Corn Production Handbook

AGRICULTURAL EXPERIMENT STATION and COOPERATIVE EXTENSION SERVICE
KANSAS STATE UNIVERSITY
MANHATTAN, KANSAS

Contents

Growth and Development

That corn crop that you're planning to harvest next fall, or the one that you are looking back on to see why it didn't yield more, started when the seed was planted in the soil and ended when the ear was successfully harvested. Certainly before planting there was considerable planning and preparation for the corn crop. The production you hope to obtain or obtained depends both upon the genetic or plant characteristics and the environmental or field characteristics in which the plant is grown.

If we understand how the corn plant grows, develops, and produces grain, we then have a better chance of knowing what will affect its growth and consequently how to manage it for best production. If you consider the "age" of the corn not in terms of days but in terms of its development, when you read other sections of this book dealing with specific production practices, they will mean more to you.

Let's start with the corn seed. It is made up of three primany parts, the embryo from which will develop a new plant; the endosperm, which provides a source of energy to get the seed germinated and emerged so that it can then function on its own; and the pericarp or seed coat which protects both the endosperm and the embryo. We want to start with seed that has a viable embryo that will grow, that contains sufficient stored energy to get the plant established and that has an intact seed coat to prevent attack by disease organisms.

Generally, seed is planted in soil moist and warm enough to allow rapid germination and emergence. Depth of planting influences the amount of growth necessary before the seedling can emerge from the soil surface and affect the time required from planting to emergence. Changes in planting depth affect the depth at which the primary roots develop, but does not affect the depth at which the permanent root system develops.

During the first 4 to 5 weeks after emergence, the plant continually develops new leaves from the growing point, which is below or at ground level during much of this time. A total of approximately 20 leaves will be developed. During this period of time, root and leaf development progress rapidly. Nutrient uptake also is occurring rapidly. Since the growing point is still below the soil surface, a frost or hail may destroy the exposed leaf area, but likely would not kill the plant. This might be of particular importance in determining whether replanting should be done following a late spring frost.

After all of the leaves have been started by the growing point, it then changes and develops the tassel. Once this occurs, the stalk starts growing rapidly and the growing point is elevated above the soil surface where any damage could affect the growing point and kill the plant. During the following 4 to 5 weeks, rapid growth occurs with the remaining leaves increasing in size and producing the "factory" that produces the grain during the latter portion of the growth cycle.

During this same period of time, the stalk grows rapidly, increasing the plant height dramatically and resulting in the tassel emerging from the whorl and developing until pollination recurs. Rapid root development and nutrient uptake also occur so that at tasseling less than half of the final weight of the corn plant has been developed. However, over 60 percent of the nitrogen, 50 percent of the phosphorus, and 80 percent of the potassium have already been taken up. This period of time is particularly important, it determines the capability of the plant in terms of grain production. During the flowering process, stress conditions have more effect on the timing of tassel development than they have on ear development. Under stress conditions the tassel may develop and shed pollen before the ear and silk formation has been completed and thus poor pollination will occur. The pollination process begins at the base of the ear and progresses to the tip, By looking at pollination problems on various ear parts, it is often possible to determine when the problem occurred and in many cases to determine the cause of the poor timing.

The final portion of growth of the corn plant is one that results in grain production. Starting with pollination, essentially all production by the plant goes into the developing kernels, The amount of production that occurs is determined by the potential of the plant set during the early stages of development, by the size of the "factory" that was developed during the middle portion of the growth of the plant, and finally by the production of the plant during this latter portion of the growth cycle. Drought or nutrient deficiency during this period of time will result in unfilled kernels and light chaffy ears.

Approximately 50 to 60 days after pollination most corn hybrids will reach "physiological maturity," This is the end of the grain filling process in which the dry weight of the grain no longer increases. This does not mean that the grain is at a moisture content suitable for harvest as physiological maturity occurs in the 25 to 35 percent moisture range, depending upon hybrid and environmental conditions. Following physiological maturity, grain drying is entirely a matter of moisture loss. If you are looking at high moisture grain or early harvest and artificial drying, harvest can occur any time after physiological maturity without any reduction in total dry weight of grain harvested.

If you consider effects of various management practices on each of the three major times in the development of the corn plant, you will be able to see how these practices can affect the yield of your corn crop. Similarly, if some unexpected problem arises and you can relate this problem to the normal growth and development of the corn plant, you will have a better understanding of how this might affect your final yields.

Select Hybrids Carefully

Corn Hybrid Development and Marketing

Currently, most commercial corn producers plant single-cross hybrids. Single-cross hybrids take full advantage of the hybrid vigor (heterosis) that results from crossing two inbred lines (Ax B). Plant breeders develop inbred lines by selecting self-pollinated corn plants for desirable characteristics for several generations. The several generations of inbreeding required to produce an inbred line usually result in a relatively low yielding, less vigorous plant when compared to hybrid corn plants. Inbred lines are quite different than the open-pollinated varieties, which predominated before hybrid seed became readily available in the 1930's and 1940's. However, several inbred lines originated as plants from open-pollinated varieties. Selection of the two inbreeds to be crossed for the production of a superior hybrid depends on how well each inbred's set of desirable traits (yield potential, stalk strength, disease resistance, etc.) compliment each other and on how well the two inbreeds cross when used as parents,

Private firms market nearly all hybrid seed sold to corn producers. Some of the larger companies have highly trained breeders and actively develop unique inbred lines. Many other firms utilize inbred lines released by public institutions and/or inbred lines and crosses provided by private seed production specialists. The later results in the marketing of the same or very similar hybrids by several companies.

Few public institutions now actively develop hybrids for public use, but several have research programs that furnish industry with basic research information, diverse gene sources, and improved inbred lines. During the past several years, there has been increased emphasis in exploring and utilizing biotechnology techniques toward these ends.

Public scientists often have skills and resources unavailable to private firms, while industry can produce and market good quality seed in a much more efficient manner than public agencies. Intense market competition ensures the steady introduction of improved hybrids developed by the combined efforts of private and public scientists.

Importance of Choosing an Appropriate Hybrid

Choosing an appropriate hybrid is essential for successful corn production. Each field has unique limitations (soil fertility, moisture intake and storage capacity, slope, insect and disease potentials, etc.), and each manager has unique financial, labor, and equipment resources available to address these limitations. Other production decisions also play a role in determining what type of hybrid is needed. For example, an early-maturing hybrid may give disappointing yields under full irrigation, heavy fertilization, and a long growing season. Conversely, a full-season hybrid may not do well on a non-irrigated site with lower potential fertility. The corn producer's challenge is to choose hybrids appropriate for each management situation, keeping in mind risks associated with potential weather extremes.

Hybrid Selection

Yield and Lodging—All other things being equal, a corn producer wants the highest yielding hybrids available. Lodging can severely decrease yields under certain conditions. Under stress conditions, high yielding hybrids with superior stalk quality are most desirable. Stake yield trial reports probably provide the most complete and unbiased information on yield and lodging comparisons.

The Kansas Agricultural Experiment Station publishes an annual Report of Progress including detailed results from over 20 Kansas Corn Performance Tests conducted at 11 sites around the state. Seed companies participate voluntarily on a cost-sharing basis by paying a fee for each hybrid entered in each test, The program has evaluated several thousand different hybrids since its inception in 1939. Of the 264 hybrids submitted for testing by 38 private companies in 1993, 125 (47 percent) were new entries. Roughly half of the entries from the 1992 tests were not repeated in 1993, This rapid turnover of hybrids underscores the need for annual examination of hybrid performance,

Tests do not include all hybrids grown in the state and do not include the same set of hybrids at all test sites because entrants choose where to enter their hybrids. However, the annual report containing current year data and period-of-years averages can provide considerable guidance toward wise hybrid choices,

Maturity—Choosing the appropriate maturity for each situation is fundamental to choosing the right hybrids. Problems may arise when comparing similar hybrids from different companies using their maturity ratings, because the industry has no standardized maturity reporting system. State trials are a good source of information on relative maturity by reporting silking dates and harvest moisture for all entries in a given test. Once you choose the desired maturity—early, midseason, or full-season (for your area)—you can sort among hybrids within that class for other characteristics that fit the intended purpose,

A hybrid attains physiological maturity when dry matter stops accumulating in the grain (somewhere between the 25 percent and 35 percent grain moisture levels). Further drying is necessary for safe storage. To lower the risk of experiencing soft corn and yield reduction problems when utilizing full-season hybrids, choose those that reach physiological maturity at least one or two weeks before the average date of the first killing frost in your area.

Deciding which maturity class to plant depends on a number of factors unique to each field. With favorable moisture, temperatures, and fertility, full-season hybrids generally produce the highest yields. However, early and midseason hybrids may be a wise choice if some of the production factors are limiting, for example on non-irrigated, upland sites with poor water-holding capacity. Early maturing hybrids are useful for later plantings, for fields that you wish to fall-pasture or till before winter, or for other special situations. Using early-maturing hybrids may reduce or avoid losses due to lodging caused by Southwestern corn borer. Early maturing corn maybe an alternative to grain sorghum or other crops on somewhat marginal land if it can be planted early, if it can set and fill seed before late summer heat and drought stress become severe, and if the producer is willing to assume a slightly greater risk. Harvesting these plantings promptly will minimize lodging losses. Plant populations should be adjusted to match the requirements of each hybrid. Early hybrids often perform better when planted at populations higher than those normally used for full-season hybrids. Planting several maturities over a several-week period is a form of insurance against severe weather losses, and if done carefully, spreads harvest over a longer period.

Other Characteristics—Many other characters may be important hybrid selection criteria, e.g., insect and disease tolerance, drought tolerance, quick-drying ears, low ear-dropping tendency, and tendency to tiller or have more than one ear per stalk. Seed company representatives can usually provide accurate information on these characters, and state yield trials occasionally reveal differential hybrid responses to some pest or stress.

Several different insect species cause much of the ear dropping and lodging seen in Kansas by boring through ear shanks and stalks. Resistance to these pests is highly desirable, if available.

Kansas tests have indicated best production from one-eared plants grown at the appropriate plant population.

Commercial hybrids normally are well-screened before reaching state tests, so they generally appear well adapted to Kansas, including the heat and occasional drought experienced on dryland. Examination of relative hybrid performance in tests subjected to stress conditions provides the best indication of adaptability to such situations. The threat of poor seed set from prolonged high temperatures and low humidities killing pollen is real, but, fortunately, rare in Kansas. Drought and heat will sometimes disrupt flowering so that all pollen has developed and disappeared by the time silks appear.

Unusual Types—Yellow dent corn for feed grain production is the predominant type grown in Kansas, but some white corn acreage is planted each year. White corn is grown primarily for sale to industry for human food purposes, but can be fed satisfactorily to livestock if supplemented with Vitamin A.

Historically, commercial, white hybrids were similar to, but often later-maturing slower-drying, lower yielding, and less stress-tolerant than the yellow endosperm types. Over the years, plant breeders and geneticists have expended much less breeding effort on white corn than on yellow corn. A breeding project initiated at Kansas State University and aided by several other public and private groups involved backcrossing the white grain character into a number of the yellow inbred lines used in high-yielding single-crosses. The project completed several conversions and made them available to private breeders. Some hybrid combinations using converted white inbred lines as parents performed much like the original yellow hybrids. This project was terminated in 1992.

Several factors, including relatively small demand and widely fluctuating supply due to weather and acreage extremes, result in considerable instability in price and profits from white corn production. A substantial premium for white over yellow corn in one season may stimulate excess production in the following year, resulting in no premium or even a discount for white grain that year.

A good proportion of the yellow corn grown in Kansas is utilized for silage. Successful silage hybrids also are heavy grain producers, but mature somewhat later than those grown solely for grain. Yield and maturity data from Kansas Corn Performance Test results provide a good source of information for choosing silage hybrids, even though no forage yields are available.

Check List for Choosing Hybrids

- Take the time to look for improved hybrids for each management situation on your farm. This little chore could potentially make you more money than anything else you could be doing.
- Try to avoid settling on one brand or one favorite seed company representative for several years. You maybe missing something.
- Take the trouble to learn or write down the good hybrid numbers that come to your attention. Each company usually has only one brand, but several hybrid numbers, each with its own distinctive characteristics.
- Try several promising hybrids on a small scale each year and keep harvest records for each.

Use of Growing Degree Units in Corn Production

For years, corn maturity has been labeled in days. A 120 day variety would presumedly reach maturity 120 days after planting. This system does not take into account complicated physiological processes that control growth and development of corn. The number of days required to reach maturity depends on location of planting, and weather the plant is subjected to in a particular growing season. In most years, the period will be more or less than 120 days. It is hard to decide which maturity to plant to achieve maximum production. A delayed planting might not provide the required number of days for your variety to mature.

Each day does not contribute equally to the growth of plants. Growth is faster during the warm season than in cold weather. On the other hand, summer temperature can be too high for optimum growth. Although factors other than temperature enter into determining rate of growth, there is a growing acceptance among seed producers to use the temperature based Growing Degree Units (GDU) concept to express maturity. There have been many of these “heat-unit” systems devised over the years, The one currently in use for corn was proposed by the Environmental Data Service of the National Oceanic and Atmospheric Administration (Formerly U.S. Weather Bureau).

In this system, Growing Degree Units are calculated by subtracting a base temperature of 50°F from the average of the maximum and minimum temperatures for the day. Corn doesn’t grow much at temperatures below 50°F. As the temperature rises, corn grows faster if moisture is plentiful. However, at a temperature higher than 86°F the roots have increasing difficulty taking in water fast enough to keep the plant growing at full speed. GDU are calculated by the following equation:

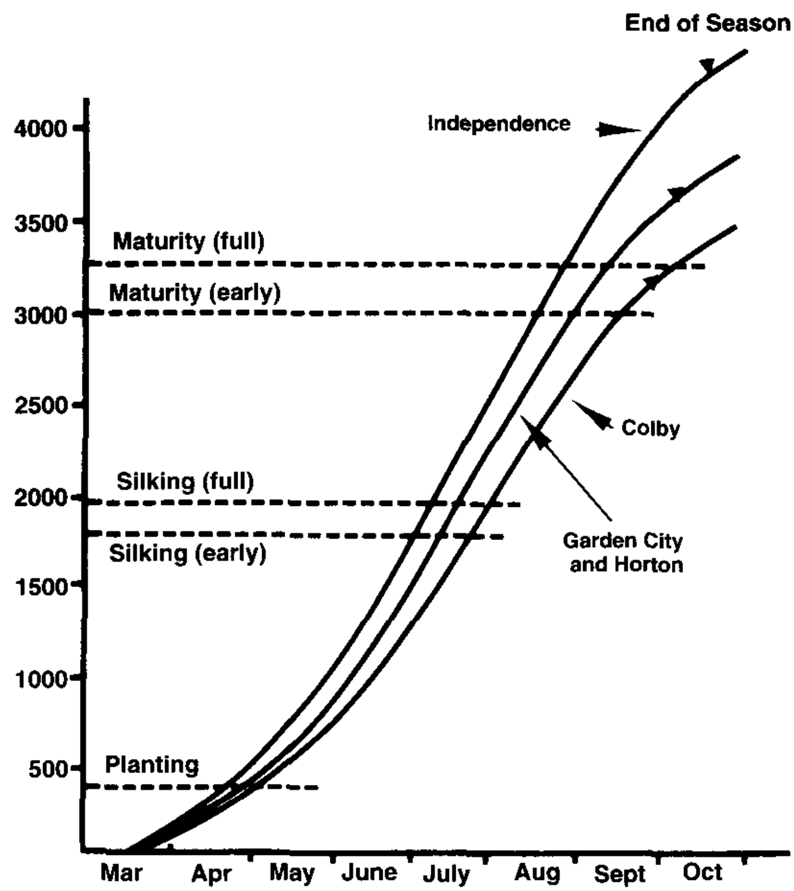
$$\text{GDU} = \frac{\text{Max Temp.} + \text{Min Temp.}}{2} - 50°\text{F}$$

NOTE: Minimum temperatures below 50°F are counted as 50°F and temperatures above 86°F are counted as 86°F.

