotton, one season may not be enough to evaluate the return on investment accurately. Succeeding years may result in higher returns on investment, due to the producer's experience and more sound management decisions.

Another factor that may affect these rules is abnormal weather conditions. If a drought occurs that particular year, the following years may be closer to normal and return on investment higher.

Government Programs

Cotton is affected by governmental regulations and subsidies. Cotton production, for instance, is addressed in the Farm Bill. Most programs in the Farm Bill are designed to increase production and competition with foreign markets.

The cotton portion of the Farm Bill addresses increased production and paying producers to raise more cotton to compete with the other markets in the world. Producers enrolled in the cotton program receive an incentive payment from the government, which can increase the overall crop income.

Summary

Once the crop is harvested, a financial analysis should be done to evaluate the success of the crop and the producer's decisions. Variable and

fixed costs need to be calculated, which figure into the total costs of the crop. Once total costs are known, the cost per acre can be calculated, allowing the producer to determine what will be an acceptable return on the investment. Finally, because cotton is a part of the federal Farm Bill, there are programs that reward the producer financially for producing cotton and increase the total profit of the crop.

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Lesson 1: Planning the Crop

Archeologists believe that rice has been cultivated for more than 5,000 years. Two-thirds of the world's population consume rice. In the United States, rice production is focused in Arkansas, Louisiana, Mississippi, Missouri, and Texas. Producers must plan their crops carefully to ensure high yield and profitability.

Environmental Conditions

Rice grows under frost-free conditions. The average planting dates are between April 15 and June 10. Harvesting usually starts on September 10, becomes most active from September 25 to October 25, and ends November 1.

Soil temperature must be above 50°F; germination occurs between 50-104°F. Soil moisture must be adequate for planting seeds but not too muddy. Do not plant seeds on dry soil. A water supply is adequate for a given field if the producer can (1) flush in 2-4 days, (2) flood in 3-5 days, and (3) maintain the flood for the growing season. Pumping rates, measured in gallons per minute per acre (gpm/A), vary for different types of soil, as illustrated in Table 1.1.

Table 1.1 - Recommended Pumping Rates for Various Soil Textures

Soil Type	Minimum Pumping Rate (gpm/A)	Desired Pumping Rate (gpm/A)
Silt loam with pan	10	10
Sandy loam	15	25
Silt loam, no pan	10	15
Clay and silty clay	15	20

Rainfall is critical for rice production, supplemented by irrigation. The water is added to the flood to maintain depth. If the field is water seeded, two types of flooding occur: pinpoint and continuous. In pinpoint flooding, water is drained out, allowing the seedlings to anchor in the soil. It is important that the soil remain moist and not dry out. Within 5 days, the field is flooded, then drained. Reflooding occurs 3-5 days later. This is a shallow flood; as the seedlings develop, the flood increases. In continuous flooding, water is maintained at a constant level and never drained.

Evaluating Field History

Several factors should be considered in evaluating field history. In rice production, knowing the previous crop provides valuable information. If the field was rotated with soybeans, red rice (a disease) is controlled. Also, because soybeans require more potassium and phosphorous than rice, there might be enough residual nitrogen in the soil for rice under tillering. If other crops were rotated (e.g., grain sorghum or wheat), fertilizer requirements for rice are affected. If the previous crop was precision graded on silt or sandy loam soils, the topsoil has been removed, which reduces productivity.

Rice producers enlist the help of the University Extension office or other professional experts to conduct a soil test to determine the fertility of the field and to assess what occurred on the acreage in the past. Soil tests diagnose whether potassium or phosphorous should be applied, based upon the crop rotation pattern. If soybeans are in a yearly rotation with rice, potassium or phosphorous may be required. If rice is in a 2-year rotation with soybeans and a 1-year rotation with rice, potassium and phosphorous may not be required. A soil test may recommend liming and if so, it would be done several months before planting rice to allow time to raise the pH in the soil. A soil test can also detect if zinc is needed when rice dies soon after flooding and help diagnose why seedling rice dies.

Knowing the previous tillage tells the producer the condition of the field. In rice production, there are two basic tilling methods: drill seeding (which includes broadcast seeding) and water seeding. Drill seeding, the most common method in Missouri, provides many options for crop rotations and herbicides, but this method is prone to sheath blight and delays tilling and planting during wet spring weather. In water seeding, red rice is suppressed; rice can be cultivated continuously without threat of this disease. However, fields are prone to insect pests and sheath blight. Limited disease controls are available.

Fertilizer Requirements

Nitrogen requirements depend on several factors: rice variety, cultural practices, crop rotations, soil conditions, and soil moisture. Early application of nitrogen is important if the following four conditions have **not** been met: (1) rice grown in rotation after soybeans, (2) soil with a pH less than 6.5, (3) optimum stand density, and (4) land in cultivation for more than 5 years. It is very important to avoid overapplying nitrogen; this will significantly reduce yield through lodging and disease.

