MP437

Corn Production HANDBOOK

UNIVERSITY OF ARKANSAS
DIVISION OF AGRICULTURE
Cooperative Extension Service

University of Arkansas, United States Department of Agriculture, and County Governments Cooperating

ARKANSAS CORN & GRAIN SORGHUM BOARD

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COOPERATIVE EXTENSION SERVICE
UNIVERSITY OF ARKANSAS
2301 S. University, P. O. Box 391
Little Rock, Arkansas 72203

EDITORS

Dr. Leo Espinoza, Extension Agronomist - Soils
Mr. Jeremy Ross, Area Extension Agronomist

CONTRIBUTING AUTHORS

Dr. Rick D. Cartwright, Extension Plant Pathologist, State Extension Office, P. O. Box 391, Little Rock, AR 72203
Dr. Leo Espinoza, Extension Agronomist - Soils, State Extension Office, P. O. Box 391, Little Rock, AR 72203
Dr. Dennis Gardisser, Associate Department Head - Biological and Agricultural Engineering, Extension Engineer, State Extension Office, P. O. Box 391, Little Rock, AR 72203
Mr. Gary Huitink, Extension Agricultural Engineer, State Extension Office, P. O. Box 391, Little Rock, AR 72203
Dr. Terry L. Kirkpatrick, Professor, Nematology - Cotton and Soybean, Southwest Research and Extension Center, 362 Hwy 174 N, Hope, AR 71801
Dr. Paul McLeod, Professor, Vegetable and Field Corn Entomology, AGRI 319, University of Arkansas, Fayetteville, AR 72701
Mr. Jeremy Ross, Area Extension Agronomist, State Extension Office, P. O. Box 391, Little Rock, AR 72203
Dr. Bob Scott, Extension Weed Scientist, Box 357, Lonoke, AR 72086
Dr. Ken Smith, Extension Weed Scientist, P. O. Box 3508, University of Arkansas at Monticello, Monticello, AR 71656
Dr. Glenn Studebaker, Entomologist, Northeast Research and Extension Center, P.O. Box 48, 1241 West County Road 780, Keiser, AR 72351
Mr. Phil Tacker, Extension Agricultural Engineer, State Extension Office, P. O. Box 391, Little Rock, AR 72203
Dr. David O. TeBeest, Professor, Rice, Sorghum Disease and Biological Control, PTSC 217, University of Arkansas, Fayetteville, AR 72701
Dr. Earl Vories, Associate Professor, Irrigation/ Water Management, Northeast Research and Extension Center, P.O. Box 48, 1241 West County Road 780, Keiser, AR 72351
Dr. Tony Windham, Agricultural Economics Section Leader, State Extension Office, P. O. Box 391, Little Rock, AR 72203

EDITING and LAYOUT

Pamela Hall, Communications Assistant

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Introduction

Leo Espinoza and Jeremy Ross

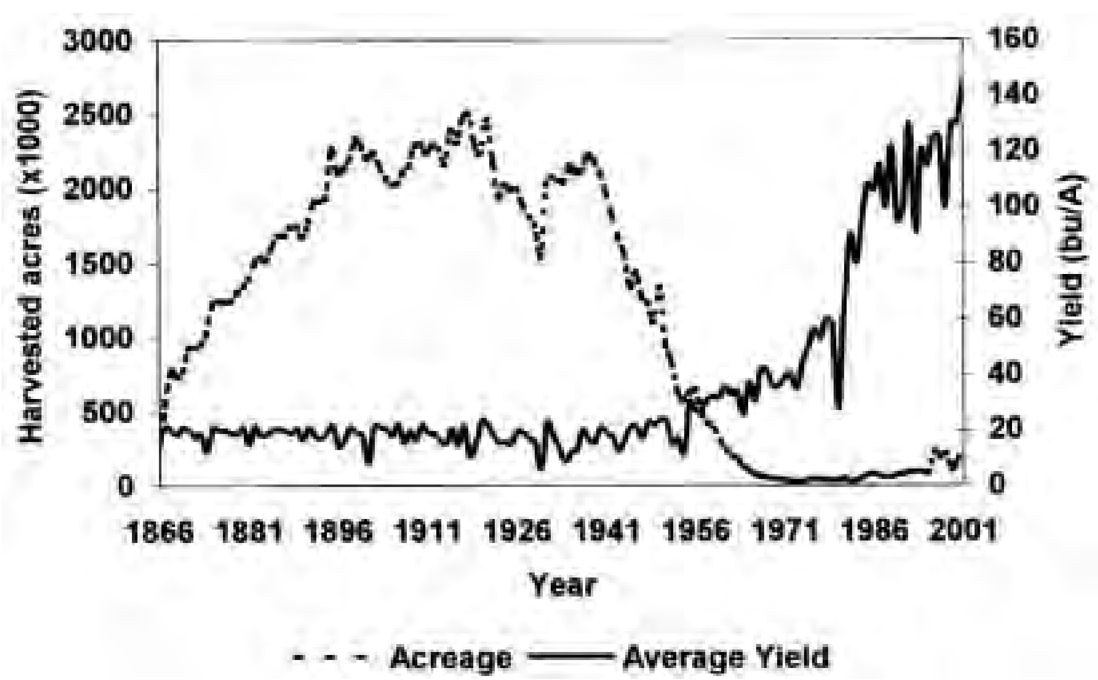
North American Indians practically saved the early settlers from starvation during their first winter by sharing their corn. In fact, Indians of North and Central America had grown corn for several thousand years prior to the arrival of the first settlers.

Early Arkansas settlers made corn a very important part of their agricultural operations. Before 1950 (from records going back to 1866) more than 1 million acres of corn were harvested each year. Increasing demand and attractive crop prices for cotton, rice and soybeans resulted in the decline of corn production in the state to less than 100,000 acres (Figure Intro-1). The increasing nematode pressure in soils planted to cotton and soybeans, in addition to high yield potentials and new market opportunities, have resulted in a 100 percent increase in corn acreage in the last couple of years.

Corn yields remained relatively flat prior to 1950, with state average yields being 18 bushels per acre. Today, thanks to more and improved hybrids developed by public and private breeding programs, as well as more efficient fertilizer, irrigation, pest management and marketing practices, average corn yields in Arkansas are in the 140 to 145 bushels per acre range. These yield levels represent a 2.5 bushels per acre increase per year since 1950, and it is very close to average yields observed in traditional corn producing states (Table Intro-1).

The Corn and Grain Sorghum Research Verification Program (CGSRVP) is contributing significantly toward increasing state corn yields. This program began in 2000, and is funded solely by Arkansas growers through Check-off contributions. The CGSRVP uses Extension management

Figure Intro-1. Historical corn acreage and average yields in Arkansas between 1886 and 2001 (Arkansas Agricultural Statistics Service).



recommendations to produce a high yielding, economical corn crop. Information from CGSRVP fields is used to improve and refine production recommendations to meet the needs of Arkansas corn farmers, in addition to identifying areas in need of more research. Through the 2002 growing season, 27 corn fields had been enrolled in the CGSRVP, with economic information collected on each CGSRVP field to estimate crop expenditures and returns.

Extension specialists and researchers with the University of Arkansas Division of Agriculture developed this handbook. Arkansas corn growers, through the Arkansas Corn and Grain Sorghum Promotion Board, provided the financial resources to create the handbook.

The handbook should be used as a reference guide. It contains information on topics such as hybrid selection, soil and water management, plant nutrition, integrated pest management, harvesting, and safety considerations in the production of corn under Arkansas conditions. Due to constant changes in laws that regulate pesticide use, the reader is encouraged to contact the appropriate Extension office for the most current information.

Table Intro-1. Average Yields for Selected Corn Producing States During 2001.

State	Yield (bu/A)
Indiana	156
Illinois	152
Nebraska	147
Iowa	146
Arkansas	145
Ohio	138
Missouri	133
Tennessee	132
Texas	118

Source: National Agricultural Statistics Service.

1 - Growth and Development

Leo Espinoza

Corn seeds, growing under the right conditions, will eventually grow into small factories with the ability to produce ample amounts of food. Understanding the conditions under which a seed may properly germinate, develop into a plant, and produce grain should help us prepare and manage the crop to achieve expected yields.

The yield of a corn plant depends on the genetic potential of a given hybrid, in addition to a number of environmental conditions and in-season management. Although there is little a corn grower can do about mother nature and the genetics of a plant (other than selecting the hybrid best adapted to a given location, and properly supplementing the site's inherent fertility and availability of water), in many instances yield losses may be due to poor planning and management, factors that are under the control of a grower.

The seed is obviously the starting point. It consists of three major parts: the pericarp, the endosperm and the embryo (Figure 1-1). The pericarp is the outer part of the seed, and is made up of several cell layers, which act as barriers to diseases and moisture loss. The endosperm is the seed's food storage compartment, which contains starches, minerals, proteins and other compounds. The embryo is in reality a miniature plant consisting of several parts: the plumule (leaves) at one end, the radicle (roots) at the other end, and the sculletum which absorbs nutrients stored in the endosperm.

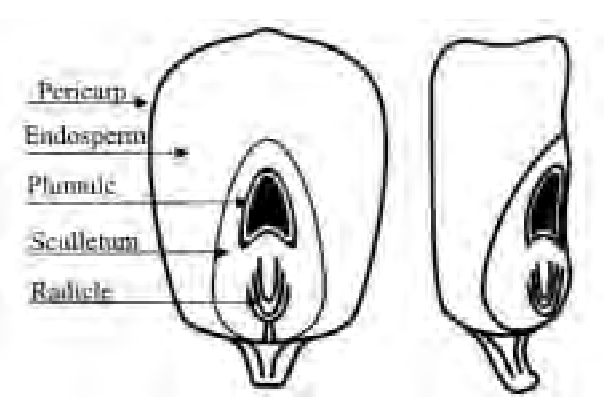


Figure 1-1. Components of a corn seed.

Table 1-1. Vegetative and Reproductive Stages of a Corn Plant

Vegetative Stages	Reproductive Stages
VE emergence	**R1** silking
V1 first leaf	**R2** blister
V2 second leaf	**R3** milk
V3 third leaf	**R4** dough
V(n) nth leaf	**R5** dent
VT tasseling	**R6** physiological maturity

When a seed is placed in moist soil, it absorbs water which in turn dissolves the nutrients stored in the endosperm. These nutrients are then absorbed by the embryo through the sculletum. The radicle will emerge from the seed and will eventually become the plant's root system. Leaves (plumule) also start to grow at this time. Under Arkansas conditions it may take between 5 and 21 days for a seedling to emerge, with depth of planting, soil moisture and soil temperature all significantly affecting the time required for seedling emergence.

A system to identify crop growth stages was developed by researchers from Iowa State University. This system classifies growth stages into vegetative (V) and reproductive (R) stages (Table 1-1), with each stage designated numerically as V1, V2, V3 and so on. Each number represents the uppermost

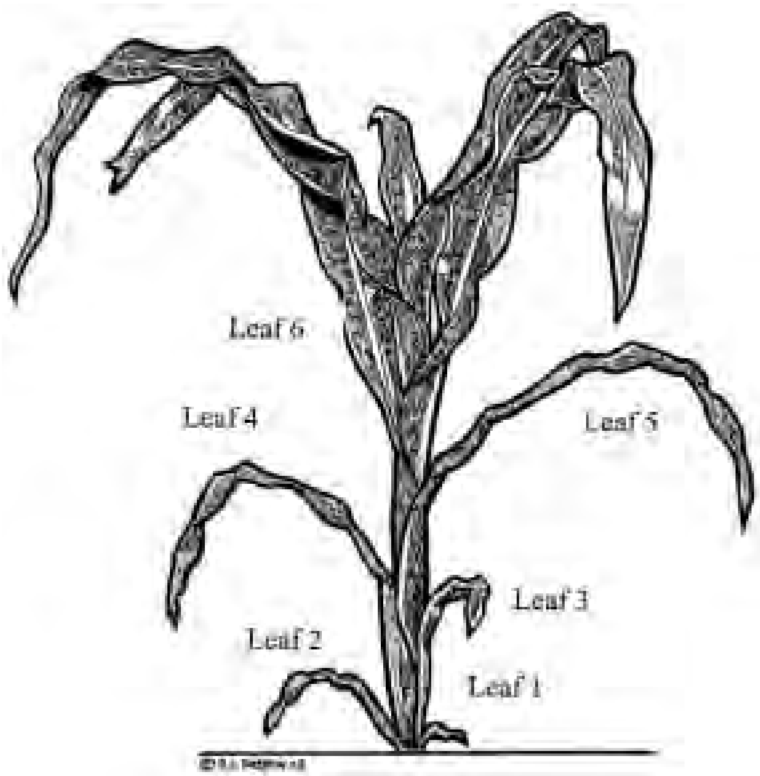


Figure 1-2. Corn plant at the V5 growth stage. Leaf collar of 6th leaf is not visible.

As stated before, it may take 4 to 5 days for a seedling to emerge if conditions are appropriate, but up to 21 days if they are not favorable. The radicle is the first part of the seed to begin elongation, with VE (emergence) observed when the growing coleoptile reaches the soil surface. The nodal root system is established around VE and eventually becomes the supplier for water and nutrients (Figure 1-3).

During the next two to three weeks following seedling emergence the plant is fairly resistant to hail and other stresses, since the growing point is still below ground. **By the V3 stage, although still very young, the plant has already finished deciding how many leaves and ear shoots is going to produce.**

leaf with a visible collar, with the leaf collar being a visible light-colored narrow band at the base of the leaf (Figure 1-2). The last vegetative stage is named VT, to denote tasseling. The last branch of the tassel is visible at this time, while the silks are not.

This classification system allows for a relatively easy way to identify growth stages when plants are young but, as they grow, it requires more detailed examination since plants will eventually slough off their first three to four leaves. Also, early-maturing hybrids may develop fewer leaves or progress through different stages at a faster rate than late-maturing hybrids. Consideration should also be given to the fact that plants in a given field may show different growth stages; **for that reason a stage should be assigned only when 50 percent or more of the plants are in or beyond that stage**.

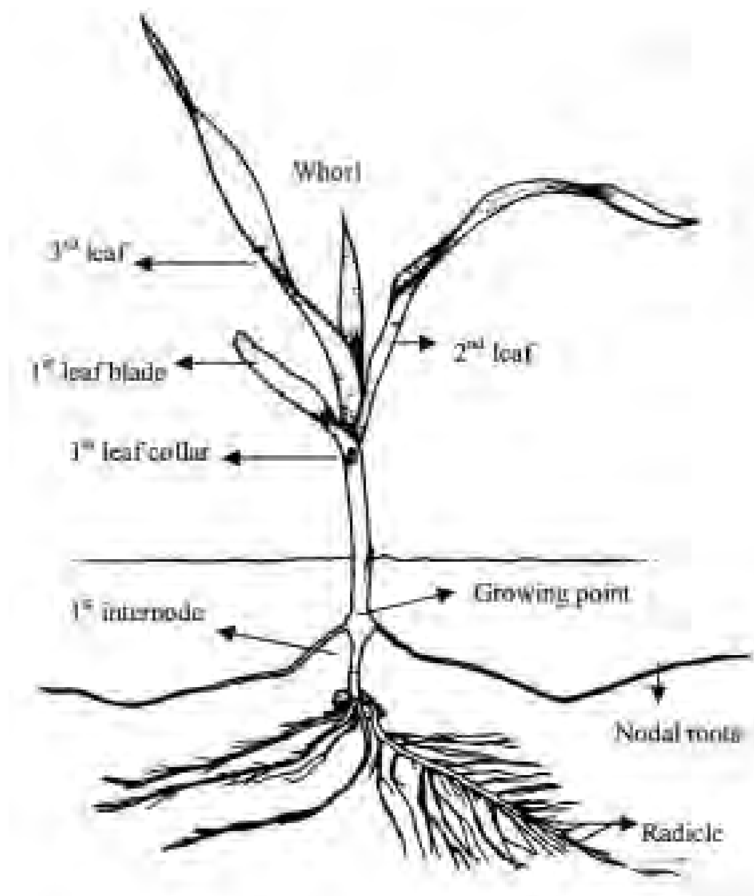


Figure 1-3. Corn seedling at the V1 (almost V2) growth stage.

By the time the plant reaches the V6 stage (plants are normally "knee high"), the growing point and tassel are above the ground and the plant becomes much more susceptible to stresses. At the V6 to V8 stage, **the plant will experience a rapid rate of growth, with proper and sufficient fertilization and irrigation, which are critical at these stages**. The number of rows per ear is established around this time, and the lowest two leaves are no longer present.

The tassel develops rapidly (inside the stalk) and the stalk continues elongating during the V9 to V10 stages. Soil nutrients and water are in greater demand at this time, and upon dissecting a corn plant at the V9 stage, ear shoots become visible.

The period between V12 and V17 is particularly important since the number of ovules (kernels) per ear and the size of the ear are being determined. **Moisture and nutrient deficiencies during this time may result in unfilled kernels and light ears**. The tip of the tassel as well as the tip of the ears may be visible by the time the plant reaches the V17 stage, and silks have started to appear at this time. Stress during the V18 stage will delay silking until after the pollen sheds, with ovules that silk after completion of pollen shed not filling and consequently not contributing to final grain yield. Tasseling (VT), the last vegetative stage, begins a few days before silk emergence. At this time the plant has reached full height, with pollen shed occurring primarily during late mornings. Silks that have not emerged by this time will not be pollinated, and consequently will not be developed.

The reproductive stages (R) relate to the development of the kernels, with the R1 stage being characterized by the silks being visible outside the husks. It is defined when even a single silk strand is visible from the tip of the husk. Every potential ovule (kernel) on an ear develops its own silk, with environmental stresses and especially the lack of water resulting in poor pollination and in some cases a bald ear tip. Pollination occurs when the pollen grains are captured by moist silks, with this process moving progressively from kernels near the base of the ear to the tip ear kernels. Kernels reach the R2 (blister) stage about two weeks after silking; at this time they physically resemble tiny blisters. Starch has begun to accumulate in the endosperm, with moisture being around 85 percent.

The milk stage (R3) is generally observed a week after blister. Fluid inside the kernels is milky white due to the accumulation of starch, and the silks turn brown and dry. **The milk line can easily be seen by breaking a cob in half**. Starch continues accumulating in the endosperm at the R4 (dough) stage. The milky fluid thickens and attains a doughy consistency, with moisture content being around 70 percent. The R5 (dent) stage is normally reached a week after the R4 stage, and is recognized by the appearance of the starch layer. This layer appears as a line across the kernel that separates the liquid (milky) and solid (starchy) areas of the kernels. As the kernel matures, this line progressively moves toward the cob. Kernel moisture has decreased to 55 percent, and any stress at this stage will affect kernel weight only, since kernel number has already been decided.

Kernels reach physiological maturity (R6) two to three weeks after R5 (dent), and no further increases in dry weight will be observed. The starch layer has reached the cob, and a black layer is formed. Black layer formation occurs gradually, with kernels near the tip of the ear developing this layer earlier than kernels near the base of the ear. Grain moisture at this time ranges between 25 and 35 percent.

It is obvious now that being able to identify the growth stage of a particular field can help in making replanting decisions, and in scheduling fertilization, irrigation, pest management and harvesting operations in a timely fashion to achieve maximum yields.

References

How a Corn Plant Develops. Special Report No. 48. Iowa State University of Science and Technology, Cooperative Extension Servce, Ames, Iowa. Reprinted 2/1996.

Growth Stage	Approximate days after emergence	Significance
V3	8 - 10	Leaves and ear shoots determined. **Flooding could kill the corn plant if conditions persist for a few days.**
V6 – V8	21 – 36	Growing point above ground. Plants are susceptible to wind and hail damage. **Moisture and nutrient stress should be prevented.**
V12 – V17	36 – 60	The number of rows per ear and ear size are determined. **Moisture and nutrient stress may result in unfilled kernels.**
VT – R1	54 – 62	Tassel and ears shoots visible. **Considerable yield loss will result from water stress at this stage.**
R2	66 – 74	Blister stage. Kernels moisture is about 85 percent. **The cob is close or at full size.**
R3	76 – 86	Milk stage. Kernel moisture is 80 percent. **Stress at this point can still reduce yields.**
R4	84– 88	Dough stage. Kernel moisture is 70 percent. **Kernels have accumulated close to half of their mature dry weight.**
R5	90 – 100	Dent stage. Kernel moisture is about 55 percent. **Stress may reduce kernel weight.**
R6	105 – 120	**Physiological maturity.** A black layer has formed. Kernels have attained their maximum dry weight.

2 - Cultural Practices

Jeremy Ross, Gary Huitink and Phil Tacker

Land Selection

Corn performs best on deep, well-drained, medium to coarse textured soils, but producers have successfully produced corn on a wide range of soil types. High rainfall amounts are common in the spring and early summer when the root system of corn is developing. Perhaps the most important consideration for land selection is drainage. Corn production will be limited if drainage is inadequate. No-tillage can be a high-yield method of planting corn if the land is well-drained. Drainage should be corrected or improved prior to planting to increase corn yield potential. In most years, drainage and timely irrigation are the primary factors determining the yield potential of well-managed corn in Arkansas.

Seedbed Preparation

Preparing raised beds and planting into a freshly-tilled seedbed is currently the most common practice in Arkansas, but planting "flat" is practiced. Planting no-till into beds from the previous crop may be cost-effective. Most farmers are satisfied with beds that are formed from fall to early in the spring, where rainfall has settled and "firmed" the bed.

The advantages of planting on a bed versus flat include: (a) beds normally warm more quickly in the early spring, thus allowing for earlier planting; (b) beds provide drainage following heavy rainfall; and (c) in a dry spring, the top of the bed can be knocked down in order to plant into moisture.

Planting no-till corn can be successful if the seedbed is not rutted from the previous harvest operation or washed out from heavy rainfall. A burndown herbicide to kill existing weeds is necessary, but little else is required to get a stand. Timing may be more vital with no-tillage; otherwise, the management of no-tillage varies little from conventional planting. Shredding stalks or a light disking complicate no-tillage planting. An undisturbed seedbed provides a firm surface for cutting through residue and obtaining a more uniform seeding depth.

Subsoiling compacted soils is needed to raise corn yield potential. Where shallow hardpans exist, a ripper-hipper, may penetrate through the root- and moisture-restricting layer. A high-residue ripper-hipper can be used to subsoil under the future row as the beds are formed in the fall. The ripper-hipper has a heavy draft, high horsepower requirement. A good approach is to use a 4- or 6-row ripper-hipper and examine several field locations to assure that the shanks are penetrating the hard soil layer. To be compatible with the number of rows on his planter and combine header, a grower follows by bedding on these rows again with an 8- or l2-row bedder. Several GPS-guided controls (for example, the John Deere AutoTrac™ assisted steering system) may provide a sufficiently accurate row spacing to make a second bedding pass unnecessary.

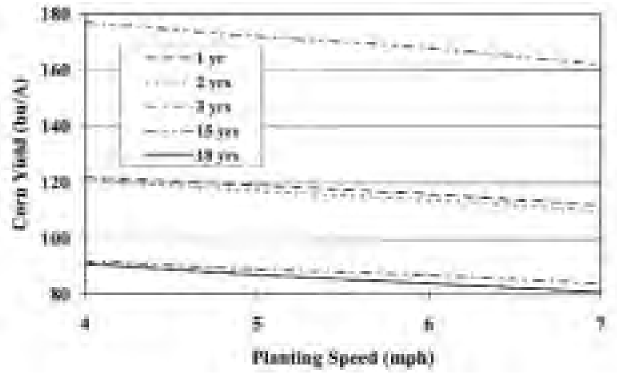
Some growers use high-residue subsoilers in the fall at an angle to the anticipated rows to eliminate deeper compaction. The advantages of a high-residue subsoiler is that preparatory tillage after the last season's crop is unnecessary because coulters cut the residue, and less tillage is required to prepare the beds after subsoiling.

Planting Precision

Uneven plant spacing and emergence may reduce corn yield potential. Seed should be spaced as uniformly as possible within the row to ensure maximum yields, regardless of plant population and planting date.

™–AutoTrac is a trademark of Deere and Co., Moline, IL.

Figure 2-1. Relationship of corn yield to planting speeds from 4 to 7 mph for selected planters



A three-state study evaluating 22 planters of various ages in good operating condition, shows that planting speed may affect yield, regardless of the age of the planter, model of the planter or acres planted per year. In addition, higher speeds modified the seeding rate and increased the seed spacing variability for about half of the planters evaluated. Figure 2-1 shows how yield dropped with increased speed for five planters. The average yield decrease from 4 to 7 mph was approximately 10 percent for the five planters.

For precision planting, try these four steps:

1. Calibrate the planter at the speed intended for planting. Don't risk obtaining a misleading seeding rate from slow speeds.

2. Calibrate on a hard turnrow to be able to locate all the seed and assure that the rate is approximately correct before taking the planter to the field. (If a seed monitor displays population per acre, verify that the monitor is displaying values that coincide with actual seed counts behind the planter. Multiple seeds don't trigger a response if they pass the sensor together. Seed monitors are helpful to warn you about skips, malfunctioning rows or undesirable seeding rates. However, they will not detect erratic spacing between seeds.)

3. Check behind the planter in the field to verify that seed placement, depth, and spacing are exactly what you intend. Once seed is planted, it is hard to be sure that you've found all the seed. Roughly prepared ground bounces the planter units and may shift seeding rates either up or down.

4. Check the planting rate every time you change seed size or hybrid. These changes as well as seed treatments or field roughness, may cause multiple seed drops or skips.

Vacuum seed selection planters typically achieve the most uniform plant densities followed by plateless or finger pickup seed selection. With all other factors equal, maximum yields occur when corn is placed uniformly deep into the soil with uniform spacing between seeds. Producers should follow the manufacturer's recommended planting speeds.

Most research in the mid-south region indicates the greatest yields are obtained in row spacings of 30 inches. Row spacings less than 30 inches are typically too narrow to pull up a sufficient bedded row for surface drainage. Experiments have generally shown little yield advantage for row spacings less than 30 inches.

Many mid-south evaluations indicate that 38-inch rows incur a 10 to 15 percent yield reduction compared to 30-inch row spacings. The yield reduction in wider rows may be due primarily to sun light reaching the soil surface; thus less total utilization of solar energy for grain production. Additionally, wider rows may fail to shade the soil, and result in more evaporative moisture loss. This can increase the irrigation cost or potentially reduce yield in dry seasons. Wide rows may also result in more lodging, especially with complications from charcoal rot or midseason windstorms since there is somewhat less mutual plant support with wider row spacings.

Planting Date

Corn growth and development responds primarily to temperature and is not controlled by day length. Thus, the calendar date is not as important as soil temperature and air temperature when considering when to plant corn. Good germination and emergence are expected when the soil temperature at a 2-inch depth is 55˚F by 9:00 a.m. for three consecutive days. This normally occurs in late March in south Arkansas and early April in north Arkansas. Frost may occur after these planting dates in some years, but corn typically withstands frost with little economic injury. Early frosts may remove a single emerged leaf, but a leaf will emerge from the seed. Severe frosts later in corn development can be destructive, but these conditions are very rare in Arkansas.

Early plantings typically yield more than late plantings and there are other possible advantages to early planting dates, including:

- Less conflict with other crop operations (cotton, soybeans, rice and wheat), including drying grain
- Fewer irrigations
- Reduced insect and virus damage
- Earlier harvest

Seed should be planted 1 1/2 and 2 inches deep into moist soil. If moisture is deeper than 3 inches, it is advisable to wait until after a rain before planting. If center pivot irrigation is available, it may be used prior to planting to obtain the soil moisture desired.

Seeding Rate and Plant Populations

The desired final plant population depends on the hybrid, whether the field is irrigated and reasonable yield expectations. The recommended plant populations range from 16,000 to 32,000 plants per acre. Recommended population for dryland production ranges from 16,000 to 24,000 plants per acre whereas irrigated corn has greater yield potential from 26,000 to 32,000 plants per acre. Most seed companies recommend a specific planting range for each hybrid. They suggest the lower end of the range if the field is not irrigated and the yield potential is less than 160 bushels per acre. Where higher yield potential exists and corn is well-irrigated, the higher end of the range is recommended.

Most seeding densities are based on "ear flex." Full ear flex hybrids can compensate for fewer plants per acre because the ear grows both in length and girth. These hybrids usually produce only one ear per stalk. Individual semi-flex hybrid ears will not compensate to the extent that full flex hybrids will, but with low stand density and excellent growing conditions they may set two or more ears. Few of the modern corn hybrids released today are "fixed" ear. Fixed ear hybrids must obtain the desired population for maximum yields.

Table 2-1 shows the number of seed required per 10 row feet for several plant populations and row widths. To check planting rates, count the number of seed placed in 10 row feet. Tractor speed,

Table 2-1. Corn Seeding Rates

Seeding Rate per Acre	Row Spacing (inches)				
	20	30	36	38	40
	Seeds per 10 Feet of Row				
16,000	6.1	9.2	11.0	11.6	12.2
17,000	6.5	9.8	11.7	12.4	13.0
18,000	6.9	10.3	12.4	13.1	13.8
19,000	7.3	10.9	13.1	13.8	14.5
20,000	7.7	11.5	13.8	14.5	15.3
22,000	8.4	12.6	15.2	16.0	16.8
24,000	9.2	13.8	16.5	17.4	18.4
26,000	9.9	14.9	17.9	18.9	19.9
28,000	10.7	16.1	19.3	20.4	21.4
30,000	11.5	17.2	20.7	21.8	23.0
32,000	12.2	18.4	22.0	23.3	24.5
Linear feet of row per acre	26,136	17,424	14,520	13,756	13,068

Seeding rates are listed as seeds per 10 row feet.
Suggested seeding rate per acres assumes 90% emergence.

Table 2-2. Final Plant Population for Corn					
Final Stand per Acre	**Row Spacing (inches)**				
	20	**30**	**36**	**38**	**40**
	Plants per 10 Feet of Row				
14,400	5.5	8.3	9.9	10.5	11.0
15,300	5.9	8.8	10.5	11.1	11.7
16,200	6.2	9.3	11.2	11.8	12.4
17,100	6.5	9.8	11.8	12.4	13.1
18,000	6.9	10.3	12.4	13.1	13.8
19,800	7.6	11.4	13.6	14.4	15.2
21,600	8.3	12.4	14.9	15.7	16.5
23,400	9.0	13.4	16.1	17.0	17.9
25,200	9.6	14.5	17.4	18.3	19.3
27,000	10.3	15.5	18.6	19.6	20.7
28,800	11.0	16.5	19.8	20.9	22.0
Linear feet of row per acre	26,136	17,424	14,520	13,756	13,068

seed size, and several other factors can affect the seeding rate. Furrow counts should be done several times during planting, especially where a planter is prone to bounce. Initially it is advisable that each row be checked, since row units may fail to plant at the same rate. If each row has a separate seed box, monitoring the fill levels will help to detect planter unit skips. However, a good seed monitor is highly recommended to detect seeding failures immediately. The corresponding number in Table 2-1 should closely estimate the planting rate of corn on a particular row spacing.

Table 2-2 shows the number of plants required per 10 row feet to determine the final plant stand on several different row widths. Several locations within a field should be checked to give a good representation of the entire field. Table 2-2 gives a good estimate of the final plant population or stand.

Hybrid Selection

Hybrid selection is one of the important decisions a producer will make. Yield is an important factor but maturity, stay green, lodging, shuck cover, ear placement, disease and insect resistance play a role in hybrid selection. In Arkansas, 112 to 120 day maturity hybrids usually produce the highest yields. Producers with a relatively large amount of rice may use 108 to 110 day hybrids, and sacrifice a few bushels of corn so they can pick corn prior to rice harvest. Hybrids that stay green later into their maturity usually retain better stalk strength and have less lodging potential. Shuck cover is important since good ear coverage reduces the introduction of soil fungi, thus less potential for kernel damage. Ear placement can be very important in corn planted later in the season.

Most corn hybrids will grow taller as day length increases due to increased day and night temperatures. Rapid growth results in more space between nodes, thus ear placement can be substantially different within the same hybrid planted at different times. Usually, the higher the ear placement, the greater the lodging potential. If possible, select late-planted hybrids that have lower ear placement. Biotechnology advances have resulted in corn hybrids that are resistant to insects due to toxins produced in the plant tissue. There are also some hybrids that are herbicide resistant. A few hybrids contain both of these traits and are referred to as “stacked” trait hybrids. Selecting hybrids and managing them to utilize genetic strengths are addressed in the weed and insect control sections.

Growing Degree Days

Yield potential and maturity are important when selecting a hybrid that will produce mature, sound grain during a normal growing season for a particular region in Arkansas. Relative maturity among hybrids is best evaluated by grain moisture content in performance reports.