Figure 1

GDU’s Required to Reach:

	Silking	Maturity
Early Season Variety	1390	2610
Full Season Variety	1560	2830



For example a day with temperature extremes of 82°F and 60°F would have contributed 21 GDU. A day with a high temperature of 90°F and a low of 48°F, will be considered as one with temperatures of 86°F and 50°F for purposes of calculation. That day would have had 18 GDU,

The average accumulation of GDU starting on March 1 for four stations are shown in Figure 1. They can be used to understand how Growing Degree Units can be used to help the corn producer plan his operation. Notice that the accumulation rate is very slow early in the season, then becomes quite rapid and finally slows down again toward the end of the season. It is because of this variable rate that maturities expressed in terms of days are not consistent. Planting one week early may mean that maturity is reached only one day earlier.

The three curves in Figure 1 represent the growing conditions that are found throughout the state. Colby represents the high elevations in northwest Kansas that have a relatively short growing season. The Garden City-Horton curve represents the broad mid-range of conditions in the state. It is interesting that a northern station at a low elevation (Horton) has about the same conditions for promoting growth as a southern station at higher elevation (Garden City). Elevation and latitude work in combination in Kansas to determine the length of growing season. Independence data represents the area of southeast Kansas that has a relatively long growing season. Periods of summer heat are more critical for corn production in this area than the chances of an early freeze.

Let's suppose that you are considering selection of a corn hybrid between the two varieties rated by the seed producer as shown in Figure 1, Further, we will assume that it requires an accumulation of about 400 GDU after March 1 before the soil temperature warms to levels favorable for planting. By following the line labeled Planting Date, we can determine the average date at each location at which this will occur, Naturally, it will be earlier in southeast Kansas (April 22), than at Garden City (May 1) or at Colby (May 7).

If we are able to plant at the time that 400 GDU have been accumulated, the seed producer predicts that his early variety will silk after 1390 additional GDU have been accumulated (a total of 1790 GDU). The full season variety will not silk until the accumulation is 1960 GDU. Silking is a critical time in the production of high corn yields. It may be important in your area to select a rating and planting date that will reduce the possibility of your corn reaching the silking stage at a time when the likelihood of moisture stress and high temperatures are great.

If we add the predicted number of GDU needed to reach maturity to our assumed planting date accumulation of 400 GDU we can predict the time when the crop will be ready for harvest. We should be concerned about the prospect of an early freeze, The end of season mark on each curve indicates the date that is 10 days prior to the average 32°F-freeze date. Note that neither variety utilizes the entire growing season in southeastern Kansas. Perhaps you might want to try a variety that requires almost 3,000 GDU to

Table 1. Growing degree units from this date to end of season

	Apr 11	Apr 18	Apr 25	May 2	May 9	May 18	May 23	End of Season*
Ashland	3821	3747	3660	3570	3467	3359	3241	Oct. 14
Belleville	3466	3406	3331	3254	3180	3068	2959	Oct. 3
Burr Oak	3246	3191	3113	3057	2958	2863	2765	Sept. 30
Colby	2986	2934	2872	2808	2733	2650	2560	Sept. 28
Elkhart	3554	3481	3399	3313	3215	3113	3003	Oct. 8
Emporia	3663	3599	3517	3432	3335	3232	3117	Oct. 10
Garden City	3412	3351	3279	3203	3115	3021	2918	Oct. 7
Hays	3387	3330	3259	3186	3100	3008	2905	Oct. 5
Horton	3456	3395	3316	3233	3141	3041	2931	Oct. 6
Hutchinson	3794	3729	3648	3564	3468	3364	3247	Oct. 13
Independence	4030	3955	3860	3763	3655	3542	3413	Oct. 17
Iola	3964	3892	3799	3702	3595	3482	3354	Oct. 15
Larned	3736	3667	3583	3498	3402	3297	3182	Oct. 11
Leoti	3133	3077	3009	2938	2855	2766	2670	Oct. 10
Manhattan	3656	3590	3507	3421	3323	3215	3098	Oct. 7
McPherson	3794	3728	3644	3559	3463	3358	3241	Oct. 12
Medicine Lodge	4016	3939	3844	3747	3637	3523	3397	Oct. 17
Minneapolis	3732	3665	3582	3495	3411	3291	3173	Oct. 8
Ottawa	3754	3688	3604	3514	3414	3305	3185	Oct. 12
Quinter	3174	3121	3057	2990	2914	2830	2736	Oct. 13
St. Francis	3055	2994	2924	2850	2769	2681	2586	Sept. 25
Syracuse	3357	3286	3203	3118	3023	2923	2813	Oct. 1
Tribune	2984	2926	2857	2786	2705	2617	2525	Sept. 25
Winfield	4072	3992	3895	3796	3685	3570	3441	Oct. 16

* End of season date is defined as 10 days before the average date of first 32°F-freeze in fall. There is a 20 percent chance that a freeze will occur before this date.

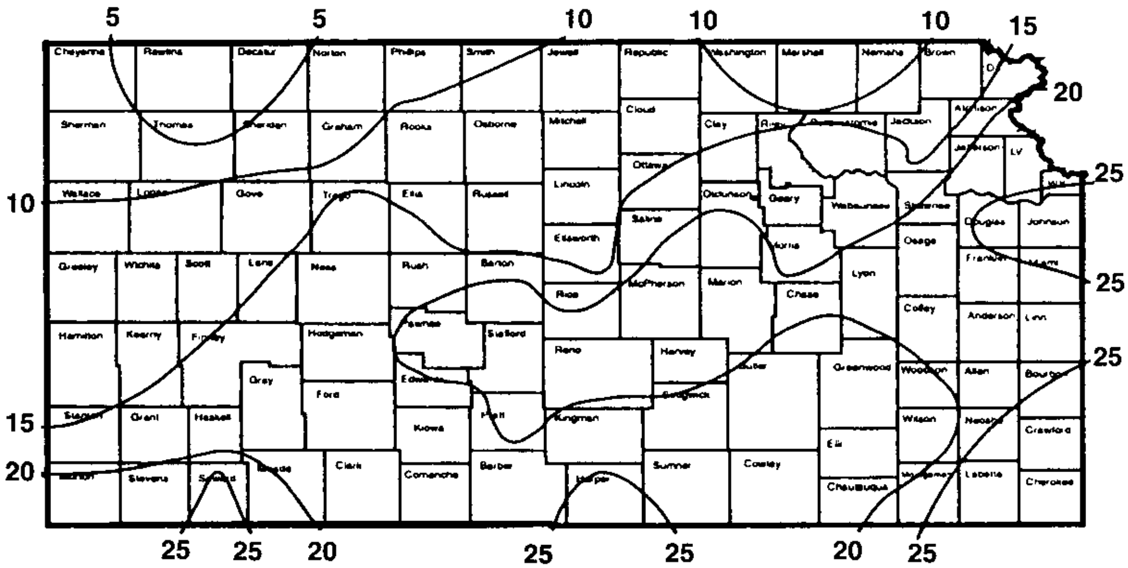


Figure 2. Average date of first 32°F freeze in fall. All dates are in October.

reach maturity. Remember however, the mid-season hot spells that affect pollination. In northwestern Kansas, and in west central Kansas, it can be seen that a full season corn that has a requirement of 2,800 or more GDU may not reach maturity before a freeze, The early season variety certainly looks to be more promising in this area.

The example given above assumes a normal year, and planting on schedule. What if your planting is delayed one week, or even two weeks? Your decision will depend on your location, but you might want to change corn varieties. Another factor to consider is that the curve represents normal (or average) conditions. As everyone knows, such conditions don't often exist. These curves can still be useful if they are shifted to fit the actual conditions on a particular date. For example, Figure 1 shows it is normal to accumulate 1,000 GDU at Independence between March 1 and May 27. What if there is a cool spring and the accumulation at Independence doesn't reach 1,000 GDU until June 7? If you assume normal conditions the rest of the year by shifting the curve so that the 1,000 level is reached on June 7, you will again have a prediction of the growth and development of your corn crop for that particular year.

Table 1 lists the number of GDU that will be available on the average for various planting dates for a number of locations in Kansas. It is assumed that the growing season ends 10 days prior to the average date of the first freeze in fall. There is only a 20 percent chance that a freeze will occur before that date. Figure 2 shows the average date of the first 32°F freeze for areas of Kansas.

If you plant corn in the Tribune area on May 2, you can expect to have a seasonal total of 2,786 GDU for your crop. You should select a variety that has a requirement less than this. Keep in mind that the number of GDU will vary from year to year. The totals will be within 150 GDU above or below the values listed in Table 1 in 70 percent of the years.

The GDU rating placed on corn varieties by seed producers can give you a great deal of insight into the growth and development of your crop. It may take a little getting used to, but it should be worth the effort.

Optimum Planting Practices

Seedbed Preparation and Planting Practices

Corn kernels need a soil that is warm, moist, well supplied with air, and fine enough to give good contact between seed and soil for rapid germination. A number of different tillage and planting systems can be used in producing corn. These systems may involve primary and/or secondary tillage, or no preplant tillage operations. An ideal seedbed should accomplish the following:

- control weeds;
- conserve moisture;
- preserve or improve tilth;
- protect water quality;
- control wind and water erosion; and
- be suitable for planting and cultivating with your equipment.

One goal of seedbed preparation is to provide a means of profitable corn production while minimizing soil erosion due to wind and water. Tillage and planting systems that accomplish this goal are often referred to as conservation tillage systems. Conservation tillage is an umbrella term that includes reduced till, mulch-till, ecofallow, strip-till, ridge-till, zero-till, and no-till. The emphasis in conservation tillage is erosion protection; however, water quality; moisture and energy conservation; and labor and cost savings may be additional benefits. Conservation tillage will be an integral part of many conservation plans for highly erodible fields as a result of the conservation compliance provision of the 1985 and 1990 Farm Bills.

Erosion Protection

In conservation tillage, the soil surface is protected from the erosive effects of wind, rain, and flowing water. Resistance to these erosive agents is achieved either by protecting the soil surface with crop residue or growing plants, or by increasing the surface roughness or soil permeability. Water erosion losses for different tillage systems are shown in Table 1.

A common goal of conservation tillage systems is to reduce soil erosion losses below soil loss tolerance or “T” value. Soil loss tolerance is an estimate of the maximum annual rate of soil erosion that can occur without affecting crop productivity over a sustained period. Soil loss tolerances for Kansas cropland are normally in the range of 4 to 5 tons per acre per year. Soil loss tolerances for specific soil mapping units can be found in soil surveys or from Soil Conservation Service personnel.

The amount of residue necessary for erosion protection depends on several factors such as climatic conditions and patterns, soil erodibility, surface roughness, field length, length and steepness of slope, cropping practices, and other conservation practices. A rule of thumb is to leave 30 percent residue cover on the soil surface after planting where water erosion is the primary concern. Where wind erosion is a concern, 1,000 pounds per acre of flat small grain residue or its equivalent is required on the soil surface during the critical wind erosion period. It is important to be aware of crop residue levels to stay in compliance with the conservation provisions of the 1990 Farm Bill.

It maybe helpful to calculate an estimate of the residue on the surface to evaluate the tillage options available for next year. This calculation method is explained on the Residue Fact Sheets available in your county extension office. A computer program, RES-N-TILL™, calculate surface residue amounts is also available from Extension Agronomy. An example output is shown in Figure 1. After a 100 bushel corn yield, the soil surface on the average, will be about 95 percent covered with crop residue. After overwintering and some limited tillage (one chiseling, one disking, and one field cultivation), the soil will still be over 30 percent covered with residue after planting, Results may differ from actual residue levels in the field, depending on initial residue amount after harvest, tillage speed, and soil moisture content. It is best to estimate residue in the field to check for conservation compliance needs. Residue amounts can be estimated by comparison to pictures of various residue covers (see the Residue Fact Sheets), line transect method, or marking your shoe and step ping out the residue (boot method),

In Kansas, almost 30 percent of the harvested corn acres will end up with less than 15 percent ground cover by the time the next crop is planted. Forty six percent of the corn acres are in reduced tillage, no-tillage or ridge-till, leaving more than 30 percent ground cover at all times. The actual level of residue required to minimize soil loss on your fields may vary above or below these limits. Local Soil Conservation Service personnel can provide assistance in determining residue needs. In certain situations, conservation tillage alone may not adequately protect the soil from erosion losses. In these situations, conservation tillage can be integrated with other conservation practices, such as terracing, contouring, strip cropping, windbreaks, etc., to provide the necessary erosion protection.

Long-term research in Kansas has shown that corn can be successfully grown in conservation tillage systems (Table 2). Careful management and planning are important. Uniform residue distribution, effective weed control, proper seed placement, correct planter adjustment soil testing, and fertilizer management are all important in conservation tillage corn production. Growing corn in a rotation with other crops such as wheat and soybeans, reduces some of the problems encountered with conservation tillage.

No-till corn planting is best suited to soils that are moderate to well-drained. Soils often remain cooler and wetter throughout the growing season under no-till conditions. This is particularly true in heavy residue conditions. While wetter

Table 1. Soil losses for various tillage systems in soybean, corn, and wheat residue.

	Corn Residue[1]		Soybean Residue[1]		Wheat Residue[2]	
Tillage System	Cover %	Soil Loss tons/a	Cover %	Soil Loss tons/a	Cover %	Soil Loss tons/a
Plow, disk, disk, plant	4	10.1	2	14.3	—	—
Chisel, disk, plant	13	8.3	7	9.6	—	—
Disk, disk, plant	—		5	14.3	—	—
Disk, plant	15	6.6	9	10.6	—	—
Plow, harrow, rod-weed drill	—	—	—	—	9	4.2
Blade (3x), rod-weed, drill	—	—	—	—	29	1.2
No-till plant or drill	39	3.2	27	5.0	86	0.2

[1] Silty clay loam, 5% slope, two inches applied water at 2.5 inches/hour.
[2] Silt loam, 4% slope, three inches applied water at 2.5 inches/hour. (Data from E.C. Dickey, University of Nebraska–Lincoln.)

Table 2. Long-term yields of corn grown under various tillage systems.

Location (Soil type)	Rotation	Number of years tested	Yield (bu/a) No-Till	Reduced Till	Conventional Till
Shawnee County[1] (Eudora silt loam)	C-SB[2]	8	166	172	175
	cont.[3]		160	171	172
Republic County[1] (Crete silt loam)	C-SB	4	155	—	156
	cont.		135	—	132
Thomas County (Keith silt loam)	WCF[4]	4	75	71	67
Brown County (Grundy silt loam)	C-SB	8	100	—	98
	cont.	8	84	—	87
Riley County (Kenebec silt loam)	cont.	3	128	—	119

[1]Irrigated
[2]Corn/Soybean rotation
[3]Continuous corn
[4]Wheat/Corn/Fallow

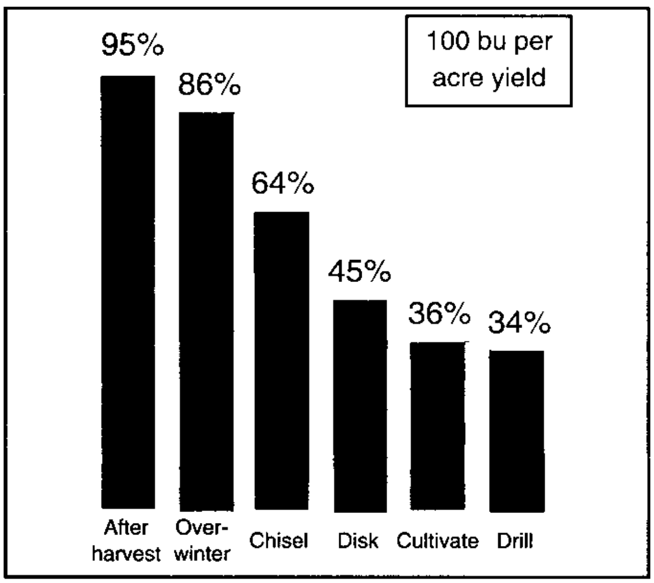


Figure 1. Surface residue amounts left on soil surface following 100 bu/a corn crop.