Lime, which is used to benefit the other crops in rotation, is required only if a soil test determines this to be the case. The preferred time to apply lime is several months before planting rice, which allows time for raising the soil's pH. Otherwise, lime is applied under these circumstances: (1) not before planting rice because this could induce a zinc deficiency or (2) immediately after the rice crop is harvested and before other rotated crop is planted.

Phosphorous is applied in limited amounts and only as recommended. Overapplication will harm development of seedlings. In southeast Missouri, Delta soils already have high levels of phosphorous.

The fertilizer source for potassium is potassium chloride, which is a salt. A few southeast Missouri soils already contain excessive amounts of sodium salt, so limited applications of potassium chloride are advisable to avoid harming seedlings.

Summary

In planning the rice crop, the producer has to determine the best environmental conditions for planting. Knowing the range of frost-free dates, soil temperature, desired level of soil moisture, and correct level of rainfall/irrigation is essential. Before actually planting producers have to evaluate the field's history: previous crops, soil tests, and tillage methods used. Rice does have basic fertilizer requirements (nitrogen, lime, zinc, phosphorous, and potassium), but specific amounts and timing of application for each fertilizer vary. The producer should follow the recommendations from the soil test.

Credits

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Lesson 2: Selecting a Variety

After planning the rice crop, the producer selects a suitable rice variety and grade and determines which diseases are prevalent locally. A consultant is a valuable resource for helping the producer manage and assess the growing crop.

Consultants

Producers seek the expertise of consultants because these professionals are usually located in the same area as the producers and therefore understand the various challenges rice growers face. Consultants have technological and scientific expertise; research capabilities; and are a source of up-to-date information, publications, web sites, and other resources. In Missouri, rice consultants are available through the Delta Research Center, Missouri Agricultural Experiment Station; and the University Extension at the University of Missouri-Columbia.

Consultants assist producers with crucial management decisions: selecting the most suitable rice seed, implementing pest control, performing soil tests to determine fertility requirements, managing tillage and seeding, and selecting and applying herbicide. During the growing season, consultants assess the rice crop for insect/disease infestation, nutrient/fertilizer deficiencies, and weed identification and treatment thresholds.

Seed Variety

Producers want a seed variety whose graining and milling yield will provide more total income from more bushels per acre. Newer varieties yield much more than older varieties. It is important to consider economics; a rice variety must be relatively high quality and risk free to produce a high yield. Tolerance to disease also determines which seed variety a producer selects. Some varieties are totally devastated by certain diseases; other varieties can tolerate some diseases but at a reduced yield and quality. Preventing diseases in rice crops is very expensive. Resistant varieties frequently do not produce the highest yield, but they are less risky, require less production costs, and provide a higher-milling quality. Producers need the guidance of their local rice consultant to help resolve these concerns with the most risk-free seed variety for the area.

Another consideration in selecting a rice variety is maturity, which refers to when the crop is produced. In Missouri there are four maturity groups for rice: (1) early short season, (2) very short season, (3) short season, and (4) mid-season. To maximize yield, a producer may wish to combine maturity groups so that harvesting is staggered, thereby extending the crop.

Cost is another factor in selecting seed variety. Newly developed seeds, which are desirable for their resistance to disease and insects, can be very expensive. Also, the amount and duration of water required for irrigation increase costs.

Another key factor in selecting a seed variety is the expected milling quality and special traits of the rice. A producer wants to grow the type of rice that will meet the standards of the mill.

Grade

Producers want maximum economic returns from the grade of rice. If a lower-yielding variety has high-milling yield and quality, the producer will realize a profit. High returns can also occur from very high-yielding varieties that have a somewhat lower-milling yield.

Value, which is the income from each bushel sold, comes from high-milling yield, called head rice, and from high-quality rice (milled rice). Value of the rice grade depends on the mill's demand for a specific rice type: long-grain of parboil quality, medium-grain, short-grain, or aromatic/waxy.

The U.S. Department of Agriculture has established six grades of rice based on standards for color and maximum limits for number of seeds, heat-damaged kernels, and chalky kernels. There is also a U.S. Sample Grade, which does not meet any of the requirements for grades 1-6.

Prevalent Diseases

In order to determine what diseases are widespread locally, the producer has to know the field history of the soil to determine which diseases infested the field in the past. Neighboring acreage that suffered infestations must be identified because diseases can drift to the producer's field.

Sheath blight is the most destructive disease for rice and has recently increased in severity. Symptoms include oblong, water-soaked lesions

that appear on the leaf sheath at or near the water line. Within 2-3 days, a grayish-white center appears, up to 1 inch long, which is surrounded by dark purplish- or reddish-brown margin.

Sheath blight is caused by the fungus *Rhizoctonia solani* and the following factors: (1) increased use of highly susceptible varieties, (2) short intervals between crop rotations, (3) thicker stands than recommended, (4) use of higher nitrogen rates, and (5) planting short maturity groups at earlier planting dates.