The number of days that are required for a hybrid to reach maturity depends on location, date of planting, and the weather during the growing season. A hybrid that is labeled as a 115-day hybrid may take 110 to 120 days to mature depending on the above factors. This system of measuring corn maturity does not take into account the complicated physiological processes that control growth and development of corn.

Growing degree days (GDD) are a daily accumulation of heat for crop growth. A hybrid's GDD rating is determined from planting to black layer formation (physiological maturity). Most seed corn suppliers include a GDD rating on their seed tags or in their hybrid descriptions. Corn does not grow when temperatures are below 50°F and temperatures above 86°F do not increase plant growth rate. Therefore, 50°F is set as the minimum temperature and 86°F is set as the maximum temperature for calculating GDD.

The formula for calculating growing degree days is to add the daily high temperature (86°F maximum) and daily low temperature (50°F minimum), divide the result by 2 and then subtract 50. The answer represents the heat units for one day.

GDD = [(daily high + daily low) ÷ 2] – 50

Example 1:

83°F (daily high temp); 63°F (daily low temp)

83 (daily high) + 63 (daily low) = 146

146 ÷ 2 = 73

73 - 50 = 23 GDD

Example 2:

95°F (daily high temp); 70°F (daily low temp)

Since the daily high temperature is greater than 86°F, 86°F will be used as the daily high temperature.

86 (daily high) + 70 (daily low) = 156

156 ÷ 2 = 78

78 - 50 = 28 GDD

Producers can use a thermometer that reads both maximum and minimum temperatures to calculate and record GDD for their crop.

3 - Drainage and Irrigation

Phil Tacker, Earl Vories and Gary Huitink

Drainage

Adequate drainage is necessary for maximum corn production. It is highly recommended that corn be planted on raised rows or beds, especially on fields that are relatively flat. Corn is typically planted early when low temperatures and significant rainfall are likely. Raised rows or beds reduce the effect that cold, wet soil conditions have on planting and early crop development. Rolling fields that have significant slopes may not need raised rows or beds for drainage, but may still benefit from the beds warming up faster than flat seed beds. Poor drainage hampers field operations from field preparation through harvest and limits the effectiveness of irrigation. Eliminating poorly drained areas preserves natural soil productivity by reducing field rutting that requires additional tillage. Poorly drained areas reduce yields and often require the most tillage. Water infiltration is also reduced if soil is tilled when it is too wet. Good field drainage complements all crop production practices and makes it possible to consider reduced or no-till corn production. **The goal for drainage is to have minimal standing water on a field 24 hours after a rainfall or irrigation.**

Surface Drainage

Field surface smoothing and forming, prior to bedding, can improve the surface drainage of a field. Use land planes to smooth out the high spots and fill in the low areas so that the field has a more uniform slope toward drainage outlets. Low areas that are larger than 100 feet across or that require more than 6 inches of fill should be overfilled and compacted before being planed. Make an effort to accurately determine a field's drainage flow pattern. Deciding where water will drain by simply looking at the field is not always easy. Some limited surveying of field elevations can be very helpful in determining where to place tail water furrows and field drain outlets.

Precision grading of a field provides a positive method of improving surface drainage as well as making furrow irrigation possible. If a field is being considered for precision grading, the soil should be evaluated to determine what problems might occur if deep cuts are made in some areas. The cut areas may expose soil with reduced production capability. County soil survey reports, published by the Natural Resources Conservation Service (NRCS, formerly SCS), can help identify soils with unproductive subsoils. Taking several deep (more than 6 inch depth) soil cores or samples may be beneficial if a problem soil is suspected. Poultry litter application may improve the productivity of cut soils. An Extension publication, *Soil and Fertilizer Information Article 2-90*, Poultry Litter as an Amendment for Precision Graded Soils, reports on results of litter application studies.

Precision grading is limited to fields with slopes of less than 1 percent, or the cost can be prohibitive. **If possible, the finished grade in the primary slope direction should range from 0.1 to 0.5 percent (% 0.1 to 0.5 ft. per 100 ft.).** This range provides good surface drainage without increasing erosion potential. Slopes of less than 0.1 percent are suitable for cross slopes but should be limited to slope lengths of a quarter mile or less. Slopes less than 0.1 percent are more difficult to construct with precision, and they tend to develop more low areas and reverse grades. It is also recommended to consider putting a field to grade in only one direction (i.e., zero cross slope) if it doesn't require a significant amount of extra cost. Building a permanent pad or elevated road on one or more sides of a field should also be considered in the grading plan. Settling often occurs in deeper fill areas and should be "touched up" before bedding if possible. The land grading design should consider the type of drain outlets and the number required for the field. If possible, it is best to provide an outlet point for every 20 acres.

An elevation survey of the field is required before any design work can be done. Survey information can be entered into a computer program that evaluates possible drainage options for a field and determines the cuts and fills required. Most land grading contractors offer the computer program design, and it is sometimes available through NRCS. The lowest expected elevation of the field should be determined before grading begins to assure that water will drain into the surrounding ditches adequately and not back up onto the field. It may be necessary to divide the field into shorter segments to ensure that the runoff leaves the field. Precision grading is usually expensive and is a long-term investment for increasing production efficiency and potential and the market value of the land. Government funded conservation programs sometimes offer cost sharing on precision grading and/or other conservation best management practices. Information on these programs can be obtained through NRCS.

Good surface drainage is even more important if corn is planted flat rather than on raised rows or beds. Low areas in a flat-planted field are likely to have poor production for obvious reasons. Drain furrows to these areas can be used to reduce the effect on the crop. Shallow and narrow drain furrows can be constructed with several different types of equipment. The equipment should spread the soil evenly away from the drain furrow, so flow into the furrow is not restricted. Construct drain furrows in the low areas of a field rather than putting them in randomly. They should generally run with or at a slight angle to the natural slope of the field but not across the direction of the slope. Furrows should have continuous positive grade to assure that the water will be directed off the field. A drain furrow is not complete until it is connected to a ditch or pipe of adequate size to carry excess water away from the field.

An important component of field drainage is the ditch system that receives the excess water and carries it away from the field. Flow restrictions in these ditches can cause excess water to remain on a field. Drainage ditches should be maintained and routinely cleaned out to effectively handle the drainage water from a field. **No tillage or reducing tillage limits the sediment leaving fields and minimizes the sedimentation that occurs in drainage ditches.** Ditch outlets and drainage structures should also be checked to assure that they are functioning properly and are not becoming restricted. Beavers often cause problems by damming ditches, culverts and drainage pipes. A Beaver Pond Leveler pipe has the potential to reduce these problems in certain situations. This device is described in Extension publication FSA-9068, *Flood Water Management With a Beaver Pond Leveler*. It may be necessary to work with neighboring farms and/or the Drainage District to correct common drainage problems. Planned drainage improvements could impact areas classified as wetlands. If this possibility exists, contact the local NRCS staff to see what help they can provide. Typically, they can visit the site and determine if there are drainage restrictions.

Internal Drainage

Many Arkansas soils, with the exception of the sandier (coarse) soils, have limited infiltration and/or internal drainage. Some clean-tilled silty soils tend to seal or crust over at the surface after rainfall or irrigation, restricting the movement of water into the soil surface and the root zone. Infiltration may be improved through crop residue management. Maintaining crop residue reduces surface sealing and crusting so water moves into the soil more freely. This improves the infiltration and water-holding capacity of the soil.

Naturally occurring restrictive soil layers and those formed by tillage equipment restrict internal soil drainage. The restrictive soil layers reduce the rooting depth and water reservoir available to the corn plant. Shattering these layers prior to planting a corn crop is recommended to improve plant root development and internal drainage. A soil probe or shovel can be used in several areas of a field to determine if restrictive soil layers are a problem.

Digging up root systems and observing the rooting depth and pattern can also help determine if there is a restriction. Restrictive soil layers are commonly shattered by using a subsoiler or ripper-hipper in the field. The depth and thickness of the restrictive layer usually determines which implement should be used. **The restrictive layer must be dry enough for the deep tillage implement to extend just below the bottom of the restrictive layer so it is effectively lifted and shattered.** If the restrictive layer begins at 8 inches and is 2 to 3 inches thick, the tillage shank must penetrate 10 to 12 inches deep. In-row subsoiling is more effective than random subsoiling paths due to the re-compaction caused by subsequent trips of the implement. The in-row pattern also reduces the likelihood the field will be too soft in the spring to support equipment and delay early field preparations. High-residue subsoilers or ripper-hippers are suggested for maintaining the same row location year to year. Surface tillage, especially disking, quickly reforms restrictive layers and should be avoided, if possible.

Irrigation

Corn production in Arkansas is only recommended with irrigation. All five locations for the Arkansas Corn Hybrid Performance Tests are irrigated, even though there is still a small percentage (estimated 20 percent or less) of corn in Arkansas that is not irrigated. Reasonable corn yields may be obtained without irrigation in some years that have good rainfall patterns and growing conditions. However, if adequate rainfall does not occur, yields can be a disaster and the drought stress can contribute to charcoal rot and aflatoxin, which can result in crop failure. These potential risks are the basis for the strong recommendation to irrigate corn in Arkansas.

Yield

Several hybrids in the Arkansas Corn Performance Tests have 2- and 3-year irrigated average yields of 175 bushels per acre or greater. In the 3 years (2000-2002) of the Corn Research Verification Program, the average yield for the 26 irrigated fields was 175 bushels per acre. Most Arkansas corn producers report irrigated yields of 150 to 200 bushels per acre, and many experienced corn growers are consistently harvesting 175 to 200 bushels per acre on much of their acreage. **Irrigated corn should yield approximately 175 bushels per acre with good production practices and management on productive soils.**

Water Needs

The total amount of water that a corn crop needs during the growing season may vary from 20 to 30 inches depending on factors such as weather conditions, plant density, fertility, soil type and days to maturity. In most seasons, the amount of water needed will be about 20 to 24 inches. The inches of irrigation water required will vary depending on the beginning soil moisture and the rainfall received during the growing season. The irrigation system needs to be capable of providing 12 to 16 inches of irrigation water to assure a good yield potential.

Moisture stress anytime after planting can affect plant development and reduce yield potential. The amount of yield loss is dependent on the growth stage of the corn when moisture stress occurs. Table 3-1 shows the general relationship of potential yield reduction due to moisture stress at different growth stages.

Table 3-1. Potential Yield Reduction From Moisture Stress at Different Growth Stages of Corn

Growth Stage	% Yield Reduction
Prior to tasseling	10-20
Tasseling to soft dough	20-60
Soft dough to maturity	10-35

Corn's daily water needs are relatively low in the first 3 to 4 weeks of vegetative growth, and rainfall is usually adequate to meet the water demand during this period. However, if it is relatively dry when the crop emerges and rainfall doesn't occur in the first 2 to 3 weeks, irrigation may be needed. When the corn has approximately 8 fully developed leaves, its growth rate greatly increases. The number of kernel rows per ear is determined at this time so plant stress needs to be avoided during this period. A sidedress fertilizer application is usually made prior to this time. The plant's nutrient and water uptake increases, and irrigation is often needed at this time to activate the fertilizer and avoid moisture stress.

If nutrient and water needs are met, rapid plant growth continues. The number of kernels on each ear and the size of the ear are being determined when the plant has 12 leaves. The number of kernels is determined by the 17-leaf stage, which is about one week from silking. At this time the crop is very near the start of the reproductive growth stage, when its water needs are greatest. **During the period from about 2 weeks prior to silking until 2 to 3 weeks after silking, the water use on days with temperatures in the upper 90s can be 0.3 inches. This 4 to 5 week period is the most critical time to make sure irrigation is applied as needed to satisfy the water needs.** Moisture stress during the silking stage may delay development so that the pollen is shed before the silks emerge. This can result in poor or no pollination and extremely low yields. Most corn producers report that if it is hot and dry and you are late starting irrigation going into this period, it is very difficult to irrigate often enough to keep up with the crop's water needs. Once the grain is developed, the water use begins to decrease because the kernels start to progressively harden as they dry and the crop approaches maturity. Table 3-2 shows the estimated range for daily crop water use as the crop develops.

Table 3-2. Estimated Corn Water Use in Arkansas*

Days after planting	Inches per day
0-30 (early plant growth)	0.05-0.10
30-60 (rapid plant growth)	0.10-0.20
60-100 (reproductive stage)	0.20-0.30
100-120 (grain fill to maturity)	0.25-0.10

*Based on planting date of April 1

Irrigation Scheduling

The timing of irrigation is commonly referred to as irrigation scheduling. Correct timing is critical to maximizing yield. **Having the ability to irrigate is important, but it is also essential that a grower have the ability and commitment to apply irrigation in a timely manner.** Too often, growers irrigate by the appearance of the crop. Visual stress, especially during reproductive growth, results in yield loss. Even if irrigation is started at the first sign of visual stress, there is still some amount of time required to finish irrigating a field. The result is that the crop in the last area of the field to be irrigated suffers even greater yield-limiting stress.

Irrigation timing decisions can be improved if the soil moisture can be determined. Determining the soil moisture by visual observation or by kicking the soil surface is difficult and can be misleading. The "feel" method can be used to determine the soil moisture condition more accurately. This method involves using a shovel or soil probe to pull a soil sample from the root area. In general, if the soil forms a hand-rolled ball, the soil moisture is adequate. A key to this method is to take samples across the field at different depths in order to better determine the soil moisture for the field. The challenge is to determine when to begin irrigation so the entire field can be irrigated before any part becomes too dry. Satisfactory results with the "feel" method can be achieved with experience.

Soil moisture can be determined more precisely with tensiometers. A tensiometer is a sealed, water-filled tube with a vacuum gauge on the upper end and a porous ceramic tip on the lower end. The tensiometer is installed in the seedbed at a depth where the majority of the roots are located. A 12-inch depth is commonly used for surface irrigation, but if a hardpan exists then the tensiometer is placed just above the restrictive layer. Shallower settings at about 8 inches deep are recommended for center pivots. Two or three tensiometers per field are recommended to avoid a problem should one of the tensiometers quit working. Starting irrigation at a vacuum gauge reading of about 50 centibars on silt loam and clay soils, and at approximately 40 centibars on sandier soils, is recommended. In addition to tensiometers, there are other soil measurement devices that are fairly reliable and effective when checked and maintained properly. However, the time and effort that this requires usually results in most producers not being able to use them very effectively.

Soil moisture accounting is used to calculate the soil-water balance in the root zone throughout the growing season. This method is sometimes called checkbook irrigation scheduling because a record is kept on the water that enters and leaves the soil like an account balance is maintained in a checkbook. Two forms of the checkbook procedure are available – the Checkbook User's Guide and the Irrigation Scheduling computer program. The Checkbook User's Guide is used to keep a written record of the soil moisture balance when a computer is not available. It is a three-page handout that shows how to use a water usage chart and a water balance table to monitor the soil moisture. The water usage chart shows an estimate of how much water the crop uses each day based on the maximum temperature and the age of the crop. Daily water use and rainfall amounts are entered into a water balance table. Maximum temperature data can be taken from the weather, newspaper, etc., but the rainfall should be measured with a gauge at each field. Adding and subtracting these numbers in the table determines the soil moisture deficit. Table 3-3 shows the recommended allowable deficits that are included in the User's Guide to help determine when to irrigate.

Table 3-3. Allowable Deficits – Corn

Predominant Soil	Flood, Furrow or Border Irrigation (Inches)	Pivot Irrigation (Inches)
Clay	1.75	1.25
Silt Loam w/pan	1.50	1.00
Silt Loam wo/pan	2.00	1.50
Sandy Loam	1.75	1.25
Sandy	1.50	1.00

w/pan – restrictive layer at 10 inches or less below soil surface
wo/pan – without shallow restrictive layer

The Checkbook User's Guide, water usage charts and water balance tables are available through your county Extension office at no cost. This method does require some record keeping, but it can be helpful in deciding when to irrigate.

If a computer is available, the Irrigation Scheduling computer program can be used for the record keeping. This program operates much like the Checkbook method just described except that the computer does the calculations. It uses daily maximum temperatures and rainfall measurements at the field to determine the field's soil moisture deficit. **The program also has the option to predict when irrigation will be needed in the next 10 days if no rainfall occurs.** This offers a real benefit to managing irrigation labor and sharing irrigation water with other crops. The program is used in research and Extension irrigation studies and demonstrations conducted in Arkansas. Growers in Arkansas, Mississippi, Louisiana, Tennessee, Kentucky and Missouri are successfully using the program on their farms. **The program is downloadable from the following Extension web page address: http://www. aragriculture.org/computer/schedule/default.asp.**

Irrigation Termination

As the crop approaches physiological maturity, a decision on when to stop irrigating has to be made. **The goal is to maintain adequate soil moisture until the corn reaches black layer, which indicates physiological maturity.** This ensures that the kernels can obtain their maximum weight so the crop's full yield potential will be achieved. The decision is best made toward the end of the season by a field determination of the maturity of the crop and the soil moisture status. An initial consideration is how many days it has been since planting. If it has been 90 days since planting and the corn is a 112-day corn, then it may be within 3 weeks of maturity and a field check should be made.

Determining how developed the starch is in the kernel is helpful in making the decision on when to terminate irrigation. The starch begins forming as a line from the top of the kernel and moves toward the tip of the kernel where it is attached to the cob. The progress of the starch line can be checked by taking approximately six (6) representative ears from the field and removing the shucks. The ears can then be broken in half and some of the kernels taken from where the ear was broken. These kernels can be sliced lengthwise so the starch development can be observed. The goal is to determine if there is at least 50 percent starch development inside the kernels sampled. If there is 50 percent starch and good soil moisture exists from a recent surface irrigation or rain, then irrigation can be terminated. However, if the soil is becoming dry at this point, then additional irrigation is needed to assure maximum seed weight and yield. A final irrigation at this stage should be as quick a flush as possible with flood (levee) or border irrigation. If the corn is irrigated with a center pivot, then it is recommended that the starch development be at 75 percent with good soil moisture before stopping irrigation.

Irrigation Methods

The surface and sprinkler irrigation methods used on corn have different characteristics that determine which would be the best for a particular situation. No one method can be labeled as the best – each has its place.

Flood (Levee) Irrigation

Flood irrigation with levees should really be thought of as flush irrigation. The challenge is to get the water across the field as quickly as possible. This is especially important if the corn is small and planted flat rather than on a raised row or bed. **It is also critical that irrigation is started before the crop experiences drought stress. If plants are drought stressed and then subjected to an extended wet soil condition, plant development can be delayed and some plants may die.**

Levees should be marked early to strengthen the commitment to pull levees and irrigate when needed. If the corn in the levee mark has been allowed to grow very much, it may be necessary to bush-hog the levees before they are pulled. This helps avoid problems caused by having too much plant material in the levee. Spacing of the levees depends on the field slope, but spacing on an elevation difference of 0.3 to 0.4 feet between levees is common. A narrower spacing of 0.2 to 0.3 feet elevation difference may be necessary on very flat fields or when trying to irrigate flat planted corn that is less than 6 inches tall. Levees are usually broken in several places or completely knocked down to get the water into the next bay. Rebuilding the levee in time for the next irrigation is often difficult because the levee area tends to stay wet. Some growers install gates or spills in the levees to avoid irrigation delays due to rebuilding the levees between irrigations. When possible, it is recommended that a few gates or spills be installed in the outside levee to provide better field drainage when a big rain occurs during or soon after the irrigation. The outside spills can be opened to avoid the “blowing out” of levees.

It is recommended that water not be allowed to stand on any area for longer than two days. This can be difficult on big flat fields. Some growers are able to divide a big field into two smaller fields so they can better manage the water when they start irrigating. If this isn’t practical, then providing multiple water inlets to the field can be helpful. Multiple inlets help avoid running water too long at the top of the field in order to get water to the bottom of the field. One multiple inlet method is to water the upper half of the field from the pump discharge or riser and then run irrigation pipe or tubing from the discharge down the field to water the lower half. A canal or flume ditch alongside the field can also be used for multiple inlets. The water can be directed from the ditch through cuts or spills into individual bays down the length of the field.

Another possibility is to run tubing the full length of the field and install several of the 2.5-inch plastic gates in each bay. These slide gates are adjustable from completely closed to fully open. When fully opened they deliver 65 to 75 gallons per minute (gpm) and they are reusable from year to year. The decision can then be made on how many bays to water at one time based on the available flow and the size of the bays. This method can be used by laying the tubing on a permanent outside levee or road along-side a field. However, with this installation, all of the water will tend to go to the low end of the tubing. When this occurs, some type of restriction has to be put on or under the tubing (choke-rope, barrel, etc.) in order to hold water back up the slope. Another option is to run the tubing over the levees. Heavier tubing (9 to 10 mil) has been laid over levees successfully as long as it is going down slope. The 9 to 10 mil grade tubing is better than the 6 to 7 mil in multiple-inlet-type applications.

Levee irrigation becomes even more of a challenge if the soil is allowed to crack severely before irrigation is started. Multiple inlets can help offset this challenge, but it is still important to irrigate on time. Planting on a raised bed or row as recommended provides improved drainage and helps avoid some of the water management challenges of levee irrigation. Planting on beds and using multiple inlets with spills installed in the levees may provide the best water management capability with flood (levee) irrigation.

A minimum irrigation capacity of 15 gpm per irrigated acre is recommended for levee irrigation. At this rate, about four days would be required to complete an irrigation. Starting late would increase the time required, resulting in severe drought stresses in the last portion of the field to get water. Opportunities for getting more pumping capacity to a field should be explored and developed whenever possible so the pumping time required to irrigate a field can be reduced. Although levee irrigation presents a challenge, it can be done successfully. There are many producers who consistently produce high yields by paying close attention to the precautions and recommendations that have been presented.

Furrow Irrigation

Furrow irrigation can be a very effective irrigation method. **One of the biggest requirements for furrow irrigation is that the field must have a positive and continuous row grade.** This usually requires precision land grading, which can be rather expensive. However, the grading results in positive field drainage that greatly enhances production. As discussed earlier, the row grade should be in the range of 0.1 to 0.5 percent, and row grades between 0.15 and 0.3 percent are especially desirable for furrow irrigation. The row length to be furrow irrigated is another key consideration. Row lengths of 1,500 feet or less generally water more effectively than longer rows. Row lengths less than 1/4 mile are usually required if sandy soils are to be irrigated effectively.

When row lengths cannot be altered, it may be necessary to control the furrow stream flow by adjusting the number of rows that are irrigated at one time. Experience shows that in most situations it is desirable to get the water to the end of the row in about 12 hours. Watering so long that the top of the row is over-watered can cause problems in this area, especially if it rains and stays cloudy soon after the irrigation. This is a concern with the expanded use of irrigation tubing with punched holes for furrow irrigation. The tendency is to punch holes in the tubing as long as water still comes out of them without much concern for how long it will take to water out the row.

Growers find that on some fields with good beds, they can use small holes with small furrow streams for up to 24 hours on a furrow irrigation set without risk of over-watering or damaging the crop. This is desirable from the standpoint of operating the tubing in sets without having to plug and open holes. The caution is to water according to what is more effective for the field and crop rather than what is easiest.

Another approach that can limit or avoid the opening and plugging of holes and the tendency to irrigate for too long is to run parallel tubing across the field. One run of tubing would go across the first half of the rows and have holes punched for each middle to be irrigated. A longer run of tubing is then laid behind the shorter tubing. Beginning where the shorter tubing ends, holes are punched in the longer tubing for the middles irrigated across the remainder of the field. This allows row sets to be changed by unhooking one run of tubing from the irrigation well or riser and hooking up the other run. If more than two sets are required for a field, then alternate rows may be irrigated to avoid the laying of additional tubing. It is also possible to get multi-valved fittings that can accommodate three or more sets and reduce the amount of tubing needed to avoid the plugging and unplugging of holes.

Furrow irrigation requires a water supply of at least 10 gpm per irrigated acre, and more capacity is desirable if available. At 10 gpm per acre, about five days should be expected to complete an irrigation. Practices like waiting until morning to change sets when rows water out at night can add significantly to the time, making it difficult to finish the field before it is time to begin the next irrigation. A well-defined furrow is needed to carry the irrigation water. Planting on a good bed is the most desirable option for having a good water furrow. If a bed is not used, then it is necessary to cultivate with a furrow plow that moves enough soil from the middle of the rows so that a good furrow is created. Some producers prefer to water alternate middles under certain conditions. Watering alternate middles can result in getting across the field quicker and not leaving the soil as saturated as it might be if every middle were irrigated. Then, if rain comes soon after the irrigation, it is possible for it to soak into the soil rather than run off or collect and stand in low spots. Producer preference and experience, along with the crop and field condition, will determine whether it is best to water every middle or alternate middles. Alternate middle irrigation will usually result in having to come back with the next irrigation somewhat sooner than when every middle is watered.

Furrow irrigation by necessity requires that there be some amount of tail water runoff from the ends of the rows. All the middles will not water out at the same rate, especially those that are wheel-track middles. Also, cracking soils can make furrow irrigation management more challenging. However, irrigating on the appropriate schedule will reduce the problems associated with extensive soil cracking.

Border Irrigation

Border irrigation may be a method to consider on fields that are planted flat rather than on raised beds or rows. Borders are raised beds or levees constructed in the direction of the field’s slope. The idea is to release water into the area between the borders at the high end of the field, flushing a large volume of water over a relatively flat field surface in a short period of time. The borders guide the water down the slope as a shallow sheet that spreads out uniformly between the borders.

Border irrigation is best suited for precision graded fields that have slope in only one direction. All field preparations should be done with the field’s primary slope, and planting should be with or at a slight angle to the primary slope. Planting across the slope tends to restrict the water flow, especially on fields with less than 0.1 percent slope. Fields with slope in two directions are not as well suited to border irrigation, but it may still be possible if the spacing between borders is relatively narrow.

The spacing between borders is dependent on soil type, field slope, pumping capacity, field length and field width. A clay soil that cracks is sometimes difficult to irrigate, but with border irrigation, the cracking actually helps as a distribution system between the borders. This factor also makes it possible to use borders on clay fields that have a slight side or cross slope. The tendency on fields with side slope is for the water to flow to the lower side and not spread out uniformly between the borders. The soil cracks lessen this affect because the water will spread laterally as it follows the cracking pattern. The border spacing on clay soil will generally be between 200 and 300 feet with the narrower spacing on fields with side slope.

The border spacing on sandy and silt loam soils that tend to seal or crust over is more of a challenge than with the cracking clays. Side slope on these soils results in the border spacing having to be narrower in order for the water to spread uniformly between the borders. The border spacing on soils that seal or crust over will generally range between 100 and 200 feet with the narrower spacing on fields that have side slopes.

The pumping capacity and field dimensions (length and width) are used to determine the number of borders needed and how many can be irrigated in a reasonable time. **The desired pumping capacity for border irrigation is 12 gpm per irrigated acre. Calculations can be made to estimate the time required to irrigate a border, and it is usually possible to work toward approximately 12 hour set times, which fit very well for managing water and labor.**

The border can be constructed in a variety of ways and with different types of equipment. It is also possible to plant on the borders if they are constructed before planting. A settled border height of 2 to 3 inches is all that is needed on ideal fields with no side slope, but a 3 to 6 inch settled height is required if the field has side slope or if the field has shallow depressions or potholes. **If the border is constructed with a disk type implement, an effort**

must be made to fill the ditch left at the base of the border so it will not act as a drain furrow. The borders need to stop at least 30 feet from the low end of the field so they will not restrict drainage. The water can be delivered into the area between the borders from a canal, gated pipe or irrigation tubing. The 2.5-inch plastic gates that deliver 65 to 75 gpm each can be installed in the tubing so sets can be changed by opening and closing the gates. If gates are installed in the irrigation tubing, the heavier 9 to 10 mil tubing should be used. When holes are punched in the tubing, the parallel tubing layout discussed with furrow irrigation may need to be used in order to avoid plugging and unplugging holes.

If border irrigation can be used on a field that is usually flood irrigated, then it can provide certain advantages:

1. less production area lost with borders than with levees,
2. improved ability to irrigate small corn,
3. don't have to repair or rebuild border between irrigations, thus a potential for time and labor savings,
4. field drainage is not restricted by borders and
5. possibility of planting on the borders.

Border irrigation will not work on all fields, and it should really only be considered when the corn is planted flat. There is not adequate space in this publication to cover all of the details associated with border irrigation. However, more information is available through your local county Extension office.

Center Pivot Irrigation

Center pivots offer the ability to irrigate fields that have surface slopes that make it impossible or impractical to irrigate with surface methods. They also offer more water management options than surface irrigation. **The need for good surface drainage still exists with pivot irrigation and should not be overlooked.**

Pivots are best suited for large square-, rectangular- or circular-shaped fields free of obstacles such as trees, fences, roads, power poles, etc. Field ditches are also a concern if the pivot towers must cross them. Pivots can cover a range of acreage depending on the allowable length, but the common 1/4-mile, full circle system will cover approximately 130 acres of a 160-acre square field. **It is possible to tow a pivot from one field to another, but it is usually best for a system not to be towed between more than two points during the season.**

Pivots provide the ability to control the irrigation amount applied by adjusting the system's speed. This gives the operator advantages for activating chemicals, watering up a crop and watering small plants. It is also possible to apply liquid fertilizer and certain pesticides through the system. This is called chemigation, and it can be especially applicable to corn for sidedress or late-season applications of fertilizer. **Any chemicals that are to be applied through the system must be specifically labeled for chemigation.** The label will give fairly specific application requirements and recommendations if a chemical is approved for chemigation application. Any pivot system used for chemigation must have some specific equipment and safety devices installed. Information on equipment requirements and chemigation is available through most center pivot dealers or companies. General information on chemigation can be obtained through the local county Extension office.

It is recommended that a pivot have a water supply of at least 5 gpm per acre that is irrigated. At that rate, nearly four days are required to apply a 1-inch irrigation. A water supply less than this leaves no room for break down time without the risk of getting behind in meeting the crop water needs. The capacity for a towable system should be greater to account for the added time needed to move the system. It is recommended that pivot irrigation be applied early enough to avoid the deeper soil moisture being extracted early in the season. If the deeper moisture is used early in the season, it becomes difficult for a pivot to keep up with the water demand unless rainfall replenishes the deep moisture. A pivot irrigation will typically soak about 8 inches of the root zone and has very little chance of replacing moisture any deeper. The goal is to save the deeper moisture for when irrigation is terminated and the crop uses the deeper moisture to take it to maturity.

Most pivots are equipped with low-pressure sprinkler packages, and many are mounted on drops that release the water closer to the soil surface. This is desirable as long as the system application rate is matched to the soil and field characteristics so excessive runoff is avoided. If a field has a rolling surface and a soil that tends to crust or seal over, this should be taken into account in the sprinkler package selection. The application amount can be adjusted to reduce runoff to some degree, and most producers find that applying approximately 1 inch works best. Minimum tillage that leaves crop residue on the surface can help reduce runoff problems. It might also be possible to put in narrow width (1 inch or less) slots at a depth of about 8 inches in some of the middles. This can be done with something like anhydrous shanks in order to give the water a path for soaking in rather than running off a sealed or crusted-over soil surface.

One of the biggest advantages of pivot irrigation is the limited labor required for operating the system. The biggest challenge with center pivots is the initial cost. However, they offer some advantages that can justify the initial cost, especially when surface irrigation is not possible and the cost is spread over an expected service life of at least 15 years.

When considering the different irrigation methods, it is important to remember that any method that is well planned and is properly installed, operated and maintained can give the results desired. **Every method requires time to irrigate the whole field, so it is very important that irrigation be started early enough that no part of the field suffers moisture stress.**

Arkansas Situation

Consistent and profitable corn production in Arkansas is difficult without irrigation. Once irrigation is in place, the irrigation operating cost for each irrigation is typically $3 to $6.50 per acre. This cost is easily justified by the yield increase that can result from the irrigation. The maximum profit usually results when the maximum yield is obtained, so the irrigation goal is to obtain the maximum yield by preventing crop moisture stress. **Irrigation is not a cure-all. Maximum yield and profit will be achieved only when irrigation is coupled with other production practices that establish profitable yield potentials.**

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4 - Fertilization and Liming

Leo Espinoza and Jeremy Ross

Soil testing is the foundation of a sound fertility program, with the goal of a soil testing program being to provide guidelines for the efficient use of lime and fertilizers. University of Arkansas fertilizer and lime recommendations are based on field research conducted under varying soil conditions, crop rotations, crop nutrient requirements and yield goals.

Soil pH

Soil pH affects the availability of nutrients to plant roots. The desirable soil pH for corn ranges from 5.8 to 7.0. Continued cultivation and the use of chemical fertilizers, especially those containing ammonium and sulfur, tends to decrease soil pH over time. Irrigation with water high in calcium carbonate, on the other hand, tends to increase soil pH.