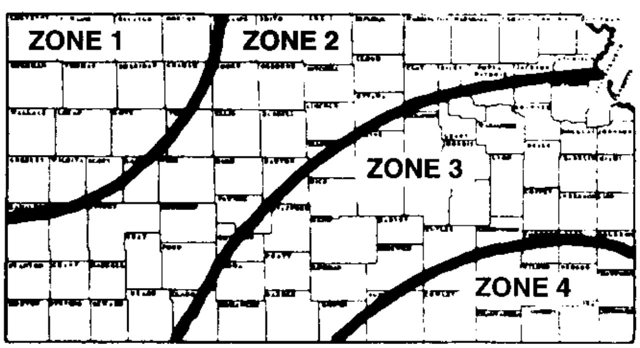


Figure 2. Suggested corn planting dates.
Zone 1 May 1–20
Zone 2 April 20–May 15
Zone 3 April 10–May 10
Zone 4 March 25–May 1

soils are an advantage during dry periods, at planting time it can mean slower seed germination, delayed maturity, and a longer period when seeds are susceptible to pests. These conditions can result in reduced yields in no-till situations, particularly in cool, wet springs, and on poorly drained soils. Other conservation tillage systems, such as reduced-till or ridge-till, would be better choices under these conditions.

Many producers trying no-till corn for the first time are doing so following a soybean crop. Fewer planting problems are encountered in this sequence because soybeans produce less residue than other crops, the residue is easily managed, and the soil is generally loose and mellow. Soybeans typically produce 45 pounds of residue per bushel of grain, whereas corn, grain sorghum and wheat produce 60, 60, and 100 pounds of residue per bushel of grain, respectively.

Planting Date

Planting corn early is important to utilize the growing season and maximize yield. Planting dates range from late March in southeastern counties to mid-May in northwest Kansas (Figure 2), Many producers use soil temperature to determine planting time. Planting when the soil temperature reaches 55°F at a 2-inch depth appears to be an excellent guide. Late planted corn is taller than optimum plantings and often used for silage. Although taller, total dry matter production is lower with late plantings and producers need to be aware of lower silage yields. Hybrids respond differently to varied planting dates. Full-season hybrids planted at optimum dates to utilize the fall growing season have a greater yield potential than early-season hybrids.

Many producers have adopted the early corn concept, which utilizes an early maturing hybrid (90 to 110 day maturity) planted 10 days to two weeks earlier than planting dates suggested in Figure 2. This allows the early corn to be in its reproductive and grain tilling stages before heat and drought stresses usually occur in Kansas (see *Early Corn Production, MF-1095).*

Plant Populations

The optimum plant populations depends on the yield level a particular environment will permit. This explains the wide plant population range across the state. The desired plant population for dryland corn in a wheat-corn-fallow rotation in northwestern Kansas may be only 13,000 to 18,000 plants/acre; whereas dryland corn in northeastern Kansas may require 18,000 to 24,000 plants/acre to maximize yield (Table 3). Most irrigated corn plant populations will range from 24,000 to 30,000 plants/acre, with some as high 32,000 plants/acre. If irrigation is limited, the desired plant population may range from 16,000 to 25,000 plants/acre depending primarily on soil type and amount of available water. Early corn should have final stands of 10 to 15 percent higher than those suggested in Table 3. The final or harvest plant population is approximately 85 percent of the planting rate. For example, if a harvest population of 12,000 plants/acre is desired, the seeding rate should be 14,100 seeds/acre to obtain that population (Table 4). Corn can compensate by producing larger ears if populations are too low to utilize growing conditions. Table 5 shows the estimated yield potential for different plant populations and ear weights. An average ear weight is near 0.5 lb.

Hybrids also respond differently to plant populations. When the population is too high, some hybrids will have barren stalks and produce lower grain yields. In addition to yield differences, the effect of population on root and stalk lodging should be noted. Lodging increases as population levels increase, but the problem is more severe with some hybrids. Consult seed company recommendations for desired plant populations of specific hybrids.

Planting Depth

The speed of germination and emergence depends on planting depth and soil temperatures. Corn emergence at 50–55°F may take 18–21 days, while at 60-65°F, corn emerges in 8–10 days. Below 50°F little, if any, germination can be expected. Soils are colder at increased depths, which may slow germination and subject the seed to diseases or insects resulting in seed injury. Early plantings will emerge quicker with planting depths of 1.5 to 2 inches than if planted deeper. Sandy soils warm more rapidly than fine-textured soils because they hold less water. Planting 2 to 3 inches deep in sandy soils is necessary to prevent drying of the seed zone if dry conditions follow planting. Planting depth over 3.5 inches under any soil condition may cause emergence problems,

Planting seed deep does not mean corn roots will be deeper. Roots that come directly from the kernel are temporary. Permanent roots develop at nodes above the seed and form at the same soil depth regardless of plantings depth.

Seed Size and Shape

Hybrid seed corn is available in different seed sizes and shapes. Seed location on the ear influences seed size and shape; large round seed comes from the ear base, small rounds from the tip and flat seed from the center. Research findings indicate yield potential is not influenced by seed size and shape.

Table 3. Suggested final corn populations.

Northwest (dryland)	13,000 to 18,000
Northeast	18,000 to 24,000
East central and Southeast	16,000 to 20,000
Central	14,000 to 18,000
Irrigated	24,000 to 30,000
Limited irrigation	16,000 to 25,000

Table 5. Yield potential of different corn plant populations at two average ear weights.

Plants/acre	.5 lb ear	.6 lb ear
8,000	57	69
12,000	86	103
16,000	114	137
20,000	143	171
24,000	171	206
28,000	200	240

Adapted from Nebguide G79-487

Table 4. Seed spacings required to obtain harvest populations of from 12,000 to 28,000 plants per acre.

Harvested population	Seeds/acre[1] planted	Row width. inches 30	36	Row width, inches 30	36
		seed spacing, inches		seeds/10 ft. of row	
12,000	14,100	14.75	12.25	8	10
14,000	16,500	12.50	10.50	10	11
16,000	18,800	11.00	9.25	11	13
18,000	21,200	9.75	8.25	12	14
20,000	23,500	9.00	7.50	13	16
22,000	25,900	8.00	6.75	15	18
24,000	28,200	7.50	6.25	16	19
26,000	30,600	6.75	5.75	18	21
28,000	32,900	6.25	5.25	19	23

[1]Assuming high germination and that 85 percent of seeds produce plants.

Nutrient Management

Total nutrient use on corn is greater than on any other crop grown in the United States. Even with good management, few mineral soils will sustain corn production of 100 or more bushels per acre without addition of chemical fertilizer, manures, or using legume rotations. The approximate removals of nutrients by grain and stover from a 150 bushel per acre crop grown on a representative soil from the Corn Belt are given in Table 1. This data shows that harvesting only the grain removes considerably less nutrients than if the entire crop is harvested for silage.

Determining Fertilizer Need

Fertilizer and lime need can be determined by several methods—soil tests, field trials, nutrient removal, plant analysis, past experience, or a combination of these. The most reliable means of determining fertilizer need is by soil testing regularly with support from the other methods listed. Remember a soil test is no better than the sample collected in the field.

Soil test interpretations are based on many years of research work conducted across the state. Reliable interpretations can be made for the likelihood of obtaining a response, provided yield potential is not restricted by other factors.

Soil test results have value in addition to determining fertilizer needs for the following crop. By keeping soil test records over a period of years on a field, these records become an excellent means of assessing the adequacy of the fertilizer program being followed. For example, an increase in the soil test values in successive samplings for an element indicate that the application rate is in excess of the amount being utilized by the plants. If the soil test level for the nutrient is above the medium interpretation level, then a reduction in rate or no application maybe desirable for a couple of years until a new soil test is taken. In contrast, a decrease in soil test values indicates the plant removal is greater than application rate. In many cases where fertilization has been practiced for several years, monitoring of soil test levels becomes an important part of the soil test program.

Nitrogen

Nitrogen (N) is the nutrient most frequently lacking for optimum corn production. Most of the Kansas corn acreage will require at least some N fertilizer. Nitrogen recommendations vary with expected yield, soil texture, cropping sequence, manure use and the level of residual N in the soil.

A soil test for available nitrogen in the soil profile is recommended where nitrogen and/or manure applications have been excessive relative to yields. The nitrogen soil test results are interpreted for reduction in the nitrogen fertilizer recommendation to utilize accumulated available nitrogen. Consult the soil sampling instructions for proper sampling procedure and handling of the samples. Samples should be taken to a depth of 2 feet and must be air-dried after collection to minimize mineralization in handling and shipping.

Another important consideration in determining the optimum nitrogen fertilizer rate is cropping sequence. Research in Kansas and adjoining states shows nitrogen credits for legumes grown in rotation with sorghum can be substantial. Table 2 summarizes nitrogen credits for legumes in rotation with corn, and the basic nitrogen recommendations should be adjusted for these credits.

Field comparisons conducted by Kansas State researchers indicate little agronomic difference between nitrogen materials when properly applied. Material selection should be on the basis of cost (applied), availability of material, adaptability to farm operations, and available dealer services.

Nitrogen application for corn can be made at several times with equal results on most land in Kansas. Nitrogen may be applied before planting, at planting time, and as a sidedressing after corn is up. The best time for application depends on the form of nitrogen fertilizer, the soil, and the climate. Nitrogen uptake by corn is quite rapid in a period starting about 25 days after emergence and by the time of silking 60 percent of the total nitrogen has been taken up (Figure 1).

Table 1. Approximate amount of nutrients removed by 150 bushel corn crop per acre[1].

Element	Quantity in Grain lb	Quantity in Stover lb	Element	Quantity in Grain lb	Quantity in Stover lb
Nitrogen	115	55	Chlorine	4	68
Phosphorus (P_2O_5)	66	16	Iron	0.10	1.80
Potassium (K_2O)	42	168	Manganese	0.05	0.25
Calcium	13	35	Copper	0.02	0.08
Magnesium	10	29	Zinc	0.17	0.17
Sulfur	11	8	Boron	0.04	0.12
			Molybdenum	0.005	0.003

[1] Barber, S.A. and R.A. Olson, 1968. Fertilizer use on corn. In Changing Patterns in Fertilizer Use

Table 2. Nitrogen credit for legumes in rotations.

Previous Legume	Nitrogen Credit lb/a
Alfalfa > 80% stand	100-140
60-80% stand	60-100
< 60% stand	0-60
Second year following, ½ first year credit	
Red clover	40-80
Sweet clover	100-120
Soybeans	30-60

Nitrogen recommendations can be calculated by using these factors:

N Rec = [YG x 1.35lb/bu]STA - PCA - PYM - PNST

where,

N Rec—nitrogen recommended in pounds per acre
YG—a realistic yield goal in bushels per acre
STA—soil texture adjustment (1.1 for sandy soils and 1.0 for medium and fine textures)
PCA—previous crop adjustment [use Table 2 for previous legumes, 20 lb for fallow (if no profile N test) and 0 for all other previous crops.]
PYM—previous years manure (50 lb for last year, 20 lb for 2 years ago and 0 for no manure history)
PNST—Profile nitrogen soil test results where,

Surface: __ppm N × .3 × __depth, in = __lb/a
Subsoil: __ppm N × .3 × __depth, in = __lb/a
Profile N = __lb/a

Note: If no available nitrogen test run, then use default value of 30 for PNST.

Example:

Expected Yield—140 bu/a	Soil test results
Soil Texture—silt loam	0–6 in—12 ppm N
Previous Crop—corn	6–24 in—6 ppm N
Previous Manure—none	

N Rec = 140 bu/a x 1.35 lb/bu) 1.0-0-0-54[1] = 135 lb/a
[1](12 ppm x .3 x 6 in + 6 ppm x .3 x 18 in)

Nitrogen applications should be timed so that nitrogen is available when needed for this rapid growth. A small amount of nitrogen may be applied in a starter fertilizer to meet early season needs. Preplant nitrogen applications, except on sandy soils, can be made in late fall or spring with little concern for leaching loss. On sandy soils, preplant nitrogen applications should be delayed until spring. Nitrogen application should also be delayed on fine textured soils subject to standing water or flooding. If nitrogen is applied sidedress, the applications should be made early (i.e. five-leaf stage) to avoid weather conditions preventing application. With sprinkler irrigation on sandy soils, application of the nitrogen through the irrigation system has been quite satisfactory. Application of nitrogen through irrigation systems under other soil conditions is possible, but remember the fertilizer distribution is no better than the water distribution. Do not use any nitrogen material that contains free ammonia when applying through a sprinkler system unless special precautions are taken.

Phosphorus

Phosphorus applications should be based on a soil test. Consistent responses to phosphorus fertilization have generally occurred on soils testing very low or low in available

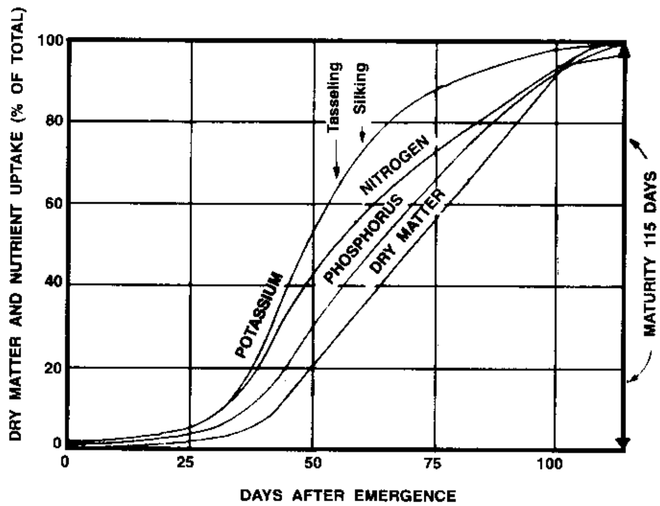


Figure 1. The uptake of nutrients by a corn plant and the increase in dry matter in relation to the number of days after emergence. (Source: Hanway, J.J., 1960. Growth and Nutrient Uptake by Corn, Iowa State University Extension Pamphlet No. 277).

phosphorus where yield potential is not restricted by low rainfall. With medium testing soils, responses have been less consistent and smaller. Phosphorus applications are recommended with medium soil tests to achieve maximum potential yield response and to maintain the soil in a highly productive condition. Phosphorus recommendations are shown in Table 3.

Phosphorus can be applied either preplant-broadcast, preplant banded with nitrogen (dual placement), or banded at seeding (starter). Banded applications are recognized as being most efficient, particularly when small amounts are applied on very acid or calcareous soils low in available phosphorus, Savings in time at seeding achieved by broadcasting rather than banding may offset lower efficiency for the broadcast application. Starter applications can be placed in direct contact with the seed or placed to the side and below the seed (preferred). If placed in contact with the seed, the starter material should contain no more than 10 pounds per acre of nitrogen plus potash. The nitrogen and potash can cause germination damage. Preplant applications, broadcast or dual applications, can be made in the fall or spring and the broadcast application should be thoroughly incorporated because phosphorus does not move appreciably in the soil.