The progression of the disease begins after jointing. The fungus survives in the soil year after year as a hard, weather-resistant structure called sclerotium, which floats to the surface of the rice flood water. After the fungus makes contact with the rice plant, it grows out from the sclerotium and moves to the leaf sheath. New sclerotia that develop on the infected stem surfaces fall from the rice plant and remain in the soil for several years. When the temperature is above 95°F and the canopy humidity is 96-97%, the *Rhizoctonia solani* fungus flourishes.

To control sheath blight, producers should plant high-yielding seed varieties that are the least susceptible to this disease. Stand density should be 15-20 plants per square foot. Plant when it is best for a specific variety. Avoid extremely early planting. Time nitrogen applications so that 30 pounds per acre or less are applied at internode elongation. A few days before heading, examine the field carefully for symptoms. Use a labeled fungicide when sheath blight reaches threshold level.

Blast, also called rotten neck, causes crop losses and has been increasing since 1984. Although it does not develop yearly, it is destructive when it does occur. In 1986, the estimated losses in Missouri from blast were $2.4 million.

Symptoms of this disease occur on leaves, leaf sheaths, nodes, and panicles. Oval-shaped leaf spots appear, with gray-white centers and brown to red margins. Fully developed leaf lesions are 0.4-0.7 inch long and 0.1-0.2 inch wide. The color and shape of the spots depend on the environment, age of lesions, and rice variety. Lesions on leaf sheath rarely develop, but if they do, they are the same as those on the leaves.

The fungus that causes blast is *Pyricularia oryzae*. Long periods of wetness and rainy, cloudy weather promote spore growth.

The disease progresses as airborne spores spread from rice seeds and infected rice stubble, which is where the fungus overwinters, to new rice plants. There are several new strains of this fungus, but it is unknown which strains are prevalent in Missouri. When spore contacts plant tissue, a sticky substance is produced that adheres spore to plant and initiates infection.

Controlling blast requires establishing a stand of 15-20 plants per square foot and selecting a seed variety that is the least susceptible to this fungus. Use a broad-spectrum seed treatment and reduce the areas where fungus might overwinter. Incorporate or roll rice stubble soon after harvest to promote early decomposition. From the time plants are 6-8 inches tall, keep the soil flooded until drained for harvest. Apply no more than 30 pounds of nitrogen per application at mid-season. If the field has a history of blast, always split applications. Fungicides should be applied 5-7 days before heading and again about 2 days after 50% heading. Check for leaf symptoms of blast beginning at the seedling stage and continue until early heading.

Summary

In selecting the appropriate rice variety and grade, rice producers benefit greatly from the expertise of consultants who help with management decisions and assess the growing crop. Selecting the best seed variety entails weighing several factors: expected yield, tolerance to disease, maturity group, and cost. The choice depends on the producer's unique circumstances. To determine grade, the producer expects the highest economic return and value. The U.S. Department of Agriculture has classified rice grades into six categories.

Credits

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Lesson 3: Tilling and Planting the Crop

As soon as the producer has planned the acreage and selected the appropriate seed variety, it is time to till and plant the crop. To develop the best possible crop, the seedbed must be prepared and the most effective seeding options and seeding rates should be selected. Using a rice planting calendar helps the producer organize all the events during the growing season. Water must be managed by means of carefully constructed levees.

Proper Seedbed Preparation

In rice production, proper seedbed preparation depends upon the seeding technique used. To prepare a drill-seeded seedbed, disk in the early spring and only if the soil moisture will not create clods. To increase straw decomposition, disk the stubble or roll in the fall and flood the field. "Landplane" (flood) the field once or twice by going in opposite or diagonal directions of disked areas. Prepare a shallow, firm seedbed with field cultivar equipment. Limit trips across the field and destroy any existing vegetation to avoid drift from the previous season's seedlings.

For a water-seeded seedbed, field grade to zero (up to 0.02 grade) to permit some field drainage, planned crop rotation, or substitution of other crops if rice fails. Dig a canal about 2 feet deep and 2 feet wide to help drainage during harvest. Fill all potholes and wheel tracks. Create ridged, rough seedbed to minimize seedling drift. Just before flooding, use a groover (similar to a flat roller), which forms small furrows on the seedbed and packs the soil. This prevents wavelike movement of water and smooths the soil surface. On clay surfaces, disk the fields and leave large clods that provide a place for seeds to settle without threat of drift.

Seeding Options

The seeding options, as stated above, are drill seeding and water seeding. Drill seeding, the most prevalent technique in Missouri, offers several advantages. Several crop rotation options are available that help control red rice. Herbicides and fertilizers can be applied by ground equipment, which is much less expensive than by airplanes. Rice weevils are controlled through field drainage. In drill seeding, the field sizes are larger. The disadvantages are that tilling and planting are delayed during wet spring weather. Sheath blight is especially serious with this seeding option and significant labor is needed to construct and remove levees. Season-long attention is required to maintain the levee and water level. Weeds in levees are a problem.