Soil samples should be collected and checked for the degree of acidity or alkalinity in a soil. Lime is generally recommended at pH values below 5.7 (Table 4-1). If rice is in the rotation, lime is not recommended without the benefit of additional information such as irrigation water quality tests. Even then, lime is not recommended unless the soil pH is below 5.7 (Table 4-2). If lime is needed, it is better to apply it during the fall to provide enough time for it to react with the soil.

Liming materials also have different Relative Neutralizing Values (RNV). The RNV of a material is based on its fineness and Calcium Carbonate Equivalent (CCE or the amount of pure calcium carbonate to which the selected material corresponds), with finer materials reacting more quickly than coarse materials. An Ag lime material with a CCE of 110 is "stronger" than an Ag lime material with a CCE of 90, consequently less volume would be needed to increase the pH of a given soil.

Table 4-1. Lime Recommendations for Corn When Rice Is Not in the Rotation

Soil pH	Soil Test Calcium (lb/A by Mehlich 3 Extraction)			
	Below 1000	1000-3000	3000-4500	Above 4500
	Tons/A			
Above 5.7	0	0	0	0
5.2 - 5.7	1	1.5	2	2.5
5.0 - 5.2	1.5	2	2.5	3
Below 5.0	2	2.5	3	3

Table 4-2. Lime Recommendations for Corn When Rice Is in the Rotation

Soil pH	Lime (tons/acre)
Above 5.7	0
5.2 - 5.7	1
5.0 - 5.2	1.5
Below 5.0	2

Nitrogen

Nitrogen is an important component of amino acids and proteins, which are the basic building blocks of all living matter – both plant and animal. Nitrogen-deficient plants normally show a pale-yellowish color (Chlorosis), which results from a shortage of Chlorophyll in the plant's "solar collection cells." A rough rule of thumb is that, based on the yield level, 1 to 1 1/2 pounds of actual nitrogen (N) are required for each bushel of corn produced. More N is normally required per bushel on the silty clays and clays (Table 4-3) than on the sandy loams and silt loam soils (Table 4-4).

Table 4-3. Fertilizer Recommendations for Corn Grown in Sandy Loams or Silt Loams According to Yield, P and K Levels

Soil Test P (lbs/A)	Soil Test K (lbs/A)		
	Above 275	150-275	Below 150
	Recommended N-P_2O_5-K_2O, lbs/A		
Up to 125 bushels			
Above 100	120-0-0	120-0-60	120-0-90
60-100	120-50-0	120-50-50	120-60-90
Below 60	120-60-0	120-60-60	120-60-90
150 bushels			
Above 100	150-0-0	150-0-60	150-0-100
60-100	150-50-0	150-60-60	150-50-100
Below 60	150-70-0	150-70-70	150-70-100
175 bushels			
Above 100	180-0-0	180-0-70	180-0-120
60-100	180-60-0	180-70-70	180-60-120
Below 60	180-80-0	180-80-80	180-80-120
200 bushels			
Above 100	210-0-0	210-0-80	210-0-150
60-100	210-60-0	210-60-80	210-60-150
Below 60	210-90-0	210-90-90	210-90-150
225 bushels			
Above 100	240-0-60	240-0-100	240-0-200
60-100	240-60-60	240-50-100	240-50-200
Below 60	240-100-60	240-100-100	240-100-200

Table 4-4. Fertilizer Recommendations for Corn Grown in Silty Clays, Silty Clay Loams and Clays According to Yield, P and K Levels

Soil Test P (lbs/A)	Soil Test K (lbs/A)		
	Above 275	150-275	Below 150
	Recommended N-P_2O_5-K_2O, lbs/A		
Up to 100 bushels			
Above 100	125-0-0	125-0-60	125-0-90
60-100	125-50-0	125-50-50	125-50-90
Below 60	125-60-0	125-60-60	125-60-90
120 bushels			
Above 100	175-0-0	175-0-60	175-0-100
60-100	175-50-0	175-60-60	175-50-100
Below 60	175-70-0	175-70-70	175-70-100
140 bushels			
Above 100	225-0-0	225-0-60	225-0-120
60-100	225-50-0	225-60-60	225-60-120
Below 60	225-80-0	225-80-80	225-80-120
160 bushels			
Above 100	300-0-0	300-0-80	300-0-150
60-100	300-60-0	300-60-80	300-60-150
Below 60	300-80-0	300-80-80	300-80-150

In Arkansas, this is due to the tendency of clay soils to fix ammonium ions between the clay particles in an unavailable form. If high carryover N is suspected, a soil nitrate-nitrogen test may be used to refine recommended N rates. For a reliable indication of N carryover, the grower should submit at least one subsoil sample along with a topsoil sample about a month ahead of planting. The topsoil and subsoil samples should each represent at least 12 inches of soil depth. Total soil profile N in excess of 40 pounds per acre should be subtracted from the preplant rate in order to achieve a particular yield goal.

Figure 4-1, shows a typical nutrient uptake pattern for a corn plant. No more than half of the total amount of the recommended N should be applied preplant, since the root system is not yet fully developed and salt damage to the young seedlings is a possibility. Also, in the event of poor stands, there remains the option of saving the fertilizer that would have been sidedressed. The remainder of the N should be sidedressed or topdressed after a stand is obtained but before the corn gets “knee high” (six leaves). At this point the corn plant will experience a period of rapid growth, the growing point is above the soil surface and the plant is “deciding” what type of yield load it can support. Thus, it is critical that the plant has an ample supply of nutrients, and water, at this time. Preliminary results of on-going research in Arkansas have shown the potential for significant yield increases when a portion of the fertilizer is applied just before the tassel emerges.

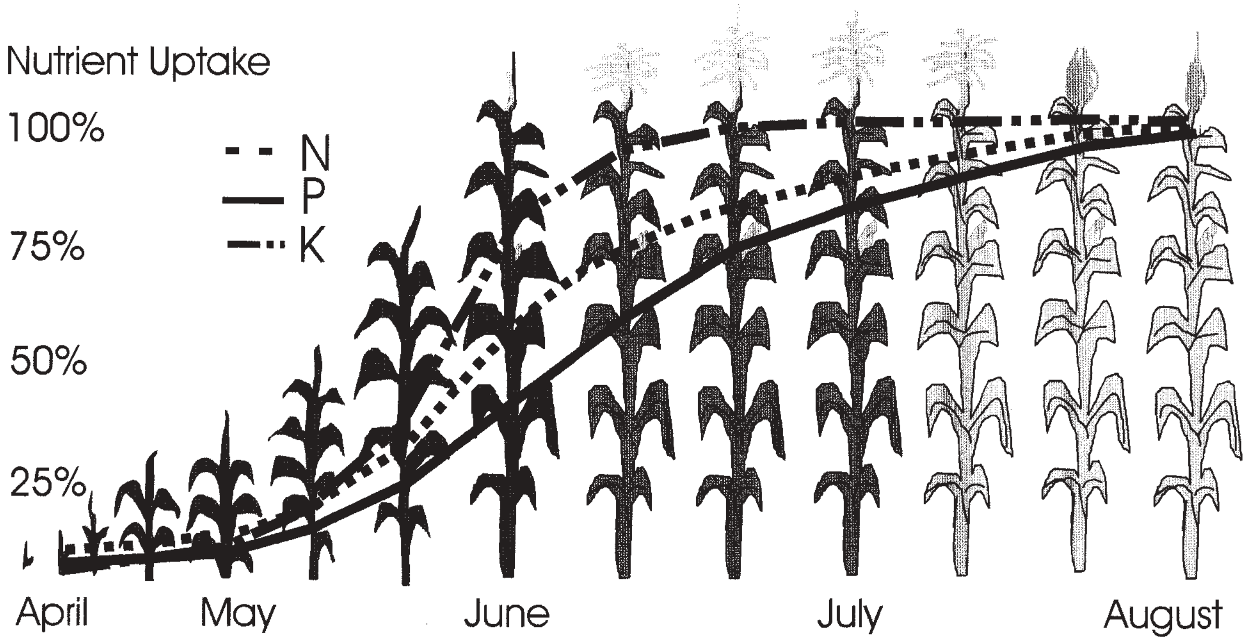
Common N-fertilizer sources include ammonium, nitrate and urea (Table 4-5). These are sold in dry or in liquid formulations (with urea ammonium nitrate

Table 4-5. Nitrogen Sources for Corn

Situation	Preferred Sources[1]
Preplant	Urea, DAP, AS
Sidedress	Urea[2], DAP, AS, 32% UAN

[1]DAP = diammonium phosphate, AN = ammonium nitrate, AS = ammonium sulfate, UAN = urea-ammonium nitrate solution.
[2]Urea post applied to dry soil.

Figure 4-1. Typical nutrient uptake pattern of a corn plant.



having a N content of 28 to 32 percent, for example). Ammonium has a positive charge that is attracted to the negatively charged surface of clay and humus and, as a result, is not as mobile as the nitrate ion. However, under alkaline conditions N, in the ammonia form, may be lost through volatilization.

Nitrate is the form used in the largest proportion by most plants. Nitrates are repelled by the negative charges of soil since nitrates possess a negative charge as well. Nitrate thus tends to remain in solution, subject to leaching and denitrification.

Urea is in reality an organic form of fertilizer, which is commercially manufactured for fertilizer purposes. Plant roots cannot use it directly, so the nitrogen first needs to be converted to an inorganic form (ammonium or nitrate). This conversion is mediated by enzymes present in the soil. In cold, wet soils, urea behaves as a slow-release fertilizer since soil enzymes are not very active under such conditions. Under dry soil conditions, urea is stable for up to seven days after surface application. Rainfall or irrigation and incorporation with cultivation are needed to reduce potential nitrogen losses. Urea itself is highly mobile in soils, and thus urea-N also can be lost from the crop root zone.

Animal Manures

Animal manures and particularly poultry litter may be used as supplements to commercial fertilizers. Rates should be based on soil test results and the nutrient content of the manure, keeping in mind that only 50 to 60 percent of the nitrogen in manure becomes plant-available the first year, and that applying manure based solely on crop N requirements may supply P in excess of plant needs. Where higher rates of animal manures are used, plant analysis should be used to monitor N needs in order to make possible adjustments during the growing season.

Phosphate and Potash

Phosphates have been called the “key of life” because they play an important role in the storage and transfer of energy within plant cells. Phosphates react rapidly with soil constituents that reduce the availability of this nutrient to plant roots. Phosphates interact positively with nitrogen and potassium, while high soil phosphate levels may also reduce plant uptake of zinc and copper. In soils of pH 7.0 or higher, phosphorus also binds with calcium, forming insoluble compounds that are largely unavailable to plant roots. Starter fertilizers may be beneficial for high pH soils and/or with rice in the rotation, with a typical starter rate being 5 gallons per acre of 10-37-0 material.

Apply all recommended P and K at or before planting, along with at least 30 pounds of N per acre. Early planted corn, and corn under no-till, may exhibit phosphorus deficiency symptoms even on soils that have high levels of soil-test P. Where this occurs, as little as 15 pounds per acre of P_2O_5 sidedressed near the row has proved effective in overcoming these temporary P deficiency symptoms. However, a warming period will usually allow the corn to recover, and seldom are yields permanently reduced by the temporary phosphorus deficiency. Phosphorus is recommended unless soil-test P is higher than 100 pounds per acre. Recommended rates range from 50 to 100 pounds of P_2O_5 per acre, depending on the soil test level, the soil type and the yield goal (Tables 4-3 and 4-4).

Potash also plays a critical role in the nutritional balance of a plant. Potash deficiency in corn results in reduced growth, delayed maturity, lodging caused by weak straw and low bushel weight, with visual symptoms including leaf burning. Potash is recommended at soil test levels below 275 pounds per acre. Recommended rates range from 50 to 200 pounds of K_2O per acre, based on needs. Potash applications greater than 90 pounds per acre should be split to avoid salt injury.

Calcium, Magnesium and Sulfur

The secondary elements calcium, magnesium and sulfur are generally considered adequate in most soils. Calcium is generally adequate for corn as long as crop lime needs (pH) are being met, but magnesium and/or sulfur deficiencies are possible on sandy soils low in organic matter. The University of Arkansas Soil Testing Laboratory routinely determines both magnesium and sulfate-sulfur. A low level of available magnesium or sulfur in the topsoil is difficult to interpret unless a subsoil test is also obtained. Both elements tend to leach downward and accumulate with the subsoil clays.

However, medium to high soil-test levels of these elements in the topsoil should indicate adequate levels for the corn crop. A good rule of thumb is that soil-test sulfur levels below 20 pounds per acre and magnesium levels below 75 pounds per acre may be an indication of a deficiency. It is not uncommon for well waters to contain 1 to 2 pounds of magnesium and 2 to 6 pounds of sulfate-S per acre-inch.

Secondary element needs are best assessed by foliar analysis of corn leaves during the growing season. When a soil test indicates very low levels of magnesium (generally on very sandy soils of low CEC), 20 to 40 pounds per acre of additional magnesium are needed.

Dolomitic lime is the most economical source of magnesium where lime is needed. Potassium magnesium sulfate, commercially known as K-Mag or Sul-Po-Mag, typically contains 23 percent potash, 23 percent sulfur and 11 percent magnesium. It has relatively high water solubility compared to dolomitic lime. There is also a granular 36 percent magnesium product that contains both magnesium sulfate and magnesium oxide.

Micronutrients

Micronutrients are needed in small amounts by corn, but deficiencies still may occur which could limit yields. The University of Arkansas Soil Testing Laboratory routinely tests soils for iron, manganese, zinc and copper. Molybdenum should not be deficient in corn under most circumstances in Arkansas. Iron, manganese, zinc, copper and boron are adequate in most soils. However, low levels and possible deficiencies of some of these could occur on leached, sandy soils of low CEC and on medium-textured soils that have an alkaline pH or that have been over-limed.

Zinc is the micronutrient most likely to be found deficient for corn. The deficiency typically occurs at the V2 through V8 growth stages. Analysis of plant tissue during the growing season and comparison of these results over time against published standards is the best way to assess micronutrient status. The University of Arkansas Diagnostic Laboratory at Fayetteville will also analyze plant tissue for a fee. Zinc sulfate (10 pounds Zn per acre)

Table 4-6. Reference Tissue Sufficiency Ranges for Corn According to Growth Stage

Growth Stage	N	P	K	Ca	Mg	S	Mn	Zn	Cu	B
	%						ppm			
Seedling	4.0-5.0	0.4-0.6	3.0-4.0	0.3-0.8	0.2-0.6	0.18-0.5	25-160	20-60	6-20	5-25
Early Growth	3.0-4.0	0.3-0.5	2.0-3.0	0.25-0.8	0.15-0.6	0.15-0.4	20-150	20-70	5-25	5-25
Tasseling	2.8-4.0	0.25-0.5	1.8-3.0	0.25-0.8	0.15-0.6	0.15-0.6	15-150	20-70	5-25	5-25

Source: Southern Series Cooperative Bull. #394.

is the preferred inorganic source for soil applications since it dissolves fairly easily and should be at least 50 percent water soluble. Foliar Zn applications should be made with chelated Zn at a rate of 1 pound Zn per acre. A 9 percent Zn solution typically requires 1 gallon per acre of product. Foliar Zn can be mixed with post-applied herbicides, unless the herbicide label recommends otherwise.

Plant Analysis

Plant analysis is a more direct indicator of plant nutrition than are soil tests. However, care must be taken in interpreting plant analysis values because of environmental and cultural factors that may interfere. If a deficiency is suspected, collect whole plant samples if the corn is less than 12 inches high, or the uppermost mature leaf if the plant is more than 12 inches high but before the tassel stage. If the tassel has emerged, collect the ear leaf.

Table 4-6 shows reference sufficiency ranges for corn grown in the southern United States. This table may be used as a guide for all plant food elements in leaf or whole corn plants, while keeping in mind that collecting the appropriate plant part at the proper stage of growth is critical for the identification of nutritional disorders. Certain elemental ratios are also important. Ratios larger or smaller than those in Table 4-7 suggest possible plant nutrient imbalances or errors in testing or reporting.

Table 4-7. Desired Elemental Ratios in Plant Tissue

N/K = 0.8 to 1.6
N/P = 8 to 12
N/S = 10 to 20
K/Mg = 8 to 16
Fe/Mn = 2 to 6

5 - Major Insect Pests of Field Corn in Arkansas and Their Management

Paul McLeod and Glen Studebaker

Field corn production in Arkansas has been relatively minor until recent years. Because of this, the majority of information available for managing insects on field corn in Arkansas has been based on data developed in the 1950s in Arkansas and on more recent data from other states. However, with the formation of the Arkansas Corn and Grain Sorghum Promotion Board in 1998, funding became available for research on field corn insects, and substantial progress has been made. Surveys have now been completed on insects and their impact on field corn throughout the state. Major insect pests have been identified, and their distribution within the state has been established. Much has been learned on the biology of major insect pests, and this information has enabled the improvement of insect management on field corn.

Although only four years of research have been completed and numerous additional studies are needed, substantial knowledge has been gained. The next step in the process is to provide the corn producers of Arkansas with this information in a usable production manual. The objective of this manual section is to provide the producer with the most current information on identification, biology and management of insect pests of field corn in Arkansas.

Emphasis has been placed on the major insect pests and their management. Additional insects, now considered to be minor pests, may pose greater threats in future years. Also, new species may migrate into the state. Thus, continual research is needed to identify these changes and develop management strategies. As these findings become available, updates to the production manual will be made. Additional information can be found on websites maintained by the University of Arkansas Department of Entomology (http://comp.uark.edu/%7Epjmcleod/) and the Cooperative Extension Service (http://www.aragriculture.org/pestmanagement/insects/corn).

From a producer's perspective, the major insect pests of Arkansas field corn can be divided into two groups; i.e., those attacking seed and seedlings early in the season, and those attacking later. Early season pests include a diverse group of insects. Among the most damaging are chinch bugs, cutworms and wireworms. Rootworms, a major pest of field corn in the Midwest, have not caused significant damage in recent years in Arkansas. The most destructive insect pest of later season field corn in Arkansas is the corn borer complex, including the southwestern and European corn borers. Also, included in this group are the corn earworm, fall armyworm and aphids. Discussions of the major pests follow.

Early season insect pests	Mid and late season insect pests
Chinch bug	Aphids
Corn flea beetle	Corn earworm
Corn thrips	European corn borer
Cutworms	Southwestern corn borer
Seed corn maggot	Fall armyworm
Sugarcane beetle	
White grubs	
Wireworms	

Chinch Bug, *Blissus leucopterus leucopterus*, Heteroptera: Lygaeidae

Description

Chinch bug adults are true bugs; i.e., the front half of the fore wing is hardened while the rear portion is membraneous. Color is generally black, but the light-colored wings give the appearance of a white band across the midsection (Photo 5-1). Adults are only about 3/16 inch long. Immatures vary greatly in appearance. Newly hatched nymphs appear as minute reddish/orange specs on corn stalks and foliage. As nymphs develop, color changes from orange to dark grey or black (Photo 5-2). All nymphs are wingless.

Distribution, Damage and Impact

In Arkansas, chinch bug population has varied greatly during the past four years. Few were detected during 1999 and 2000 except for Lafayette County in extreme southwest Arkansas. Surveys during the last two years, however, have detected chinch bugs throughout the state. Also, very high numbers (20 adults per three-leaf plant) have been found in the White River Delta near Des Arc, the Arkansas River Valley near Clarksville and Alma and near Dumas in southeast Arkansas. Outside of Arkansas, chinch bug occurs in all states east of the Rocky Mountains and into southern Canada. Its impact on field corn in more northern states is minimal. On seedling corn, adult chinch bugs can be found either on the ground or on stems near the ground, often under leaf sheaths. Here they insert their stylet mouth parts into the plant and remove plant fluids. Infested plants often become yellow and distortion of seedlings is common (Photo 5-3). Impact in Arkansas from chinch bug has been substantial. Where chinch bugs have been controlled, yields have been increased up to 25 bushels per acre over areas not managed.

Life History

Generally, adult chinch bugs migrate from overwintering grasses into seedling corn. Once in corn they mate and begin egg laying. When orange nymphs emerge, large numbers of nymphs can often be detected by peeling back the lower leaves on corn seedlings. Nymphs develop for a few weeks before becoming the winged adult form. This process continues throughout the growing season. Mature corn may harbor many chinch bugs in all developmental stages. In Arkansas, about three generations of chinch bug can develop each season.

Management

Successful chinch bug management can be accomplished with four approaches. First, **early planting** may avoid high chinch bug populations. Also, chinch bug damage is generally greater under dry conditions. Plants with **sufficient moisture** are more able to out grow the damage. Thus, irrigation during periods of drought may reduce the impact of chinch bugs on field corn. Irrigation also may aid the uptake of insecticides applied to the seed or soil. In areas with a history of chinch bug problems, it may be beneficial to use seed treated with insecticide or apply a soil insecticide at planting. However, chinch bug populations may experience great fluctuations between years, and preventative soil or seed insecticides may not always be justified. In areas with a history of chinch bug problems and where **treated seed or soil insecticides** are used, it is suggested that a small portion of the field be left untreated and periodically checked for chinch bug. The final approach to chinch bug management is with the use of **insecticide sprays** applied to the foliage of seedling corn. The chinch bug threshold is variable and depends on the rate of plant growth and size. Slow growing smaller plants are most susceptible to severe damage. A general threshold for chinch bug has been established on seedlings less than 6 inches in height. Foliar treatments should be justified when 20 percent or more of the sampled plants harbor a minimum of 5 chinch bugs per plant. Fields should be sampled in several areas due to the variability in chinch bug distribution. Because the chinch bug is often found between the leaf sheath and stem, spray coverage is critical. Foliar insecticides must be applied in a minimum of 20 gpa and directed at the top of the seedling. Also, surfactants will likely increase effectiveness.

Insecticide Recommendations for Chinch Bug on Field Corn

See Tables 5-1 (page 41) and 5-2 (page 42) for insecticide recommendations current at time of publishing. Current updated recommendations can be found in the Cooperative Extension Service publication MP-144 and on the world wide web at www.cdms.net/manuf/default.asp. Always follow instructions on pesticide labels.

Corn Flea Beetle, *Chaetocnema pulicaria*, Coleoptera: Chrysomelidae

Description

The corn flea beetle is a very small (1/16 inch long) black beetle found on the foliage of grasses and field corn (Photo 5-4). As the adult beetle is approached, its common defensive behavior is to use its enlarged hind femurs to jump; hence the name flea beetle.

Distribution, Damage and Impact

Little is known about the corn flea beetle in Arkansas. Surveys have detected low numbers on field corn at Marianna and Des Arc; however, it likely occurs throughout the state. Adults damage field corn by feeding on the epidermis of the leaf. Damaged foliage has light-colored streaks that may give the corn a silver appearance. In addition to foliar damage, the corn flea beetle is capable of transmitting Stewart's wilt disease.

Life History

In Arkansas, the corn flea beetle adult overwinters on grasses including weeds and grass crops like wheat. With warm temperatures in late winter, adults begin to feed, mate and lay eggs in the soil near grasses and corn seedlings. Larvae develop on roots and stems within the soil, pupate and adults emerge to begin the process again. Multiple generations occur each year. Flea beetle problems are greatest following mild winters.

Management

The threshold for corn flea beetle is not clearly defined, but more than two adults per seedling (5-leaf or smaller) may warrant **foliar insecticide** application. In fields with soil-applied **insecticides at planting**, it is unlikely that high numbers of flea beetles will develop. Many of the current field corn hybrids possess some resistance to Stewart's wilt.

Insecticide Recommendations for Corn Flea Beetle on Field Corn

See Table 5-2 for insecticide recommendations current at time of publishing. Current updated recommendations can be found in the Cooperative Extension Service publication MP-144 and on the world wide web at www.cdms.net/manuf/default.asp. Always follow instructions on pesticide labels.

Corn Thrips, *Frankliniella* spp., Thysanoptera: Thripidae

Description

Corn thrips are minute insects found on the leaf surfaces of field corn. Adults are black and about 1/16 inch long (Photo 5-5). Two pairs of wings are present and long hairs occur on the edges of the wings. Immature thrips are smaller and lighter in color.

Distribution, Damage and Impact

Thrips occur throughout Arkansas and may be abundant on seedling corn adjacent to maturing wheat. Adults and immature stages "rasp" the leaf surface with their mouthparts and feed on the exuding plant sap. The impact of thrips on field corn is not well documented, but large populations of thrips can cause yellowing of foliage and stunting of seedling field corn.

Life History

Overwintering adult thrips migrate from maturing weeds and wheat into field corn in spring and early summer. Mating occurs and females insert eggs into the corn tissue. Larvae emerge and feed by scraping the plant surface and ingesting plant sap. Maturity is reached in less than one week and pupation occurs in soil. Adults emerge in about four days and the cycle is repeated. Several generations occur annually in Arkansas.

Management

Because of the sporadic occurrence of thrips on field corn, their impact is not fully understood and management decisions are difficult. **Foliar insecticides** directed at the top of corn seedlings and applied in large volumes of water can be used to reduce the number of thrips. Economic benefits of these applications are not well established, however. **Field location** may play a major role in thrips management as large thrips populations may move from maturing wheat into adjacent crops.

Insecticide Recommendations for Corn Thrips on Field Corn

See Table 5-2 for insecticide recommendations current at time of publishing. Current updated recommendations can be found in the Cooperative Extension Service publication MP-144 and on the world wide web at www.cdms.net/manuf/default.asp. Always follow instructions on pesticide labels.

Cutworms Including the Black Cutworm, *Agrotis ipsilon*, Lepidoptera: Noctuidae

Description

Cutworm larvae are dark grey to black caterpillars that can generally be found just below the soil surface feeding on seedling field corn. Although larvae are minute, less than 1/8 inch long at hatching, they are not likely to be detected until they are at least 1/2 inch long. At maturity larvae are almost 1.5 inch in length (Photo 5-6). The caterpillars have three pair of true legs on the thorax and five pair of fleshy "prolegs" on the abdomen.

Distribution, Damage and Impact

Cutworms occur throughout the U.S. and throughout Arkansas. Recent surveys have detected large populations near Stuttgart and Des Arc. Larvae feed on emerging seedlings and often cut off the plant near or below the soil surface (Photo 5-7). Several adjacent plants within the drill line can be killed by a single cutworm. During 2002, damage was severe in field corn near Des Arc, and several fields required replanting. Also, rough or cloddy soil appears to harbor larger cutworm populations.

Life History

Cutworms generally are capable of overwintering as pupae in soil in Arkansas, especially in southern counties. In addition to adults emerging in late winter from the overwintered pupae, adult moths fly into Arkansas from more southern states. Moths lay eggs on many weed hosts and crops, including field corn. Newly hatched larvae can produce "shot holes" in corn foliage. Larger larvae often cut the seedling and feed below the soil surface. Where damage occurs, larvae can be detected by removing the upper layer of soil near a damaged plant. The number of generations per year varies from one to three depending on cutworm species.

Management

The first step in cutworm management is proper **crop rotation**. Corn that follows corn or corn planted in recently turned pastures tends to have more damage from cutworms. Also, adults are attracted to fields with weeds on which eggs are laid. Thus, **early seedbed preparation** prior to planting reduces the likelihood of cutworm damage. Providing a minimum of two weeks of host free time prior to planting should reduce the attractiveness of the field to cutworm adults. Reduced or no-till fields are more susceptible to economic losses from cutworms. Also, seed beds prepared during wet conditions are often cloddy. These may later harbor increased numbers of cutworms. Bed knockers or flat rolling beds can reduce the chances of developing damaging cutworm populations. In areas with histories of cutworm problems, **treated seed or soil insecticides** applied at planting may be justified. **Foliar insecticide sprays** may be used to reduce cutworm populations, but early scouting for damage is critical. Foliar insecticide sprays should only be used when the damage levels exceed the threshold of 6 to 8 percent of the seedlings with cutworm damage above the surface of the ground or 2 to 4 percent of the plants cut below the surface. Finally, insecticide success may be reduced when late stage larvae are targeted as most of their time is spent underground.

Insecticide Recommendations for Cutworms on Field Corn

See Tables 5-1 and 5-2 for insecticide recommendations current at time of publishing. Current updated recommendations can be found in the Cooperative Extension Service publication MP-144 and on the world wide web at www.cdms.net/ manuf/default.asp. Always follow instructions on pesticide labels.

Seedcorn Maggot, *Delia platura*, Diptera: Anthomyiidae

Description

Adult seedcorn maggots resemble house flies but the body is somewhat slimmer and, at rest, wings are held more backward directly over the abdomen. The damaging form is the larval stage. Larvae can be found attacking germinating seed. At maturity, they are creamy white and about 1/4 inch long (Photo 5-8). A distinct head and legs are lacking.

Distribution, Damage and Impact

Seedcorn maggots occur worldwide and throughout Arkansas. Many crops are attacked, including field corn. Most problems in field corn occur in fields high in organic matter content. Freshly plowed fields with decaying grass and weeds are especially attractive to adult flies which lay eggs near the decaying plant material. When corn is seeded into this ground, the developing maggots often move to the corn seed and can reduce germination, seedling vigor and stand.

Life History

In northern states, the seedcorn maggot overwinters as a pupa within the soil. All stages can be found during mild winters in Arkansas. As spring nears, adults seek decaying organic matter for egg deposition. After hatching, larvae feed for one to three weeks and pupate within the soil. Adults emerge and renew the cycle. Multiple generations occur each year in Arkansas.

Management

Planting in soils with fully **decomposed plant material** should reduce the attractiveness of the field to adult flies. Damage also is more severe in fields where seed are slow to germinate and where seedling growth is retarded. Thus, **delaying planting** until soil is warmer will reduce the impact of the seedcorn maggot. **Treated seed and soil insecticides** applied at planting are effective tactics. Use of insecticide sprays after maggot problems are detected on germinating seed or seedlings is of no benefit.

Insecticide Recommendations for Seedcorn Maggot on Field Corn

See Table 5-1 for insecticide recommendations current at time of publishing. Current updated recommendations can be found in the Cooperative Extension Service publication MP-144 and on the world wide web at www.cdms.net/manuf/default.asp. Always follow instructions on pesticide labels.

Sugarcane Beetle, *Euetheola humilis regiceps*, Coleoptera: Scarabaeidae

Description

Adult sugarcane beetles are hard, shiny black scarab beetles found in seedling corn at or just below the soil level (Photo 5-9). Larvae can be found in mid-season corn through late summer. Larvae are cream colored grubs also found in the soil.

Distribution, Damage and Impact

Surveys have detected adult sugarcane beetles in southern Arkansas near Pine Bluff and Arkadelphia. The adult produces the major damage. Seedling corn is burrowed into at the base of stems generally at the soil line (Photo 5-10). Plants are weakened and may not fully develop. The greatest threat is in fields recently converted from pastures to corn and in reduced tillage systems with substantial grasses. In Arkansas, impact of sugarcane beetle on field corn has been minimal during the last four seasons.

Life History

Adult beetles overwinter in soil, particularly in grassy areas. With warm spring temperatures, adults are attracted to emerging corn seedlings and begin to cut a small chamber in the stem near or just below the soil level. Eggs are laid in soil in corn fields, and developing larvae feed on corn roots but cause little damage. Larvae pupate in late summer and adults emerge and seek overwintering sites. One generation occurs each year.

Management

In south Arkansas **avoidance of recently plowed grassy fields**, including pastures, will reduce the attractiveness of the field to adult sugarcane beetles. Damage also is more severe in fields were seed are slow to germinate and where seedling growth is retarded. Thus, **delaying planting** until soil is warmer will reduce the impact of the sugarcane beetles. **Treated seed and soil insecticides** applied at planting also are effective tactics.

White Grub, *Phyllophaga* spp., Coleoptera: Scarabaeidae

Description

White grub is generally a term given to the larvae stage of a group of over 200 species of scarab beetles. Adult descriptions vary greatly, but the most common is referred to as the May beetle. These adults are commonly found at lights during late spring and summer nights. May beetles are about 1 inch long and tan to dark brown in color. Larvae are cream colored scarabs with a tan head capsule and dark internal markings on the end of the abdomen (Photo 5-11). Six true legs are easily seen on the thorax.

Distribution, Damage and Impact

White grubs occur in the soil of corn fields throughout Arkansas. Damage may occur when the grubs feed on underground roots. However, in recent surveys the impact of white grub has been minimal. Fields recently converted from pastures are most susceptible.

Life History

The biology of white grubs varies greatly due to the many different species. In general, adults emerge in the spring, mate and deposit eggs in a cell below the soil line. Larvae hatch and can complete their development through the summer and fall or may take two or more years to mature. Pupation occurs in the soil.

Management

In south Arkansas **avoidance of recently plowed grassy fields**, including pastures, will reduce the attractiveness of the field to adult beetles. **Rotation** of corn with broadleaf crops, especially soybean, will reduce the likelihood of damage. Use of **treated seed or soil insecticides** applied at planting may reduce larval populations but is not likely to be economically effective if directed only at the white grub.