Liquids and solids, as well as varying chemical forms of phosphorus (ortho- and poly-phosphates), are available on the market. Research conducted by Kansas State researchers indicates that, in general, all are agronomically equal. Therefore, selection of a phosphorus source should be made on the basis of cost, availability, and adaptability to your operation.

Table 3. Phosphorus Recommendations for Corn

Management[2]	Area of State	Soil Test Phosphorus, ppm[1] Very Low (0–5)	Low (6–12)	Medium (13–25)	High (26–50)	Very High (>51)
		Pounds of P_2O_5 per Acre				
Irrigated	Entire	60–80	40–60	20–40	0–20	None
Non-irrigated	Eastern	40–60	20–40	0–3	None	None

[1]Soils extracted with 0.025 N HCl in 0.03 N NH_4F using a 1:10 soil to solution ratio.
[2]These recommendations are for both grain and silage production.

Table 4. Potassium Recommendations for Corn

Management[2]	Area of State	Soil Teat Potassium, ppm[1] Very Low (0–40)	Low (41–80)	Medium (81–120)	High (121–160)	Very High (>161)
		Pounds of K_2O per Acre				
Irrigated	Entire	80–100	60–80	40–60	20–40	None
Non-irrigated	Eastern	60–80	40–60	20–40	0–20	None

[1]Soils extracted with 1 N ammonium acetate using a 1:5 soil to solution ratio.
[2]If corn is used for silage, then add 40 pounds of K_2O to recommendations.

Potassium

Like phosphorus, a soil test is your best guide to potassium need. The uptake of potassium is almost 80 percent completed at silking time (Figure l.) Most of the potassium taken up is returned to the soil in the leaves, stalks, and plant residue, unless these plant parts are removed for silage or other forms of feed (Refer to Table l). Additional potassium should be applied in the cropping sequence when corn is grown for silage. Potassium deficiencies are most likely to be found in southeastern Kansas and on sandy soils in other areas of the state. Potassium recommendations are shown in Table 4.

Potassium can be applied preplant-broadcast or as a starter. Broadcast applications should be thoroughly incorporated to place the potassium in the root zone. The most common potassium source is muriate of potash (potassium chloride), however, potassium sulfate, potassium nitrate, potassium-magnesium sulfate and mixed fertilizers are other sources of potassium. Little difference exists between materials in potassium availability. Selection should be based on cost, availability and adaptability to the overall farm operation.

Lodging of corn at maturity has been a problem in some areas of Kansas and has resulted in considerable harvest loss. Research has shown that lodging occurs due to many stress factors, weather, insect and disease damage, varieties, date and rate of planting, and nutrient imbalance. Adequate potassium is essential for sturdy stalks. Research has shown that potassium fertilization can reduce lodging on medium to low test soils. However, application of high rates of potassium fertilizer for insurance against lodging is not recommended. Proper fertilization with adequate levels of all nutrients plus general good crop management practices are the best way to minimize lodging. Weather conditions also play a major role in lodging.

Liming

Lime recommendations are based on a program of maintaining the soil in a productive condition. Although corn is not the most responsive crop to lime, the liming of acid soils should not be ignored. The benefits in any one season may not be great, but for the continued production of corn and other crops on the land, liming is a sound farming practice. Little corn yield response to lime is likely in most areas of Kansas (except Southeastern Kansas) at soil pH's above 5.5 because of higher soil pH's in the subsoil. In the eastern third of Kansas, lime is recommended on all soils with a pH of 6.0 or less. For the Western two-thirds of Kansas, lime is recommended on soils with a pH of 6.0 or less and a subsoil pH of less than 6.4.

Other Elements

Secondary and micronutrient research on corn has demonstrated the need for added sulfur, zinc, and iron in some situations. Calcium is relatively abundant in the majority of Kansas soils. Liming of acid soils supplies sufficient calcium and a deficiency of this element would not be expected. Research with boron, copper, and manganese has not revealed any consistent responses and these elements should not be a problem for optimum corn yields.

Magnesium research in Kansas has not shown a grain yield response to magnesium. Observations have been made of relatively low magnesium in plant samples analyzed, but with no yield increase to added magnesium. Sandy soils of low cation exchange capacity would be the most likely soils to be low in magnesium.

Sulfur may be of concern on sandy, low organic matter soils. Sulfur yield responses have been noted on irrigated sandy soils in Kansas only when sulfur levels in the irrigation water are low. Much of the irrigation water in Kansas contains appreciable sulfur and this reduces the likelihood of sulfur response. Soil test sulfur levels alone are poor

Table 5. Zinc Recommendations for Corn[1]

Management[2]	Area of State	DTPA Zinc Soil Test (ppm Zn) Low (0–0.5)	Medium (0.51–1.0)	High (above 1.0)
			lb/a Zn	
Irrigated	Entire	8–10	2–5	None
Non-irrigated	Eastern	8–10	2–5	None

[1]Based on the use of zinc sulfate as source of zinc; check general guide for other materials.

predictors of the likelihood of sulfur response. More research is needed on magnesium and sulfur before any general recommendations or soil test interpretations can be made. Farmers concerned with these two elements should try them on a small area on their own farms.

The need for zinc and iron can be predicted by soil tests. Table 5 shows zinc recommendations for corn. Zinc is most likely deficient on areas where the topsoil has been removed and under high yield conditions. Iron deficiency is most likely to occur in the western half of Kansas on soils where erosion or leveling has exposed highly calcareous subsoil, low in organic matter.

The zinc will usually be applied in conjunction with the phosphorus and potassium and time and method of application discussed in those sections are applicable to zinc.

Inorganic and organic (chelate) sources of zinc are available for application with the chelates being in general 3 to 5 times more effective per pound of metal. Remember, however, that low application rates are more effective if banded close to the seed.

No economical soil applied source of iron is available at this time for correction of iron deficiency in corn. Foliar sprays of iron and manure application are the most effective methods of correcting iron chlorosis. For more details on iron and zinc recommendations, see Kansas State University Extension circular *Soil Test Recommendations.* C-509.

Weed Management

Introduction

Summer annual broadleaf and grass weeds typically inhabit Kansas corn fields. The common broadleaf species include pigweeds, velvetleaf, cocklebur, kochia, smartweed, and puncturevine. Common grass weeds include shattercane, large crabgrass, foxtails, field sandbur, fall panicum, and barnyardgrass. Perennial weed species important in corn fields include johnsongrass, field bindweed, and bur ragweed,

Weedy plants and corn plants require the same resources for growth: nutrients, water, and sunlight. Use of these resources by growing weeds makes them unavailable for corn growth. Typically, there is a pound for pound tradeoff of corn dry matter for weed dry matter. In other words, every pound of weed dry matter in the producer's field comes at the expense of a pound of corn dry matter that could have grown there. It is vital, therefore, that weeds be managed in the corn crop.

Integrated Weed Management

A variety of methods are available for weed management in corn. Crop rotation with soybeans, forage crops, or cereal grains provides many more opportunities for low-cost weed control, than does continuous corn cropping. Many Kansas corn producers find row-crop cultivation to be a cost-effective weed management practice.

Field corn is well adapted to early planting, which allows it to become established before many summer annual weeds germinate. Corn is vulnerable to weed competition for about the first four weeks, a time span that often coincides with cold spring temperatures, Thereafter, the established corn plant grows rapidly and the crop becomes highly competitive. Thus, a successful weed control strategy should assure weed-free conditions for about a month after planting. Weeds germinating after that time pose little threat of yield reduction, but may interfere with harvesting,

No-Tillage and Low-Tillage Corn

Field corn production lends itself readily to low-tillage or no-tillage planting. Corn may be planted into undisturbed crop residues from the previous year, as well as directly into killed alfalfa or smooth brome sods, Before planting, winter annual weeds such as mustards, marestail, prickly lettuce, cheat, downy brome, etc. must be controlled with tillage or with foliar-absorbed herbicides. Most often, herbicide mixtures containing atrazine, *Bladex,* and crop oil concentrate adjuvant are applied before planting to destroy emerged weeds, and provide residual weed control. Addition of 2,4-D is advised if herbicide applications have been delayed and weeds are more than 2-inches tall. Paraquat *(Gramoxone Extra)* may he added to atrazine for additional preplant weed burndown. Sometimes, acetamide herbicides such as

Dual, Micro-Tech, or *Frontier* are applied in place of, or in addition to, *Bladex.* These herbicides do not help burn down emerged vegetation, but play an important role in residual control of grasses and small-seeded broadleaf weeds. In fields where triazine herbicide use is not advisable, *Roundup* plus 2,4-D may be used to control emerged weeds before planting.

Enhanced water use efficiency of no-till planted corn has expanded the range of dryland corn production in Kansas. Higher rates of atrazine may be applied to wheat stubble in fields with a wheat-corn-fallow (ecofallow) rotation. Weed and volunteer wheat control is necessary during the 9-month period between wheat harvest and corn planting, to enhance the soil moisture storage required for successful dryland corn production. This innovation permits producers in traditional wheat-fallow areas to intensify production, and use soil-conserving crop rotations.

Some corn growers elect to perform some tillage to control weeds prior to planting corn. Preplant incorporated herbicides such as *Sutan+* and *Eradicane* may then be used. The acetamide herbicides maybe shallow incorporated before planting, or surface applied before, during or shortly after planting. *Prowl* must not be incorporated, or serious corn injury may occur.

Weed Control after Emergence

Many Kansas corn producers cultivate their corn. Advantages are the control of weeds that have escaped previous treatments and the opportunity to side-dress additional nitrogen fertilizer. Heavy duty cultivators now on the market permit cultivation even in no-till planted corn. Guidance systems improve cultivator precision, reduce operator fatigue, and increase driving speed. Significant herbicide savings result from banding residual herbicides over the row at planting, and then controlling inter-row weeds with cultivation. Furrow-irrigated corn, and ridge-tilled corn, is often managed with very low herbicide inputs. Such herbicide savings are accompanied by increased risk of yield-reducing weed competition, however, if timely cultivation is not achieved.

Certain annual weed problems may emerge in corn, especially where atrazine rates have been kept low. Velvetleaf, common sunflower, cocklebur, and kochia maybe controlled with postemergence applications of *Buctril+atrazine, Laddok, Marksman,* or *Sencor* plus *Banvel.* Timely use of these herbicides provides excellent control of most broadleaf weed species, with less potential for corn injury than higher rates of *Banvel* or 2,4-D applied alone.

Recent herbicide innovations permit control of shattercane and seedling johnsongrass in corn. *Accent, Beacon* and *Pursuit* herbicides, with appropriate adjuvants, provide excellent control of emerged shattercane and johnsongrass seedlings. Weeds of other species are controlled to different degrees, and may require tank mixtures. *Pursuit* may be applied only to imidazolinone resistant or tolerant corn hybrids. Good rhizome johnsongrass control can be achieved with *Accent* or *Beacon.*

Special Situations

Alternative methods of weed control are sometimes needed. For example, planting-time herbicides may be short-lived, especially on irrigated sands. Residual herbicides such as trifluralin *(Treflan)* or *Prowl* may be applied at lay-by, and incorporated mechanically or with irrigation water, to extend control of grass weeds such as longspine sandbur and shattercane. These herbicides do not injure established corn or weeds. Therefore, emerged weeds must be controlled by other means, and corn must be at least 4-inches tall before applying these two herbicides,

Where corn and weeds differ greatly in size, nonselective herbicides such as *Evik* and *Gramoxone Extra* may be applied postdirected. Corn should be at least 12-inches tall, with no more than the bottom 3 inches coming in contact with the herbicide. As with all postemergence herbicides, thorough coverage is required for good control.

Additional Information on Chemical Weed Control

This bulletin explains some of the alternatives available for weed management in corn. For more specific information on herbicides and their use in corn, request a copy of Chemical Weed Control for Field Crops, Pastures, Rangeland, and Noncropland, which is updated annually, from your county extension office or from the Distribution Center, Umberger Hall, Kansas State University, Manhattan, KS 66506.

Insect Management

Below Ground Insect Problems (seed-destroying or root pruning insects)

Several insects can attack and destroy corn seed before it germinates, leadlng to reduced plant populations. These insects are most likely to cause economic damage where cool-to-cold soils occur at planting and where inadequate or excessive surface moisture combine to delay germination. Seed protectants are insecticides applied to the surface of the seed to minimize this damage. Seed maybe pretreated or receive a “planter-box” treatment.

Seed protectants may be most beneficial where a recent field history of sod, alfalfa, reduced tillage, and/or favorable soil conditions delay germination. In most instances, insecticide seed protectants should be considered where planting time soil insecticides for rootworms, grubs, and/or wireworms are not used and planting occurs before June 2 in southeast Kansas, June 4 in south central Kansas, June 5 in northeast Kansas, June 7 in southwest Kansas, and June 12 in northwest Kansas. Be especially concerned if many adult seed corn maggot flies, seed corn beetles, and/or wireworms are noticed when the soil is worked before planting.

Root pruning and below-ground stalk chewing insects include corn rootworm larvae, wireworm larvae, and white grubs. Because seed protectants do not protect the plant after the seed coat is ruptured at germination, different application methods must be used when applying insecticides. Western and northern corn rootworm larvae are probably most consistently avoided if crops are rotated annually. Rootworms rarely cause economic damage except where corn follows corn because the adults prefer to lay eggs in corn fields and the larvae have a very difficult time surviving on any other plants.

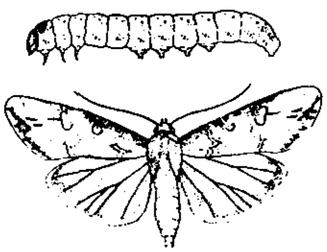
Banding the insecticide gives better rootworm suppression, whereas wireworms are probably more effectively suppressed if the insecticide is applied in-furrow. Expect to hear more about control strategies directed against adult corn rootworms to prevent egg laying. Frequent (weekly) scouting of fields is necessary for this strategy to work as a substitute for soil-applied planting time treatments. Where wireworm or white grub infestations are very heavy, replanting (sometimes more than once) may be necessary. Wireworm and white grub problems are typically most severe where corn follows a sod crop such as brome. When the soil surface is dry, cutworms may cut plants below the soil surface.

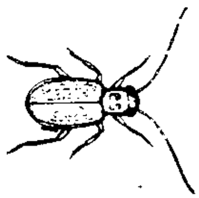
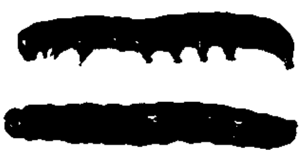
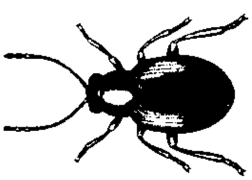
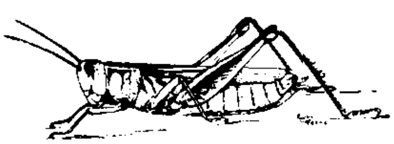
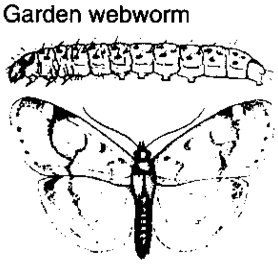
Above Ground Insect Problems (leaf chewing, stalk boring, sap feeding, or silk feeding insects)

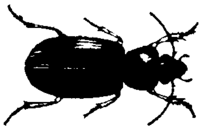
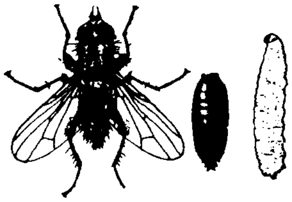
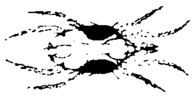
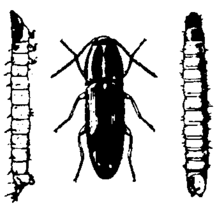
Insects attacking seedling plants above ground include thrips, flea beetles, chinch bugs, stalk borers, cutworms, and garden webworms. Black cutworm larvae are most commonly a problem in the eastern $^{1}/_{3}$ of the state. The risk of cutworm injury is greater in fields that were weedy just prior to planting. Sometimes cutworms are more serious in no-till or reduced tillage operations.