The advantages of water seeding are that it does not require construction, maintenance, or removal of levees. Rice can be in continuous cultivation without the threat of red rice. If a field is infested with red rice, water seeding suppresses the disease, which simplifies weed control. Water management is precise and facilitates uniform crop emergence. Water seeding's disadvantages are that the field must be smaller in order to pinpoint flood and maintain season-long flood. There is a strong risk of sheath blight, various insects, and aquatic weeds; limited control options are available. Higher seeding rates are required and pregermination and pumping costs are greater. Seeding an established flood and applying nitrogen fertilizer at first tillering growth stage must be performed by airplanes, which is a very expensive method.

Seeding Rates

Seeding rates, measured in pounds per acre, vary according to the number and weight of seeds per variety. Soil texture, seeding date, seedbed, and seeding option all affect the recommended seeding rate.

For drill-seeded crops, calibrate the grain drill to deliver 40 seeds per square foot when planting under ideal conditions. The rate is increased by 10% for early seeding and increased by 20% if seeding in clay soil or a poorly prepared seedbed.

For water-seeded crops, seeds are pregerminated, which means they are soaked for 24-36 hours and then drained for 24-36 hours before planting. Increase the seeding rate by 30% over the drill-seeding option to compensate for poorer germination, insect injury, and reduced tillering.

Rice Planting Calendar

A rice planting calendar helps the producer determine when to prepare the field and seedbed. It also indicates when to plant the selected seed variety. Times for irrigation, fertilizer application, and monitoring for disease are noted as well. The

calendar tells the producer when to drain for harvest and when to deliver the grain to the elevator. See Table 3.1 for a sample rice planting calendar.

Table 3.1 - Rice Planting Calendar

Dates	Activity
March	Start preparing field: plane land & disk
Mid-April - early June	Prepare final seedbed & planting
1-2 weeks after planting (May & June)	Flush irrigate field if necessary for emergence
4-6 weeks after planting (May & June)	Apply herbicide(s) to control very young weeds
Immediately after weed control (late May to July)	Top dress bulk of nitrogen fertilizer
Immediately after fertilizing (late May to July)	Flood field & maintain even water depth
10-14 days after flooding (late May to June)	Scout for rice water weevil & treat if necessary
20-30 days after flooding (June & July)	Measure plant growth for nitrogen sufficiency
30-40 days after flooding (late June to July)	Apply mid-season nitrogen according to variety & growth
After mid-season nitrogen (late June to mid-August)	Monitor crop for sheath blight and blast
July & August	Treat for disease control as necessary
10 days before harvest	Drain for harvest
Mid-Sept. to Oct.	Harvest & dry crop
After harvest	Roll the stubble
Throughout the year	Deliver grain to the elevator as scheduled

Levee Construction

To construct a levee, the field is surveyed first, usually on 0.2-foot vertical intervals. For flat fields with more than 10 acres per levee, survey on 0.1-foot vertical intervals. Increase vertical intervals 0.3-0.4 foot for fields with steep slopes and stacked levees.

A plow, consisting of two sets of disks, is pulled across a field. The height of the levee is obtained by making two to eight passes with the levee disk. To minimize formation of clods on clay soils, allow several hours of drying. Disks then dig out two parallel ditches. The soil thrown up from the center forms the levee. If the field was already graded, the levee runs at right angles to the edge of the field; otherwise, the levees run along the contour of the existing slope and wind across the field.

Install levee gates in each levee where they can be checked daily; ensure that the bottom of each levee gate is directly on the soil line. The gates in the levee are set to run the water across depressions in the soil and to leave no more than 2 inches in drop from levee to levee.

Importance of Levees

The main purpose of levees is to regulate the amount of water. Controlling amount and duration of water on rice plants is critical to yield and productivity.

Importance of Water

Rice grows best in shallow water, 4-6 inches. Water in the plant dissolves and carries nutrients through the cell wall and roots. On hot, dry, windy days, water is especially necessary for the survival of the rice plant. Water also controls weeds, which is a critical factor for a productive yield.

Summary

In tilling and planting rice, the producer must prepare the seedbed according to which seeding option is used. Drill seeding is the most prevalent option in Missouri; water seeding is another technique. Each option has advantages and disadvantages. Seeding rates, based on pounds of seed per acre, differ according to seed variety, soil texture, and other factors. A rice planting calendar helps producers ensure timely

completion of important tasks. Levees provided needed water and regulate the amount used. Water is critical for the rice plant's survival. Shallow water (4-6 inches) is sufficient for growth. Most important, water controls weeds and thereby helps improve the yield.

Credits

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Lesson 4: Scouting and Maintaining the Crop

The producer must continually evaluate, or scout, the rice crop throughout the growing season. At each phase of the plant's development, the producer monitors various factors and might determine that replanting is necessary.

Plant Condition Factors

In examining the rice crop, the producer monitors for damage from disease, weeds, or insects. At various points during the growth stages, flooding and preventive treatment are used to minimize these pests. The times for treatment applications are at critical points: ½-inch internode, early boot, and 10% heading.

Moisture levels influence how well the rice plant grows. Throughout the growing season, 4-6 inches of water must be maintained. If drought stress is a threat, the producer should flush over the field quickly, close the gates, and raise the flood level to the appropriate depth.