Insecticide Recommendations for White Grub on Field Corn

See Table 5-1 for insecticide recommendations current at time of publishing. Current updated recommendations can be found in the Cooperative Extension Service publication MP-144 and on the world wide web at www.cdms.net/manuf/default.asp. Always follow instructions on pesticide labels.

Wireworm, Coleoptera: Elateridae

Description

Several species of wireworms occur in Arkansas, and descriptions of the different species vary. In general, wireworm adults, also known as click beetles, are dark brown hard-bodied beetles. The term “click” comes from the ability to snap the hinge between the thorax and abdomen, resulting in a flip that rights the upturned insect. Size varies but adult wireworms in field corn are about 1.25 inch long. Larvae occur in the soil. Although the larvae of some species are white, the most common in Arkansas is tan and at maturity about 3/4 inch in length (Photo 5-12). True legs are evident and the head is somewhat flattened.

Distribution, Damage and Impact

Wireworms occur throughout the state, but the major damage resulting from their feeding has been observed in Clay County in northeast Arkansas and near Paris in Logan County. Larvae feed on newly planted seed, emerging seedlings and can be found infesting the lower stems of larger corn plants (Photo 5-13). Damage in some fields has been substantial, and at times fields have been replanted due to stand loss.

Life History

The biology of wireworms is also quite variable. Some species complete two generations per year while some require up to 5 years for a single generation. In general, adults emerge from overwintering larvae in the spring and search for grassy fields. Eggs are laid in the soil, usually where grasses are available for the larvae to feed. When corn is planted, the seed and emerging seedlings are burrowed into. Seedlings can be weakened and killed. Wireworm larvae can be found by carefully digging up weak seedlings and searching the soil. In dry conditions, wireworm larvae move deep into the soil and are difficult to detect.

Management

In Arkansas, **avoidance of recently plowed grassy fields**, including pastures, will reduce the likelihood of damage from wireworms. **Crop rotations**, i.e., corn following a broadleaf like soybean, will reduce damage, but with wireworms that require multiple years for development, damage may be substantial. Damage also is more severe in fields where seed are slow to germinate and where seedling growth is retarded. Thus, **delaying planting** until soil is warmer may reduce the impact of the wireworms. Although the use of treated seed and soil insecticides applied at planting may provide some control, wireworm problems persist in Clay County despite insecticide application. Foliar insecticide application to seedlings is of no benefit.

Insecticide Recommendations for Wireworms on Field Corn

See Table 5-1 for insecticide recommendations current at time of publishing. Current updated recommendations can be found in the Cooperative Extension Service publication MP-144 and on the world wide web at www.cdms.net/manuf/default.asp. Always follow instructions on pesticide labels.

Aphids, including the Corn Leaf and Bird Cherry-Oat Aphids, *Rhopalosiphum* spp., Aphididae: Homoptera

Description

Aphids found on Arkansas field corn are minute (less than 1/8 inch long) blueish-green insects (Photo 5-14). Clear membranous wings may be present, but wingless forms are more common. Aphids occur in colonies which contain different size nymphs and adults. As the newly born nymphs increase in size, molting occurs and the white exoskeleton is left on the leaf surface.

Distribution, Damage and Impact

Aphid species that attack field corn occur throughout the state and are often found in the whorl of the plant during mid to late summer. Late planted corn is generally more susceptible to damage from aphid feeding. Aphids feed by inserting their stylet or beak into the plant tissue and removing plant sap. Large amounts of sap are removed and the partially digested contents are excreted onto the plant surface in the form of a clear sticky honeydew. A dark grey mold may later form on the honeydew. The level of injury in Arkansas field corn appears to be minimal and generally does not require management. Aphids also transmit viral diseases, but aphid control is not effective in viral disease management.

Life History

Aphids are capable of overwintering on alternate host plants in Arkansas. Also, winged aphids are carried into the state each spring on winds coming from more southern areas. Adults colonize grassy hosts and field corn seedlings, and reproduce asexually through the summer. Development of nymphs is rapid, and many generations occur each season. As temperatures peak during mid to late summer, reproduction rate declines. Thus, early planted corn that matures in August generally is less susceptible to aphid population increase. Later planted corn, however, may experience large aphid populations in early fall. Also, foliar insecticides applied for corn borer management in mid to late summer may reduce beneficial insect populations, and result in aphid population increase.

Management

Early planted corn rarely harbors large aphid populations. In late planted corn, aphid populations may be very high, but when this population buildup occurs on maturing corn, aphid management will likely have little economic benefit. Excessive aphid populations on actively growing corn may be managed with **foliar insecticides**, but the benefits may be very limited. Numerous **beneficial organisms** affect aphids, including naturally occurring insect pathogens, parasites and predators, and insecticide use may reduce their effectiveness. Some corn hybrids possess some level of **resistance** to the aphid.

Insecticide Recommendations for Aphids on Field Corn

See Table 5-2 for insecticide recommendations current at time of publishing. Current updated recommendations can be found in the Cooperative Extension Service publication MP-144 and on the world wide web at www.cdms.net/manuf/default.asp. Always follow instructions on pesticide labels.

Corn Earworm, *Helicoverpa zea*, Lepidoptera: Noctuidae

Description

Adults of the corn earworm, also known as the cotton bollworm, are light tan in color and are about 1.25 inch long. Moths generally have green eyes. Eggs are near white when laid but darken just prior to larvae emergence. Larvae are initially minute, about 1/16 inch, but at maturity can reach 1.75 inch in length. Three pair of true legs occur on the thorax and four pair plus an anal pair are found on the abdomen (Photo 5-15). Color of larvae varies greatly. Mature larvae that have developed on foliage are mostly green while those developing on ears are reddish brown with longitudinal lines. The pupal stage occurs in soil, and color ranges from light tan shortly after pupation to dark brown just prior to moth emergence.

Distribution, Damage and Impact

All stages of the corn earworm can be found throughout Arkansas, and resulting damage may be severe. This damage occurs in several forms, including foliar damage to young corn, damage to tassels and silks and direct damage to kernels (Photo 5-16). The corn earworm also plays a role in occurrence of aflatoxin. Damage to corn ears may serve as an entrance for the fungi responsible for producing aflatoxin.

Life History

Adults that are active in late winter arise from two sources – overwintering pupae and flights of moths from southern areas. Adults are attracted to many host plants, but flowering plants are favored. Eggs are deposited on foliage of seedling corn and larvae consume large amounts of foliage. When accurate counts are made, however, the percentage of seedling corn plants infested with corn earworm is generally very low and control is not feasible. Later generations deposit eggs on silks and emerging larvae chew down the silk channel to the developing ears. Again, use of foliar insecticides to reduce damage on ears is not economically effective on Arkansas field corn. Regardless of host plant structure on which the larvae develop, mature larvae move to the ground and pupate within the upper 6 inches of soil. In Arkansas three or four generations occur each year.

Management

Foliar insecticides are not practical for corn earworm management on field corn, and their use may ultimately increase the problem. Numerous **beneficial organisms** affect corn earworm, including naturally occurring insect pathogens, parasites and predators, and insecticide use may reduce their effectiveness. Soil insecticides may have some effect on larvae attacking seedling corn but are not practical if directed only at the corn earworm. Some corn hybrids possess some level of **resistance** to the corn earworm. Finally, the use of **transgenic Bt corn** likely has some impact of reducing damage to foliage and ears. Future transgenic lines may possess much stronger toxicity to the corn earworm.

Insecticide Recommendations for Corn Earworm on Field Corn

See Table 5-2 for insecticide recommendations current at time of publishing. Current updated recommendations can be found in the Cooperative Extension Service publication MP-144 and on the world wide web at www.cdms.net/manuf/default.asp. Always follow instructions on pesticide labels.

European Corn Borer, *Ostrinia nubilalis*, Crambidae: Lepidoptera

Description

Corn borers, including the European and southwestern corn borers, are the two most destructive insect pests of field corn in Arkansas. European corn borer adults are small, about 3/4 inch in length, and fragile moths. At rest the wings are held back over the abdomen but with a more pronounced “V” shape than wings of the southwestern corn borer. Wings are yellow and brown and exhibit a zigzag pattern (Photo 5-17). Males are slightly smaller and darker than females. In Arkansas, European corn borer adults may be confused with adults of the garden webworm, *Achyra rantalis* (Guenee), a much more common but slightly smaller moth. European corn borer eggs are laid in masses of up to about 25 cream colored eggs in an overlapping fish scale arrangement. Upon hatching, European corn borer larvae are about 1/16 inch in length and resemble newly hatched southwestern corn borer larvae. Their abdomens, however, lack the reddish tint on newly hatched southwestern corn borers. As larvae mature, they become more easily distinguished (Photo 5-18). The tubercles of the European corn borer larvae are less pronounced than on southwestern corn borer larvae, and the upper integument is darker than the lower integument.

Distribution, Damage and Impact

The European corn borer is more widely distributed in Arkansas than the southwestern corn borer. European corn borers can be found throughout the Arkansas River Valley, north central, northeastern and eastern Arkansas. None have been found in southwestern or southeastern Arkansas during recent surveys. Impact of European corn borer larvae on Arkansas field corn is severe. Shortly after hatching, first generation larvae wander over the leaf surface and begin to feed on unfolding leaves. This feeding removes most of the leaf surface, leaving only a thin layer of the upper or lower epidermis. Damage often appears as elongated "window panes" parallel to the leaf veins. Young larvae also feed completely through leaves still rolled in the whorl. As these leaves unfold, a "shot-hole" appearance may be observed (Photo 5-19). Second generation larvae attack most structures on the corn plant. Ear shank tunneling results in ear loss at harvest and stalk tunneling reduces kernel size and yield. Additionally, European corn borer larvae are likely to feed directly on ears. Although ear feeding likely has little adverse impact on yield, this feeding may serve to introduce pathogens that increase losses.

Life History

Mature European corn borer larvae overwinter in corn stubble and other host plant material in Arkansas. In April and May, European corn borer adults begin to emerge from overwintering sites and mate. Egg laying begins about two days after emergence and continues for about one week. Most eggs, however, are deposited during the first two nights. Eggs are very small, less than 1/32 inch in diameter and, like the southwestern corn borer, are overlaid in a mass resembling fish scales. Egg masses generally consist of about 25 eggs. The entire egg mass is only about 1/4 inch in diameter. Eggs are laid primarily on the top and bottom of fully expanded leaves and when ears are present, second generation eggs are most often found on leaves within three nodes above or below the ear. Egg development also resembles that for the southwestern corn borer. With warmer temperatures, larvae hatch in about five days while requiring six or seven days in early season when temperatures are lower. European corn borer larval behavior is also similar to the southwestern corn borer larvae. First generation larvae feed on the outer leaf layers for about 10 days and later tunnel into the whorl and stalk. Damage consists primarily of "shot holes." Second and later generation larvae damage ears, ear shanks and stalks. European corn borer larvae are also capable of tunneling within the upper stalk just below the tassel. This often results in tassel breakage. In 1998, numerous corn fields in eastern Arkansas experienced complete tassel loss due to European corn borer.

Management

Management tactics follow the description of the southwestern corn borer.

Southwestern Corn Borer, *Diatraea grandiosella*, Crambidae: Lepidoptera

Description

Adults are inconspicuous white moths about 3/4 inch in length and have no obvious patterns on the wings (Photo 5-20). Females are slightly larger than males. At rest, adults fold wings almost parallel to the abdomen. Newly hatched larvae are less than 1/8 inch long and have a black head capsule and reddish tint on the abdomen. At maturity, larvae are about 1.25 inch in length, have a reddish head capsule and possess numerous black tubercles on their integument (Photo 5-21). These spots and the consistency of off white color of the integument on both the dorsal and ventral sides of the larvae are the most obvious distinguishing characteristics of southwestern corn borer larvae. In contrast, the spots are reduced and the dorsal integument is darker on European corn borer larvae.

Distribution, Damage and Impact

The center of southwestern corn borer activity in Arkansas is likely near West Memphis. Recent surveys have detected almost 100 percent of non-Bt field corn plants near Marianna and Marion infested with southwestern corn borers. As distance from West Memphis increases, frequency of southwestern corn borer generally decreases. However, damage is severe into Clay, Monroe and Woodruff Counties. Damage is similar to that caused by the European corn borer as described above. Loss of foliage by first generation southwestern corn borer larvae is generally minimal and has little direct effect on corn plants in Arkansas. However, some larvae may tunnel down through the whorl to the growing point of the plant. Leaf tissue above the point of feeding can turn white, a condition called "white heart." If feeding is extensive the plant may be stunted or killed. This condition is called "dead heart" (Photo 5-22).

When the southwestern corn borer first invaded Arkansas during the 1950s, entire fields were lost to "dead heart." Recent surveys of field corn in eastern Arkansas detected only low numbers of plants with "dead heart." In these fields, non-infested plants adjacent to plants with "dead heart" appeared to compensate for the lost plants and thereby limit yield loss. Stalk tunneling is often severe, and as much as 50 percent of the entire length of stalk can be damaged. Yield losses are difficult to assess, but use of the highly effective Bt corn has resulted in yield increases of up to 80 bushels per acre. Tunneling by southwestern corn borer in stalks may weaken them to the point of breaking and falling across the rows. This is called "lodging" (Photo 5-23). In Arkansas, lodging from southwestern corn borer has been common in the eastern and northeastern portions of the state. In 1998, lodging in some corn fields was about 30 percent of the total number of stalks. Lodged stalks slow harvest operations, and yield can be significantly reduced.

Second and third generation southwestern corn borer larvae also feed on the ear shanks – the stem connecting the ear to the stalk. Near harvest, affected ears droop instead of pointing upward like non-infested ears. In a field located at Marianna, 46 percent of the ear shanks were infested by corn borers in 1999. Although many of the infested ears are still harvested, many fall to the ground before or during harvest, which significantly reduces yield.

Yet another way in which the southwestern corn borer affects corn yield is by reducing the size of kernels. Preliminary studies conducted during 1999 sought to correlate the extent of tunneling in stalks below the ear with kernel size. Although the effect was limited, kernel size was negatively correlated with increase in tunneling in stalks below the ear. Tunneling may reduce water and nutrient movement within stalks, thereby limiting kernel development.

Life History

The southwestern corn borer overwinters as a mature cream colored larvae just below the soil line in the stem/root mass of field corn. Adults emerge from corn stubble in spring (May). Mating begins within one night from emergence, and moths generally initiate egg laying or oviposition on the second night after emerging. Eggs are off white in color when laid, and may occur singly or in a small group (Photo 5-24). Individual eggs are very small; i.e., less than 1/16 inch across, elliptical and flattened on the leaf surface. Female moths may lay more than 300 eggs. However, under field conditions it is uncommon to find more than four southwestern corn borer eggs in a group.

The eggs laid by overwintering corn borers represent the first generation of the year. Common plant locations to find first generation eggs are upper and lower leaf surfaces of young corn plants. Although eggs from subsequent generations may be detected on much of the plant, most will occur on leaves within the area located two or three nodes above or below the ear. About one day after being laid, each southwestern corn borer egg develops three reddish orange bars (Photo 5-25). Tiny black spots, which are the head capsules of the developing larvae become visible after three or four days. Larvae within these eggs will emerge within about one additional day. The duration of the egg stage is dependent on temperature. Rolston (1955) reported that most southwestern corn borers hatched six or seven days after being laid in early July, when temperature averaged 71°F. With average temperatures of 80° to 83°F, most eggs hatched in four to five days, respectively.

First generation larvae that complete development, pupate within corn stalks, and second generation moths emerge in mid summer. These moths behave similarly to those of the first generation by mating and ovipositing. By the time oviposition of the second generation occurs, the corn plant is decidedly different in structure. At this time ears are often present. Second generation southwestern corn borer moths exhibit a strong preference for depositing eggs on foliage near the ear. About 80 percent of the second generation eggs can be found within three nodes above or below the ear. When these second generation larvae hatch, the corn plant offers much more structure for the young larvae to penetrate and hide within. The outer layers of ear shuck are often penetrated by young southwestern corn borer larvae. By searching for brown spots on the shuck and carefully removing the outer layer, young larvae may be detected.

Second generation larvae can develop within the ear, particularly the ear shank, but more commonly develop by feeding within corn stalks. Second generation southwestern corn borer larvae affect corn plants in several ways. Most commonly, larvae form extensive tunnels within stalks. When stalks are infested with multiple larvae, the tunnels can run from the soil line up through about 15 plant nodes. Just prior to pupation, larvae can terminate a tunnel just below the stalk surface. They leave only the outermost layer of stalk, which soon turns brown. This forms an exit hole. After larvae pupate within the tunnel, the adult moth pushes out through the exit hole and leaves the stalk to again mate and begin egg laying.

Management – Southwestern/European Corn Borer

Both the southwestern and European corn borers are managed with four methods.

1. Early planting – Corn planted early in the season may reach maturity before the second generation corn borer larvae can negatively impact yields. Planting dates vary with location, weather and ground preparation. In eastern Arkansas corn planted before April 15 can often avoid much of the damage caused by the second generation of corn borers.

2. Stalk destruction following harvest – Both the southwestern and European corn borers overwinter as larvae within old stalks. With environmental changes associated with spring, the larvae initiate pupation and emerging adults begin the cycle of egg laying. Research has consistently shown that stalk destruction can reduce overwintering corn borer populations by greater than 80 percent. From the insect management view, the most effective method of stalk destruction is to mow and disc stalks shortly after harvest in late summer or early fall. This leaves the overwintering larvae on or near the soil surface where the effects of low temperatures and rainfall have their greatest effect on producing larvae mortality. Natural enemies, including beneficial insects, rodents and birds, also contribute to larvae mortality in stalks left on soil surfaces. In late winter, prior to corn borer pupation, the stalk residue should be turned under as much soil as possible. This makes it more difficult for the emerging moths to make their way out of the soil.

3. Soil and foliar insecticides – Much of the corn acreage in Arkansas receives a soil insecticide at planting. This may be directed at chinch bugs, rootworms, cutworms or nematodes. The impact of currently registered soil insecticides on corn borers is not clearly understood. At present, it is doubtful that currently registered soil insecticides directed only at corn borers provide economically acceptable returns. Additional research is currently underway to more clearly define the benefits of these insecticides.

Corn borers are susceptible to several insecticides applied to corn foliage. Difficulties with foliar insecticide effectiveness are associated with corn borer biology. First generation corn borers penetrate corn structures within about 10 days of hatching and second generation within about 7 days. After entering the plant, corn borers are very difficult to target. Thus, foliar applications must be timed precisely to be effective. While the most effective method of timing insecticides is by scouting for corn borer eggs, it is a very difficult task. Use of pheromone trap collections may provide a good indication of when to initiate scouting.

Another method of monitoring adult flight is to search for infested corn stalks. By visually inspecting the ground for insect frass and the lower portion of corn stalks for damage, corn borer larvae can be easily detected. Once found, the stalk can be cut with use of a large knife and carefully split. Both larvae and pupae can be detected. When pupae color changes from tan to dark brown, the moth will emerge within a day or two. Mating and egg laying begins one or two days after moth emergence and eggs will hatch in about five days. Thus, foliar sprays should be applied approximately seven days from first detection of dark corn borer pupae.

If scouting is attempted, one method is to cut 20 plants from each of five locations in a field. Plants should be removed from the field and foliage searched. Applications should be initiated if greater that 25 percent of the plants are infested. For first generation corn borers, granular insecticides are often chosen. Granules likely drop into the whorl better than water based sprays. Granular insecticides are not effective against second generation corn borer. For second generation larvae, sprays are the preferred choice. Spray volume is very important. In 1999, correctly timed foliar sprays provided acceptable levels of corn borer management when applied in 20 gpa. Another method of foliar insecticide application that should be successful is through center pivot irrigation where available.

4. Use of genetically modified corn hybrids – Although field corn has been bred for many years to resist attack by corn borers, the recent development of field corn with the gene that codes for the *Bacillus thuringiensis* (Bt) toxin has met with phenomenal success. Research in eastern Arkansas and numerous other states in recent years has demonstrated that Bt corn is highly effective against both the southwestern and European corn borers. With current populations of corn borers, planting of Bt field corn will likely reduce corn borer impact to more than acceptable levels. Critical in use of Bt corn is managing its use to delay the development of resistance in corn borers to Bt. Insects have a well documented resistance to foliar applications of Bt. As highly effective as Bt corn is against corn borers, selection pressure is very high. Thus, the corn producer is faced with insects that have developed resistance to similar Bt strains and are now placing substantial selection pressure on the same insect populations. Resistance development is only a matter of time. Currently, the accepted method of delaying resistance development is to maintain a susceptible corn borer population through the planting of a portion of land with non-Bt corn. In addition to resistance development, the other major problem with use of Bt corn is with the public's acceptance of genetically modified organisms (GMO's).

Insecticide Recommendations for Corn Borers on Field Corn

See Table 5-2 for insecticide recommendations current at time of publishing. Current updated recommendations can be found in the Cooperative Extension Service publication MP-144 and on the world wide web at www.cdms.net/manuf/default.asp. Always follow instructions on pesticide labels.

Fall Armyworm, *Spodoptera fugiperda*, Lepidoptera: Noctuidae

Description

Fall armyworm adults are large bodied moths with dark grey forewings that have lighter banding. A light spot occurs near the apex of the forewings. Mature larvae are up to 1.5 inch long, and are dark brown in color with numerous black spots (Photo 5-26). The head capsule has a distinct light colored inverted "Y."

Distribution, Damage and Impact

Fall armyworm occurs throughout Arkansas and its impact on field corn is similar to that of the corn earworm. This impact occurs in several forms including foliar damage to young corn, damage to tassels and silks and direct damage to kernels. The fall armyworm also plays a role in occurrence of aflatoxin. Damage to corn ears may serve as an entrance for the fungi responsible for producing aflatoxin.

Life History

In early spring, adults migrate into Arkansas from more southern states, mate and seek suitable host plants for egg laying. Eggs are laid in masses that contain up to a few hundred eggs. Emerging larvae feed for two to three weeks and then pupate just below the soil surface. Multiple generations occur each year.

Management

Foliar insecticides are not practical for fall armyworm management on field corn, and their use may ultimately increase the problem. Numerous **beneficial organisms** affect larvae, including naturally occurring insect pathogens, parasites and predators, and insecticide use may reduce their effectiveness. The use of **transgenic Bt corn** likely has some impact of reducing damage to foliage and ears. Future transgenic lines may possess much stronger toxicity to the fall armyworm.

Insecticide Recommendations for Fall Armyworm on Field Corn

See Table 5-2 for insecticide recommendations current at time of publishing. Current updated recommendations can be found in the Cooperative Extension Service publication MP-144 and on the world wide web at www.cdms.net/manuf/default.asp. Always follow instructions on pesticide labels.

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Much of the original knowledge about southwestern corn borers was developed by Dr. L. H. Rolston, Department of Entomology, University of Arkansas, in the early 1950s shortly after the insect invaded Arkansas. Dr. Rolston studied the basic biology of this new corn pest and used the information to devise successful management programs. This information was reported in *The Southwestern Corn Borer in Arkansas*, June 1955, University of Arkansas Bulletin 553. Today, information reported in the bulletin continues to serve as the basis for corn borer management.

Dr. William Johnson, formally with the University of Arkansas Cooperative Extension Service, and Dr. Frank Davis, formally with the USDA, Starkville, Mississippi, have provided much information used in this manual. Several county agents including Hank Chaney, Mitch Crow, Roger Gipson, Brent Griffin, Brady Harmond, Kevin Lawson, Bob Rhodes, Larry Stauber, Eugene Terhune, Andy Vangilder and Joe Vestal have assisted in locating insect damaged fields and in data collection.

Funding for recent corn borer studies and for production of this manual was provided by the Corn/Grain Sorghum Promotion Board. The authors also are ultimately indebted to the corn producers of the state of Arkansas who have permitted use of their fields and supplied funds through their check off program to the Board.

Table 5-1. 2002 Recommendations for Insecticides Applied to Soil at Field Corn Planting

Insecticide	Amount of product per 1000 row ft.	Armyworm	Chinch Bug	Cutworm	Seed Corn Maggot	Corn Rootworm	Corn Thrips	White Grub	Wireworm
Ambush	.5 fl. oz.	X		X					
Aztec 2.1G	6.7 fl. oz.			X	X	X		X	X
Capture 1.15G	6.4 - 8.0 oz.			X	X	X		X	X
Capture 2EC	.15 - .3 fl. oz.			X	X	X		X	X
Counter 15G	8 oz.		X	X	X	X		X	X
Force 3G	3 - 5 oz.		X	X	X	X		X	X
Furadan 4F	2.5 oz.				X	X			X
Fury	.16 oz.			X					
Pounce 3.2EC	.3 oz.			X	X				X
Regent 4SC	.24 oz.		X	X	X	X		X	X
Cruiser 5FS*	1.28 - 9 oz./100 lb. Seed		X	X	X	X		X	X
Gaucho*	1.34 mg AI/kernel		X		X	X	X	X	X
Prescribe*	1.34 mg AI/kernel		X		X	X	X	X	X

*Seed treatment

Table 5-2. 2002 Recommendations for Insecticides Applied to Field Corn Foliage

Insecticide	Amount per acre	Armyworm	Aphids	Chinch Bug	Corn Earworm	Cutworms	European Corn Borer	Fall Army-worm	Flea Beetles	Grasshoppers	Southwestern Corn Borer	Stink Bugs
Ambush	6.4 - 12.8 fl. oz.	X			X	X	X	X	X		X	
Asana XL	5.8 - 9.6 fl. oz.	X	X	X	X	X			X	X	X	
Capture 2EC	2.1 - 6.4 fl. oz.	X	X	X	X	X	X	X	X	X	X	X
Fury	1.4 - 2.9 fl. oz.		X			X	X		X	X	X	
Lannate LV	.75 - 1.5 pts.	X	X		X			X	X			
Lorsban 15G	5 - 5.6 lbs.						X				X	
Pounce 3.2EC	4 - 8 fl. oz.	X				X	X	X	X		X	
Sevin XLR	1 - 2 qts.	X		X	X			X	X			
SpinTor 2SC	1.5 - 6 fl. oz.	X			X		X	X			X	
Warrior T	1.92 - 3.84 fl. oz.	X	X	X	X	X	X	X	X	X	X	X

Photo Descriptions

The following descriptions correspond to the numbered photographs on the next pages.

5-1 Adult chinch bug on field corn foliage.

5-2 Chinch bug nymph.

5-3 Field corn seedling damaged by chinch bug and showing distortion, yellowing and delayed leaf unfolding.

5-4 Adult corn flea beetle and foliar damage.

5-5 Adult thrips on field corn foliage and resulting damage.

5-6 Mature black cutworm larvae.

5-7 Cutworm damage to seedling field corn.

5-8 Seed corn maggot larvae and associated damage on seedling field corn.

5-9 Adult sugarcane beetle.

5-10 Gouged out feeding damage from an adult sugarcane beetle on seedling field corn.

5-11 Mature white grub larvae.

5-12 Mature wireworm larvae.

5-13 Wireworm feeding damage in seed and newly emerging corn seedlings.

5-14 Immature and mature aphids on field corn foliage.

5-15 Mature corn earworm larvae that has developed on field corn.

5-16 Corn earworm damage to the whorl of field corn.

5-17 Adult European corn borer.

5-18 Mature European corn borer larvae with dorsal integument darker than ventral integument.

5-19 Shot holes produced by corn borer larvae on seedling field corn.

5-20 Adult southwestern corn borer.

5-21 Mature southwestern corn borer larvae within corn stalk.

5-22 Dead heart of field corn produced by corn borer larvae feeding into the growing point of the whorl.

5-23 Lodging of field corn resulting form corn borer feeding damage in the lower portion of the stalks.

5-24 Newly laid southwestern corn borer eggs.

5-25 Southwestern corn borer eggs after two days of development.

5-26 Mature fall armyworm larvae feeding on kernels of corn.

Photographs are referenced throughout Section 5 – Major Insect Pests of Field Corn in Arkansas and Their Management


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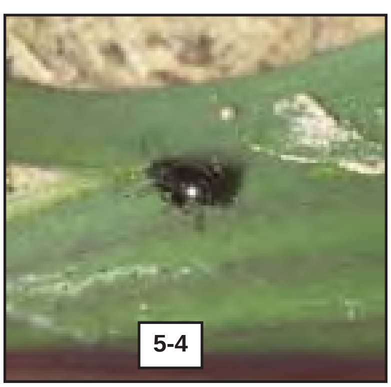
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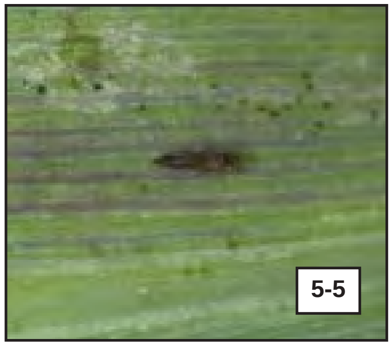
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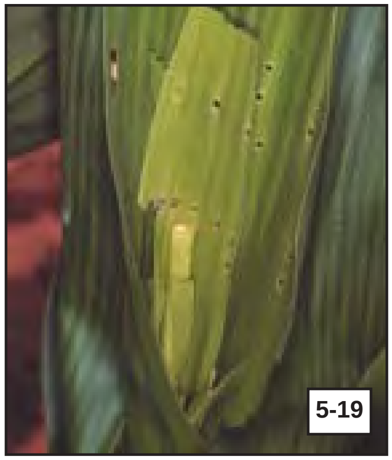
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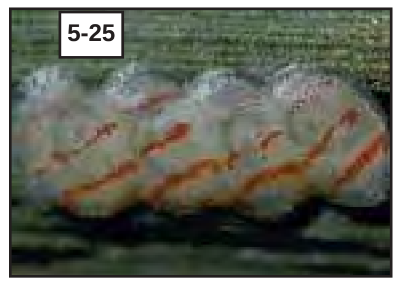
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6 – Diseases and Nematodes

Rick Cartwright, Dave TeBeest and Terry Kirkpatrick

Corn diseases are important yield-limiting factors in many production areas of the U.S. In Arkansas, corn has been a minor field crop for many years, and little disease research has been conducted. Corn hybrids grown in Arkansas are developed by private seed companies. Each company collects information on diseases on their lines. Seed company information is sometimes the only source of disease resistance data on hybrids.

Good management practices, as outlined elsewhere in this guide, can reduce the impact of many diseases on corn. For example, many disease organisms survive from crop to crop in infected residue, which means that diseases can be worse in minimum tillage corn than where the residue is thoroughly incorporated into the soil each year. Stressed plants are also often more susceptible to diseases, so drought stress or poor drainage should be avoided. Balanced fertility can also reduce disease problems, so it is especially important to complete a soil test, apply adequate potassium and other elements as recommended, and to avoid excessive nitrogen use.

For specific problems, effective disease management begins with correct identification of the disease and its cause. The Cooperative Extension Service offers two excellent diagnostic services for Arkansas corn producers in this regard. The Plant Disease Clinic at the Lonoke Research and Extension Center can diagnose most corn diseases, and the Nematode Assay Laboratory at the Southwest Research and Extension Center near Hope provides nematode diagnosis. These services can be accessed by submitting diseased plant samples – or soil samples for nematode analysis – to the local county agent. The county agent can advise you on the proper way to sample and what you can expect in the way of results, in addition to sending the sample to the appropriate lab. Currently, plant disease diagnosis is free, while a small fee is charged for nematode assays.

The following information offers brief descriptions of some of the more common diseases of corn in Arkansas and several suggested management options, when they are known. If you need additional information, please contact the loca1 county agent.

Seed Rots and Seedling Blights

Corn seeds and seedlings may be attacked by various seedborne or soilborne fungi (e.g., *Pythium, Diplodia, Fusarium, Pencillium*, etc.) that cause seed rot or seedling blight. These fungi may cause significant stand loss in poorly drained, excessively compacted, cold and/or wet soils. Seed rot and seedling blight severity are also affected by planting depth, soil type, seed age/viability, seed coat injury and genetic resistance.

Symptoms – Aboveground symptoms of seedling blights can be confused with mechanical, insect or chemical injury. A soft rotting of stem tissues near the soil, yellowing, wilting and death of leaves are common symptoms on blighted seedlings.

Control – Plant high quality, injury- and disease-free seed into a warm (soil temperature consistently above 55°F), moist, but firm seedbed. Use the most appropriate equipment to assure proper placement of seed, pesticides and fertilizers in order to promote the establishment of healthy, vigorous seedlings. All commercial hybrid corn seed is also treated with one or more fungicides, which provides additional protection against seed rots.