Between 2-feet tall and tassel stage, corn plants maybe attacked by first generation European and southwestern corn borers, fall armyworms, and corn earworms. After tassels have emerged, most insect problems will be caused by western bean cutworms, adult corn rootworm beetles, grasshoppers, fall armyworms, corn earworms, beet armyworms, true armyworms, second generation European and southwestern corn borers, spider mites, and/or corn leaf aphids.

See *Insect Management for Corn,* MF-810 for currently recommended insecticides. Check with your county Extension agent for information on the availability of corn insect diagnostic and management software currently being developed for microcomputers by specialists at Kansas State University.

Insect	Description	Injury
Armyworm (true)	*Pseudaletia unipuncta* Greenish-gray larvae have pinkish lines long the body that extend over the eye,	Infestations occur in May in wheat, barley or brome grass. "Armies" may migrate across seedling corn; a later generation may injure corn foliage. Treat when 2 larvae/30 percent plants or 1 larvae/75 percent of plants occur. Larvae should be less than 1¼" long.
Beet armyworm	*Spodoptera exigua.* Greenish larvae.	Moth flights into grassy corn defoliate leaves as true armyworms, leaving only midrib.
Black cutworm 	*Agrotis ipsilon.* Blackish larvae below ground.	Larvae destroy seedling plants up to 6-10" high; stands disappear. Apply rescue treatments when 3 to 5 percent of plants (2-leaf stage) are being cut and worms are ½ inch or less long.
Chinch bug 	*Blissus leucopterus.* Adults are ¼" long red-and-black bugs with a distinct color. Migrate from small grain; found behind the leaf sheath of lower leaves.	Plants die from sucking injury of bugs. Infestations may be damaging on seedling corn where populations of 4-5 bugs per plant are present. Larger corn may be able to tolerate light to moderate infestations.

Insect	Description	Injury
Corn earworm 	*Heliothis zea.* Larvae have 4 prolegs, brown heads and microspines which give a rough appearance to body surface. Color may be pink, green or brown with a distinct white line along side. Moth flights come from the south.	Ragworm (large holes in leaves of whorl before tassel). Later generations attack tip of ear. Not practical to control in ear tips of field corn.
Corn leaf aphid	*Rhopalosiphum maidis.* Green aphid with dark green head and thorax. Black antennae and cornicles. Populations concentrated in the whorl. Heavy populations on sterile plants.	Not considered of economic importance.
Corn rootworm 	*Diabrotica virgifera or Diabrotica longicornis.* Yellowish-green beetles, $^{3}/_{8}$" long with or without 2 black-stripes. Milky white larvae may be up to ½" long with a dark abdominal plate which makes them appear to have 2 heads.	Adults lay eggs in cornfield for next year's problem. Adults may clip silks before pollinating. Larvae destroy roots causing goose-necked plants.
European corn borer 	*Ostrinia nubilalis.* Light tan moth with indistinct lines and spots on wings. Larvae 1" long, dirty gray in color with indistinct spots.	June larvae tunnel into stalks; August larvae tunnel into both stalks and ear shanks. Economic levels vary but an average of 1 larvae/plant that hasn't entered the stalk usually requires treatment. More precise thresholds can be calculated by hand or with KSU-developed microcomputer software. See your county agent.
Fall armyworm 	*Spodoptera frugiperda.* Larvae have inverted "Y" on head and 4 black spots forming a square at the top rear of the larvae.	Ragworm injury in whorls; attack tip or shank or ears. Only treat whorl infestations if larvae are present on 75 percent of the plants.
Flea Beetle 	*Haltincinae.* Tiny black beetles.	Strip surface from seedling leaves. Treatment not usually jusfified unless 4 to 5 beetles/plant occur and plants are stressed by low temperature or soil moisture levels.
Grasshoppers 	*Acrididae.*	Destroy leaves or cut silks especially in field margins. Field sprays may be justified if 5 to 8 hoppers per square yard are present from just before pollination through anthesis.
Garden webworm 	*Loxostege rantalis.* Slender green worms with black spots.	Strip foliage of plants less than 3 feet tall.

Insect	Description	Injury
Maize billbug	*Sphenophorus maidis.* Black snout beetles. Legless larvae bore into base of stalk.	Minor Problem in overflow land with sedge growth.
Seed corn beetle 	*Agonoderus lecontel.* Brown beetles, $\frac{3}{8}$" long with 2 black stripes.	Destroy seed before germination.
Seed corn maggot 	*Hylemya platura.* Larvae of fly; no head or legs.	Destroy seed before germination.
Southwestern corn borer	*Diatraea grandiosella.* White larvae with distinct black spots; loses spots in winter.	First generation larvae tunnel into stalks in June; second generation larvae tunnel into stalks in August. In September larvae girdle stalks. A programmable calculator model is available to direct scouting efforts. See your county agent.
Spider mites 	*Tetranychidae.* Size of pencil dots. Four pair of legs.	Leaves blasted by dried-out cells on leaf surfaces. See MF 762 "Managing Spider Mites on Field Corn and Grain Sorghum" for management information.
Stalk borer 	*Papaipema nebris.* Striped worms with purple margin behind heads.	Bore into plants less than 3 feet high along field margins.
Thrips	*Thysanoptera.* Tiny insects with rasping mouthparts.	Leaves of seedling plants blasted.
Western bean cutworm	*Loxagrotis albicosta.* Light brown worms in tassel before entering ear at tip, shank or side.	Severe damage to ears. Treat if 8 to 14 plants/100 plants have eggs or small larvae and corn is 95 percent tasseled.
White grub	*Scarabaeidae.* C-shaped larvae found in soil.	Prune plant roots.
Wireworms 	*Elateridae.* Slick brown worms live several years in the soil.	Destroy seed or bore into stalks below ground.

Disease Control

Corn in the Midwest is vulnerable to a number of diseases that reduce yield and quality. Yearly losses range from 7 to 17 percent on the average with this figure being higher in localized areas. Ear and kernel rots decrease yields and quality while increasing the cost of harvesting. Leaf diseases reduce the photosynthetic area of the plant and limit the production of sugars, which in turn prevents kernel development.

Diseases of corn, like those of other crops, vary in severity from year to year and from one locality or field to another, depending on the presence of the pathogen, weather and soil conditions, and the relative resistance or susceptibility of the corn. Even when the proper combination of disease-causing organism and favorable environmental conditions are present, only limited disease losses will occur if the corn hybrid is tolerant or resistant.

The potential for disease epidemics is always present. One cause is genetic uniformity, typified by single cross hybrids. Another is the intensive cultivation of corn resulting from continuous cropping, higher plant populations and heavy fertilizer applications to achieve maximum yields. Changes in tillage operations from conventional tillage to various reduced tillage systems also have allowed some pathogens to become more firmly established.

Diseases Caused by Fungi

Seed Rots and Seedling Blights

Seed rots and seedling blights can be a problem of early planted corn in Kansas. Severity is often determined, in part, on weather conditions following planting. Seedling diseases are more prevalent in cold, wet soil than in warm soil. Additional stresses such as planting too deep, incorrect rates or placement of herbicides and insecticides, and old seed can all lead to increased amounts of disease. Even seed protectant fungicides cannot always overcome the effects of poor germination conditions that result in delayed emergence. Seedlings that survive attack may be less vigorous and develop into less productive plants than healthy seedlings.

Symptoms

Seed rot diseases usually result in the rotting of the seed prior to germination. Above ground symptoms of seedling blights include a general lack of vigor, yellowing, wilting, and death; symptoms that could easily be confused with mechanical or chemical injury, or insect damage. Careful examination of the plants at or below the soil line, however, will show that water-soaked or decayed seedling tissue is cutting off the plant's supply of essential water and nutrients and causing the problem.

Management

1. Seed protectant fungicides.
2. Use of injury free seed of high germination.
3. Delay planting until soil temperatures attain a minimum 55°F and the threat of extended periods of cold weather has passed.
4. Use good cultural practices that will allow for proper soil-seed contact and the correct placement of fertilizers and pesticides.

Stalk Rots and Root Rot

Stalk and root rots are the most prevalent diseases of corn in Kansas. Annual losses are estimated at 5 percent of the crop and in some areas the losses may approach 50 percent. These losses may be direct (poor filling of ears or light-weight and poorly finished ears) or indirect through harvest losses because of lodging or stalk breakage as ears lost on the ground. When rainfall is above normal, fungi soon destroy ears in contact with the soil. Generally, stalk and root rots are caused by a complex of fungi and bacteria that attack the plants after silking; the most common being the fungi causing Diplodia, Gibberella, Fusarium, Anthracnose, and Charcoal rots. The symptoms of these rots are very similar.

The development of stalk rots is favored by dry weather early in the growing season followed by extended periods of rainfall shortly after silking. Unbalanced fertility, low potassium (potash) in combination with high nitrogen levels, poor soil drainage, mechanical and insect damage, susceptible hybrids, plant populations, and row spacing are factors responsible in disease severity. Rots are commonly found in soils high in organic matter content with very high levels of available nitrogen and low levels of potassium. Excessive plant populations increase the incidence of stalk rots and stalk lodging, especially when plants are under stress from a lack, or imbalance of nutrients or water. Locally adapted, full-season hybrids are generally more resistant than earlier maturing plants. It is important to choose a hybrid with strong stalks, particularly if a field has a history of stalk rot.

Symptoms

The symptoms generally appear several weeks after silking as the leaves wilt, become dry, and appear grayish-green resembling frost injury. The stalk dies several weeks later. The diseased stalk is easily crushed and breaks readily during wind or rainstorms. The most characteristic symptom of stalk rot is the shredding of the internal part of the stalk in the lower internodes. This shredded tissue may be brown, red, salmon or black depending on the fungus involved.

Management

1. Tolerant hybrids
2. Balanced soil fertility; avoid high levels of nitrogen and low levels of potassium.
3. Reduce plant populations or at least match populations to fertility and water availability.
4. Supply sufficient water throughout the growing season and especially from silking through filling.
5. Control insects—especially corn rootworm and corn borer.
6. Crop rotation.

Ear and Kernel Rots

Corn is susceptible to a number of ear and kernel rots, especially when rainfall is above average from silking to harvest. Losses are increased by hail, insect and bird damage to the ear, and by lodging of stalks that will enable the ear to touch the soil. Corn ears that are well covered by husks and those that mature in a downward position have less rot than ears with open husks or those that mature upright.

Symptoms

Numerous fungi are capable of inciting ear and kernel rots. Those observed in Kansas include: Diplodia, Fusarium, Penicillium, Trichoderma and Aspergillus ear rot. Symptoms among these diseases are similar. Generally, there is a discoloration of the kernels. This may be white, pink, gray, or black. A bluish-green or grayish mold also maybe present. Often the affected ears are light-weight, poorly finished, and a portion or all of the ear may be rotted. The husks are often prematurely bleached and may be completely rotten.

Ear rot caused by *Aspergillus flavus* has been found to produce aflatoxins, which can affect the health of both animals and man. The fungus enters kernels through growth cracks and injuries caused by insects and birds. It is most severe in years when there is drought stress during kernel development followed by wet conditions late in the season.

Management

1. Several hybrids are reported to be tolerant to several ear and kernel rots.
2. Early harvest.
3. Proper storage; below 18 percent moisture initially for ears, 15 percent for shelled grain, and temperatures below 50°F.

Leaf Spot and Blights

Corn is susceptible to a large number of fungal leaf diseases, particularly during prolonged periods of rainy weather with mild temperatures. Some of the common diseases found in Kansas are: northern leaf blight, brown spot, gray leaf spot, eyespot, and anthracnose.

Symptoms

The symptoms are basically characterized by necrotic lesions, which can range from as little as $^{1}/_{16}$ inch in width (eyespot) to as much as 5 to 6 inches in length (northern leaf blight). They may be oval, oblong or rectangular depending on the pathogen. The lesions often have a distinct border which can vary in color from tan to red depending upon the disease. A laboratory diagnosis is usually required for positive identification.

Management

1. Resistant varieties.
2. Fungicide applications maybe utilized during severe disease outbreaks.
3. Fall plowing to eliminate residue will reduce early season infections,
4. Crop rotation.

Common and Southern Rust

In Kansas, two rusts are commonly found on corn. They are common rust, which is the most often observed disease in the state, and southern rust, which is usually confined to late season infections which cause little or no damage. Although widespread, losses to rust are usually less than 2 percent. Common rust is favored by cool temperatures and high relative humidity, while southern rust is favored by high temperatures and high relative humidity.

Symptoms

The most characteristic symptom of rusts are the development of cinnamon-brown pustules on the leaves. Common rust pustules are found on both sides of the leaf and are often elliptical in shape. Southern rust, on the other hand, is usually found only on the upper side of the leaf and pustules are more circular in shape. Late in the season the pustules turn black as the overwintering spores develop. When infection is severe, yellowing and death of the leaves and leaf sheaths may occur.

Management

1. Resistant hybrids.
2. Fungicide applications maybe utilized during severe disease outbreaks.

Corn Smut

Smut is found wherever corn is grown. Economic losses are variable and may range from a trace to 40 percent. The average grain loss in Kansas is around 1 percent. The number, size and location of smut galls on the plant affect the amount of yield loss. Large galls on or above the ear are more destructive than galls below the ear or on the leaf.

Smut incidence appears higher among plants grown on soil high in nitrogen, particularly if applications of barnyard manure have been heavy. Injuries due to hail, insects, cultivation, or spraying, increase the smut incidence.

Symptoms

Corn smut symptoms are easily recognized. Galls are initially covered with a glistening, white membrane and upon maturing, will burst to release millions of powdery, black spores. Galls on leaves seldom develop beyond pea-size and become hard and dry without rupturing. The smut fungus over-winters as spores in crop refuse, manure, and soil. The development of corn smut is favored by dry conditions and temperatures between 78 and 94°F. Smut does not affect feeding quality of the grain.

Management

1. Resistant hybrids.
2. Reduce mechanical damage to the plant.

Diseases Caused by Bacteria

Holcus Spot

This disease is generally found in a few fields in Kansas each year but losses are negligible. The lesions are at first dark green and water soaked but later they become dry and brown with a reddish margin. They are round to elliptical and range from small spots up to about ½ inch in diameter. Warm, rainy, and windy weather, especially early in the season, seems to favor disease development.

Management

1. Resistant hybrids.
2. Crop rotation.

Diseases Caused by Viruses

Maize Dwarf Mosaic Virus

Maize dwarf mosaic virus (MDMV) is commonly detected in dent or field corn in Kansas, although the disease is more severe in sweet corn.

There are two strains of the virus (A and B) common to Kansas. Over 200 species are susceptible to Strain A, however, Johnsongrass is the main overwintering host of the virus. Eastern gammagrass is an overwintering host of Strain B, other hosts are not known.