The timing of nitrogen application is another critical factor for the producer to observe. Early application of preflood nitrogen determines potential grain yield. Nitrogen applied mid-season (beginning at 1/2- or 3/4-inch internode elongation) is 65-80% efficient, depending on preflood rate, soil fertility, and seed variety.

The quality of the seedbed helps the producer evaluate the status of the growing crop. A past history of red rice, insect infestation, sheath blight, or blast adversely affects crop yield. The previous tillage method must rid the field of past vegetative growth to prevent seedling drift.

Replanting Decisions

Deciding whether to replant a crop involves several factors. The producer must evaluate the extent of the plant stand. For all rice varieties except Katy and Millie, the optimal plant density stand is 15-20 plants per square foot. If the stand is thinner, larger panicles are produced with more grains per panicle. This does compensate for thickness but additional insecticides, herbicides, and nitrogen are required. Thick stands are susceptible to lodging, incur greater severity of diseases, and require extra seed, which increases cost.

Additional factors to consider is the amount of damage from disease, weeds, and insects. If the crop has sustained a devastating amount of loss, replanting might be considered. On the other hand, some varieties can sustain damage and still produce an acceptable yield. Producers can manage pest damage through integrated pest management (IPM) that emphasizes using biological control, host-plant resistance, and various cultural practices to maintain low pest populations while preserving the majority of the crop. By using natural enemies of insect pests and diseases, IPM helps keep pest populations below damaging levels. Natural biological controls, combined with specific field management practices and diverse rice varieties, provide an alternative to managing pests without chemicals.

A producer may choose to plant different maturity groups to offset losses. For example, planting a very short season can compensate for crop failures. By combining different types of maturity groups on the same field rather than just one variety, the producer can avoid total crop loss.

Summary

Throughout the growing season, the producer has to evaluate, or scout, the field for signs of distress and then must consider whether replanting is appropriate. The producer will evaluate the degree of damage from disease, weeds, and insects; the level of moisture and irrigation; timeliness of nitrogen applications; and overall quality of the seedbed. In deciding whether replanting is a reasonable option, the producer will examine the extent of plant stand density, assess the degree of damage from pests, and consider planting different maturity groups on the same field.

Credits

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Lesson 5: Harvesting the Crop

If the rice crop is successfully managed throughout the growing season, the producer's efforts are rewarded at harvest time. Managing the harvest and postharvest activities involves several factors.

Timing of the Harvest

The maturity of the rice variety indicates the ripening, or grain filling stage, and the time of ripening differs with each variety. The size and weight of rice grain increase, and the color of the plants changes from green to straw or gold. At this point, light intensity is crucial because 60% or more of the carbohydrates are now photosynthesized. Temperature is another factor that affects the ripening stage.

Grain moisture content should be 17-21% to avoid reduced quality or yield. The producer should plan to complete harvesting when rice reaches 16% moisture.

The timing of seeding also affects when harvest occurs. It is advisable to avoid extremely early- or late-season seeding.

Levee Breakage

Deciding when to drain the levees is an important decision for the producer. Water management entails maintaining the flooded field until 2 weeks before harvest unless draining is required to control straighthead. Stop pumping the field to prepare for harvest 10-14 days after heading if enough flood is on the field to prevent drought stress. If it is exceedingly hot, continue pumping for 5-7 days. When the rice plant has fully matured, it is time to drain the levee.

Seed Damage

The producer wants to harvest whole, undamaged rice kernels because they will be more marketable. However, rice seeds can be damaged during harvest under the following circumstances.

Harvesting at either high or low moisture content damages the seed. If the rice kernels get wet, the ends grind off and become dust. If dried below 15%, rice could crack. Lowered yields of head rice occur with rapid rewetting once rice reaches 15% or less moisture content.

Environmental stress differs among rice varieties. Drought, inadequate or excessive nitrogen, low intensity of sunlight, disease and insect infestation (for example, kernel smut, blast, straighthead, and sheath blight), and draining water too soon during hot weather are factors that damage the rice seed.

Crop Loss During Harvest

The entire crop can be lost during harvesting if the producer is not careful. Poor harvesting practices account for a major source of crop loss. The optimal operating speed on threshers differs among rice varieties. Lower speeds will not separate rice very well. The speed and efficiency of the thresher are affected by moisture content, amount of material entering the combine, and weeds. The level of a stripper/combine must be adjusted according to the height of the rice heads and ease of grain detachment. The producer should obtain and calibrate a separation loss monitor based on local conditions. Separation losses increase when the stripper overspeeds. Stripper headers can help avoid crop losses because they are fast, efficient, and collect most of the leaves, trash, and stems from the field. Platform headers are slower and tend to miss a lot of the leaves, trash, and stems.

Foreign matter, such as stems, weed seed, and other trash can have more moisture than rough rice and will lower the total yield for milling.