Crazy Top

This disease is caused by the soilborne fungus *Sclerophthora macrospora*, and it is occasionally seen in Arkansas, usually in corn fields that have been waterlogged early in the growing season.

Symptoms – Infection usually occurs in young plants (before the 5-leaf stage) exposed to flooded soils for at least 24 to 48 hours. After infection, the fungus grows within the plant, causing various symptoms including excessive tillering (up to 10 tillers per plant), stunting, whitish striped leaves or narrow, leathery leaves. The most striking symptom occurs at tasseling, when the tassel develops a twisted, leafy appearance that may resemble tiny ears (Figure 6-1).

Control – Plant in fields with good drainage and not prone to sustained flooding. Flooding early in the season predisposes corn to infection. It is also recommended that grassy weeds be controlled because they may also be hosts of the fungus.

Anthracnose

Anthracnose is a widespread disease of corn, and it is caused by the fungus *Colletotrichum graminicola*. The disease is favored by long periods of warm, wet weather. Although the fungus attacks many grasses, including johnsongrass, it is believed that isolates from corn do not attack grain sorghum, and vice versa.

Symptoms – The first symptoms of the disease are small spots that appear on the leaves of seedling and mature plants. The lesions appear water-soaked at first and enlarge to about 1/2 inch long tan with reddish-brown bordered lesions over time, depending on the variety and environment (Figure 6-2). The lesions may grow together, killing large leaf areas or entire leaves. Fruiting bodies of the fungus may be observed in the dead tissue with a hand lens as clusters of dark, hairlike structures (called setae) sticking out of the leaf.

Control – Use resistant varieties if available. Practice crop rotation with soybean or rice and plow under old crop residue. Maintain a balanced soil fertility program and control weedy grasses. Minimum tillage favors this disease.

Gray Leaf Spot

A fungus, *Cercospora zeae-maydis*, causes this disease, which appears to have increased in many corn production areas of the U.S. since the adoption of minimum tillage. Heavy yield losses have been reported in no-till corn fields of the eastern U.S. under favorable weather conditions.

Symptoms – Leaf lesions develop on the older, bottom leaves first, and the disease moves up the leaves as the plant matures. The disease is favored by long periods of warm, humid weather. The tan to gray lesions are narrow and rectangular and occur typically between the leaf veins (Figure 6-3). Under favorable conditions, the lesions may join, killing the whole leaf.

Control – Practice crop rotation with a non-grass crop. Destroy infected corn residue with good tillage practices. Use resistant varieties, if available. Practice good weed control as johnsongrass and barnyard grass are hosts of the fungus.

Southern Corn Leaf Blight

Several "*Helminthosporium*" leaf blights attack corn in the U.S. but the most common one in Arkansas is probably Southern Corn Leaf Blight. This disease is caused by the fungus *Bipolaris* (*Helminthosporium*) *maydis*, and it attacks many other grasses besides corn. In 1970, an epidemic of this disease destroyed about 15 percent of the U.S. corn crop, costing an estimated one billion dollars. Resistant corn hybrids have kept it under control since then.

Symptoms – Leaf lesions vary in shape, color and size but are generally oval to elongated, tan in color, with yellow green halos to reddish brown borders (Figure 6-4). Lesions may occur on leaf blades, sheaths, stalks, husks and shanks. The fungus may also attack ears causing a black, felty mold on the kernels.

The fungus overwinters in soil and infected crop debris as well as on infected kernels. The disease may be favored by minimum tillage. Spores produced by the fungus are windborne over long distances or splashed by rain to other plants. The disease is favored by long periods of cloudy, warm and wet weather.

Control – Plant resistant varieties and plow under crop debris. Rotation with non-host crops can be effective. Fungicides are available but rarely economical except in seed corn production (Table 6-1).

Table 6-1. Fungicides Available for Foliar Diseases of Corn in Arkansas *				
Diseases	**Fungicide**	**Active Ingredient**	**Rate/Acre**	**Comments**
Rusts Leaf Blights Gray Leaf Spot	Tilt 3.6E	propiconazole	4 fl oz	Do not apply after silking. See label for other restrictions.
	Propimax EC	propiconazole	4 fl oz	See label for restrictions.
	Stratego	propiconazole + trifloxystrobin	7-12 fl oz	See label for restrictions.
	Quadris 2.08 SC	azoxystrobin	6.2-15.4 fl oz	Not labeled for Southern Rust. Use higher rates for gray leaf spot and leaf blights. See label for warnings and restrictions.
*Notes: Table information was current as of October 21, 2002, and applies only to Arkansas and may not be appropriate for other states. The listing of any product does not imply endorsement of or discrimination against any product by the University of Arkansas Division of Agriculture. Every effort was made to ensure accuracy but the user and/or applicator of any crop protection product must read and follow the most current label of the product – THE LABEL IS THE LAW.				

Rusts

Two similar rust diseases, common rust and southern rust, occur on corn in Arkansas. Common rust is caused by the fungus *Puccinia sorghi*, and the disease often develops when susceptible varieties are grown under cool, wet weather conditions. Southern rust is caused by the fungus *Puccinia polysora*, and it may develop on susceptible varieties when hot, moist weather persists. Although rusts have not been of major concern in Arkansas corn for several years, they remain a potential problem.

Symptoms – Lesions or pustules that contain the rust spores appear on all above-ground parts but are most abundant on the leaf. Pustules are circular to elongated, golden-brown to cinnamon-brown early in the season (Figure 6-5). Pustules become brownish-black as the plant matures. Southern rust pustules are more common on the upper leaf surface and less so on the lower surface than pustules of common rust. Southern rust pustules also remain covered by the epidermis longer than common rust pustules. When the infections are severe, leaves and leaf sheaths may turn yellow and die (Figure 6-6).

Control – Plant resistant varieties if available (check seed company data). Avoid late planting and excessive nitrogen fertilization. Fungicides are available but can rarely be justified economically (Table 6-1).

Charcoal Rot

The soilborne fungus *Macrophomina phaseolina* causes disease on more than 400 different plants including corn. Severe yield losses may result if hot, dry weather persists during and after tasseling.

Symptoms – Infection can occur at any stage from seedlings to plants approaching maturity. Early symptoms include brown, water-soaked lesions on the roots that later turn black. The fungus spreads up into the lower stalk causing premature ripening and lodging. Inside the stalk, symptoms include a dry, stringy appearance rather than a solid pith.

Numerous black sclerotia inside the stalk give the appearance of powdered charcoal, thus the name. The rotting of the stem leads to lodging, with plants bending over a few inches above the soil line where it has become stringy inside.

Control – Charcoal rot losses can be minimized by proper irrigation during the growing season. Excessive nitrogen rates and low potassium dramatically increase charcoal rot damage. Thus, timely irrigation, combined with a well-balanced fertility program based on soil tests, can effectively reduce charcoal rot. Resistant varieties are not available. The planting of high stalk strength varieties is encouraged to reduce lodging.

Other Stalk Rots

Various soil and seedborne fungi, including species of *Diplodia*, *Gibberella*, *Fusarium*, *Macrophomina* and *Pythium*, can cause stalk rot of corn. The exact causal organism can be difficult to identify. Stalk rots cause yield losses by increasing lodging of the crop or by cutting off the supply of water and nutrients from the roots. Stalk rots are usually increased by drought stress, hail damage, leaf diseases, high stand density, excessive nitrogen fertilization, low soil potassium levels, lack of rotation, possibly minimum tillage and stalk feeding insects.

Symptoms – Stalk rots normally begin soon after pollination, and become more severe as the plant matures. Rotting affects the roots, crown and lower internodes. Various discolorations of the pith, including whitish-pink to salmon, are common as is stalk breakage and premature ripening.

Control – Plant strong-stalked varieties to reduce lodging. Practice balanced fertilization based on recent soil tests and avoid excessive nitrogen. Avoid narrow rows and excessive seeding rates if possible. Control stalk insects and harvest as early as possible.

Smut

Three types of smut generally occur on corn – common, head and false smut. While these diseases occur worldwide, only common smut is regularly observed in Arkansas. Losses of 10 percent from smut have been reported, but recently have tended to be negligible as a result of the use of resistant varieties.

Symptoms – All aboveground parts of the plant are susceptible to common smut, but the tender ears and tassels are more commonly attacked. Symptoms are easily recognized on the corn ear as 1/4- to 1/2-inch diameter galls covered with glistening, greenish to silvery-white skin (Figure 6-7). The interior of the galls darken over time and turn into masses of powdery, dark brown to black spores (teliospores). Some galls at maturity may be 5 to 6 inches in diameter. Older affected plants may appear reddish, similar to those heavily infested with aphids.

Soilborne teliospores overwinter and produce spores in the spring that are carried onto young plants by wind or by splashed water.

Control – Plant resistant varieties and avoid mechanical injury to plants during spraying or cultivation. Avoid excessive nitrogen fertilization.

Ear and Kernel Rot

Several widely distributed fungi are responsible for ear and kernel rot. Economic losses are common, especially in rainy years and on insect or bird-damaged ears.

Symptoms – Early infections may be noticed as bleached or straw-colored husks on the ear with heavily infected ears remaining upright due to poor grain fill and light weight. Late infections may show no external symptoms, but when husks are removed, mold growth is commonly found between the kernels on ears with discolored tips (Figure 6-8). Mold colors may range from white to black, with pinkish color quite common.

Control – Plant only adapted corn varieties known to have few ear rot problems. Fertilize properly and control ear feeding insects as needed. Harvest early to avoid increased ear rot on corn standing too long in adverse weather. Store harvested ears and grain at the proper moisture to avoid increased rot in storage.

Storage Rots and Mycotoxins

Storage diseases of harvested corn grain in on-farm bins are potentially serious problems in Arkansas as they are throughout the southeastern U.S. Not only can storage rots lower the quality of grain through discoloration, mustiness, heating and caking, but some of the causal fungi can produce chemicals, known as mycotoxins, that are poisonous to animals and humans. The most important fungi involved include *Aspergillus flavus* and *Aspergillus parasiticus*, which produce aflatoxin, and *Fusarium* species that produce zearalenone, vomitoxin and other toxins. Not all moldy corn grain in storage necessarily has mycotoxins, but if suspected, laboratory testing must be conducted to confirm their presence or absence. Various lab tests are used including UV light to detect “glowers” (Figure 6-9) but this method is no longer considered as accurate as new “Elisa” test kits.

Symptoms and Control – See the section on aflatoxin and proper grain storage for detailed information.

Nematode Damage

More than 40 species of nematodes have been reported to feed on corn. There is little information, however, on the level of damage nematodes cause on corn grown in Arkansas.

Symptoms – Evidence of injury may vary with species of nematode, its population level, soil type and soil moisture. The major symptoms are stunting, restricted root growth, lesions or galls on roots, stubby roots, chlorosis and wilting (Figure 6-10).

Control – Cultural practices, including crop rotation with non-host or less susceptible plants, and prevention of soil compaction, which restricts downward root growth, are often good nematode management practices. Many corn varieties are excellent hosts for root knot nematode (RKN) and should not be used as a non-host rotation crop when attempting to manage RKN in other crops such as cotton or soybean. The reniform nematode and the soybean cyst nematode, on the other hand, do not appear to attack corn; and corn in rotation with either soybean or cotton where these nematodes are present will lower nematode populations. Resistant corn hybrids may be available for some nematodes.

However, if nematodes are suspected, a soil sample should be sent through the local county agent to the Cooperative Extension Service Nematode Assay Laboratory for assessment. There is a small fee for this service but the correct diagnosis can greatly help plan future rotations and variety selection.

Virus Diseases

Several virus diseases attack corn. Maize dwarf mosaic virus (MDMV) and maize chlorotic dwarf virus (MCDV) are the most common in Arkansas. Symptoms caused by double infections of these two diseases are more severe than either alone.

Symptoms – MDMV symptoms are highly variable, but usually first appear at the base of the youngest leaves as an irregular, light and dark green mottle or mosaic which may develop into narrow streaks along veins. These can appear as dark green "islands" on a yellowish background. Leaves may become entirely yellowish-green as infected plants mature. Plants with these symptoms are sometimes stunted with excessive tillering, multiple ear shoots and poor seed set. Early infection, which is vectored by several species of aphids, may predispose maize to root and stalk rots and premature death. Aphids usually acquire the virus from johnsongrass in early spring and infect corn plants later. The symptoms of MCDV include yellow to white narrow stripes on young, infected corn leaves. Infected plants are stunted to various degrees and leaves may turn partially or completely yellow and/or red, depending on the severity of the disease (Figure 6-11). Unlike MDMV, MCDV is transmitted by leafhoppers which acquire the virus from infected johnsongrass.

Control – Plant only resistant varieties (seed company information). Use good weed management that especially reduces infestations of johnsongrass, as well as other grassy weeds. It is critical to plant as early as possible to avoid later buildup of insects and increased disease. Rotate with cotton, soybean or other non-grass crops.

Photographs reference Section 6 – Diseases and Nematodes

Figure 6-1 Crazy Top
by Jeremy Ross

Figure 6-2 Anthracnose
by Dave TeBeest

Figure 6-3 Gray Leaf Spot
by Jeremy Ross

Figure 6-4. Southern Leaf Blight
by S. M. Lim

Figure 6-5 Common Rust
by Jeremy Ross

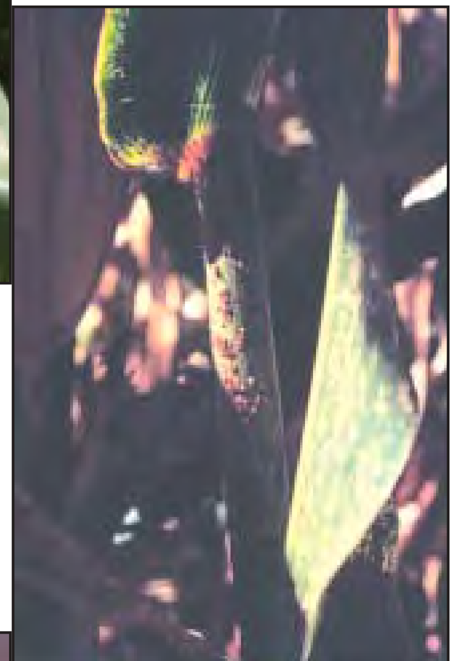


Figure 6-6 Southern Rust
by Dave TeBeest

Figure 6-7. Corn Smut
by Jeremy Ross

Figure 6-8. *Aspergillus flavus* ear rot
by Steve Vann

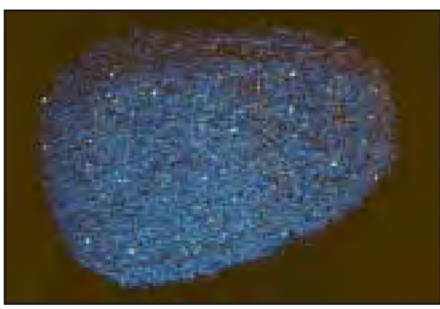


Figure 6-9. "Glowers" of corn particles contaminated by aflatoxin under UV light
by Steve Vann

Figure 6-10. Nematode Damage to Corn Roots
by Rick Cartwright

Figure 6-11. Southern Corn Virus Complex
by Rick Cartwright

7 - Weed Control In Corn

Kenneth Smith and Bob Scott

Weeds compete with corn to reduce yields, cause harvesting losses and produce seed that increase the soil seed bank. Even a light infestation of weeds can reduce yields by 10 to 15 percent. Heavy infestations may reduce yields as much as 50 percent if left unchecked during the season. Ideally, weeds should be controlled throughout the season. However, the most critical period is for the first six weeks after planting.

The potential size of the ear is determined over a three-week period starting about six weeks after emergence. It is critical to have the corn growing well without stress from competing weeds at this time. Research has shown that one morningglory or pigweed plant per 4 feet of row that is allowed to remain uncontrolled for four weeks after emergence will reduce yields by 4 percent.

Late season weed infestations have less effect on produced yields, but may interfere with harvesting and reduce harvestable yields. Late season weeds are also very efficient at producing seed to replenish the soil seed bank. Effective and economical weed control in corn requires an integrated program that includes good cultural practices such as crop rotation and water management, judicious mechanical practices, proper herbicide selection and proper weed identification.

Your county Extension agent receives extensive training on weed identification and weed control technology and is available to assist in developing economical and effective control programs. *Recommended Chemicals for Weed and Brush Control*, often referred to as MP-44, is updated annually to reflect the most current information on herbicide label changes and revised recommendations based on research data. This publication is available from county Extension offices throughout the state. The color photographs at the end of this chapter depict some of the more common weeds found in corn in Arkansas.

Farmers have known for many years that **cultivation often prunes corn roots and can reduce yields**. Better available herbicide technology has allowed more reliance on chemical weed control and less on cultivation. It is estimated that near 100 percent of the corn grown in Arkansas receives at least one herbicide application. Approximately 20 percent of this acreage is not cultivated after the crop emerges. A very small percentage receives cultivation after the corn reaches 8 inches in height and roots begin to expand to the sides of the beds.

Possibly no other crop has as many weed control options as corn. There are currently over 130 different herbicide brand names labeled for weed control in this 75 million U.S. acres crop. However, many of these brand names are simply various mixtures of a much smaller number of active ingredients. There are approximately 30 brand names listed in Arkansas' MP-44, *Recommended Chemicals for Weed and Brush Control*.

The ten most troublesome weeds in corn in Arkansas are morningglory, pigweed, johnsongrass, broadleaf signalgrass, barnyardgrass, nutsedge, sicklepod, velvetleaf, prickly sida and crabgrass. Recommended control measures for these weeds are usually quite effective. Adverse weather conditions can cause control failures. The grassy weeds usually compete most heavily with corn during the early season, while morningglory and pigweed are often most troublesome by germinating after layby and causing harvesting problems.

Atrazine is the basis of most chemical weed control programs in Arkansas corn, with over 80 percent of the acres treated receiving at least one application. Atrazine may be applied alone or in combination with other herbicides either preemergence or postemergence. Other herbicides are often mixed with atrazine to broaden the weed spectrum or to offer more residual weed control.

Metolachlor (Dual Magnum), alachlor (Lasso) and dimethenamid (Outlook) are acid amide – sometimes called chloroacetamide – herbicides. Although atrazine has some activity on grassy weeds, it is considered a broadleaf product. The acid amide herbicides have much more activity on grassy weeds than on broadleaf weeds. Mixtures of atrazine and one of the acid amides offer broad spectrum weed control with good residual properties. (See Table 7-1.)

Due to concerns about atrazine moving into underground aquifers, there are some label restrictions governing mixing, loading and application in proximity to water wells and reservoirs. EPA is considering additional restrictions that, if implemented, could make atrazine use in Arkansas impractical. University and industry scientists have worked diligently over the past few years to identify a herbicide with similar weed control attributes as atrazine but without the regulatory restrictions. Callisto (mesotrione) has been added to MP-44 as an alternative in atrazine sensitive areas.

Preemergence herbicides are applied after the corn has been planted and prior to emergence. Some herbicides such as Dual Magnum are taken into the weedy plants through the emerging coleoptile and have little or no activity on emerged weeds. These herbicides must be applied before targeted weeds germinate. Dual, Lasso and Outlook primarily control grasses such as crabgrass, barnyardgrass and broadleaf signalgrass, but also suppress yellow nutsedge and offer some control of pigweeds.

Combinations of these products with atrazine as tankmixes or premixes applied preemergence will control most seedling grasses and broadleaf weeds for three weeks. Rainfall or irrigation is required to incorporate the herbicides with the soil for activity. This is often referred to as "activation" of the herbicide. However, large rains immediately after application may move some of the herbicide into contact with the germinating corn seedling and may actually be taken into the germinating seed as it imbibes water. This usually results in delayed emergence and some crop injury. Typical injury symptoms include buggy whipping and slowed growth. Under good growing conditions, the symptoms are usually only cosmetic and the corn resumes normal growth seven to ten days after emergence.

Postemergence herbicides are applied after the corn has emerged and most often after the weeds have emerged. Postemergence herbicides are used to control emerged weeds that have escaped through the preemergence herbicides or to extend the residual weed control beyond what can be achieved with preemergence herbicides alone.

Atrazine, 2,4-D, Clarity (dicamba) and Callisto control broadleaf weeds when applied postemergence. Atrazine may be applied until corn reaches 12 inches tall, Clarity and 2,4-D over the top to 5-leaf corn and Callisto may be applied on corn up to 30 inches tall. Callisto and atrazine have some activity postemergence on grassy weeds, but may provide unacceptable control if used alone on grasses over 1 inch tall. Accent (nicosulfuron) is very effective

Buggy whipping or leaf wrapping is caused when the leaves fail to unfurl. New leaves are trapped in the leaf below, resulting in abnormal growth as shown. Factors other than herbicides can also cause this symptom. Buggy whipping is usually a temporary condition, and plants will likely recover except under the most extreme conditions.

when applied to grassy weeds less than 4 inches tall. Accent is often mixed with a broadleaf herbicide such as Clarity, Basis (rimsulfuron) or atrazine to offer both broadleaf and grass control.

Nutsedge and rhizome johnsongrass are particularly troublesome perennial weeds. Permit herbicide applied at 1.33 ounces per acre when nutsedge is 4 to 12 inches tall is the most effective treatment in conventional corn. However, if nutsedge is allowed to reach 4 to 12 inches tall, severe crop competition has already occurred. Heavy infestations of nutsedge may require sequential applications. An earlier treatment may be required to prevent nutsedge from competing with the crop. No more than 2.66 ounces of Permit may be applied in one growing season. Repeat applications of Accent or Beacon (primisulfuron) may be required for acceptable rhizome johnsongrass control. Accent and Beacon may be applied over the top of corn until the 20- and 24-inch stage of growth, respectively.

Herbicide tolerant corn varieties are available that will allow use of glyphosate (Roundup Ready® varieties) or imazethapyr/imazapyr (Clearfield® varieties). There are several formulations of glyphosate available and labeled for use on Roundup Ready® corn. Rates and use patterns vary by formulations, and labels should be checked prior to using any herbicide. Sequential applications of glyphosate are very effective for control of a broad spectrum of both grass and broadleaf weeds. Because glyphosate has no soil residual properties, multiple applications are usually required to provide a level of weed control that will not allow competition to reduce yields.

A soil residual herbicide should be applied to prevent late season weeds from germinating and causing harvesting problems. Lightning (imazethapyr + imazapyr) used in conjunction with Clearfield® varieties is very effective on a broad spectrum of broadleaf and grass weeds when applied early postemergence at 1.28 ounces per acre. Lightning does have some soil residual activity and may offer season long control of many troublesome weeds. Cotton and rice rotation restrictions following Lightning may reduce the utility of this system for some Arkansas corn farmers.

Herbicide resistant weeds are becoming more of a problem in all crops. Pigweeds with resistance to atrazine are common in other states, but have not been found in Arkansas at this time. Due to the fact that most corn in Arkansas is rotated with other crops, there have been no weeds identified as being resistant to corn herbicides. This does not diminish the importance of resistance management and maintaining a close watch for suspected resistance. If weeds are not controlled by a particular herbicide application and resistance is suspected, they should be treated with an alternative herbicide and the local county agent should be contacted. The University of Arkansas will collect weed specimens and test for resistance. Weeds that are suspected to be herbicide resistant should not be allowed to produce seed in the field.

Table 7-1

WEED RESPONSE RATINGS FOR CORN HERBICIDES

HERBICIDES / WEEDS	Red Rice	Barnyardgrass	Crabgrass	Goosegrass	Broadleaf Signalgrass	Rhizome Johnsongrass	Seedling Johnsongrass	Fall Panicum	Foxtail	Shattercane	Pigweed	Cocklebur	Morningglory	Common Ragweed	Prickly Sida	Smartweed	Purslane	Velvetleaf	Lambsquarters	Sicklepod	Yellow Nutsedge	Burcucumber	Giant Ragweed	Horsenettle
Preemergence																								
Atrazine	8	6	7	6	4	0	2	3	6	0	9	9	8	9	9	9	9	8	9	8	0	4	6	5
Axiom + Atrazine	-	-	9	-	9	-	-	-	-	-	9	8	8	-	9	-	-	8	10	-	9	-	-	-
Callisto	7	7	9	-	7	0	0	-	7	0	9	8	9	7	9	9	-	9	9	5	7	-	9	-
Dual II Magnum + Atrazine	9	8	9	9	8	0	4	9	9	7	9	8	8	9	9	4	9	6	9	8	7	4	6	3
Lasso + Atrazine	9	8	9	9	7	0	3	8	9	7	9	8	8	9	9	8	9	6	9	8	6	3	5	3
Prowl + Atrazine	8	9	9	9	6	0	7	9	9	7	9	8	8	9	9	9	9	6	9	7	4	3	5	2
Harness or Surpass + Atrazine	8	9	9	9	7	0	6	9	9	7	9	8	8	9	9	4	9	6	9	8	7	4	6	3
Outlook + Atrazine	8	9	9	9	8	0	6	9	9	7	9	8	8	9	9	6	9	6	9	8	7	4	6	3
Postemergence																								
Accent	-	8	5	-	8	9**	10	7	8	9	8	5	6	6	-	7	-	6	3	7	3	7	2	2
Exceed	-	0	0	0	0	0	4	3	2	-	8	9	7	9	-	9	-	7	-	6	0	8	-	6
Atrazine + oil	9	6	6	6	6	0	3	5	7	0	9	9	8	8	8	9	9	7	8	8	5	4	6	4
Beacon	-	3	3	-	3	8**	9	6	3	10	8	8	7	9	-	7	-	6	9	7	7	8	-	3
Banvel or Clarity	0	0	0	0	0	0	0	0	0	0	9	8	9	9	-	9	-	8	9	8	0	8	9	6
2,4-D	0	0	0	0	0	0	0	0	0	0	8	9	9	9	8	5	9	8	8	8	0	3	9	4
Basagran	0	0	0	0	0	0	0	0	0	0	0	9	4	8	7	9	7	8	5	0	7	3	5	0
Buctril	0	0	0	0	0	0	0	0	0	0	5	9	7	7	-	9	-	7	8	3	0	7	7	4
Callisto	7	7	9	-	7	0	0	-	7	0	9	8	9	7	9	9	-	9	9	5	7	-	9	-
Basis Gold	-	8	7	8	8	6	9	8	9	9	9	9	9	9	9	9	-	9	9	9	9	8	7	-
Liberty 1.75 pt 1 app	9	8	8	-	9	6	9	9	-	-	4	9	8	9	8	9	-	5	-	9	6	-	-	-
Gramoxone directed or Hood	9	9	9	9	9	0	8	8	8	0	9	4	4	8	3	5	8	7	9	9	3	-	-	-
Permit	-	-	3	3	3	3	3	3	-	-	8	9	5	-	7	-	-	-	5	4	-	-	-	-
Lightning	8	7	7	5	8	7	7	7	8	8	9*	9*	8	5	3	6	-	8	5	2	5	6	8	-
Roundup Ultra (1 qt/A once)	8	9	9	9	9	9	10	9	9	8	9	9.5	7	9	8	-	-	7	9	9	4	-	7	-

*Rating will be O on ALS inhibitor resistant weeds.
**Repeat application may be needed to achieve these ratings.

Rating scale – 0 = No Control 10 = 100% Control.

Table 7-1 (cont.)

Crop Replant and Rotation Guide for Corn and Grain Sorghum Herbicides*

Herbicide	Replant/ Crop Rotation	Time Interval	Precautions
Accent	C W S CT	I 4 months 15 days 10 months	Sweet corn and popcorn - 10 months. All crops not specified - 10 months if pH < 6.5 or 18 months if pH > 6.5. Grain sorghum - 10 months if pH < 7.5 or 18 months if pH > 7.5.
Atrazine	C,GS All	I FY	If applied after June 10, only corn and grain sorghum can be planted the following year.
Axiom	C S W, R, AL O	I I 12 months	
Banvel	C,G, W All	I 45 days/pt† Following normal harvest of C,G,W,GS	† Wheat planting must be delayed 45 days after application per pint of Banvel used.
Basagran	All	I	
Basis Gold	W,S, GS, CT sweetcorn, popcorn All other	10 months 18 mos	If Basis Gold is applied after July 1, do not rotate to crops other than corn or sorghum the next year.
Beacon	W A,CT,P,S,SF All	3 months 8 months 18 months	Sweet corn and popcorn - 8 months. Replanting of field corn - 14 days.
Bicep	C,GS† S,CT SG All	I FY 15 months 18 months	† Use Concep treated seed. If applied after June 10, only corn and grain sorghum can be planted the following year.
Buctril	C,GS SG All	I Fall FY	
Buctril + atrazine	C,GS S CT,FG,FL,R SG All others	I FY Do not plant the year following application.	If applied after June 15, plant only corn or grain sorghum the next year.

Herbicide	Replant/ Crop Rotation	Time Interval	Precautions
Callisto	All SG	12 months 4 months	Do not apply post if soil was treated with Counter or Lorsban.
Dual II Magnum	C,S,GS† SG Rice All	I 4.5 months Next spring 18 months	† Use Concep treated seed.
Exceed	C SG S,CT,GS,R All	4 weeks 3 months 10 months 18 months	IMI or IR corn can be planted immediately.
Guardsman Max	GS,S,CT All	FY Do not plant the year following application.	
Gramoxone			No Restrictions.
Lightning	W,S,P,A Cotton on sands and loamy sands Cotton on heavier soils Rice	4 months 9.5 months 18 months 40 months	
Outlook	C,S SG All	I 4 months Next spring	
Permit	W S	3 months 10 months	
Prowl	CT,S W,B All	II 120 days† FY	† 90 days after post-incorporated application, cannot plant using no-tillage practices.
Roundup			No Restrictions.

*Always refer to product labels before using a pesticide or replanting into treated fields. Refer to Arkansas' MP44, "Recommended Chemicals for Weed and Brush Control" for the most current information.

Key

Crop					**Timing**
All = All crops not specified	C = Corn	FL = Forage Legumes	R = Rice	SF = Sunflowers	I = Immediately
A = Alfalfa	CT = Cotton	GS = Grain Sorghum	S = Soybeans	W = Wheat	FY = Following year (usually spring)
B = Barley	FG = Forage Grasses	P = Peanuts	SG = Small Grains		

Table 7-1 (cont.)

Crop, Situation, and Active Chemical Per Broadcast Acre	Weeds Controlled	Formulated Material Per Broadcast Acre	Time of Application	Method of Application and Precautions
FIELD CORN				
Preemergence				
atrazine @ 2 lb/A	Most small-seeded annuals, annual morningglory, cocklebur, velvetleaf, smartweed, sicklepod.	**AAtrex, Atrazine, Griffex** 2.5 lb/A 80W or 2 qt/A 4L or 2.2 lb/A Nine-0.	At planting.	Do not plant fall cover crops. Do not plant crops other than corn or grain sorghum in treated fields during the same season. Do not apply more than 2.5 lb/A active atrazine per season. All atrazine labels have been revised because of surface and groundwater concerns. Special precautions are required on new labels.
alachlor + atrazine @ 1.5 to 2.25 lb/A + 1 to 1.6 lb/A	Annual grasses, pigweed, annual morningglory, common cocklebur, velvetleaf, smartweed, sicklepod.	**Lasso 4E + AAtrex, Atrazine** 1.5 to 2.25 qt/A Lasso + 1.25 to 2 lb/A 80W or 1 to 1.6 qt/A 4L or 1.1 to 1.75 lb/A Nine-0. or **Lariat/Bullet 4F** 2.5 to 3.75 qt/A.	Preemergence or preplant. **Note** – This treatment can be applied to emerged corn before it exceeds 5" tall. However, weed control will be reduced if weeds exceed 2" tall.	Add additional atrazine where cocklebur and morningglory are severe. Rainfall in 5 to 7 days is necessary for best results. With preplants shallow incorporate 2 to 3 inches within 7 days of planting. All atrazine labels have been revised because of surface and groundwater concerns. Special precautions are required on new labels.
metolachlor + atrazine @ 0.75 to 1.3 lb/A + 1 to 1.6 lb/A	Annual grasses, pigweed, annual morningglory, common cocklebur, velvetleaf, smartweed, sicklepod.	**Dual II Magnum + AAtrex, Atrazine** See label for specific formulations in question. 0.8 to 1.4 pt/A + 1.25 lb/A 80W or 2 pt/A 4L. or **Bicep II Magnum** 1.3 to 2 qt/A.	Preemergence or preplant.	Same as above.
dimethenamid + atrazine @ 0.56 to 0.98 lb/A + 0.75 to 2 lb/A	Annual grasses, pigweed, annual morningglory, common cocklebur, velvetleaf, smartweed.	**Outlook + AAtrex, Atrazine** 12 to 21 + 0.75 to 2 qt/A 4L or **Guardsman Max** 3 to 4.6 pt/A.	From 45 days preplant to preemergence up to 8" tall corn.	Same as above. Rates depend on percent organic matter. See label.
acetochlor/safener + atrazine @ 1 to 2 lb/A + 1.25 to 2 lb/A	Annual grasses, pigweed, morningglory, cocklebur, velvetleaf, smartweed, sickle pod.	**Harness + Atrazine** 1.25 to 2.25 pt/A + 1.25 to 2 qt/A 4L or 1.4 to 2.2 lb/A 90.	Preplant or preemergence.	Add additional atrazine where cocklebur and morningglory are severe. Rainfall in 5 to 7 days is necessary for best results. With preplants shallow incorporate 2 to 3 inches within 7 days of planting. All atrazine labels have been revised because of surface and groundwater concerns. Special precautions are required on new labels.
acetochlor/safener + atrazine @ 1.2 to 2.4 lb/A + 1 to 2 lb/A	Same as above	**Surpass 6.4 EC + Atrazine** 1.5 to 3 pt/A + 1.1 to 2.2 lb/A 90 or 1 to 2 qt/A 4L.	Preplant or preemergence.	See above comments.