Twelve different species of aphids are known to transmit the virus including the corn leaf aphid, greenbug, and green peach aphid.

Symptoms

The disease is first observed on the youngest leaves as a mottle or mosaic of irregular, light and dark green areas. This may develop into narrow, light green or yellowish streaks along the veins. The plants are generally stunted and reduction in ear size and seed set may occur. As the season progresses and temperatures increase, the mosaic appearance often disappears and leaves become more yellow. Early infections may predispose the plants to root and stalk rots and premature death. If plants are not infected until silking, they grow to a normal height and produce normal yields.

Management

1. Resistant hybrids.
2. Control of Johnsongrass maybe helpful in reducing the disease in nearby fields but is not practical over a wide area.
3. Control of aphids is not feasible,

Corn Lethal Necrosis

This disease was first discovered in Kansas in 1976 and is found only in north central Kansas and south central Nebraska. Yield losses in severely infected fields have been estimated at 50 percent or more. The disease is caused by the combination of maize chlorotic mottle virus (MCMV) and either maize dwarf mosaic virus (MDMV) or wheat streak mosaic virus (WSMV).

Symptoms

Corn is susceptible at all stages of development. The first symptom is a bright yellow mottling of the leaves or husk similar to MDMV. This is followed by leaf necrosis moving inward from the margins. In maturing plants, the necrosis usually begins at the tassel and progresses downward. A large number of barren plants can be observed. If ears are produced, generally they are small, often distorted, with limited or no kernel development.

The vector of MCMV is unknown. MDMV is vectored primarily by the corn leaf aphid and greenbug and WSMV by the wheat curl mite. An overwintering host of MCMV is not known.

Management

1. Crop rotation with sorghum, soybeans, small grains or alfalfa in fields in which MCMV or corn lethal necrosis has occurred.
2. Tolerant hybrids.

Diseases Caused by Nematodes

There are two nematodes that occasionally cause problems for Kansas corn growers. They are the root-lesion nematode and the sting nematode. Both nematodes are usually only a problem in very sandy soils such as those in some areas of southwestern Kansas. Damage almost always occurs in irregularly shaped areas ranging from 100 square feet to over an acre. Nematode damage is commonly confused with soil compaction, low fertility, herbicide injury, and soil insect injury.

Symptoms

The root-lesion nematode is among the most common parasites of corn. When populations reach damaging thresholds, stunting and nutrient deficiency symptoms such as yellowing, reddening or purpling of the foliage may occur. The reduced root system frequently is brown to black and lacks root hairs.

Damage by the sting nematode can be devastating and even small populations can cause serious damage, apparently because the nematodes inject roots with a powerful toxic enzyme while feeding. Root injury symptoms include a greatly reduced root system with a proliferation of short, stubby roots. The above ground portion of the plant may be stunted, yellow, and have a tendency to wilt easily. Severely affected plants may die. Yield losses from the sting nematode are generally from 60 to 100 percent in the areas of the field where the nematode is present. Sting nematode injury is often confused with injury from the herbicide trifluralin.

Management

1. Crop rotation or fallowing.
2. Preplant or planting time treatment with granular nematicides maybe effective. Chemical treatment should not be done without first sampling the soil to determine that a nematode problem exists.

Irrigation

Corn has regained the title of premiere crop for irrigation in Kansas. Although irrigated corn acreage varies annually, currently over one-third of the approximately 3 million irrigated acres in Kansas is dedicated to corn. In 1992, this was 400,000 acres more than the next largest irrigated crop of wheat and more than three times the amount of irrigated grain sorghum production (Figure 1).

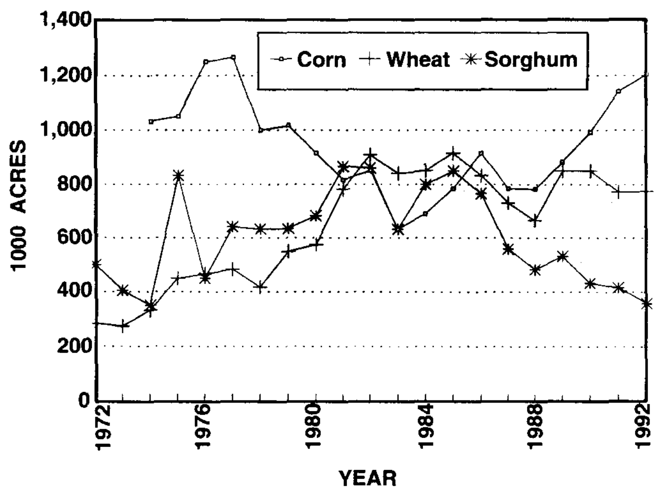


Figure 1. Irrigated Corn, Grain Sorghum and Wheat Acreage Trends From 1972 to 1992

Although concern over declining groundwater levels and rising production costs have been sited as reasons to switch to less water use intensive crops, corn still has an excellent water use-yield response curve and is often the most economically sound crop for irrigation. Corn does have a very sensitive or critical crop growth stage at the beginning of its reproductive stage. A water shortage at tasseling and silking can ruin yield potential. Water management and system capacity are important issues for maintaining adequate soil water.

Plant Characteristics

Corn requires 24 to 30 inches of water use for the full season varieties grown in Kansas. The amount varies depending on the weather conditions and can be influenced, to a degree, by population and maturity (see *Early Corn Production,* MF-1095 for additional details). Population affects water use by influencing the amount of leaf surface that is available to capture solar radiation, which is the energy source for crop production. Leaf Area Index (LAI) is a measure of the leaf surface area relative to the ground surface. It takes an LAI of about 2.7 to fully capture all incoming energy (Figure 2). If LAI is less than this full cover value, then less water use will occur. The more plants in a field to provide leaf surface, the quicker the full threshold is reached, and the longer this level is maintained, which means the corn plant is capturing more of the available sunlight. This will increase water use. Crop production, however, is also influenced by other factors; not only by sunlight capture.

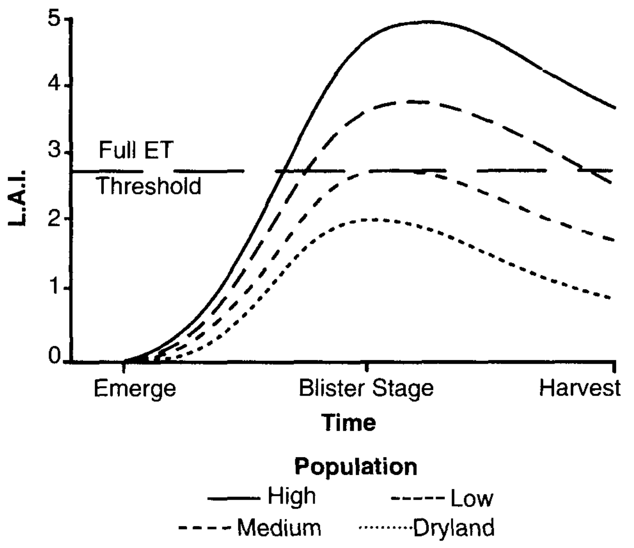


Figure 2.

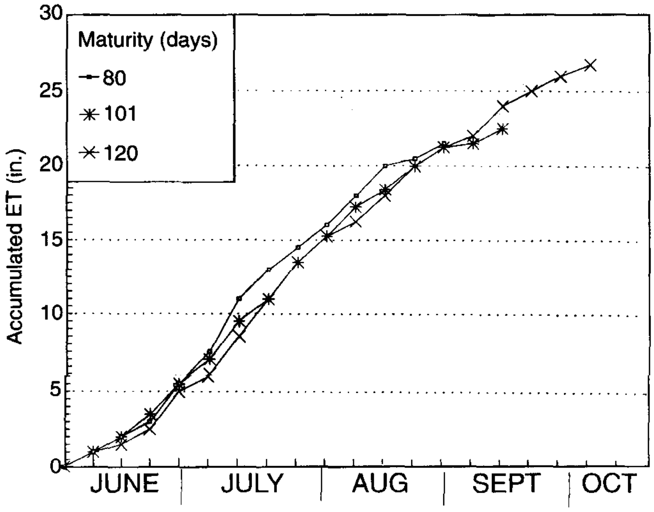


Figure 3.

Maturity length effects are illustrated in Figure 3. The earlier maturity varieties will have less water use, in some cases, as much as 4 to 6 inches less. However, yield is also reduced, so the trade off between water cost, yield, and other production factors must be considered when selecting a maturity length.

Regardless of maturity, a characteristic water use pattern of corn occurs (Figure 4) and shows corn can use water at a rate of 0.35 inches/day. Single day peak use rates can approach 0.50 inches, however, it would be unusual for such a high peak use to continue for more than several days. The use curve shown is smoothed because average weather and corn growth are presumed. Actual water use during any season would be irregular. Water use is related to stage of growth, soil water availability, temperature, humidity, wind, and sunlight.

Average net seasonal irrigation requirements for corn in Kansas range from about 5 inches in the east to nearly 16 inches in the west. Net irrigation requirements for dry year conditions (80 percent chance rainfall—the amount of rain one would expect to exceed 8 out of 10 years) are

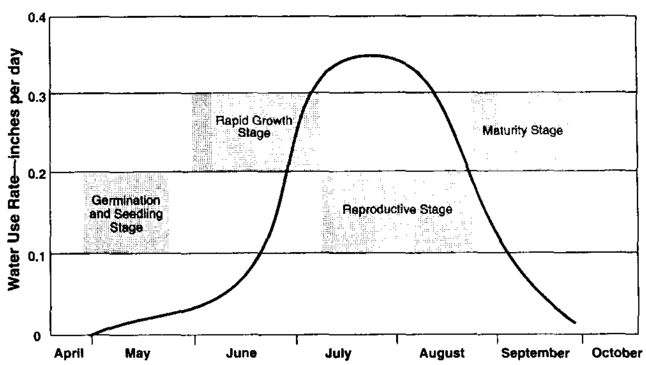


Figure 4.

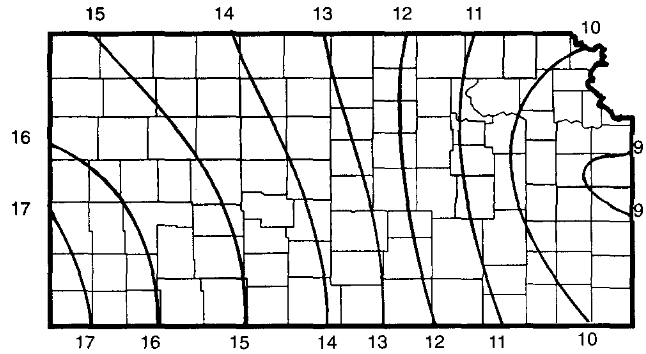


Figure 5. Net Irrigation Requirements for Corn in Inches (80% chance of rainfall—Dry year) SCS Kansas Irrigation Guide

shown in Figure 5. The dry year net irrigation requirement increases to a range of about 9 to over 17 inches. Yield response to irrigation by corn is excellent.

In western Kansas, well managed irrigated corn will produce, on the average, 10 to 15 bushels for each inch of water within the production limits of corn. A crop water use curve for western Kansas is shown in Figure 6. Yield and water use data for the past 15 years, collected at three irrigation experiment fields, was used to compile the graph. Yield potential of corn varieties has improved over time so the data was normalized by dividing by the maximum yield of each individual test (left vertical axis). On the right vertical axis, a scale showing a yield of 210 bushel/acre, typical of the region today, is shown. The graph shows that total water use above 30 inches does not result in additional yield. Also, near maximum yield potentials are possible with 18 to 21 inches of gross irrigation application. This graph was

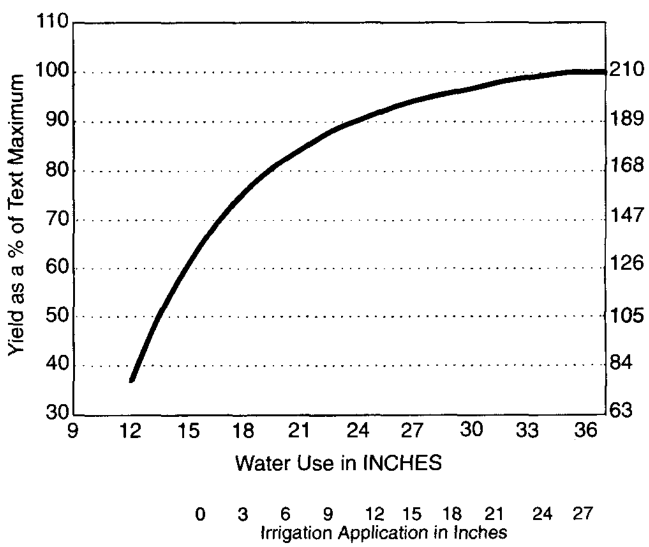


Figure 6.

developed using information from small research plots watered with high irrigation efficiency. Irrigation farmers may need to add 1 to 2 inches to account for less efficiency on large fields.

Figure 6 also illustrates that corn can be used effectively as a limited irrigation crop, although the water applications should be aimed at reducing or eliminating water stress during the critical growth stage of tasseling and silking.

The corn root system develops at about the same rate as the aerial portion of the plant. When the plants are small, the root system is shallow and not very extensive. As the plant develops toward maturity, the root system extends deeper and spreads out into the adjoining space. Corn roots may reach 6 to 8 feet in depth, where good aeration, soil water, and soil structure will allow easy growth. Excess or insufficient soil water, compaction, poor aeration, or low temperatures inhibit root growth. Without a strong root system, water and nutrient uptake may be affected.

Germination and Seedling Stage

Only a very small amount of soil water is necessary to germinate the seed but adequate water in the top 12 to 18 inches of soil is essential to produce strong seedlings. On medium to fine textured soils, this early season water requirement is normally supplied by rainfall. On low water holding capacity soil, like sands, surface water may be an issue. Knowing where and how much water is in the soil profile is very important. Roots only develop where there is water. If a dry zone exists between the upper portion of the root zone and the lower portion, root development may be inhibited. Early season irrigations should be large enough to produce contact between the upper and lower soil water if such a condition exists.

On light textured soils (sands), irrigation maybe required to germinate the seed and continue proper development anywhere in Kansas. Sands hold little water, so a physiological drought may occur at any time where soil water storage is very limited.

During the rapid growth stage, leaves appear rapidly and the root systems extend rapidly. The corn plant is reasonably tolerant of soil water stress during this period. The water use rate is increasing rapidly and some wilting in late afternoon may be tolerated without harm if the plant regains turgor during the early evening. An available soil water depletion of 70 percent can occur without loss of production as long as the soil water is increased prior to the reproductive stage of growth.

On the medium to fine textured soils in eastern and central Kansas, irrigation is seldom required during the rapid growth stage. In western Kansas, irrigation normally begins during the middle to late part of this growth period.

Reproductive Stage

From 2 weeks prior to tasseling until 2 weeks after the tassel appears is the most critical period for corn. The critical time is actually much shorter, but to remain safe and allow some margin for error in applying irrigation water, starting 2 weeks prior to tassel emergence is a reasonable rule if soil water is deficient. The critical period is actually from a few days prior to tassel emergence through pollination, but most irrigation systems do not have the capacity to allow such critical water management. To err on the side of being too early at this stage of growth is better than the reverse.

The potential water use rate is normally near its high point at the critical period. If weather is hot, the plants need a lot of water. Holding the soil water in the top 20 to 30 percent of the availability range during the critical period is even better than the top 50 percent of the available range if the system will allow. Once the ear is pollinated, however, the critical period is past. Keeping the soil water in the upper 50 percent of the availability range will ensure continued development and short periods of stress cause less and less effect as the ear matures.