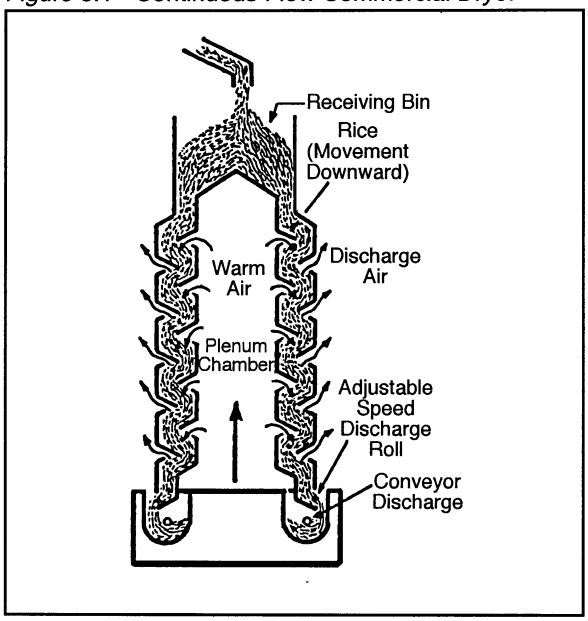
A major cause of crop loss is rapid field rewetting, such as from abundant rainfall. The yield for head rice that has reached 15% or less moisture is lowered measurably. Not all rice varieties are as susceptible to this head rice reduction; Lemont is vulnerable but Newbonnet is not.

Rice Storage

Storing and drying rice require special attention and care. Missouri rice producers have access to commercial elevators that will dry and store the crop. Other producers prefer to dry and store their rice on the farm.

Rice stored in commercial elevators is first dried through continuous flow dryers, as seen in Figure 5.1. For a short amount of time, large volumes of heated air move through layers of rice, 12 inches or less. The rice is passed through the dryer several times; the dryer removes 2-3% moisture with each pass. The continuous flow dryer is used

Figure 5.1 - Continuous Flow Commercial Dryer

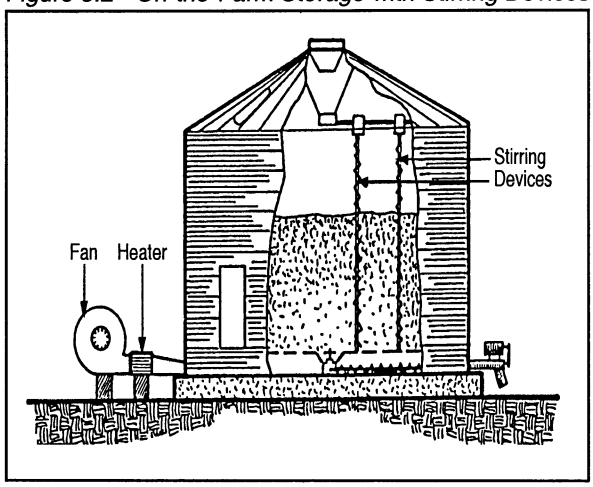


again to remove additional moisture. The air temperature is higher in commercial dryers; rice is exposed to the heated air for a shorter period of time.

In storage, the moisture at the center of the rice kernel slowly moves to the outer layers in tempering bins within 4-12 hours, depending on the temperature and moisture of the grain. Rice is transferred to storage bins after the last pass and aerated until the temperature of the grain kernels reaches about 50°F. At this point the rice is moved to different bins and aerated as needed to prevent the top layers from spoiling or hot spots from developing within the bin.

On-farm facilities have two methods of drying: layer drying and continuous flow, in-bin drying. In layer drying, rice is dried in 4-foot-deep layers to a moisture level of 15% or less. Then 2- to 3-foot layers are added and dried until the bin is full. Overdrying the bottom layer before the top layer reaches proper moisture content can cause problems. It is important to maintain the moisture equilibrium between the drying air and the desired moisture content of the rice. To help maintain this equilibrium, stirring devices in the storage bin mix and level the rice. The rice producer must not rewet the rice or keep the fan on. It is also important to avoid overdrying the kernels because they will crack when milled. The drying process must be very slow and conducted over a low heat. See Figure 5.2.