Table 7-1 (cont.)

Crop, Situation, and Active Chemical Per Broadcast Acre	Weeds Controlled	Formulated Material Per Broadcast Acre	Time of Application	Method of Application and Precautions
pendimethalin + atrazine @ 0.75 to 1 lb/A + 1 to 1.6 lb/A	Same as above.	**Prowl + Atrazine** 1.8 to 2.4 pt/A Prowl 3.3EC + 1.25 to 2 lb/A 80W or 1 to 1.6 qt/A 4L or 1.1 to 1.75 lb/A Nine-0.	Preemergence. **Do not incorporate.**	Plant corn at least 1 1/2 " deep. All atrazine labels have been revised because of surface and groundwater concerns. Special precautions are required on new labels.
flufenacet/metribuzin + atrazine @ 0.55 to 0.94 lb/A + 1.2 to 2 lb/A	Annual grasses and broadleaf weeds.	**Axiom 68 DF + Atrazine** 13 to 22 oz/A + 1.2 to 2 qt/A Atrazine 4L or equivalent.	At planting.	**Cotton rotation not yet determined. Wheat rotation interval 12 months.**
mesotrione @ 0.188 to 0.24 lb/A	Annual broadleaf weeds.	**Callisto 4L** 6 to 7.7 oz/A.	At planting.	**Do not plant crops other than corn in treated fields during the same season.**
Postemergence				
atrazine @ 2 lb/A	Most small-seeded annuals. More effective on broadleaf weeds, red rice, and sicklepod.	**AAtrex, Atrazine, Griffex** 2.5 lb/A 80W or 2 qt/A of 4L or 2.2 lb/A Nine-0. Select rate according to soil texture. No surfactant recommended on label. Dual, Lasso or Frontier may be added if no soil applied grass herbicide was used. **AAtrex, Atrazine + oil** 2.5 lb/A 80W or 2 qt/A 4L or 2.2 lb/A Nine-0 + 1 qt/A oil concentrate.	After corn emergence, before grass weeds reach 1/2 inch, or broadleaf 1 1/2 inches.	Do not apply if corn is taller than 12 inches. Do not plant crops other than corn or grain sorghum in treated field until following season. After June 10, do not plant any crop other than corn or grain sorghum the following year. Do not apply more than 2.5 lb/A active atrazine per season. All atrazine labels have been revised because of surface and groundwater concerns. Special precautions are required on new labels.
2,4-D amine @ 0.5 lb/A	Morningglory, cocklebur, and most other young broadleaf weeds.	**2,4-D amine** 1 pt/A of 4 lb/gal 2,4-D.	Apply when weeds are small and corn is under 12 inches; however, effective results can be obtained with later application.	After corn is more than 12 inches, apply spray directly on weeds with a drop-type nozzle between the corn row and not on the terminal growth of corn. AVOID DRIFT. **Follow all State Plant Board Regulations.**
dicamba @ 0.25 lb/A	Same as above.	**Banvel or Clarity 4SL** 0.5 pt/A.	From corn emergence up to 36 inches tall. Best results on weeds 36 inches or less. Use drop nozzles if corn leaves canopy weeds.	Ground application only. **Drift is extremely toxic to soybeans.** Do not apply after soybeans begin to emerge in general area. Less toxic than 2,4-D to cotton. **Follow all State Plant Board regulations.**

Table 7-1 (cont.)

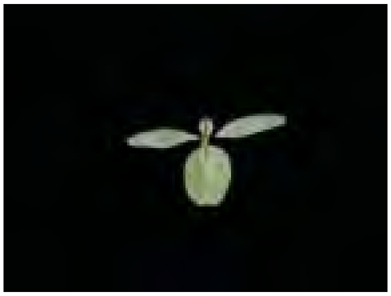
Crop, Situation, and Active Chemical Per Broadcast Acre	Weeds Controlled	Formulated Material Per Broadcast Acre	Time of Application	Method of Application and Precautions
FIELD CORN Postemergence [cont.]				
bentazon @ 0.75 to 1 lb/A	Cocklebur, ragweed, jimsonweed, smartweed, prickly sida, velvetleaf, yellow nutsedge.	**Basagran 4SL** 0.75 to 1 qt/A. **Can be tank mixed with 0.5 to 0.75 lb/A active atrazine.**	Postemergence. See label for specific timing for weed desired. Corn tolerant at all stages.	May be tank mixed with atrazine. See label. Best treatment for smartweed.
bromoxynil @ 0.25 to 0.375 lb/A	Cocklebur, smartweed, morningglories, pigweed.	**Buctril 2EC** 1 to 1.5 pt/A. **On larger weeds, tank mix with 0.5 lb/A active Atrazine.**	Postemergence to weeds in seedling (2-4 leaf) stage.	Use high rate on morningglories and pigweed. Weeds **must** be small. Expect some temporary burn.
nicosulfuron @ 0.031 lb/A	Johnsongrass, broadleaf signalgrass, foxtail, and shattercane.	**Accent 75DF** Accent 75 DF + nonionic surfactant (80%) or crop oil concentrate and 28% or 32% UAN liquid fertilizer (optional). 0.66 oz/A + 2 pt/100 gal or 1 gal/100 gal and 4 gal/100 gal. Tank mix with atrazine for broadleaf weeds.	Apply to 4-10-inch seedling and 8-12-inch rhizome johnsongrass. If regrowth occurs, apply a second application when johnsongrass is 8-10 inches tall. May be applied to 2-6 leaf stage of corn. 1 to 2 leaf broadleaf signalgrass.	Repeat application may be required to control regrowth. **Do not apply to corn treated with Counter or Counter 20CR insecticide unless IT (Clearfield) corn is planted. See label for restrictions with other organo-phosphate insecticides, and postemergence herbicides.** **Do not apply during cool cloudy weather.** **In Johnsongrass fields, only virus tolerant hybrids are recommended.**
primisulfuron @ 0.018 (split) to 0.036 (single) lb/A	Johnsongrass and shattercane.	**Beacon 75DF** Beacon 75DF + nonionic surfactant (80%) or crop oil concentrate and 28 to 34% UAN liquid fertilizer (optional). 1 water soluble packet per 2 acres (single application) or 1 packet per 4 acres (split application) + 2 pt/100 gal or 1 to 4 pt/A and 1 to 2 pt/A.	Apply to 4-12 inch tall seedling and 8-16 inch tall rhizome johnsongrass. Apply a second application when regrowth is 8-16 inches tall. May be applied from 4-inch tall corn up to the 6 leaf stage.	Split application will be required for rhizome johnsongrass control. **Do not apply to corn treated with Counter or Counter 20CR insecticide unless IT (Clearfield) corn is planted. See label for restrictions with other organophosphate insecticides and postemergence herbicides. Some corn hybrids may be susceptible to injury. See your dealer for a list of restricted hybrids.** **Do not apply during cool cloudy weather.**
primisulfuron/prosulfuron @ 0.035 lb/A	Cocklebur, pigweed, morningglory, sicklepod and other broadleaf weeds.	**Exceed 57WG** 1 oz/A. Add 0.25% non-ionic surfactant or crop oil concentrate at 1-2 pt/A. May be tank mixed with Accent at 0.33 oz/A for grass control.	Over the top where corn is 4 inches tall up to 6 leaf stage.	**Do not apply to corn previously treated with Counter 15G or 20CR. Ground application only. See label for other precautions/ restrictions.**
halosulfuron @ 0.032 to 0.063 lb/A	Nutsedge, cocklebur. See label for tank mixes to broaden weed spectrum.	**Permit 75WG** 0.67 oz/A for cocklebur. 1 to 1.33 oz/A for nutsedge. Add a non-ionic surfactant or crop oil concentrate. May use two applications not to exceed 2.67 oz/A total rate.	Postemergence from corn spike through layby. 4- to 12-inch nutsedge 1- to 9-inch cocklebur	Ground application only. See label for mixtures and other precautions. Clean tank with ammonia.

Table 7-1 (cont.)

Crop, Situation, and Active Chemical Per Broadcast Acre	Weeds Controlled	Formulated Material Per Broadcast Acre	Time of Application	Method of Application and Precautions
nicosulfuron/rimsulfuron/ atrazine @ 0.79 lb/A	Annual grass and broadleaf weeds.	**Basis Gold 90WG** 14 oz/A. Add a crop oil concentrate.	Apply to small weeds and before corn exceeds 12 inches. Apply to annual grasses less than 2 inches tall.	Do not apply to corn treated with Counter or Counter 20 CR insecticides. See label for other insecticide precautions.
paraquat @ 0.25 lb/A	Emerged annual grasses.	**Gramoxone Max 3SL** 0.67 pt/A + surfactant (p. 3).	Apply when corn is at least 10 inches and weeds are 4 inches or less.	DIRECTED OR HOODED SPRAY ONLY. Avoid fine spray. Corn plants less than 10 inches may be injured and not recover.
paraquat + atrazine @ 0.25 + 0.5 to 1 lb/A	Same as above but better control of broadleaf weeds.	**Gramoxone Max 3SL + AAtrex** 0.67 pt/A + 0.67 to 1.25 lb/A 80W or 1 to 2 pt/A 4L. Add a surfactant (p. 3).	Apply when corn is at least 10 inches and weeds are 4 inches or less.	DIRECTED OR HOODED SPRAY ONLY. Avoid fine spray. Corn plants less than 10 inches may be injured and not recover.
mesotrione @ 0.094 lb/A	Annual broadleaf weeds.	**Callisto 4L** 3 oz/A.	May be applied up to 30 inches or 8 leaf stage of corn.	Do not apply to corn treated with Counter or Lorsban insecticides. See label.
HERBICIDE TOLERANT CORNS – Check suitability of available hybrids with county agent.				
glyphosate @ 0.75 to 1 lb/A	Most annual grass and broadleaf weeds and Johnsongrass.	**Roundup Ultra, Touchdown or equivalent 4SL** 1.5 to 2 pt/A. or **Roundup Ultra Max 5SL** 1.2 to 1.6 pt/A. or **Roundup Weather Max 5.5SL** 1 to 1.33 pt/A.	To emerged weeds from corn emergence to V8 or 30-inch stage.	**Apply only to Roundup Ready corn. Single in-crop applications not to exceed 1 lb/A and multiple in-crop applications not to exceed 2 lb/A total. Best used following Atrazine preemergence. See label for tank mixes.**
glyphosate + atrazine @ 0.75 to 1 lb/A + 1 lb/A	Same as above plus residual control of broadleaf weeds. Improved morningglory control.	**Roundup Ultra, Touchdown or equivalent 4SL + Aatrex** 1.5 to 2 pt/A + 1 qt/A. or **Roundup Ultra Max 5SL + Aatrex** 1.2 to 1.6 pt/A + 1 qt/A. or **Roundup Weather Max 5.5SL** 1 to 1.33 pt/A + 1 qt/A.	Prior to 12-inch corn.	**Apply only to Roundup Ready corn. Single in-crop applications not to exceed 1 lb/A and multiple in-crop applications not to exceed 2 lb/A total. Best used following Atrazine preemergence. See label for tank mixes.**
imazethapyr/imazapyr @ 0.056 lb/A	Small annual grasses and broadleaf weeds.	**Lightning 70DG** 1.28 oz/A or 1 water soluble bag per 2 acres. Add a surfactant. If in atrazine use area, add atrazine at 1.2 to 2 lb ai/A to broaden spectrum.	Early postemergence.	**For use only on (Clearfield) hybrids or death will occur.** Good choice where atrazine cannot be used. **Read crop rotation section of label very carefully.**

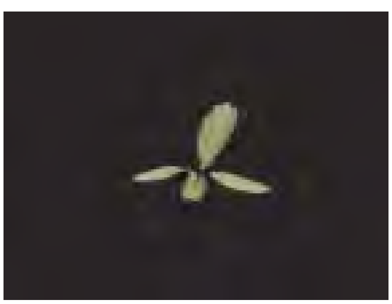
Common Weed Seedlings in Corn

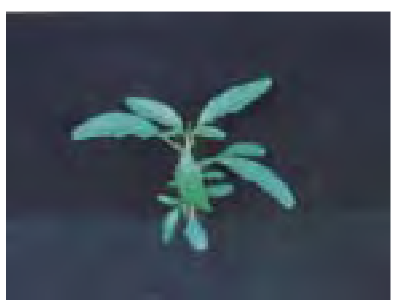
smooth pigweed, redroot pigweed



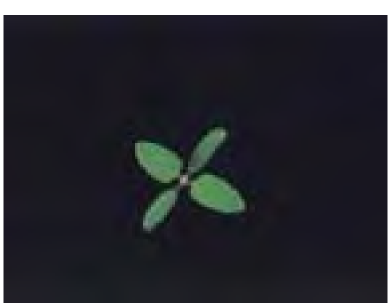
Palmer amaranth

tall waterhemp





common lambsquarters



common cocklebur

ivyleaf morningglory

pitted morningglory

palmleaf morningglory

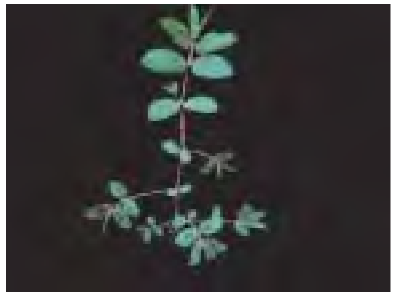
entireleaf morningglory

purple moonflower

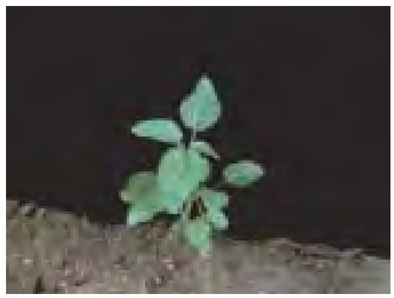
smallflower morningglory

bigroot morningglory

spotted spurge

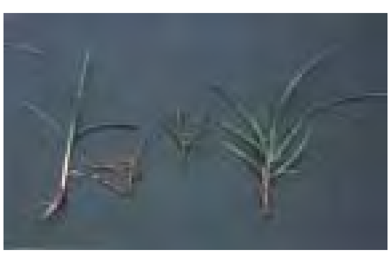


prickly sida



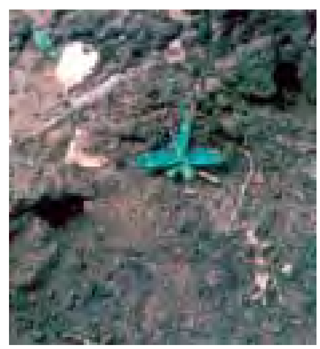
Pennsylvania smartweed

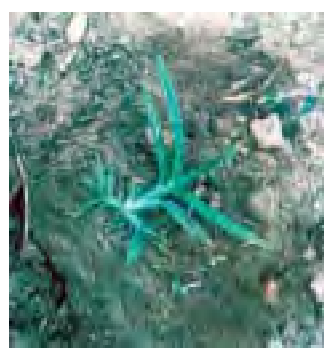
nutsedge



large or southern crabgrass

goosegrass



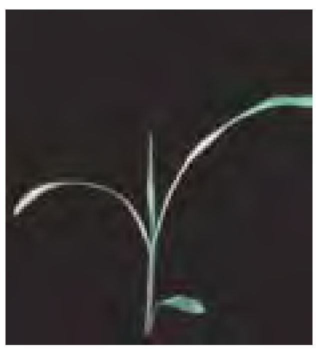


broadleaf signalgrass

barnyardgrass

fall panicum

johnsongrass



red rice

8 – Corn Harvesting

Gary Huitink

A combine equipped for corn is the starting point for successful harvesting. In the midsouth, combine components vary, requiring you to confirm that your combine has proper options to obtain full capacity and efficient cleaning in corn. Plan to **harvest the bulk of your corn between 15 and 18 percent moisture content,** for an economical choice based on recent grain terminal moisture discounts and long-term Arkansas weather patterns. Other considerations, such as scheduling rice harvest, are briefly noted in the section "Corn Harvest Moisture." Fine tune the combine in the field. Have a bit more handling and drying capacity than shelling capacity to prevent field delays.

Corn Equipment

A corn head and rasp-bar cylinder or rotor modifications are needed for corn. Check your combine before purchasing a corn head. New costs for conversion to corn vary from $25,000 to $50,000. The cost is lower if you already have some of the corn options and if good used equipment can be found. Due to differences between combine models, your dealer can help identify corn features appropriate for your combine. Certain models require a corn head drive and feed elevator. A variable speed header drive allows faster synchronized (with the stalk roll speed) forward speed. If your combine has a feed elevator compatible with corn, conversion cost is less.

> To equip a combine for corn, check with your dealer after determining:
>
> - Combine model
> - Serial number
> - Thresher (Rasp, Spike or Rotor)
> - Header drive option

Corn Head

Row spacing should match the planter. Research indicates gathering loss can increase 2 1/2 bushels per acre if the gathering opening is 4 or 5 inches off the row. If damage from windstorms or corn borers causes ears in misaligned rows to drop off, field losses often exceed 10 bushels per acre. Corn heads aligned with combine wheels and matched with planters and row bedders improve combine performance.

Rasp-Bar Cylinder or Threshing Rotor

A rasp-bar cylinder, concave and filler bars or a threshing rotor are needed for corn. Check your operator's manual for the correct concave wires or rotor grates and transport vanes. Converting from a spike-tooth to a rasp-bar cylinder reduces the combine's ability to handle downed rice, weedy fields and rank, green stalk. A rasp-bar cylinder normally improves head rice yield and reduces field loss in corn, grain sorghum, wheat and soybeans.

Counterbalance Weights

Due to the extra weight of a corn head, steering improves by adding extra rear weights and/or fluid in the rear tires.

Corn Harvest Moisture

Harvesting causes some kernel damage; the relationship of kernel damage to moisture content is summarized in Figure 8-1. Depending on the variety and seasonal conditions, minimum kernel damage occurs between 19 and 24 percent moisture content (m.c.). In some cases, damaged corn has been discounted as foreign material or dockage.

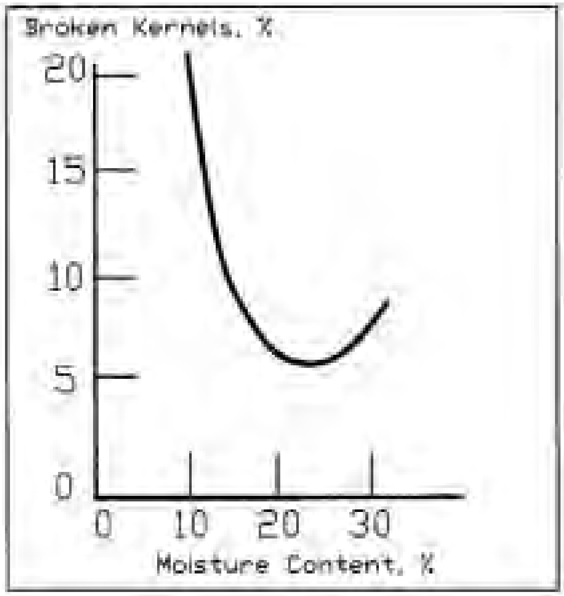


Figure 8-1. Broken Kernels vs. Corn Moisture Content

Preharvest and gathering losses vary with insect damage, lodging and how tightly ears are held. Ear droppage begins in the 20s (percent m.c.) and accelerates as corn dries. Storms come without much warning; therefore, verify if stalk rot or insect damage exists in each corn field. If the risk of lodging is high, harvest early (around 20 percent m.c.) to avoid a potential 10- to 20-bushel per acre field loss.

Rice harvest may also conflict with corn harvest. It may be desirable to harvest corn at 18 to 24 percent moisture to allow time to clean and empty equipment before handling rice. In most cases this requires farm drying, so allow sufficient time to dry the corn properly. If rice and corn production schedules aren't planned, inadequate drying or grain storage may prevent timely harvest. Corn drying rates in the field vary from 1/2 to 1 percent moisture content loss per day. Starting harvest at 24 percent instead of 18 percent moisture may get the combine into the field 6 to 12 days earlier (or more if high humidity conditions persist when corn nears 18 percent m.c.).

Aflatoxin isn't likely to be a problem in well-managed corn. However, aflatoxin proliferates so rapidly in midsouth fields that a grower should consider his options. If corn can be dried to 15 percent or below within a day, the spread of aflatoxin is minimized by early corn harvest. Corn with as much as 28 percent moisture can be harvested by adjusting the combine for reduced kernel damage and improved separation. See your county Extension agent for the options on harvest strategy and adjusting the combine to remove more aflatoxin-prone grain. More suggestions are included in Chapter 10, *Grain Storage and Aflatoxin in Corn*. The Arkansas State Plant Board will perform an analysis on a sample of corn to identify sample field aflatoxin levels, These tests are a good basis for evaluating your situation and avoiding severe discounts.

Drying costs or high-moisture market discounts cause some to wait too long to harvest corn. Corn that remains in the field too long suffers weight shrinkage, damage and field loss. Gathering loss increases as corn moisture falls below 20 percent; field loss may get unnecessarily high – above 5 bushels per acre.

Economical harvest timing depends on the drying cost or high-moisture discounts, field loss and damage penalty. Look at your circumstances, including the risk of field loss, how quickly all of your corn can be harvested and your drying and market options. Recover most of the drying cost by reducing field loss and kernel damage. On this basis, beginning corn harvest at 20 percent m.c. is a sound decision for some; starting harvest around 18 percent m.c. fits many situations. Exposure to weather risks, shrinkage, field loss and damage are compelling reasons to complete all corn harvest before it reaches 14 percent m.c.

Gathering Corn

Height

Operate the corn head low enough in good, upright corn that all gathering chains enter the row below the lowest ears. Lodged stalks may require lowering the gathering height so row dividers follow the ground contour freely. Keep the stalk rolls well above the soil to prevent rapid wear. Slowing forward speed recovers more ears that tend to drop easily from lodged stalks, etc.

Synchronize Speeds

Properly matching forward speed, stalk-roll speed and gathering chain speed reduces corn loss and plugging. Choose a forward speed that synchronizes with the gathering chain speed to guide stalks gently into stalk rolls. Excessive chain speed can break stalks, plug the rear of the stalk rolls, increase chain wear and overload the combine. Synchronize the gathering chain flights, positioning the tip about 1/4 inch beyond the edge of the snapping plate.

Snapping Opening

Stalk rolls pull stalks down between two snapping plates that strip the ears from the stalks. The rear of all snapping plates needs a 1/8-inch wider gap than the front. Refer to your corn head manual; typically, adjust the front 1 1/4 to 1 3/8 inches apart and the rear 1 3/8 to 1 1/2 inches apart. Use narrow spacing for small ears. A wide spacing is one cause of shelling from the butt of the ear and may cause small ears to drop partially below the snapping plates. Check that stalk roll spacing and snapping plate spacing are the same on all rows.

Excessive forward speed

- Knocks ears off before they enter the gathering throat.
- May cause plugging in high-yielding corn due to overloaded gathering units.

Excessive stalk roll speed

- Chews stalks and may wedge ears on the snapping plates causing shelling loss along the row.
- May shake ears off before stalks are fully in the throat.

Inadequate stalk roll speed

- May break or pull up stalks, causing plugging at the back of the rolls.
- Extra stalks entering the combine potentially can overload separation.

The stalk roll gap should allow stalks to enter without restriction. The rolls have several flutes or adjustable knives that, properly adjusted, grip stalks and pull them down without slippage. Stalk roll replacement is expensive, but field capacity is reduced when flutes are worn. Field loss becomes high as rolls wear and “slip” in contact with corn stalks.

Stalk Roll Spacing

- Wide for dry crops
- Narrow when stalks are damp and tough (to reduce snapping plate shelling)
- Center all snapping plate gaps over center of roll openings to avoid breaking weak stalks

Troubleshooting

(Refer to your Corn Head Operator’s Manual)

Excessive Shelling at Stalk Rolls

1. Snapping plate gaps should be narrower at the front than at the rear to avoid wedging ears into stalk rolls.
2. Adjust stalk rolls to pull stalks firmly down through the snapping area. Ears should snap off quickly about half way up the snapping plates.
3. Excessive wear on stalk rolls. Replace.
4. Loose gathering chains. Adjust tension.

Pulling Up Stalks

1. Forward speed may be too fast in relation to gathering chain speed.
2. The snapping plate gap may be too narrow. Spread the snapping plates a little farther apart to get stalks to feed through freely and snap the ear cleanly. Try 1/8-inch adjustment increments on each side of the row.
3. Not operating on rows planted together; i.e., rows not centered.

Weeds, etc., Wrapping Stalk Rolls

1. Shields on the front of the stalk rolls should cover half of the spiral points to minimize wrapping.

2. Weed knives along the back side of the stalk rolls should be adjusted just as close as possible without touching rolls. Replace missing, worn or bent knives.

Row Alignment

1. Select harvest speed to keep units centered on the row.

2. Pick "matched rows." Rows not planted together have spacing variations that may increase stalk breakage or plugging.

Plugging

Never allow anyone to work on a corn head while it is running. Plugged stalk rolls can be cleared one stalk at a time while the rolls are stationary.

1. If stalks break in the snapping rolls, recheck that the snapping plates are centered over the roll opening.

2. Operating too fast in high-yielding corn may overload gathering units or the cross auger. Stalks should move through smoothly. Check whether your header has a faster speed option for cross auger.

Threshing and Separating

Thresher speed and concave gap are basic to good shelling. Whole cobs with some attached kernels behind the combine are a clue that a narrower concave spacing or a faster thresher speed may improve shelling. If a few soft, immature cobs break up without removing all the kernels, don't be concerned.

A fast thresher speed breaks cobs excessively and increases kernel damage. If too many wet cobs shell poorly, don't thresh too aggressively. Delaying harvest to allow more field drying may solve this. Splitting cobs down their length is usually due to a narrow concave gap.

Corn Quality

Within the typical harvest moisture range, threshing is the likely cause for cracked kernels. Concave gaps narrower than 5/8 inch or thresher surface speeds above 3500 feet per minute can lower corn below USDA Grade No. 2 requirements. "Fines" or broken kernels are the primary cause of "heated," "sour" and "weevily" corn, especially if they are allowed to remain in the center of the bin.

Table 8-1. Converting Thresher Surface Speed to Thresher RPM

Thresher Diameter (inches)	Thresher Surface Speed (feet per minute)			
	2500	3000	3500	4000
20	480	570	670	760
22	430	520	610	700
24	400	480	560	640
26	370	440	510	590
30	320	380	450	510

Research indicates that damaged shelled corn deteriorates in storage three times faster than undamaged samples. Corn damaged, either by a combine or handling, develops mold and may deteriorate from No. 2 corn to No. 3, 4 or 5 corn, depending on the storage conditions. If adequate aeration is available in storage, corn kernel damage essentially determines the maximum allowable storage time.

About 90 percent of the separation should occur at the thresher. Gentle threshing aids corn recovery on the grates or walkers and sieves. Corn carries out over the straw walkers or chaffer sieve if they become plugged with cobs. Walker risers ("fishbacks") or walker grate covers may help, especially when the crop is damp.

Cleaning requires a high-speed fan. Use the operator's manual for initial combine settings and fine tune fan speed for field conditions.

Table 8-2. Initial Corn Setting Suggestions	
Thresher speed:	3000-3500 fpm (See Table 8-1)
Concave spacing:	5/8 inch or greater
Chaffer sieve:	1/2 - 5/8 inch
Cleaning sieve:	5/8 - 9/16 inch

(Consult operator's manual for specific adjustments.)

Field Loss

Field loss was sampled behind 84 combines in Iowa (Table 8-3). Failure to gather ears was the greatest loss (cost) category in Iowa and may be in Arkansas. Separating losses and shelling at the stalk rolls are other common problems. Some producers may increase corn income by reducing field loss by several bushels per acre.

Table 8-3. Summary of Corn Field Losses (Iowa)

Sources of Loss	Average growers (bushels/A)	Top 10% of growers (bushels/A)
Failure to gather ears	1.5	0
Shelling from stalk rolls	0.9	0.3
Separating loss	1.3	0.2
Total combine loss	3.7	0.5
Ears dropped before harvest	2.1	1.0
Total field loss	5.8	1.5

Estimating Field Loss

Everyone wants to do an expert job of harvesting. One way to gain expertise is to check field losses and compare them to top growers. Field loss can be estimated quickly. Losses are determined by counting shelled corn and ears left in the field.

Corn normally dries at the rate of 1/2 to 1 percent moisture content per day in the field. Approximately two weeks before harvest is a good time to begin measuring corn moisture and counting field ear loss. Counting ears on the ground prior to harvest as well as behind the combine provides facts to optimize harvest profit. If loss is high, the kind of loss is a clue to making adjustments. Keeping losses low doesn't cost; it pays!

Procedure

To count field loss, choose a representative field portion at least 100 yards from the end. Disconnect the straw spreader or straw chopper to aid in diagnosing the source of loss. Otherwise, kernels thrown into adjacent rows will add confusion about where the loss really occurred.

Ear Loss

Ear loss is sampled in 436 square foot areas (1/100 acre) (Table 8-4) and kernel loss in 10 square foot areas. Sample the field ear loss first and then determine what portion occurred at the corn head.

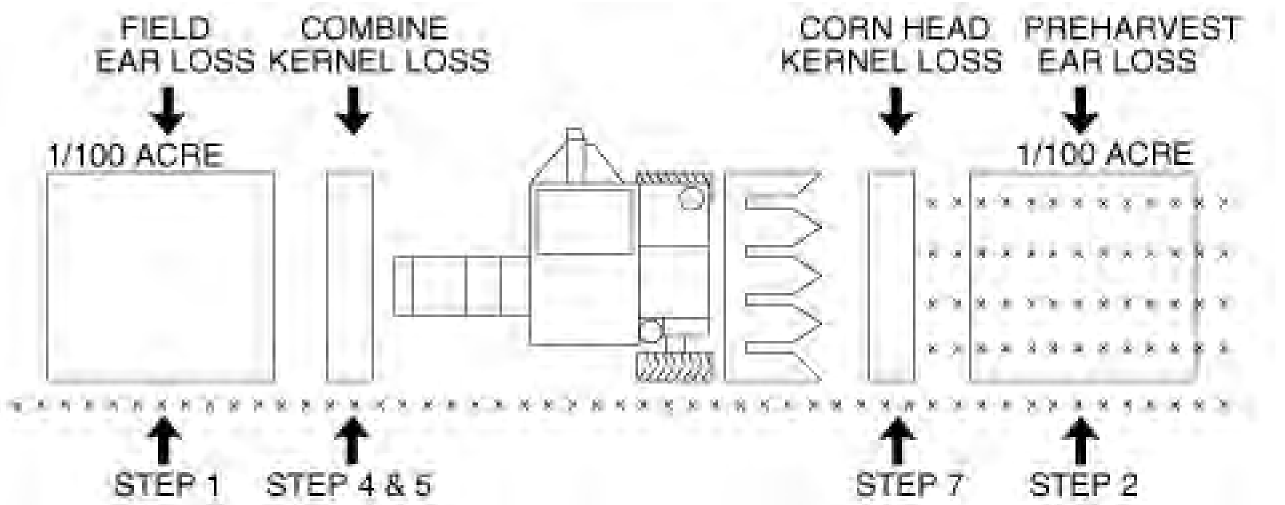
Then measure preharvest ear loss. In fact, making early preharvest loss samples prior to entering the field with the combine helps to identify which field to harvest first and, possibly, when to start.