Maturity Stage

As the plant enters maturity, the kernels have been formed. Adequate water is necessary to complete kernel development, but, as noted above, the plant is more stress resistant. Holding the soil water in the upper 50 percent of the availability range until dent occurs has long been recommended, but opting for a lower soil water content may be more economical. There is no reason to complete the season with the soil water in the upper 50 percent at harvest. The root system usually penetrates below the managed root zone and it is most economical to allow the plant to draw water from these deeper depths during the late season.

Soil texture always plays a role in irrigation management. On light sandy soil, most of the crop needs will need to be met through irrigation. The soil water below the managed root zone is frequently no greater than above, and irrigation will need to continue through the dent stage, at least. Sandy soils require more irrigations over a longer period because they retain so little water.

Irrigation Management

Corn is a relatively deep rooted crop, but only the top 3 to 4 feet of the root zone is usually monitored for irrigation management. In a uniformly wetted profile, 70 percent of the water and nutrients are removed from the upper half of the root zone. Thus, when monitoring the top three to four feet, at least 80 percent of the active root zone is managed.

Most of the roots are in the upper portion of the root zone. Roots remove water from the soil differentially. The easiest water is removed first and the more difficult later.

Therefore, if one zone is wet and another is drier, the plant will extract more water from the wetter zone. Research has shown that at least half of the root system can supply all of the necessary water if the soil water content is high enough. As a consequence, soil water in the managed upper zone is most important and water at deeper depths may not be significantly used.

The soil water below the managed root zone should be viewed as a marginal insurance supply. Some portion of the mid-season needs can be taken from this source, but the rate of removal will be slow and the amount will not be great. The time to use this deeper supply is late in the season when the use rate is low and the consequences of soil water stress are also low.

Irrigation management means using scheduling to determine when to irrigate and how much water to apply. As mentioned above, timing can be very important. If it is not possible to apply enough water at the critical period of tassel emergence through pollination, some other crop or sequence of crops should be considered.

Scheduling can take many forms: calendar date, plant stage of growth, crop condition, soil water status, and scheduling using evapotranspiration (ET). The calendar date method does not work well in Kansas because of weather extremes. It is very difficult to initiate irrigation at a given time and do so efficiently when the demand is highly variable. Plant stage of growth, on the other hand, has proven itself quite well in north central Kansas on the medium and heavier soils (Table 1) and should work reasonably well in the eastern portion of the state. Applying 3 to 4 inches of water, at tasseling and again 1 week later, has shown consistently good results at the Scandia Irrigation Field. In very dry conditions, a third irrigation 2 to 3 weeks after the second irrigation may be necessary.

Table 1. Effects of Irrigation on Corn Yields Scandia Experiment Field, 1980-1991

	Yield (Bu/Acre)	
Time of Irrigation	1991	1980–1991
No Irrigation	3	56
Tassel	124	141
Tassel & 1 Week	148	159
Tassel & 1 and 2 Weeks	155	164
65% Depletion	159	172

Using plant conditions as a basis for scheduling has not worked well with corn. Waiting for the crop to wilt prior to irrigation is too late. Corn shows few other obvious signs of water stress. Watching for stress signs in corn is the poorest of methods for scheduling. The damage is done before the stress signs are obvious enough to act.

Monitoring soil water is a safe routine with universal applicability. The soil water may be measured periodically using soil water blocks, tensiometers, or the hand feel technique shown in Table 2. If measurements are made at frequent enough intervals, no other data is needed. When the soil water reaches a given level or is anticipated to reach a given level, irrigation is started. In the Scandia results, maintaining soil water above 65 percent depletion resulted in best yields and with less water applied than the treatment watered at tasseling and 1 and 2 weeks later. This procedure does require some commitment of time to take the measurements. Several sites in each field should be monitored and the evaluations must be made frequently enough to start irrigations on time. Tensiometers are the easiest to read, but are only meaningful in sandy soils. Soil water blocks will work in any soil, but the blocks take time to place and must be read with an electrical meter attached to wires that lead from each block. A soil probe works rapidly for the feel and observe technique, but is less exact. It takes time to learn to judge the water content, but the method is cheap and very flexible.

Scheduling can also be done using crop water use or ET information. Making use of estimated water use rates in a checkbook routine is highly recommended. A soil water estimate is necessary at the start of the scheduling period for each field, but need only be taken again occasionally to confirm the results. The soil water measurement at the start is treated like money in the bank. Daily use amounts are deductions and rainfall and irrigation amounts are deposits. The amount of soil water is known at all times. A check at mid-season to make sure the process is not drifting is recommended. Observing the trend of use values, one may anticipate quite precisely when to irrigate.

Agricultural consultants also provide irrigation scheduling as a part of their service. It is possible for those who do not choose to learn scheduling techniques to hire it done. Consultants have computers to calculate use rates from weather data and people to monitor soil water on a regular basis. They advise when to start irrigating, how much to apply, and when to stop.

Limited irrigation of corn is possible. Single irrigation applications, especially if soil water is low during the critical growth stage, can result in substantial yield increase. For example, in 1991 at Scandia, a single irrigation at tassel increased yield by 121 bushels/acre. With yield responses in western Kansas averaging 10 to 15 bushels/acre for every inch of irrigation water, yields of 130 to 150 bushels/acre may be possible, with timely applications of 6 to 10 inches of gross irrigation application.

System capacity is important for individuals wishing to maintain full yield potential. A use rate of 0.35 inches/day requires a net supply of 6.6 gpm per acre. If the system is 85 percent efficient, as new center pivots are presumed to be, the gross water supply must be 7.8 gpm. This translates into a system capacity of 1,000 gpm for a full quarter system that irrigates 130 acres. Obviously, few center pivots have such a capacity. The key to success is to keep the soil water storage reasonably full before the peak use period occurs and using soil water storage during periods of excessive use that cannot be supplied by the system.

Table 2. Interpretation Chart for Soil Water

Soil Water Remaining	Very Coarse Texture	Coarse Texture	Medium Texture	Fine and very Fine Texture
0 percent	Dry, loose, single-grained, flows through fingers.	Dry, loose, flows through fingers.	Powdery, dry, sometimes slightly crusted but easily breaks down into powdery condition.	Hard, baked, cracked, sometimes has loose crumbs on surface.
50 percent or less	Still appears to be dry; will not form a ball with pressure.*	Still appears to be dry; will not form a ball.*	Somewhat crumbly, but will hold together from pressure.	Somewhat pliable, will ball under pressure.*
50 to 75 percent	Same as very light texture with 50 percent or less moisture.	Tends to ball under pressure but seldom will hold together.	Forms a ball,* somewhat plastic; will sometimes slick slightly with pressure.	Forms a ball and is very pliable; slicks readily if relatively high in clay.
75 percent to field capacity	Tends to stick together slightly, sometimes forms a very weak ball under pressure.	Forms weak ball, breaks easily, will not slick.	Forms ball; will ribbon out between thumb and forefinger.	Easily ribbons out between fingers; has a slick feeling.
At field capacity (100 percent)	Upon squeezing, no free water appears on soil but wet outline of ball is left on hand.	Same as very coarse texture.	Same as very coarse texture.	Same as very coarse texture.
Above field capacity	Free water appears when soil is bounced in hand.	Free water will be released with kneading.	Can squeeze out free water.	Puddles and free water form on surface.

* Ball is formed by squeezing a handful of soil very firmly with fingers.

This is where scheduling can be a real asset. Scheduling center pivots will indicate when the system may be shut down. Allowing the center pivot to run continuously during the bulk of the season is a common but costly procedure, There are some days every season when the system catches up with soil water storage and may be safely stopped. Without scheduling, the operator is never sure when these periods occur, and may be afraid to shut down. Water, energy to pump and valuable nitrates may all be lost through this practice.

Surface systems generally require a greater rate of flow, although with surge irrigation and tail water reuse, irrigation efficiency can be quite good. The major difficulty with surface irrigation of corn is the lack of flexibility. Furrow irrigation systems are normally used only on medium to fine textured soils and apply at least 3 to 4 inches of water per irrigation. At a use rate of 0.30 inches per day, irrigation would be required every 10 to 14 days. A quarter section system of 160 acres would require a net flow rate of 900 gpm or about 1200 gpm at 75 percent irrigation efficiency.

The tendency to try to spread too little water over too many acres creates most of the management difficulties. Lack of scheduling or measuring soil water compounds the problem. If the system is short of water, the soil water storage must be relied upon more heavily to supply water during peak use periods. Pre-irrigation is practiced in many areas to insure a full profile at the beginning of the season.

The major difficulty with this practice is that it wastes water and irrigation fuel. Studies in northwestern Kansas indicated that 60 to 80 percent of the pre-irrigation water was wasted. A reason waste occurred was that water was added in excess of the soil water holding capacity because the irrigators did not know how much water storage capacity was available. The profile is often filled so early that much water drained below the root zone before the growing season started and early season rains would have supplied much of the water that had been added by irrigation.

Pre-watering should be done as close to planting time as the system will allow. If water is added, if possible, only fill to 50 to 75 percent of the available soil water storage. A full profile (field capacity) will slowly drain down into the deeper soil zones. The movement is so slow that during the growing season, it does not occur because the roots absorb it before it has a chance to escape. However, during the dormant season, about 25 percent may become deep seepage.

Surge irrigation is a method to consider for furrow irrigation. Surging can reduce the amount of water necessary to get water through the field initially by 30 to 50 percent on some soils. The benefits are usually reduced with subsequent irrigations. Surge should make it possible to apply smaller irrigations also. Light early season applications have generally not been possible with current practices. The irrigator is forced to apply 4 or more inches of water when only 2 inches maybe needed. Surge irrigation shows promise of doing this. Furrow packing, shorter row lengths and a good tail water recovery system can also help increase the efficiency of operation.

Summary

To insure profitable production from irrigated corn, it is necessary to maintain soil water in the upper 50 percent of the availability range during the critical tasseling and silking stage. Knowing the system capacity and the soil water storage capacity, it is possible to evaluate and manage to maintain these conditions. Corn does use a lot of water but is very good at turning water into yield. To maintain high production, the irrigator needs to insure that water is available.

Systems with limited capacity on medium and fine textured soil can normally be managed to produce good crops in all but the worst of years. Systems on light soils, however, must have greater capacity. More water will not be used by the crop but the soil water storage is so limited that most period of high water use must be met by the system. Even with these systems, scheduling pays because there will be times when the system will surpass the crops' needs and water, fertilizer, and energy may be wasted.

Good management needs to consider:

- Crop stage of growth.
- Crop water use rate.
- Soil water status and holding capacity.
- Irrigation system capacity.

Harvesting Suggestions

An efficient corn harvest is the result of attention to details throughout production and harvest. Decisions made as early as planting time may have a disastrous affect on harvest losses if, for example, the variety matures too late. Other details such as combine preparation and repair also require careful planning, but the payoff makes it all worthwhile. Estimates have put average corn harvest losses anywhere from 5 to 10 bushels/acre, with expert operators reducing this to about 2 bushels/acre. The added income from this grain is almost pure profit, so the few minutes you spend on careful combine adjustment could be extremely profitable.

Where Do Corn Harvest Losses Occur?

There are several points where grain can be lost during combining, and much research has been directed at finding and reducing these losses. Loss can be divided into three categories:

1. Ear losses are ears that are left on the stalks or dropped from the header after being snapped.
2. Loose kernel losses are kernels that are left on the ground either by shelling at the snapping rolls or by being discharged out the rear of the machine.
3. Cylinder losses are kernels left on the cob due to incomplete shelling.

The amount of these losses varies widely, but Table 1 outlines what losses can be expected from the average combine operator as well as an expert.

The "Expert" loss levels are attainable if at least 90 percent of the stalks are still standing and moisture content is below 25 percent. The difference (4.3 bushels/acre) is almost pure profit, since little extra time and expense is involved in achieving the "expert" levels. It only requires measuring losses and then making adjustments to correct them.

Table 1. Loss in bushels/acre for different operators

	Average	Expert
Loose Ear Loss	4.0	1.0
Loose Kernel Loss	1.4	.5
Cylinder Loss	.7	.3
	6.1 bu/a	1.8 bu/a

How Can You Measure Your Losses?

Before you can judge what combine adjustments are needed, you should determine if and where your combine is losing grain. You can check your losses in about 10 minutes, and for the preliminary checks it is not even necessary to stop the machine.

1. First, determine ear loss. Pull the combine into the field and harvest at the usual rate for about 300 feet. Then pace off an area behind the machine that contains 1/100 acre. The distances needed for 1/100 acre area are shown in Table 2.
2. After the area is marked off behind the combine, gather all unharvested ears from the area. Each ¾ pound ear (or equivalent) represents a loss of one bushel per acre.

Table 2. Row length in feet per 1/100 acre

Row Width Inches	Four Rows	Six Rows	Eight Rows	Twelve Rows
30	43.6	29.0	21.8	14.5
38	34.5	23.0	17.2	11.5
40	32.7	21.8	16.3	10.9

3. If the ear loss determined in step 2 is above one bushel/acre, you should then check an adjacent area in the unharvested corn. It may be that the ear loss occurred before the combine pulled into the field. To check this, pace off another 1/100 acre area in the standing corn, then retrieve any down ears and figure loss on the basis of a ¾ pound ear as in step 2.

4. Now subtract the preharvest loss (step 3) from the header loss (step 2). If over 1 bushel/acre is due to the machine then you may have to adjust the header or change your operating techniques to reduce the loss.
5. Next check loose kernel loss. Loose kernel loss is easily checked by counting kernels within a 10 square foot frame. First, construct a wood or wire frame that encloses a 10 square foot area. The dimensions of the frame are given in Table 3.

Table 3. Length for 10 Sq. Ft. Frame

Row Width Inches	Row Length Inches
30	48
38	38
40	36

6. Now place the 10 square foot frame over each row behind the machine and count kernels lying loose on the ground. This is loose kernel loss. Also count the kernels still attached to broken cobs. This is cylinder loss. Divide each of these counts by 20 to obtain the loose kernel loss and cylinder loss in bushels/acre. (Each 20 kernels counted within the 10 square foot area represents one bushels/a)
7. If loose kernel loss is .5 bushels/acres or less and cylinder loss is .3 bushels/acres or less, you are doing an excellent job, and no adjustment is necessary.
8. If cylinder loss is above .3 bushels/acre, try to adjust the cylinder for better shelling.
9. If loose kernel loss is over .5 bushels/are, make one additional check to determine the source. Do this by stopping the combine and back in it up about 20 feet. Then check for loose kernels in the area that was previously under the snapping rolls. This will tell you whether the loose kernels that you found behind the combine are coming from the snapping rolls or from the walkers and shoe.

What Adjustments Reduce Loss?

Measuring losses is important, but it is just as important to know where and why they occur. Generally, you should try to make only one adjustment at a time, and then determine the results of that adjustment. (One exception is shoe adjustment when both opening and air flow should be adjusted together).

General Adjustment and Operation

1. Proper engine speed is often overlooked, but a bad setting here can reduce the performance of the entire combine and make adjustment nearly impossible.
2. Ground speed should be correlated with snapping roll speed, but generally about 3 mph produces best results.
3. Accurate driving is important, and take special care in aligning the machine at the start of each row.