Figure 5.2 - On-the-Farm Storage with Stirring Devices



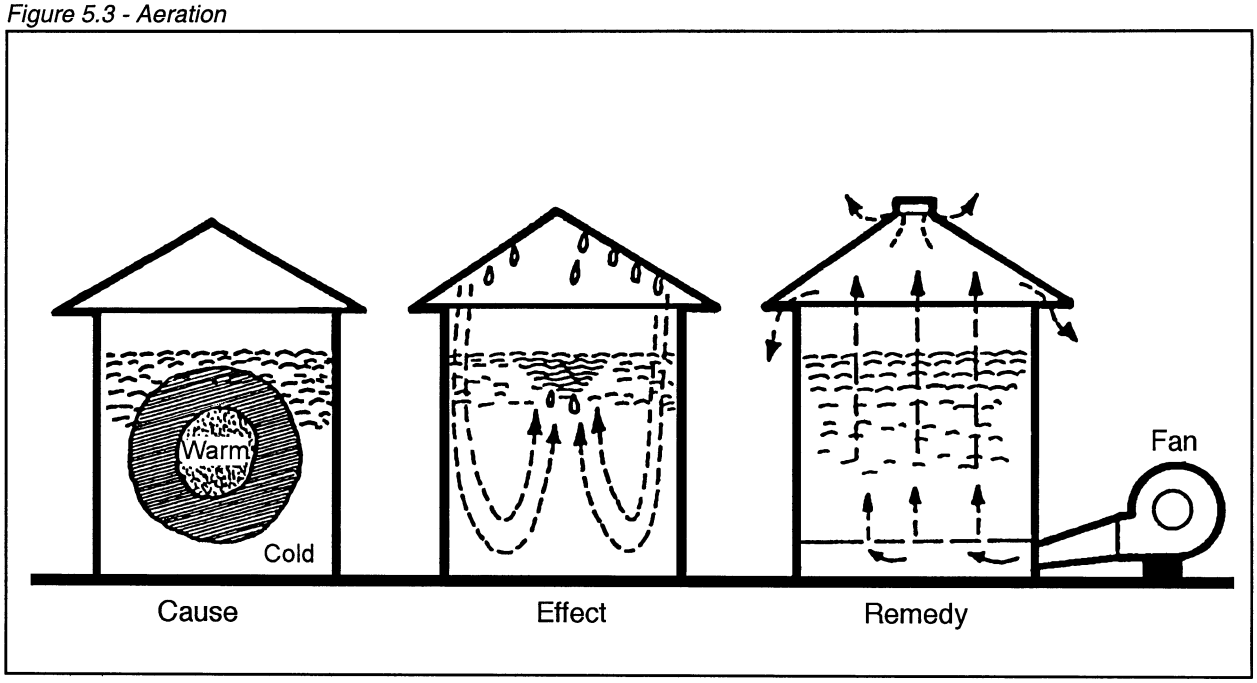
In continuous flow, in-bin drying, a tapered auger rides on top of a perforated floor and removes 5- to 6-inch layers of rice in a circular sweep. The depth of the rice is kept at 3-4 feet. The spreader at the top of the bin maintains equal distribution and depth across the drying bed at all times. Aeration is provided by a constant airflow of 25-35 cubic feet per minute per square foot of floor surface. The air temperature during drying is 110°F. This temperature can vary above or below 10 degrees if the rice kernel temperature does not exceed 100°F before removal from the sweep auger,

On-farm storage is in circular bins with perforated floors or ducts at the bottom, which promotes air circulation. After rice is dried in batches 6-12 feet deep, it is transferred into storage where it is cooled through aeration. Figure 5.3 illustrates the aeration process.

Storage Problems

Because harvested rice is a valuable commodity, storing it properly is a major concern. Storage bins contain many insects, some of which are pests. The severity of insect infestation depends on the amount and type of insect, condition of the new rice, grain moisture, and temperature. If the storage bin is unclean, insect populations can survive in the feed for years. The floors and walls contain lodged grain, sweepings, and old rice, which harbor insects. Insects can migrate to the new rice in unsanitized storage bins.

Figure 5.3 - Aeration



Maintaining Crop Quality During Storage

The producer should take the following steps to guarantee that the rice crop will retain its quality during storage. Sanitize the storage area by removing all waste grain, dust, and other trash. Then remove or bury waste away from the storage area.

Clean all equipment that handles rice. After they are cleaned, spray storage bins with an approved protective insecticide treatment. Then spray the rice as it enters the cleaned storage bin.

Fungi also affect the growing plant. Fungi grow when moisture content is below 13.5%. Temperature is a major factor in the growth of fungi. At 40-50°F fungi grow slowly; at 80-90 F fungi grow rapidly.

Summary

All of producer's efforts are focused on harvesting the rice crop. Several factors dictate the proper time for harvest: maturity stage, grain/moisture content, and when rice variety was seeded. The producer must decide when to drain the levee. A potential problem during harvest is that seeds can be damaged and the crop itself could be lost. Storing rice requires careful attention. All equipment that handles rice and all storage bins must be kept clean to maintain the quality of the rice crop.

Credits

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Lesson 6: Marketing the Crop

This lesson addresses how the producer markets the rice crop, determines when to sell or store the rice, and assesses the effect of rice quality on the price. The purpose of rice checkoff dollars is also discussed.

Marketing Options

Rice producers can contract with commercial mills or use producer-operated cooperatives to market their harvested rice. Riceland Foods Cooperative, in Stuttgart, Arkansas, is the world's largest miller and marketer for rice growers. In Jonesboro, Arkansas, Anheuser-Busch has a mill. The Louis Dreyfus Corporation rice mill in New Madrid, Missouri, offers rice producers a new market and options for pricing. Rice producers can also use marketing consultants, satellite, and Internet marketing services.

Rice producers can use forward contracting as a marketing option. The rice is contracted before it is processed and delivered. The sale price is already established and does not reflect fluctuations in the cash market at harvest time. This system has some risks, however. If the market moves upward to a higher price, the producer receives only the negotiated price. On the other hand, if the crops fail, the producer must purchase rice to meet the contract.