Table 8-4. Row Length, Feet, to Obtain 1/100th of an Acre

Row Spacing (inches)	Distance, Feet, for Measuring 1/100 Acre According to the Number of Rows on Corn Head					
	3	4	5	6	8	12
28	62.2	46.7	37.3	31.1	23.3	15.6
30	58.1	43.6	34.8	29.0	21.8	14.5
36	48.4	36.3	29.0	24.2	18.2	
38	45.8	34.4	27.5	22.9	17.2	
40	43.6	32.7	26.1	21.8	16.3	

Step 1: Field Ear Loss. Back the combine about 10 feet out of the row to provide space to count loss. Due to extra discharge when stopped, note how far behind the combine to count loss (Figure 8-2). Step off the correct distance behind the combine according to your corn head and row spacing (Table 8-4). Mark this distance down the row and count all whole or broken ears (not those that have been threshed). Estimate the number of full ears (one 3/4-pound ear in 436 square feet

Figure 8-2. Where to measure corn harvest losses.



equals one bushel per acre). Record the field ear loss in bushels per acre in Table 8-5.

Step 2: Preharvest Loss. Pace off the same distance in standing corn (Figure 8-2). This is the same sample size (Table 8-4), 1/100th acre, which was measured behind the combine. Gather and count all the dropped or “unrecoverable” ears in these rows and record this in bushels per acre in Table 8-5.

Step 3: Corn Head Ear Loss. In Table 8-5, subtract the preharvest loss from the field ear loss to determine loss caused at the corn head.

Table 8-5. Ear Loss Data

Loss Category	Number of Ears One ear = 1 bushel/acre
Step 1: Field Loss	
Step 2: Preharvest Loss	
Step 3: Corn Head Ear Loss	

Kernel Loss

Count **loose kernels** on the ground **and those still attached to threshed cobs**. Do this by measuring a distance down the row to enclose 10 square feet (Table 8-6), one row at a time. A frame appropriate for your row spacing can be constructed. A PVC pipe frame or a plastic clothesline, with pegs at the corners of a rectangle is helpful. Complete steps 4 and 5 (Table 8-8) for each row and then move the frame to sample the next row.

Table 8-6. Frame Dimensions to Enclose 10 Square Feet for Kernel Loss Counts

Row Width (inches)	Row Length (inches)
28	52
30	48
36	40
38	38
40	36

Step 4: Corn Head and Separation Loss. Place the frame behind the combine and **count loose kernels** (not those remaining on threshed cobs). Record the number of kernels as **corn head and separation loss**, by row, in Table 8-8. Convert the number of kernels in 10 square feet to bushels per acre by dividing by 20.

Step 5: Threshing Loss. Before moving the frame, **count kernels on threshed cobs** (not loose kernels) and record the number of kernels as **threshing loss**, by row, in Table 8-8. Ignore small kernels on the tips of cobs. Convert the number of kernels in 10 square feet to bushels per acre by dividing by 20.

Step 6: For each row, add the second (Step 4, Corn Head and Separation Loss) and third (Step 5, Threshing Loss) columns to obtain a **Combine Kernel Loss** value in the fourth column of Table 8-8. The average of all rows indicates the field shelling losses caused by the combine. These typically increase as corn dries in the field.

Step 7: Corn Head Kernel Loss. Place the 10 square foot frame over each harvested row in front of the corn head where the separator has not yet discharged. Count the loose kernels by row within the frame (disregard ears). This corn head kernel loss can also be converted to bushels per acre by dividing by 20. Note if there is a particular row that has an unusually high or low value.

Step 8: Separation Loss. For each row, subtract corn head kernel loss, Step 7, from corn head and separation loss, Step 4, and enter the value in the last column as **separation loss**. This is the corn that was not separated from chaff.

Table 8-7. Corn Loss Measurement

Uniformly Distributed		
2 kernels / square foot	=	1 bu/A
One 3/4 lb ear / 436 square feet	=	1 bu/A

With timely harvest, field loss may be as low as 1 to 2 bushels per acre. Weak stalks, poor ear retention or lodged corn are causes of high preharvest loss and high gathering loss. Poorly equipped, maintained or operated combines may leave 5-10 bushels of corn per acre in the field. Preharvest repairs, field adjustments and careful operation prevent most costly field losses.

Evaluate both gathering and separating losses to determine the best field speed. Adjust for tough stalks, ears that drop easily and lodged fields. Time your harvest to balance field loss and damage with the costs of higher corn moisture using your drying cost or current market discounts.

Table 8-8. Kernel Loss Data

	Step 4		Step 5		Step 6	Step 7		Step 8
	Corn Head and Separation Loss		Threshing Loss		Combine Kernel Loss	Corn Head Kernel Loss		Separation Loss
Row Number	no. per 10 sq. ft.*	bu/A	no. per 10 sq. ft.*	bu/A	bu/A	no. per 10 sq. ft.*	bu/A	bu/A
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
Average loss								

*Divide by 20 = bushels per acre

Citations

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9 - On Farm Storage and Drying

Dennis R. Gardisser

A good deal of Arkansas corn will be dried and stored on the farm each year. Corn has the highest quality it will ever have at harvest. Grain has a limited storage life. The way that corn is handled during the drying and storage process will determine how much of this quality is retained. Proper management practices may also prolong the storage life of grain.

Corn should be quickly dried down to a moisture level of about 12 percent for storage – particularly if it is going to be stored for several months. Corn is typically dried to 15.5 percent when it is expected to be marketed right away. The reduction of grain moisture is done by passing relatively large quantities of dry air over the corn after it is placed in the bin. The quality of this air determines the final moisture content of the corn kernel. This "air quality" is typically referred to as the equilibrium moisture content (EMC). If the air has an EMC of 12 percent and is moved over the grain long enough, then the grain moisture will eventually reach 12 percent.

A given volume of air has the capability of holding a given amount of moisture. The amount of moisture that air can hold will depend on the quality. One way to increase drying potential or cause the grain to reach equilibrium with the air sooner is to pass larger amounts of air over the grain. Doubling the air flow will typically cut the drying time in about half.

Pass or continuous flow dryers are often utilized to speed up the drying process. These high flow driers pass very large amounts of high temperature air over the corn. Three to six moisture points may be taken from the grain in a single pass. This helps to prepare grain for shipment if the desire is to market the grain quickly. Quickly drying the grain down to values of 16 percent or less will lessen potential spread of toxins if that is a concern. In-bin drying is more gradual and may cause less stress and potential damage on the kernels.

As grain bins are filled and the grain depth increases, it becomes more difficult to pass air up through the grain. As the grain depth increases, there is also less air available for each bushel of grain in the bin. High volumes of air are needed to carry the moisture away in a timely fashion when the grain is at high moisture levels. Most on-farm

bins have a limited amount of available air capacity. These criteria dictate that bins should not initially be filled too full if the grain is at a high moisture content. Once grain moistures reach 15 percent or less throughout the bin, the bin filling process may be completed. Graph 9-1 illustrates the dramatic increase in fan horsepower/capacity needed to push grain through varying depths of grain. Requirements can quickly overwhelm available power as the grain depth and air requirements (CFM – cubic feet per minute) increase.

Several rules of thumb have been developed for sizing fans for dyring systems[1]: (1) doubling the grain depth at the same cfm/bushel air flow rate requires 10 times more horsepower and (2) doubling the cfm/bushel air flow rate on the same depth of grain requires 5 times more horsepower.

Air flow rates for drying vary from 0.5 cfm/bushel to more than 50 cfm/bushel for commercial or batch dryers. Most on-the-farm air flow rates for drying vary from 0.5 to 6 cfm/bushel dependent on the initial moisture content of the grain and the amount of heat added to the drying air. Recommended minimum air flow rates for different moisture contents are as follows.

% moisture	cfm/bushel
11 to 13	0.5
13 to 15	1
15 to 18	2
18 to 20	3
20 to 22	4
>22	6

When air flow rates are less than 1 cfm/bushel, add little or no heat. A rough guide for temperature increases through the heaters at various air flow rates is as follows.

- For an air flow rate of 1 to 2 cfm, limit the temperature rise to 6°F.
- For an air flow rate of 2 to 3 cfm, limit the temperature rise to 12°F.
- For air flow rates above 3 cfm, a 20°F temperature rise is permissible. A temperature rise above 20°F is satisfactory for some feed grains when drying depths are less than 4 feet or stirring depths are used.
- Batch and/or pass dryers typically use much higher temperatures, but also have much higher air flow rates. Grain kernels may protect themselves somewhat as long as they are giving up water and there is evaporative cooling in or near the kernel.

In most on-the-farm storage, the grain is subjected to modest temperatures for long periods of time. There must always be sufficient air flow to cool the upper portions of the bin to eliminate the possibility of mold development in that area. The top layers are the last segment of the bin to reach a safe moisture level.

Grain may be dried without adding any heat if the EMC is low enough. Careful monitoring of the EMC and managing drying times to optimize low values will provide the most economical drying. Many times Mother Nature simply will not provide dry enough air, particularly at night, and the addition of heat is needed to condition the air to the correct EMC.

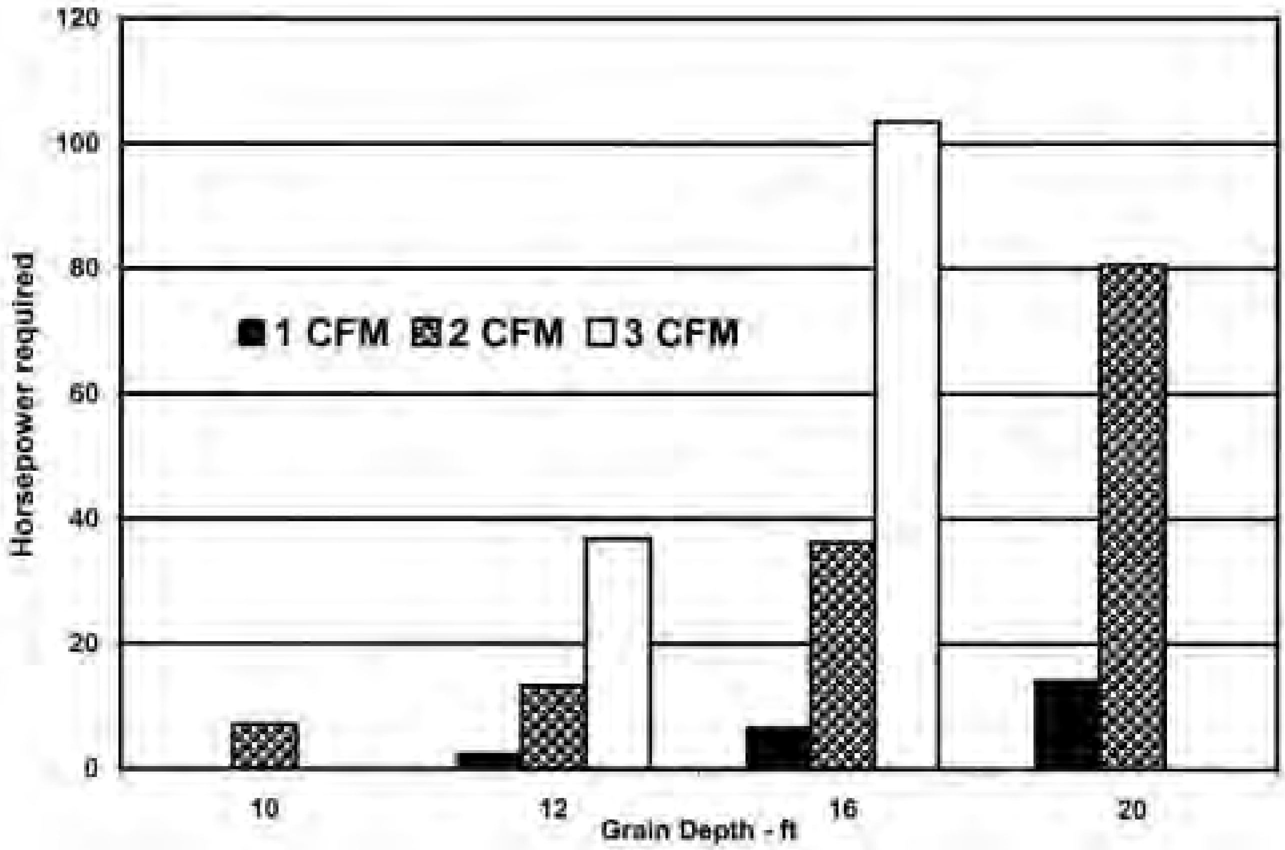
Fan Types

Vane-axial fans supply more cfm per horsepower at static pressures below 4.0 to 4.5 inches of water, low grain depths, than centrifugal fans. For this reason, these fans are generally better adapted to shallow-depth bin drying systems, such as batch-in-bin and continuous-in-bin systems, and to deep bin drying up to 20-foot depths requiring 1 cfm/bushel air flow or less. They are generally lower in initial cost, but operate at a higher noise level than centrifugal. These fans are generally not acceptable for use with bins that will also handle rice because of the high static pressures that are expected – typically, air is more difficult to move up through a column of rice.

Centrifugal fans supply more cfm per horsepower at static pressures above 4.0 to 4.5 inches of water than vane-axial fans. These are especially advantageous when the application requires relatively high air volumes through deep grain levels (12 to 20 feet), and where low noise is

[1]AE-106, *Fan Sizing and Application for Bin Drying and Cooling of Grain*, Purdue University CES.

Graph 9-1. Fan Power Requirements vs. Depth



important. Larger diameter centrifugal fans typically move more air per horsepower.

All fans are susceptible to a reduction in the amount of air that can be moved as the static pressure increases. Air flow will be less when fan blades are coated with lubricants, dust and other foreign materials. Keep all fan blades clean for maximum performance.

Care should be taken not to mix dry grain (moisture content less than 15 percent) with moist grain (moisture content greater than 18 percent). Re-wetting may also occur if damp air is pumped through the grain.

The EMC may be determined by measuring air temperature and relative humidity. A sling psychrometer is one the best tools for measuring relative humidity, and is relatively inexpensive. A sling psychrometer works by measuring the air temperature with a wet and dry bulb thermometer, and then using a table to determine relative humidity.[2]

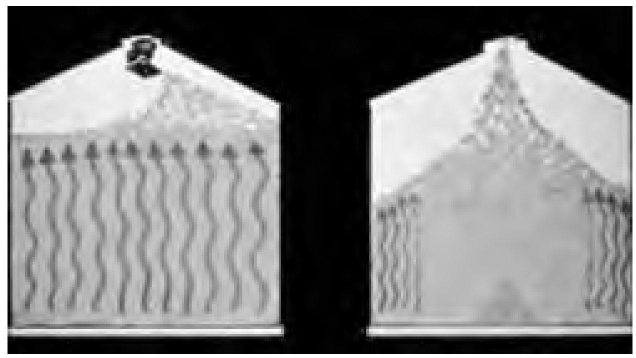
One should strive to maintain a steady EMC that is very close to the target storage moisture content. There are typically numerous days during and shortly after the harvest season when the EMC is at or below the desired level without adding any heat. At night or during damp weather conditions it may be necessary to add some heat to condition the air to a desirable EMC – or to maintain the same level available during the daylight hours. If heat is

[2]Sling Psychrometer sources: www.seedburo.com and www.forrestrysuppliers.com.

not available, it may be better to turn the fans off at night instead of pumping in moist air. Moist air that is pumped in at night has to be removed later. This increases drying cost and may result in significant HRY reductions. Fans should be turned off almost any time the EMC of the air is greater than that of the grain. The exception might be for very damp corn – to avoid heat buildup.

Stir alls help to mix the upper and lower portions of grain in the bin. This speeds up the drying process and loosens the grain so that additional air may be moved up through the grain. Stir alls also help to keep the grain level in the bin. Stir alls should not be turned on unless the bottom end of the auger is about 1 foot deep in grain. They can run almost continuously after that point, when the drying fans are running. There is a concern among many producers that the stir alls may grind away at the corn if left on, but there is no research evidence to support this. There will be a small amount of flour-like substance formed around the auger top, but the small particles were most likely already there and are just being gathered in one place with the auger action.

Grain should not be allowed to cone or pile to one side as the bin is being filled. If coning or sloping occurs, the large particles will migrate to the outside and the flour-like small particles and trash will remain at the center of the cone. This results in a very non-uniform amount of air being passed through each portion of the grain. Most of the air will pass up the outside of the bin through the larger and cleaner grain. A level height should be maintained throughout the filling process. Once the separation occurs, it is hard to remedy – even if the bin is later shoveled level. Do not fill a bin to a peak or until the grain touches the roof. This will interfere with uniform air flow and prevent moisture movement out of the grain surface. Level fill works best at any level!



Drying Costs

$$\text{Fuel Cost (\$/bu)} = \frac{\text{(BTU/lb water x lb water removed/bu x cost of fuel per unit x 100}}{\text{(BTU/unit of fuel x burning efficiency (\%))}}$$

The number of BTUs to extract 1 pound of water will vary from 1,100 to 1,400 and is a function of how easily moisture is given up by the kernel. As the kernel begins to dry, it takes more energy to get the last bit of moisture out. A good estimate is to use an average number of 1,200 BTU/pound of water. BTUs/unit of fuel are LP Gas – 92,000 BTU/gal, natural gas – 1,000 BTU/ft^3, and electricity – 3,413 BTU/kWh. Burning efficiencies are 80 percent for LP and natural gas and 100 percent for electricity.

Long-Term Storage Management

- Cool grain off as soon as possible in the fall. Target temperatures should be initially around 60°F.

- Continue to aerate and uniformly cool grain down to 30° to 40°F if possible. This will help avoid internal moisture migration and insect activity.
- Monitor grain and aerate monthly to maintain uniform temperature and moisture levels throughout. Aerate more often if moisture or temperatures increase.
- Keep grain cool as long as possible into the early spring.
- Do not aerate in early summer unless problems develop.
- Cover fans and openings when not in use to help avoid air, moisture and potential insect movement.
- Monitor carefully and fumigate if needed. The grain surface should be inspected at least every week throughout the storage period. Walk over the grain and poke around with your arm or a rod, smelling, feeling and looking for indications of trouble. Evidence of hot spots, warming, insect infestations or other problems that start in the grain mass soon migrate to the surface. Be particularly sensitive to damp, warm or musty areas.

Safety

- Always think safety around grain bins.
- Wear appropriate masks when working around dusts – particularly from moldy or spoiled grain. Exposure to and inhaling mold can cause severe allergic reactions.
- Never enter a bin when grain is being unloaded.
- Beware of crusted grain.
- It is best to work in pairs – one inside with a safety harness and one outside to assist if needed.
- Grain suffocation accidents happen all too often – think before you act or enter a bin!

These drying concepts and other details are discussed in MP213, *Grain Drying*, available at your local county Extension office. Corn drying is not overly complicated, but does require a good manager to maintain the highest corn quality.

Additional Resources

Internet resources at http://www.agcom.purdue.edu/AgCom/Pubs/AE/

AE-90, *Managing Grain for Year Round Storage*
AE-91, *Temporary Corn Storage in Outdoor Piles*
AE-93, *Adapting Silage Silos for Dry Grain Storage*
AE-106, *Fan Sizing and Application for Bin Drying/Cooling of Grain*
AE-107, *Dryeration and Bin Cooling for Grain*
AE-108, *Solar Heat for Grain Drying*
AED-20, *Managing Dry Grain in Storage*

Mid West Plan Service-Publications, 122 Davidson Hall, Iowa State University, Ames, IA 50011-3080

MWPS-13, *Planning Grain-Feed Handling* ($2.50)
MWPS-22, *Low Temperature and Solar Grain Drying* ($3.00)

10 - Grain Storage and Aflatoxin in Corn

Dennis Gardisser, Gary Huitink and Rick Cartwright

Introduction

Arkansas farmers and grain dealers are concerned with aflatoxin in corn. Aflatoxin is a major problem for corn producers and handlers in some years and only a minor problem in others. This chapter describes aflatoxin, methods of managing corn to reduce aflatoxin and remedial treatments for contaminated corn.

What Is Aflatoxin?

Aflatoxin is a chemical produced by several *Aspergillus* fungi, primarily *Aspergillus flavus* and *Aspergillus parasiticus*, under certain conditions when they grow in ears or on grain. These fungi also cause ear rots, but their presence does not always mean aflatoxin contamination.

Aflatoxin is most commonly found in corn, peanuts, cottonseed and their processed products and only rarely is noted in wheat, oats, sorghum, rice and soybeans. Aflatoxin in the diet adversely affects the growth and development of cattle, poultry, swine, fish and other animals. Liver disease and certain cancers have been associated with diets containing aflatoxin in some animals. High levels of aflatoxin can be lethal in all farm animals, but young pigs, pregnant sows, calves and young poultry are more susceptible than mature animals.

The Food and Drug Administration has established "action levels," measured in parts per billion (ppb), for aflatoxin in animal feeds or food. This makes animal feeds subject to regulatory action if aflatoxins are detected above the following levels:

- 300 ppb for corn intended for finishing (i.e., feedlot) beef cattle and for cottonseed meal intended for beef cattle, swine or poultry;
- 200 ppb for corn intended for finishing swine of 100 pounds or greater;
- 100 ppb for corn intended for breeding beef cattle, breeding swine or mature poultry;
- 20 ppb for corn intended for human food, immature animals (including immature poultry) and for dairy animals, or when its destination is not known;
- 20 ppb for animal feeds other than corn or cottonseed meal.

How Corn Is Contaminated with *Aspergillus* sp.

Aspergillus overwinters primarily in plant debris and litter on the soil. Spores of *Aspergillus* spp. are airborne and fluctuate in number during the growing season. Spores tend to increase during tillage and harvest and may be further increased in dryland corn.

Infection of corn by *Aspergillus* spp. occurs through the silk. The fungus appears to grow from the ear tip toward the base by colonizing the silk first, then the glumes and the kernel surface. After the silks die, the growth of the fungus is rapid in hot weather.

Factors influencing infection of corn ears by *Aspergillus* spp. and aflatoxin contamination include stress-related situations and insect damage. Corn plants exposed to drought stress are more susceptible to infection and contamination by aflatoxin than unstressed plants. Although insect damage is not necessary for aflatoxin formation, the incidence of *Aspergillus* and levels of aflatoxin contamination can be higher in insect-damaged kernels.

Prevention or Reduction of Aflatoxin in Corn

If conditions are favorable for the production of aflatoxin, it is much more difficult to prevent infection from *Aspergillus* spp. and subsequent aflatoxin production. Thus, a realistic goal is to minimize the preharvest infection with sound agronomic practices and minimize post-harvest fungal growth with careful handling and storage practices.

Since the fungus normally colonizes stressed, cracked or broken kernels, reducing in-field stress and kernel injury is recommended, including:

- Plant early to avoid drought stress and insect damage. Corn may be planted successfully when the morning soil temperature is 55˚F at a 2-inch depth for three consecutive days. This normally occurs in late March in south Arkansas and early April in north Arkansas. Sometimes frost may occur after these planting dates, but corn normally withstands frost with very little injury.

- Irrigate properly to avoid drought stress. Irrigation scheduling can prevent moisture stress and protect yield potential by allowing uniform kernel development. A computerized irrigation scheduling program and a manual checkbook program for scheduling irrigation are available at county Extension offices. If tensiometers are used to schedule irrigation, initiating irrigation at 50 centibars on silt loam and clay soils and 40 centibars on sandier soils is recommended.

- Plant Bt corn hybrids adapted to the south and with good husk cover to minimize insect and other stresses.

- Control late-season ear- and stalk-feeding insects as needed.

- Harvest unstressed portions of fields separately from portions of fields that suffered drought stress (e.g., in a field irrigated with a center pivot system, harvest inside the irrigated circle first and leave the nonirrigated corners for later). Mixing clean grain with moldy grain on the truck is not recommended. The best approach is to keep clean grain separate from grain that is suspected to be contaminated.

- Research indicates the best kernel quality usually results when corn is harvested within a range of moisture levels between 19 and 24 percent. The routine recommendation, based on discounts/drying costs and field losses, is that corn be harvested between 15 and 18 percent moisture. This is an economic decision based on a typical crop that has no increased risk for lodging, charcoal rot or aflatoxin contamination.

If high-moisture corn can be dried rapidly, at-risk fields should be harvested earlier, before they reach 18 percent moisture. This reduces kernel damage and the potential sites for aflatoxin contamination. High-moisture corn harvest also reduces field loss, but it increases drying costs. To reduce damage during combining:

- Use a rotary thresher, if available.

- Start with a thresher speed that is slow enough to leave a few kernels on the cob. Don’t overload the thresher or the cleaning sieves.

- Replace worn grain augers. Grain augers damage kernels if their diameter is worn to the point that kernels slip past the flighting.

- Adjust the combine airflow and sieve settings to remove foreign material from the corn sample. Separating foreign material from grain eliminates a primary source of moisture and material that restricts air movement in the bin. Some broken kernel portions will blow over the sieves and onto the field. Proper thresher settings and post-harvest screen separators are practical ways to eliminate broken kernel portions. Start with the combine manufacturer’s suggested settings and fine-tune the combine to obtain a clean sample.

Eliminating fines is economically done with a screen as grain is emptied from the truck hauling it in from the field. This rotating screen fastens to the grain auger and eliminates fine material. If these fines are contaminated with aflatoxin, they should be burned or buried. Contaminated fines should never be used for livestock feed. Clean combines, grain carts, trucks, conveyors and bins thoroughly after they have been used for corn.

Grain Storage to Preserve Quality

Many aflatoxin problems arise during grain storage, which begins the moment the kernel enters the grain tank on the combine. At that moment, the quality of the grain is the best it will ever be. The first objective in preserving grain quality is to determine grain moisture level, amount of trash in the grain, amount of grain damage that has occurred and best utilization of facilities and manpower available.

Grain that is cracked or has a lot of foreign matter is susceptible to mold growth and is hard to dry because of decreased airflow. The kernel seed coat offers protection from invasion of a variety of pests including insects and molds. Grain should be handled carefully so as not to mechanically damage the seed coat. Also, stress cracking due to overheating or drying too rapidly should be avoided.

Air movement through grain helps avoid the natural heating process that occurs with any material containing high moisture. It is essential that grain not be held in the field for any period of time to avoid heat stress and fostering mold systems. If possible, move grain to the drying and storage area immediately after harvesting and begin to move air through it to start the drying process. Ideally, move grain to a drying operation in less than six hours from the time it is harvested. A 24 hour delay may cause problems, including high rates of *Aspergillus* growth and aflatoxin production.

Relative humidity, kernel moisture and temperature play a role in aflatoxin development on corn. Conditions favoring the growth of *A. flavus*, include:

Factor	Optimum
Temperature	80˚-100˚F
Relative Humidity	85%-100%
Kernel Moisture	18% and above

These factors act in combination. If the relative humidity can be lowered with air movement and the grain moisture is reduced, the potential of mold problems decreases. Development of the fungus usually stops when the temperature is below 55°F and grain moisture is 12 percent or less, but it is greatly reduced at moisture levels of 15 percent or less.

Store Grain at Low Moisture Content

The relationship between the moisture content of stored grain and the relative humidity of the air profoundly affects mold growth and grain spoilage. The moisture content of stored grain determines the relative humidity of the air in which it is stored. High moisture content causes high relative humidity in the air surrounding the grain in storage. Molds grow rapidly when the air has a high relative humidity and slowly at a low relative humidity. In fact, each mold has a specific relative humidity below which it will not grow. When grain is stored with low moisture content, air contained in the grain mass has low relative humidity and grain deterioration by mold growth is controlled. The best way to control mold growth is to store grain with low moisture content. The safe moisture storage level for corn in Arkansas is approximately 12 to 13 percent. Long-term storage should be 12 percent.

Avoid Pockets of Damp Grain

For safe storage, all the grain must be below this safe storage moisture level. An isolated pocket of damp grain supports mold and/or insect growth which can spread upward and outward to drier grain. A load of damp grain placed in storage with dry grain limits the storage time of the entire lot to that of the wettest grain. Research has shown that even when damp and dry grain are carefully mixed and moisture is allowed to equalize, moisture differences of 2 percent between kernels may remain. When the grain is poorly mixed, much greater differences result.

Pockets of high moisture can be the result of adding a damp load to dry grain, even when mixed. A column of fine and heavy foreign material often accumulates under the filling spout creating a trouble spot. Light trash, especially green trash, usually accumulates near the walls of storage bins as it rides down the cone of grain during filling of the bin. Don't allow the incoming grain to cone inside the bin. Any leaks in the storage bin also cause pockets of high moisture grain.

Avoid Moisture Migration

A frequent cause of pockets of higher moisture grain in storage is moisture migration. Grain in the mid-south region is usually warm when harvested and stored. Since grain is a good thermal insulator, it remains warm until cooled by aeration. During cold seasons, air near the bin wall cools, and convective currents are set up in the bin. Warm air in the center of the grain mass tends to rise and absorb moisture due to its greater moisture carrying capacity. As this air reaches the cool grain surface at the top and center of the grain column, it is cooled and gives up some of its moisture, which is absorbed by the grain. This moisture migration causes a pocket of higher moisture grain at the top center of the stored grain. During the winter, this process can cause a pocket of 18 to 20 percent moisture in a bin of grain that was originally uniformly 14 percent or lower. When the temperature rises in the spring, moist grain may germinate and storage mold will rapidly invade the grain.

Moisture migration can be prevented by aeration. Aeration during dry, cool days equalizes temperatures within stored grain and prevents convective currents.

Do Not Rely on Grain Turning

Turning grain (moving it from one bin to another) is used by farmers in an attempt to prevent or stop heating and deterioration. Research has shown that turning does not make any important reduction in average temperature or average moisture content of a bin of grain. Also, turning scatters mold and insects throughout the bin. Only when moisture content is uneven will turning be effective in temporarily slowing heating and deterioration by mixing damp grain with dry grain in the bin. Grain turning should be considered a last resort to save a deteriorating lot of grain. Aeration is more effective for maintaining grain quality during storage, and excessive handling increases kernel damage.

Control Insects and Rodents

Insects which invade stored grains are also sensitive to temperature. Their growth and reproduction are greatly reduced at temperatures below 70°F and cease at 50°F. Good housekeeping and spraying operations are generally sufficient for control. Rodents are controlled by storing grains in rodent-proof bins. Both insect and rodent control are enhanced by keeping grain facilities clean of old grain, debris and vegetation. For details see fact sheets:

- Gardisser, D. R., 1989, *Chemical Applicators for Spraying Liquid Materials on Grain*, FSA-1006, University of Arkansas Cooperative Extension Service.

- Gardisser, D. R., 1989, *Calibration of Stored Grain Chemical Applicators*, FSA-1004, University of Arkansas Cooperative Extension Service.

Check Moisture Content During Storage

Anyone who stores grain should own or have access to a grain moisture tester and know how to use it properly. Calibrate the moisture tester before each harvest season. It can be shipped to the manufacturer for calibration or checked against another tester known to be accurate. When buying a moisture tester, check with the manufacturer for the best method of calibration.

When making moisture tests to determine the condition of grain in storage, don't enter a grain bin without a safety harness and tether manned by at least one adult outside the bin whose sole responsibility is aiding the entrant. Turn off all unloading equipment and lock out electrical controls so no one can unwittingly engage the power while you are sampling the areas which are likely to have the highest moisture content. Collect a sample near the top center of the grain. Use a grain probe to collect a representative sample from the area beneath the fill-in spout where fine material tends to collect. If the grain contained light trash that collected near the bin walls, sample these areas as well. Remember, the wettest sample determines how well the grain will keep.

To determine the average moisture content of the grain, take three samples – one on top, one near the center and one near the bottom. Openings in the bin wall or a grain sampling probe are required.

Keep samples that will not be tested immediately in airtight containers with as little air space as possible left in the container. Metal cans or glass jars with airtight lids or tight plastic bags are suitable for holding samples.

Don't test cold grain in a warm room. A thin film of moisture may condense on the kernels and cause erroneous readings. Either let the grain warm up in a closed container or operate the tester in an unheated room. Some electric moisture testers require temperature corrections. In this case, accurate temperature measurement is a must.

Check for Hot Spots During Storage

A "hot spot" in stored grain indicates activity or mold growth. It may be due to a pocket of high moisture grain or a collection of fine material restricting aeration airflow. Temperature measurements in stored grain can detect "hot spots" before they do serious damage.

Temperature readings can be made using a probe consisting of a sensing element, probe handle and meter. Sections can be coupled together to check grain at depths up to 18 feet or more. If a "hot spot" is detected, make several checks to determine its size. Cool any "hot spots" as soon as possible by aeration. If the hot spot is due to fine material that is restricting airflow, break up the "hot spot" by removing grain from the bottom of the bin and returning it to the top.

Drying

Four commonly used drying systems include natural air or low temperature, layer, batch-in-bin and high temperature pass dryers. Drying air is forced up through the grain mass in each of these systems. Each system has advantages. Bin drying is most practical for small volume producers. High temperature drying is fastest but requires the greatest amount of investment and energy input.