Determining When to Sell or Store Rice

The rice producer's decision when to sell or store rice is affected by many factors: storage costs, interest rates, and price trend predictions. Predicting the rice market depends on supply and demand, governmental programs that promote exporting and importing, and the global market.

Rice Quality and Effect on Price

The quality of the rice crop affects the price that the producer will receive. Basically, the rice must meet the

Table 6.1 - Grades and Grade Requirements for Rough Rice

Grade	Maximum limits of							Color requirements
	Seeds and heat-damaged kernels			Red rice and damaged kernels (singly or combined) (%)	Chalky kernels		Other types (%)	
	Total (singly or combined) (number in 500 grams)	Heat-damaged kernels and objectionable seeds (singly or combined) (number in 500 grams)	Heat-damaged kernels (number in 500 grams)		In long grain rice (%)	In medium or short grain rice (%)		
U.S. No. 1	4	3	1	0.5	1.0	2.0	1.0	Shall be white or creamy
U.S. No. 2	7	5	2	1.5	2.0	4.0	2.0	May be slightly gray
U.S. No. 3	10	8	5	2.5	4.0	6.0	3.0	May be light gray May be gray or slightly rosy
U.S. No. 4	27	22	15	4.0	6.0	8.0	5.0	May be dark gray or rosy
U.S. No. 5	37	32	25	6.0	10.0	10.0	10.0	May be dark gray or rosy
U.S. No. 6	75	75	75	15.0	15.0	15.0	10.0	
U.S. Sample grade shall be rough rice that: (a) Does not meet the requirements for any of the grades from U.S. No. 1 to U.S. No.6, inclusive; (b) Contains more than 14% of moisture; (c) Is musty, sour, or heating; (d) Has any commercially objectionable foreign odor; or (e) Is otherwise of distinctly low quality.								

mill's standards. The grains must be whole and the length must conform to the designated criteria. There should be no diseases or foreign matter in the harvested rice. The amount of weeds and red rice in particular must be limited. Table 6.1 shows the grades and grade requirements for rough rice.

Checkoff Dollars

For every bushel sold at the elevator or mill, the Missouri Department of Agriculture collects 2¢. These checkoff monies are used to promote and market rice in the United States and overseas and to conduct rice production research. By comparing newly released varieties from breeding programs, agronomists can help rice producers with future crops. Scientists observe how plants respond to various diseases. This type of analysis can help develop disease-resistant varieties. Thanks to checkoff dollars that fund rice performance trials, producers gain greater knowledge of what seed varieties will flourish in their fields.

Summary

Cooperatives, mills, professional marketing consultants, satellite, and Internet marketing services are all options for marketing rice. Forward contracting is a marketing option that can be used. Farm-related expenses, price trends predictions and fluctuations, and global markets are factors that the rice producer must consider in determining when to sell or store rice. The price the producer can receive depends on the quality of the rice. Marketing efforts and research activities result from checkoff dollars.

Credits

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Lesson 7: Figuring Crop Costs

Throughout the growing season, the rice producer faces several types of expenses that must be accurately recorded. This lesson examines the various costs the producer must calculate in order to determine if he/she has earned a profit on the crop.

Variable Costs

Variable costs (also known as direct, or operating, costs) depend on the extent of rice production. For high-yielding acreage, more plants are produced, which increases the costs of seed, maintenance, equipment, and water. If there is a lower planting rate, yield is lower but less seed is required. Examples of variable costs in rice production are seeds, fertilizer and lime, fungicides, herbicides, pesticides, and labor. The expenses associated with maintaining, repairing, and fueling equipment are also variable costs.

Fixed Costs

Fixed costs are those expenses that the rice producer cannot avoid, despite the level of production. Also known as ownership expenses, fixed costs include items that are a one-time purchase, such as equipment: tractors, threshers, combines, stripper heads, seed drillers, land planes to level land, and airplanes to cast seeds over dry or flooded fields. Depreciation and interest on machinery are also fixed costs. The rice producer's grain separator monitor and chlorophyll meter, levee, gates, and laser guidance systems that determine placement of levees also represent fixed costs. Finally, mortgage payments, interest, taxes, rent, and insurance on land are fixed costs.

Determining Acceptable Return on Investment

In order to evaluate whether an acceptable return is received on the investment, the producer must consider the variable and fixed costs. If these expenses are less than the net return from sales of the rice crop, the producer has earned a profit. Profitability also depends on supply and demand.

Calculating Cost per Acre

As with any crop, the cost of producing an acre of rice is the combination of the variable costs and the fixed costs per acre. If all expenses have been listed and categorized, this total is readily apparent to the producer.

Red Rice and Effect on Price

Because red rice is a weed, it can reduce profit if there is too much of it. Red rice can kill off healthy plants and reduce stand density.

Summary

To figure the cost of the rice crop, the producer adds the variable and fixed costs and subtracts those expenses from the sales received from the crop. To determine an acceptable return on investments, the variable and fixed costs should be less than the labor and expenses. The price can be adversely affected if there is too much red rice.

Credits

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