The top or outer layer is always the last to dry. The drying layer moves up from the bottom so the top layer of grain is held longer at conditions which are ideal for aflatoxin production. Dry the top layer to below 18 percent moisture quickly. Following are some guidelines:

Initial Grain Moisture	Drying System
Above 20%	High temperature batch, continuous flow or batch-in-bin.
Below 20%	Layer drying in bins with supplemental heat (if needed) to reduce the relative humidity of the incoming air to 50% to 55% or high temperature drying.
Below 16%	Natural air drying when climatic conditions permit or drying with supplemental heat in bins during the high relative humidity days. Aerate as needed to control temperature.

Equipment

- Use a properly sized fan to provide an adequate amount of airflow through the grain. As the grain depth in a bin increases, a larger fan is needed because of the additional power needed to move air through a column of grain. Also, higher moisture levels require more air to obtain a satisfactory drying level. The following table is a guide to determine how much air movement is necessary for safe drying at various moisture levels.

Moisture Level (%)	Minimum Airflow (CFM per Bushel)
11 to 13	0.5
13 to 15	1
15 to 18	2
18 to 20	3
20 to 22	4
22 and above	6

- Equip all drying fans with heaters. Heaters are necessary for 24-hour drying. During the nighttime hours, relative humidity increases and heat is necessary to continue drying. Layer drying is slow even with 24-hour operations. Checking the relative humidity of the air manually or using thermostat and humidistat controllers for the heaters is necessary. (Controllers should be checked manually to ensure they are working correctly.)

- If you know the air temperature and relative humidity, you can determine the equilibrium moisture level of the air. If the moisture level of the grain is higher than the air equilibrium moisture level, drying occurs when air is moved through the grain. The speed of drying is determined by the difference between these moisture levels and the amount of air moved. The dryer the air and the larger the volume of air moved through the grain, the faster the drying process occurs.

- Bins should have adequate air exhaust in the roof to avoid choking the fan. Any bin larger than 2,500 bushels needs extra roof vents in addition to the standard manhole (inspection door) and the center fill hole. A good rule of thumb for determining the number of square feet of roof vent area needed is to multiply the fan horsepower by 1.25. (Example: 20 horsepower fan multiplied by 1.25 = 25 ft^2 of roof vent area needed.)

- Level each layer of grain as it is placed in the bin. Use a grain distributor to help level grain and distribute any fines evenly across the surface. Do not let the fines form a core in the center of the bin.

- If the equilibrium moisture level of the drying air is below that of the grain moisture, the drying process should continue until the top layer is dried to 13 percent. Air should be conditioned as necessary during high humidity swings to ensure that re-wetting of the bottom layer does not occur.

- More details on grain drying may be obtained in Extension publication MP-213, *Grain Drying – Using Psychometric and Moisture Equilibrium Charts as Guides*.

Storage Tips

- If grain is stored with uniform moisture contents (maintained below 13 percent for corn), the grain will store safely without spoilage.

- When grain is stored with moisture contents above this safe level, reduce the grain temperature to inhibit mold development.

- For every combination of grain temperature and moisture content above safe levels, there is an allowable storage time before serious mold growth develops. Lower temperatures and lower moisture contents allow longer safe storage times.

- Moisture migration is caused by temperature differentials in stored grain and is prevented by aeration.

- Grains germinate when they are moist and warm enough. They heat when invaded by insects or storage molds.

- Be sure all old corn and trash are cleaned out of the storage bin before any new corn is added.

- Clean bins and the plenum area, including below the floor, and maintain the burners. Monitor the drying process to avoid fire in a corn bin.

- Immediately after drying is completed, cool the grain to outside air temperature.

- Treat corn while it is being placed into storage to control insect infestations.

- Operate the fan whenever the outside air is below 65 percent relative humidity and 10˚F cooler than the corn until the corn reaches 50˚F.

- Operate fans for aeration at least 4 hours every 2 weeks after the corn is cooled to 50˚F.

- Consider fumigation if insect problems develop in storage.

- Inspect corn frequently for mold, insects, hot spots or other signs of spoilage. The best insurance for stored grain is frequent inspection!

Detection of Aflatoxin

Most farms in Arkansas do not have high levels of aflatoxin in corn, but occasionally grain has enough aflatoxin to cause problems in marketing and feeding. Farmers, elevator managers and feed manufacturers need to be aware of proper detection and identification of contaminated corn. Rapid detection of contaminated corn is important because aflatoxin normally survives processing and may be concentrated in products or processed fractions.

Many elevators in Arkansas use a high intensity ultraviolet light (UV) to detect a byproduct of *Aspergillus* growth in grain or feed. Infected corn emits a bright blue-green-yellow fluorescence when exposed to UV light. However, the fluorescence only indicates the presence of fungal activity and does not prove the presence of aflatoxin. Many elevators use a UV black light to screen grain samples.

Since the black light can result in false positives for aflatoxin, the grain industry now generally use ELISA test kits to directly detect aflatoxin in grain. These test kits are based on an antibody specific for aflatoxin. While these test kits are much more accurate in trained hands than the black light, they are only as representative as the sample collected from the truck. Since aflatoxin-contaminated grain is not randomly distributed in a truck load and since even a single contaminated kernel in a sample can cause the sample to exceed regulated levels of aflatoxin, these tests still result in inaccurate readings for the load, albeit the reading for the sample is probably accurate.

A new state law in Arkansas requires the Arkansas State Plant Board to investigate claims of aflatoxin contamination in commercial grain, so any grower receiving a positive result should contact the Plant Board for help.

What Can Be Done with Contaminated Grain?

Occasionally, corn may be contaminated with aflatoxin at levels which disqualify it from normal marketing channels. When loads of grain are rejected for high aflatoxin, farmers and other users have some remedial treatments or options for their grain including:

- Blending aflatoxin-contaminated corn with aflatoxin-free corn is not legal.

- Grain preservatives such as propionic acid, isobutyric acid and other organic acids prevents the growth of *Aspergillus* sp. if properly applied to grain as it is augered into bins. However, these acids will not lower levels of aflatoxin in grain that is contaminated prior to treatment. Furthermore, these materials are very corrosive and should not be used in metal storage bins unless the metal is protected. If grain treatments are used, follow manufacturer’s recommendations carefully.

- Fumigating corn with anhydrous ammonia is an effective means of detoxifying corn that could not otherwise be fed to livestock. However, the process is time-consuming and hazardous to those ammoniating grain. The FDA has not yet approved ammoniation as a process to salvage aflatoxin contaminated corn. Anytime anhydrous ammonia is used, all plumbing should meet O.S.H.A. standards and eye protection should be used.

- An activated clay, hydrated sodium calcium aluminosilicate (HSCAS), may be added to aflatoxin-contaminated feed to reduce the toxic effects of aflatoxin in swine, poultry and cattle. Some commercial products containing HSCAS are registered as anti-caking materials and may be added at labeled rates (0.5 to 2 percent of finished feed) to animal feed. These products appear to be the most cost effective method of using contaminated grain for animal feed.

Summary

Aflatoxin can reduce the quality and marketability of corn. Contamination can originate in the field and increase dramatically during grain storage. Proper management of the crop, careful handling and proper storage of the grain are critical in preventing aflatoxin. Once contaminated, affected corn is very difficult to deal with.

11 - Estimating Production Costs for Corn in Arkansas

Tony Windham

Corn production cost estimates are published each year by the University of Arkansas Cooperative Extension Service. The most recent edition of these publications can be located on the Cooperative Extension Service web site at:

http://www.aragriculture.org/farmplanning/Budgets/default.asp

Enterprise budgets represent a type of information that can be used by a wide variety of individuals in making decisions in the agricultural industry. They are used:

- by farmers for planning,
- by Extension personnel in providing educational programs to farmers,
- by lenders as a basis for credit,
- to provide basic data for research and
- to inform non-farmers of the costs incurred by farmers in the production of food and fiber crops.

The purpose of these publications is to provide a systematic procedure for estimating the cost of producing corn. Users of this information should think of these budgets as a first approximation and then make appropriate adjustments using the "YOUR FARM" column provided on each budget to add, delete or change costs to reflect the specific situations. For example, each of these corn enterprise budgets includes an estimated drying cost. Many producers believe this cost can be reduced by allowing the crop to dry in the field prior to harvest. However, since these estimates are intended to be a planning guide, drying costs are included which allows the user the opportunity to make adjustments.

Each budget estimates the direct and fixed expenses associated with producing corn. Input price data used in estimating direct costs are updated annually by obtaining prices from farm input suppliers throughout the crop's production area. Quantities of inputs are based on the recommendations of Extension and Research faculty within the Division of Agriculture. Data obtained from the Corn Research Verification Program is also used in developing these estimates.

Fixed expenses include depreciation, interest, taxes and insurance and represent an average cost allocated over the entire useful life of the machinery. Various financing arrangements and tax depreciation methods can produce costs that vary significantly from these estimates in a given year. The ability to estimate the actual cost is a complex economic procedure whereby cash accounting and economic costs may vary greatly.

Each budget also includes a sequential listing of all operations used in the estimation procedure. This information can be used to determine the cost of a specific tillage operation, pesticide application or irrigation practice. The user can also compare the number of tillage operations or irrigations with their own expectations.

12 - Identify Hazards and Prevent Accidents

Gary Huitink, Phil Tacker and Earl Vories

Injury and death rates in almost every survey published are higher from April to September for agricultural work. Obviously, these months coincide with corn production. What can be done on your farm to prevent the trauma and cost of severe injury or death? Top managers maintain timely crop practices and also place a consistent emphasis on reducing field, traffic and shop hazards in day-to-day management.

Table 12-1. Factors Involved in Agricultural Fatalities (1996 National Safety Council data)	
Tractors	37%
All other agricultural machinery	17%
Farm trucks or other vehicles	11%
Animals	6%
All other fatalities	29%

Have a Plan to Reduce Hazards

One approach is to set long-range goals to eliminate hazards while finding safer ways to complete routine tasks. Assess the potential kinds of severe accidents and how frequently a person is exposed to that hazard. Develop a simple plan that you can follow to minimize these exposures. Serious concern should be given to the risks of road collision, tractor overturn and a person being run over or crushed by farm equipment. Consider all aspects of your farming operation to identify weaknesses, and then seek remedies.

If a person must work alone, make sure another person knows where the lone worker is and that regular contact is made. If a lone operator sees a hazardous situation, getting help to resolve it is essential. Everyone should be trained to contact the manager immediately about any serious safety concern.

Field

A few field dangers cause many Arkansas fatalities. These are tractor overturns, equipment running over victims and crushing them, jump-starting tractors, hitching equipment or folding equipment for road travel.

Most tractors used for corn production have a Roll-Over Protective Structure (ROPS). It has been well documented that the risk of serious injury from an overturn is essentially zero if the operator fastens his seat belt on a tractor equipped with ROPS! Practicing this safety habit may also reduce injury from a traffic collision. Operating a tractor, sprayer or combine too fast for conditions causes many overturns. Turning too short can cause an overturn. Misjudging your distance from an embankment can be serious, because the bank may crumble under the weight of the tractor or implement. FSA-1026, *Safe Tractor Operation*, available from your county Extension office, has more suggestions that may be useful for training farm help.

Whether calibrating a planter or sprayer or moving a combine, don't move equipment until you **see** that everyone is out of danger. Starting a tractor in gear from the starter terminal (jump-starting) is possibly the most common reason Arkansans have been run over. Transmission interlocks prevent tractors from starting in gear, unless the safety is bypassed. A victim doesn't have enough time to jump away from a tractor left in gear before the engine builds hydraulic pressure and the tractor rolls over him.

Whenever noise prevents you from hearing someone, stop the engine and what you're doing and move where you can talk to clear up any confusion. Hand signals are easily misunderstood, unless both of you understand the meaning of a hand movement in advance. It takes good communication and cooperation for two people to safely hitch heavy toolbars or towed implements. Make sure signals aren't confusing before moving the tractor to align the connection.

Using a proper hitch support may prevent a dangerous hitching incident. If the hitch or lift pins do not align, movement may knock the support from under equipment; the toolbar or hitch may spring out of control or drop and crush someone's foot. Two severe accidents in 2002 may be instructive: One employee was killed trying to remove a pin when the hitch broke free and smashed his face. Another victim removed a latch pin and was crushed by a folding cultivator; the hydraulic cylinder didn't support the weight. If supports aren't sturdy, stable and at the proper height when disconnecting an implement, difficulty is likely when hitching the next time. Set the safety locks on the lift cylinders before working under a combine header. Never work under hydraulic lifts, mowers or toolbars without **sturdy** supports.

Combine entanglements don't usually happen the first time a row unit plugs. It's the fourth or fifth time, or later, when you're tired or irritated, in a hurry and your judgment lapses. Vibration and excessive noise dull an alert person's senses to hazards. Fatigue also slows your reaction, so take breaks for refreshment. Falls from combines, grain bins, etc., may be prevented with proper work platforms or sturdy ladders. Keep work areas neat and free of hose or electric cord loops, etc., which could pose trip hazards.

Professionals mount large implement tires with a protective cage. Mishaps while inflating tires can maim or kill. If you don't have equipment to handle tires safely, it is wiser to call a tire service company.

Irrigation risers, discharge pipes and "washout" holes where water discharges may become hazards if they are not clearly visible. If field equipment hits a riser or washout, it could cause temporary loss of control in addition to damaging the equipment and/or the riser. Placing some type of readily visible marker at each riser and controlling weeds so they don't hide the marker should alert drivers. Anchor and guy wires from power poles located near or in fields should also be permanently marked. Putting some type of solid protection around guy wires for power poles is a good idea to help avoid clipping or dislodging them with field equipment. Fill washout holes and use some erosion control structure or method to prevent large washouts under discharge pipes.

Agricultural aviators have little reaction time to dodge hazards as they apply fertilizer and pesticides. Always warn the pilot of any risks that you're aware of to help him be better prepared. If a field has aerial hazards, consider whether it would be more appropriate to use ground equipment.

Traffic and Road Transport

The National Highway Traffic Safety Association recently reported that approximately **40 percent more fatal crashes and fatalities occur in rural compared to urban areas**. Experience over the last four years in crop areas of Arkansas seems to reinforce national statistics. Changes like wider road shoulders, adding warning signs for curves with poor visibility, updating narrow bridges and, possibly, adding crossbars at railroad crossings should reduce rural traffic accidents. In some situations it may be possible to convince the town, county, state or railroad to clear a right-of-way to obtain better traffic visibility.

Modern toolbars, combines and wide equipment typically require almost two normal traffic lanes. Motorists are often poor judges of the slow speed, width or weight of your implement, regardless of what you're transporting. Using an escort with flashing lights is probably the best way to alert a motorist. Being diligent to keep SMV signs, reflectors and taillights bright, cleaning them before entering a road, will improve their visibility during night and day.

Lock both of your brakes together and start onto a road slowly, even when traffic is heavy. Go slowly enough to manage the momentum of a tractor with a full grain cart, planter or toolbar, especially those that raise overhead. Dump all of the corn from your combine bin into a grain cart or truck prior to road travel to lower the center of gravity and gain control in a sudden emergency. Always check traffic from both directions before making a turn off a road, especially a left turn, to prevent a collision and extensive damage, if not injury.

Railroad crossings are increasingly dangerous for growers on farm equipment. Some cabs may "tune out" the diesel train noise. In order to hear better, reduce the speed of the cab fan and turn off the radio as you approach a crossing. If you gear down well in advance, you can control the load, either to stop or to proceed when the track is clear. In some cases, either historical evidence and/or community effort may help to get the railroad to add crossbars.

General Precautions

Work can be done safely on equipment powered by electricity with a "lock-out, tag-out" approach. Anyone working with equipment powered by electricity should carry a lock with his personal key and tag. These are readily available from local electrical suppliers. Before starting work, always disconnect the power supply and lock the switch "off." If you're interrupted by a phone call, or are not visible from the switchbox, no one else can reconnect the electricity. You can remove the lock from the switch lever after completing the work. Always use the heel of your left hand to throw lever switches and turn your face away as you move the control to minimize bad flash-fire burns.

Figure 12-1. Proper method to safely bump or switch a disconnect lever on an electrical box.

A federal regulation intended for your personal safety prohibits anyone or any equipment from coming within 10 feet of an overhead power line. If field equipment or other traffic cannot maintain a 10-foot gap under the power line, request that your power supplier raise the power lines.

Diesel-powered generators, electric-powered pressure washers and hand tools (drill, angle grinder, etc.) and welders should all be adequately grounded. Grinders, drills and other electric tools bouncing around in a truck tool box can develop "shorts." If the electric service entrance at the shop is grounded with an 8-foot ground rod (National Electric Code standard), all ground wire leads, including the extra grounding plug on power cords, should be connected to reduce the risk of electrocution when a short occurs. Use electric tools on dry soil, concrete, etc., to reduce the potential of a fatal current surge passing through your body.

Someone, maybe several people on your farm, should keep current on CPR rescue techniques. The local EMT, ambulance and fire department numbers should be posted by every permanent phone and programmed on "speed dials." Each one on the farm should be prepared to call emergency rescue, should an accident occur.

Observe pesticide labels for proper use, mixing and disposal. Appropriate personal protective equipment is specified on the label. The label and the Material Safety Data Sheet (MSDS) should have specific inhalation, dermal, ingestion and emergency information. If a mishap occurs, use the label to help your physician and the poison center to start the proper treatment.

Fire extinguishers on tractors and combines may also protect your safety and equipment investment. Dry chemical all-purpose 3A-40B:C or 4A-80B:C extinguishers are good choices for tractors and combines. Once a fire extinguisher is 10 years old, it is generally wise to replace it unless it exceeds requirements in a thorough test.

Irrigation

A qualified electrician should routinely check electrical circuits on irrigation pumps and center-pivot systems. Items to review are proper grounding and adequate circuit protection, including immediate replacement of circuit boxes damaged by electrical storms or circuit overheating. If a box has overheated or shorted, switching the disconnect may cause arcing and severe flash burns that may take months for merely partial recuperation. Always use the heel of your left hand to throw switch levers and turn your face away to minimize your hazard exposure as you move the control.

Be cautious when working around electrical circuits, especially when opening electric control boxes and around any circuits that are “hot.” Wasps commonly nest in and around electric control boxes and may also appear from electric motor shrouds, gear head covers, power unit platforms, irrigation well sheds and irrigation pipe openings. In order to prevent an injury, it may be wise to keep wasp and hornet spray handy when working on irrigation wells. Stings are not only painful; they can be fatal for one who is severely allergic to insect stings. Further injury can also occur if a wasp startles you and causes you to jump back. A sudden reaction that puts you in contact with an unguarded drive or an energized electric circuit may cause permanent disability.

Entanglements may occur with irrigation well power shafts, if safety shields aren’t replaced. In general, power-take-off (PTO) hazards are respected, but more emphasis needs to be placed on shielding unguarded power shafts on irrigation wells. Power shaft covers can be obtained from suppliers, including Menard Mfg. in DeWitt, AR (1-888-764-3130) to protect those doing maintenance around diesel, propane or electric power units. Power shafts for relifts or well pumps should be shielded; any concentric sleeves that don’t spin free should be repaired or replaced.

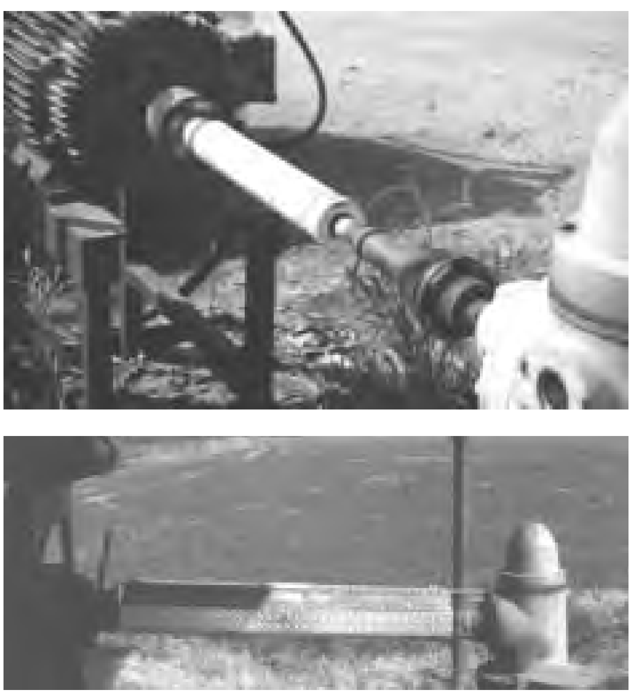


Figure 12-2. Install shields to protect anyone working around well power shafts.

If a power unit is not securely mounted and anchored, vibration may misalign the drive or break it loose from the supports. A loose power unit may cause a dangerous flailing power shaft or other hazards due to broken electrical wires, fuel lines or battery cables. Power units and battery mounts should be securely anchored to a substantial support platform and routinely checked for stability. A secure latch to keep the clutch of the power unit in neutral is a good safety device. This can help prevent accidentally bumping and engaging the clutch when working close to the power unit.

Typically, weather is very hot when irrigation is needed, and physical stresses may bring on heat stress. Anyone working in these conditions should drink plenty of fluids such as water and nutrient-replenishing drinks. Breaks and rest periods should be taken as needed to avoid heat stress, fatigue and exhaustion. Fatigue and exhaustion, of themselves, are health hazards, but they may also contribute to poor judgment, causing other accidents and injuries.

Reservoirs and open irrigation distribution ditches may present concerns. Normally, a clear warning on a sign about the water hazard, unusual currents around culverts, etc., and potential bank washouts will caution outdoorsmen or others who may enter. Evaluate a location with respect to residences or public access to determine whether it may attract youngsters. Gates and fencing may be used around accessible areas to prevent ATV riders or children from getting into danger. Posting no trespassing signs or a drowning warning is primarily useful only for adults.

Grain Drying

The primary grain-handling hazard is entanglement, but the potential for both suffocation under flowing grain and electrocution should also be reviewed. Certainly, all auger covers should be in place **every** time the power is engaged. In addition, don’t reach across belt drives or power shafts; take the time needed to walk around your tractor or power unit. Fans and drives should be shielded to prevent anyone from getting caught. Children shouldn’t be around grain handling facilities; fencing the area may be a practical choice.

A qualified electrician should routinely check electric circuits to confirm proper grounding and adequate circuit protection, including making immediate repairs of faulty wiring, conduits or control panels. Disconnect electric power and use the lock-out, tag-out procedure every time before beginning work around an auger, fan, motor or powered component. Before tilting truck beds, moving augers or tall equipment, check for overhead power lines; too many times an auger is raised or pulled into a bare overhead wire. When grain bins are built or facilities are remodeled, power lines should be routed well away from any work areas so accidental contact with wires isn't possible.

Before entering a grain bin, put on a NIOSH-approved toxic dust respirator for molds and dust to prevent a reaction called farmer's lung or toxic organic dust syndrome. Turn off all unloading equipment and lock out switches with a padlock before entering a bin so that someone doesn't unwittingly engage the power. This applies to all loading auger, sweep auger, stirring auger and unloading auger circuits. Don't enter a grain bin without a safety harness and tether manned by at least one adult outside the bin whose sole responsibility is aiding the entrant. Crusted grain has been a factor in a number of deaths to growers. Spoiled or caked corn may "cave in" onto a man if the crust suddenly fractures. If some corn is removed from a bin with a crusted surface, the undermined surface may suddenly collapse under your foot, releasing an "avalanche" of corn. More than 500 pounds of pull are required to move a man who is covered with corn to his shoulders. If you're covered, you can't get yourself out and you're likely to suffocate if no one is watching. More details are included in FSA-1010, *Suffocation Hazards in Grain Bins*.

OSHA

Only farms with 11 or more employees are required to meet all OSHA labor regulations. All growers, however, are to comply with these standards:

1) Roll-over protective structure (ROPS)

2) Slow moving vehicle emblem (SMV)

3) Agricultural machinery guarding (of moving parts, i.e., PTOs, combine safety shields, auger inlet covers and other moving machinery guards)

4) Anhydrous ammonia standards

5) Temporary labor camps standards

6) Pulpwood logging standards

7) Hazard communication (right to know). If you are an employer and store farm diesel fuel, pesticides, etc., then labels, MSDS, information, training and a written Hazard Communication Program are required.

If your farm is under OSHA jurisdiction, OSHA requires reporting an accident within 8 hours. They define a reportable incident as hospitalization of three or more employees in one accident or a death of one or more employees. A Washington, D.C., phone number, 1-800-321-6742, is available 24 hours a day. You can report to the federal OSHA office in Little Rock during working hours at 501-324-6291, extension 235.

If an OSHA officer requests admittance to a workplace, an employer may deny it. The officer can, however, obtain a search warrant. The inspection should include only the immediate accident scene. Inspections may result in setting a penalty or formal warnings, with penalties enforced later (often 30 days), if the hazard isn't remedied. Inspectors can ask that employees be removed from areas of imminent danger. An owner can appeal to the federal OSHA office in Little Rock, phone 501-324-6291, extension 235.

Other considerations that may be important:

1) When is a CDL operator's license required?

2) What training should be provided for all employees and others? Training at the time of employment, as tasks are assigned, and at minimum, every year, instructs every employee on farm hazards and on safe operation. Keeping signed records is the best way to document training and record your progress removing farm hazards, should a major injury or death occur on your farm.

3) Are 14-15 year-olds employed? Training for hazardous machinery operation is specified and work criteria apply to those under 18 who are employed in agriculture.

4) Are your insurance policy liability limits and deductibles appropriate for your present farm?

5) Have you considered whether workmen's compensation is feasible?

6) Are employment procedures for non-citizens applicable?

Summary

These suggestions are a start to help you manage hazards and find ways to avoid them. These hazards are only highlights. Review your techniques and farm work sites in order to reduce potential hazards.

A grower's leadership is the key to influencing employees and others on the farm. Employees must know that working safely is expected, for their welfare, as well as that of their employer. During the non-crop season, it is wise to make a careful hazard audit. Review the previous season's activities and field records to bring to mind hazards or incidents, especially considering situations when someone narrowly avoided serious injury. Making changes may save someone's life the next season.

In most situations, **equipment isn't the underlying cause of an accident**. A single thoughtless reaction can make you a victim. Never get in a hurry. Plan ahead to ensure there is enough time to do the job properly and safely.

Contacts that May Prove Helpful

Emergency Rescue	911 or ________________
Poisoning	1-800-222-1222
Family Physician	________________
Local Electric Power Supplier	________________
County Sheriff	________________
Local Implement Dealer (assist with extrication)	________________
Local Implement Dealer (assist with extrication)	________________
Arkansas State Highway and Transportation Dept. (Police: Oversize and over-weight permits, etc.)	501-569-2381
Commercial Driver's License (CDL) info.	501-682-1400
State Fire Marshal, Arkansas State Police	501-618-8624 (Fuel storage questions)
Arkansas State Plant Board	501-225-1598
Arkansas Department of Environmental Quality	501-372-0688
LPG (Liquefied Petroleum Gas) Board	501-324-9228

13 - Renewable Energy

Dennis R. Gardisser

The United States is overly dependent on foreign oil. Using corn as a renewable resource reduces this dependency and provides an alternative use for our farm products. As corn acreage increases in Arkansas, so will opportunities to use corn as a renewable resource in the area.

Corn Products[1]

Corn refiners use shelled corn which has been stripped from the cob during harvesting. Refiners separate the corn into its components – starch, oil, protein and fiber – and convert them into higher value products.

Corn sweeteners (http://www.corn.org/web/sweeten.htm) are the most important refined corn products. Last year, corn sweeteners supplied more than 56 percent of the U.S. nutritive sweetener market.

The second major refined corn product is **ethanol** (http://www.corn.org/web/ethanol.htm) which is gaining increasing acceptance as a cleaner burning option for motor fuels. The ethanol industry continues on its record production pace. When 2002 is over, the United States ethanol industry will have produced over 2 billion gallons of high octane, American-made ethanol. That's 2 billion gallons of fuel that we didn't have to import from the Middle East.[2]

The third major corn product – a mainstay of the industry and of the U.S. economy – is **Starch** (http://www.corn.org/web/starch.htm). Americans rely on corn refiners for over 90 percent of their starch needs.

Corn refining is America's premier **bioproducts** (http://www.corn.org/web/bioprod.htm) industry, with increasing production of amino acids, antibiotics and degradable plastics adding further value to the U.S. corn crop.

In addition to starches, sweeteners and ethanol – all made from the starch portion of the corn – refiners produce **corn oil** (http://www.corn.org/web/cornoil.htm) and a variety of important **feed products** (http://www.corn.org/web/feed.htm).

Ethanol Information[3]

Consumer Benefits

U.S. consumers use more than 18 billion gallons of high performance, cleaner burning ethanol-blended gasoline each year.

- Ethanol increases oxygenate supplies, reducing the need for MTBE, methyl tertiary butyl ether, imports and helping to reduce consumer costs.
- Ethanol is a high-octane blending component used by many gasoline marketers – helping to keep this important class of trade viable and creating competition for the major oil companies.
- Since the petroleum refining industry is running at near capacity, the ethanol industry helps extend our petroleum supply, thereby helping moderate fuels costs to consumers.

Taxpayer Benefits

- The partial excise tax exemption available to gasoline marketers for ethanol and ETBE blends saves money. A General Accounting Office (GAO) study has shown that reduced farm program costs and increased income tax revenues offset the cost of the incentive.

[1]http://www.corn.org/web/products.htm; [2]http://www.ethanol.org - American Coalition for Ethanol;
[3]www.ethanol.org/information/ethanol_information.htm

- The economic activity attributable to the ethanol industry will generate $3.5 billion in additional income tax revenue over the next five years – $1 billion more than the cost of the exemption. The U.S. ethanol industry will create a net gain to the taxpayers of almost $4 billion over the next five years.

Economic Benefits

- More than $3 billion has been invested in 60 ethanol production facilities operating in 20 states across the country.

- The ethanol industry is responsible for more than 40,000 direct and indirect jobs, creating more than $1.3 billion in increased household income annually, and more than $12.6 billion over the next five years.

- The ethanol industry directly and indirectly adds more than $6 billion to the American economy each year.

- The demand for grain created by ethanol production increases net farm income more than $12 billion annually.

- As the economic activity created by the ethanol industry rippled throughout the economy, it generated $30 billion in final demand between 1996 and 2000.

- Increases in ethanol production offer enormous potential for economic growth in small rural communities. USDA has estimated that a 100 million gallon ethanol plant could create 2,250 local jobs.

Agricultural Benefits

- Industrial corn use, which includes ethanol and sweetener production, is now the second largest consumer of corn in America. Each $1 of upstream and on-farm economic activity generates $3.20 in downstream economic stimulus attributable to ethanol processing, compared to just $0.31 when corn is exported.

- Ethanol production consumed 535 million bushels of corn in 1994 (5.3 percent of the record 10 billion bushel corn crop). About 667 million bushels of corn were used for ethanol in 2001.

- The demand for corn created by the ethanol industry increases crop values – accounting for approximately $0.14 of the value of every bushel of corn sold, or $1.4 billion.

- If the market for ethanol did not exist, corn stocks would rise and net income to American corn farmers would be reduced by $6 billion over the next five years, or about 11 percent.

- Many farmers now own and operate ethanol plants, allowing them to add value to their own corn.

Energy/Trade Benefits

- Domestic ethanol production reduces demand for imported oil and imported MTBE which drain our economy. Oil and MTBE imports now represent almost 80 percent of the U.S. trade deficit.

- Currently, imported oil accounts for about 56 percent of oil used, and imported MTBE is at a record 31 percent of domestic production.

- Today, ethanol reduces the demand for gasoline and MTBE imports by 98,000 barrels per day. A 98,000 barrel/day replacement of imported MTBE would represent a $1.1 billion reduction to our annual trade deficit.

- Ethanol production also generates exports of feed co-products, such as corn gluten, further enhancing our balance of trade.

- Ethanol production is extremely energy efficient, with a positive energy balance of 125 percent, compared to 85 percent for gasoline. Ethanol production is by far the most efficient method of producing liquid transportation fuels. According to USDA, each Btu used to produce a Btu of gasoline could be used to produce 8 Btus of ethanol.

Environmental Benefits

- 10-percent ethanol blends reduce carbon monoxide better than any other reformulated gasoline blend, more than 25 percent.

- Ethanol is low in reactivity and high in oxygen content, making it an effective tool in reducing ozone pollution.

- Ethanol is a safe replacement for toxic octane enhancers in gasoline such as benzene, toluene and xylene.

- Oil companies are now starting to acknowledge the environmental and energy benefits of ethanol. For example, see the brochure published by Mobil.

The information contained in this chapter is intended to be an awareness introduction to the many possibilities available to use corn as a renewable resource. The internet is an excellent resource for additional contacts and information on this topic. Search engines for renewable resources, ethanol, alternative fuels, corn byproducts and others will uncover a wealth of data.