Corn Head Adjustment

1. Gathering snouts should be adjusted so that the center snout is just touching the ground when the gathering chains are two inches above the ground. Each successive snout (working out from the center) should be about one inch lower than the adjacent snout. Then drive with center snout just touching the ground. This insures that all snouts will float at ground level while combining rough ground.
2. Gathering chains should extend at least ¼ inch beyond the snapping plate when measured at the front of the plate. Chain speed should be controlled so that stalks are guided into the rolls without uprooting.
3. Snapping rolls should be set according to stalk thickness with speed correlated closely to ground speed so that the ear is snapped in the upper $^1/_3$ of the roll. This helps reduce ear loss.
4. Snapping plates should be set as wide as possible without losing ears or shelling corn off the ear. This reduces the amount of trash taken into the machine. The spacing between the plates should be $^1/_8$ to $^3/_{16}$ inch tighter at the front of the plates than at the rear.
5. Trash knives should usually be set as close to the rolls as possible to prevent wrapping.

Cylinder Adjustment and Kernel Damage

As with most other crops, cylinder adjustment has a great affect on corn quality. As much as 80 percent of corn kernel damage occurs during the shelling process, so careful management at this point will produce dividends throughout storage and drying.

Moisture content has a great affect on the amount of damage, with fines increasing rapidly at high moisture. If possible, harvest should be delayed until moisture is below 25 percent.

Concave clearance and cylinder speed require careful adjustment, and although a great variation in varieties exists, a few rules of thumb have been developed. Overshelling the grain (by too high a cylinder speed or too tight a clearance) not only produces excess fines, but also consumes more power and fuel. A good way to adjust the cylinder is to begin with the clearance and speed recommended by the manufacturer (or in the middle of the suggested range), then make small changes after checking the discharge of the machine.

1. Cylinder clearance should be set so that cobs are discharged in cylinders and not fractured into halves or pie-shaped segments. If the cobs are halved or quartered, higher cylinder speeds will be necessary to remove the grain.
2. Cylinder speed should then be reduced to the point that an occasional kernel is left on the cob. Several studies have shown that the best compromise between unshelled grain and excessive kernel damage occurs when about 0.2 percent of the kernels are left on the cob.

Summary

Careful harvesting can increase the amount of corn in the bin and reduce potential storage problems. There are three key points:

1. Manage your corn production system to give the best chance of harvesting below 25 to 28 percent moisture.
2. Measure your combine losses frequently to determine the amount and cause of loss.
3. Adjust and operate your combine in a manner that minimizes harvest losses.

Drying and Storing

Dryer Selection

Weather interferes with optimum time of harvest at least once in three years in Kansas where corn is harvested. Without commercial or on-farm drying facilities, a portion of the crop is lost in the field while waiting for the corn to dry enough to store or sell on the dry grain market. Many types of corn drying systems are available. High temperature dryers require more energy and may cause quality problems. Stress cracks are a result of improper cooling of a dryer and cause fines and broken kernels during grain handling operations. However, harvesting, drying, and storing of the grain are accomplished in less than 24 hours. Low temperature drying prevents overdrying and maintains the corn quality, but requires more management and drying time depending on the weather conditions.

Table 1 shows the pounds of water that have to be removed from a bushel of corn at different harvest moisture contents and dried to 15.5 and 14 percent (note: all moisture content will be given as percent wet basis). Theoretically, about 1,100 BTUs of energy are required to evaporate one pound of water. However, due to inefficiency in the dryers and burners, the actual energy required may range from 1,500 to 3,500 BTUs per pound of water removed. A gallon propane has 92,000 BTUs and a kW of electricity 3,400 BTUs. Energy use depends mainly on dryer type, column thickness or grain depth, airflow per bushel, drying temperature, and amount of exhaust air recirculation. It depends to a lesser extent on corn variety, level of maintenance, moisture range (less energy is required per point removed at high moisture), and outdoor temperature and relative humidity. Since drying requires a much energy as all other corn production and harvesting phases, the efficiency of a dryer should be examined by the BTUs of energy required to evaporate a pound of moisture from corn.

The drying unit should also be selected on the basis of its ability to dry corn before deterioration begins. Table 2 shows the allowable days corn can be held at certain moisture contents and temperatures before a reduction in grade. Corn harvested in early fall at high moisture contents must be dried within a couple days to prevent deterioration. The drying phase must not be a bottleneck in the harvesting, handling, or storing system.

Drying rates can range from 1 to 2,000 bushels per hour depending on the systems. Farm-type dryers are available as: bin layer, batch-in-bin, in-bin continuous, thin-layer batch (sometimes called a column), or continuous. The capacity and kind of system that best fits your needs and plans may be completely different from that of your neighbors. Size of crop, harvesting capacity, and marketing capabilities will dictate the size of investment. Table 3 provides a general comparison and energy requirements of different types of dryers. Other things to consider when selecting a dryer include: moving grain to and from the dryer, availability of fuel and electricity, wet holding tank, and management required.

Table 1. Pounds of Water to be Removed to Reduce Moisture Content of Shelled Corn with 47.32 lb Dry Matter (56 lb/bushel at 15.5% moisture)

Original Moisture Content %, Wet Basis	Final Moisture Content (%, Wet Basis)	
	15.5	14
30	11.6	12.8
28	9.7	10.9
26	8.0	9.1
24	6.3	7.4
22	4.7	5.7
20	3.2	4.2
18	1.7	2.7
16	0.3	1.3

Storage Consideration

Molds and insects need moisture to live and reproduce. Making sure the grain is dried is the first step in preventing spoilage and insect damage, Corn must be uniformly dried to 15.5 percent if the storage period is expected to be less than 6 months and dried to 13 percent if longer periods of storage are desirable. Although corn must be dry enough to store safely, overdrying is both costly and unnecessary, The moisture content at which corn can be stored depends on the climate, length of storage, and corn quality. Good storage management can greatly influence the storability of corn. Normally, more mold related storage problems occur with corn than insect problems if the corn is cooled below or harvested at temperatures less than 70°F.

Table 2. Allowable Holding Time for Shelled Corn.

Grain	Corn Moisture						
	18%	20%	22%	24%	26%	28%	30%
Temperature	days	days	days	days	days	days	days
40°F	195	85	54	38	28	24	20
50°F	102	46	28	19	16	13	11
60°F	63	26	16	10	8	6	5
70°F	37	13	8	5	4	3	2
80°F	27	10	6	4	3	2	1

Good quality corn can be stored at higher moisture contents than corn that is damaged or has foreign material. Poor quality corn will also reduce the dryer efficiency. The fines restrict the airflow through the corn and provide a source of food for insects and mold. Pockets of fines have a tendency to accumulate in a storage bin in the spout line. Such pockets provide a place for insects and molds to live, and inhibit effective aeration and fumigation of the grain. Screening corn to remove the fines with a rotary cleaner or a scalper reduces long-term storage problems. A grain distributor or spreader helps even out the fines in a bin and should be used if the corn is not cleaned.

In Kansas, over 20 different species of insects are adapted to survive in grain or grain products. When combined with the long life cycle (typically 4 to 12 months at minimum) and the short time required to pass from egg to adult under optimal conditions (30 days for many species), the high reproductive rate per individual (often 300 or more eggs per female) ensures that only a few individuals are necessary for serious numbers to develop in a relatively short period of time. Therefore, overlooking only a small amount of infested grain when cleaning out the storage structure, may hinder future efforts at keeping newly stored grain free of insects.

For many reasons, only **clean, dry grain** should be considered for storage. Combines and other harvesters, transportation equipment, conveying equipment, and storage structures should be cleaned and existing insect infestations eliminated before new grain is harvested. Destroy or feed the first few bushels of grain augered through each piece of equipment as harvest begins. The initial passage of new grain “scours out” the machinery, removing a high percentage of potentially insect-infested material that remained inside since last season. Many otherwise good operators forget this small step and unintentionally, but routinely, “reinfest” their cleaned storage structures every year. Adjusting combines to minimize dockage or non-grain foreign material is a sound practice. Dockage, usually composed of plant fragments, often helps insects survive less favorable conditions.

To minimize contaminating newly harvested grain, remove all leftover grain from bins and sweep down the walls, ceilings, sills, ledges, and floors. Destroy the sweepings. Clear trash and litter from outside the bin areas and remove spilled grain from under and around the bins. Make all necessary repairs while the bin is empty to ensure a weatherproof seal, particularly where side walls join the floor and roof.

Special formulations of malathion and methoxychlor have been registered as outside perimeter sprays and/or inner plus outer bin-wall treatments. In general, these treatments should be applied three to four weeks before the grain is binned but after all old grain and sweepings have been removed.

One of the most important steps in limiting insects from developing in farm-stored grain is to apply an approved insecticide to the grain as it is binned. Properly applied, this treatment will protect grain from insect damage for about the storage season. If a protectant is not used on all incoming grain, it is advisable to apply malathion or Actellic to the grain surface at currently labeled rates as a “capout” treatment. Malathion and Actellic (primiphos methyl) are the only major ingredients labeled for direct treatment of stored grain as “protectants” at this writing. Actellic has shown more persistence and a wider range of effectiveness than malathion in several research trials where higher grain moisture conditions prevailed. Reldan (chlorpyrifos-methyl), which is now labeled for use on wheat and grain sorghum, **has not** yet received clearance on corn.

Slow-release DDVP or dichlorvos strips and several formulations of *Bacillus thuringiensis,* a biological insecticide, are available for use against Indian meal moth adults and larvae, respectively. The strips are hung in the overspace at the rate of one strip per 1,000 cubic feet. *Bacillus thuringiensis* is an insecticide that is a derivative of an insect disease agent effective only following ingestion by certain moth larvae—including Indian meal moth. This product, marketed as Dipel or under other commercial names, is mixed with the surface 4 to 6 inches of grain.

Until recently, several volatile fumigants were labeled for eliminating existing insect infestations. The Environmental Protection Agency has revoked all registrations for the carbon tetrachloride-containing fumigants (often known as the liquid 80-20s). Therefore, no more general-use fumigants are available. The remaining alternatives (aluminum phosphides, chloropicrins, and methyl bromides) are restricted use products which means the user must be certified (by exam) through the Kansas State Board of Agriculture located in Topeka. Users should realize that, to be effective, different application techniques are required for the many people that have experience with the liquid 80–20 formulations. Uncertified grain managers should hire a certified and properly equipped commercial applicator to eliminate the problem through fumigation.

Optimal feeding and reproduction of storage insects typically occurs from 70° to 90°F. As grain temperatures drop near 60°F reproduction falls off rapidly. Most visible insect activity, including feeding, ceases when grain temperatures fall below 50°F. In addition, mold activity may double with each 10°F rise in temperature, but is normally controlled at temperatures below 50°F. Thus, proper use of aeration fans can slow or halt pest damage with the onset of cooler weather. In addition, insects have a more difficult time developing to serious levels as grain moistures are lowered to 12 percent or below.

Storage bins should be equipped with an aeration system that provides a reasonably uniform airflow of about $^{1}/_{10}$ cfm of air per bushel. Aeration controls grain temperature to prevent or reduce spoilage and insect and mold activity. Aeration brings the corn to an uniform temperature, which prevents moisture migration. Aeration is **not** a drying process, although small moisture changes of up to 1 percent do occur with a change in temperature. During aeration (cooling or warming) a temperature zone moves through the corn, much like a drying front during drying, only much faster.

Insects are not able to grow and reproduce in an environment where the temperature is below 50°F. The corn should be maintained at 40°F during the winter and 50° to 60°F during the summer. To cool the corn in the fall, the average outdoor temperatures (average of high and low for a day) should be 10° to 15°F lower than the corn temperature. The fan should run continuously until the corn is completely cooled, unless the fan is automatically controlled. The temperature of corn should be measured at multiple points within the bin to be sure it has cooled adequately.

Careful observation is the best way to detect unfavorable storage conditions. The corn should be checked every week in the fall, spring, and summer and every 2 weeks in the winter. Turn the fan on for about 20 minutes while checking grain conditions. Be observant for changes in temperature, moisture and odors. A faint musty odor is the first indication that something may be happening. This is particularly true during the spring when heating may be occurring due to warm weather or molds and insects. A long $^{3}/_{8}$ inch diameter rod can be used to detect hard compact layers of corn, which indicate spoilage. Also, a probe can be used to remove samples to determine moisture content and insect activities below the surface of the bin. To inspect grain properly, you will need: a grain probe; a section of eaves trough or strip of canvas for handling the grain from the probe; screening pans for sifting insects from the grain samples; and a means of measuring temperatures in the grain. A record book of grain temperatures can help you detect gradual increases in grain temperature. Slight increases are early signs that heating and potential spoilage may be occurring. Thermometers or temperature monitoring systems can be used to measure the grain temperature.

Alternatives to Drying Corn

Shelled corn storage options common today include dry storage, ensiled, and preservative treated. Corn produced for feed on the farm need not be dried if properly stored. Whole, shelled high-moisture corn can be stored in oxygen-limiting silos; but a medium grind is needed for proper packing if “wet” corn is stored in conventional silos. Wet corn may also be bin-stored if preserved with propionic acid or a propionic-acetic mixture. If the acids are inadequately applied or become diluted, molds will grow and spoil the corn.

Select the method that fits your use or marketing situation. The key fact to remember is ensiled or preservative treated corn is an animal feed. It is not suitable for the cash grain human food market. It does, however, offer another storage option to the producer who feeds his corn or has a dependable market agreement with a local feeder. Research shows livestock feeding performance on ensiled or treated corn equals or exceeds dry grain feeding performance. Some guidelines on wet corn storage management are as follows:

Wet Corn, Open Non-Sealed Silo, Upright or Bunker

- Moisture level when stored—25 to 30 percent
- Process—roll or grind when placed in storage
- Thoroughly pack corn placed in trenches or bunkers and cover to reduce surface losses
- Feed within 24 hours after removal from silo in winter—12 hours in summer

Wet Corn, Sealed or Oxygen Limiting Storage

- Moisture level when ensiled—20 percent or more
- Process corn as it is removed from silo
- Feed within 24 hours after removal in winter— 12 hours in summer

Wet Corn, Preservations Treated Bin Storage

Apply treatment at rate recommended for material used. The rate increases as the grain moisture content increases. If improperly applied, molds will grow and spoil the corn. Treatment is more economical and successful at moisture levels under 22 percent. Make sure the corn is thoroughly and uniformly treated. Coat bin wall with an approved paint or protective seal to prevent corrosion. Process corn as necessary as fed.

Treated grain will keep in intermediate storage after removal from storage. The per bushel cost of wet grain storage units will vary from about the same as dry bin storage for treated and open non-sealed silos to approximately two times this cost for the sealed type storage units, excluding the grain handling equipment in both cases. The cost of preservative on a per bushel basis is usually about equal to the cost of energy for drying corn of equal moisture content.

Table 3. Grain Drying Equipment Comparisons (taken from Grain Drying, Handling and Storage Handbook, MWPS No. 13)

Type of drying system	Drying capacity	Airflow rate, cfm/bu	Air temperature, °F	Grain Quality	Investment or equipment cost	Typical Seasonal volume, bu	Disadvantages
Low temperature drying	Low	1–2	0–10 above outside air	Excellent	Low to Medium	up to 50,000	Limited capability at high moisture contents
Bin-batch	Medium	10–25	90-180	Good	Low to Medium	10,000–30,000	May require manual leveling. Batch transfer requires labor and downtime. Limited expansion capability.
Continuous flow bin	Medium	5–10	120–180	Good	Medium	20,000–100,000	Metering equipment may require frequent servicing. Many mechanical components, tends to be spread out.
Heated air manual batch (PTO Batch Dryer)	Medium	20–70	140–220	Good	Low to Medium	10,000–30,000	High labor requirements to load and unload dryer.
Heated air automatic batch	High	70–125	140–240	Good	Medium to High	15,000 & up	Requires support handling systems. Requires wet holding. High drying and cooling rates cause brittle, easily damaged kernels. Low energy efficiency.
Heated air continuous flow	High	70–125	140–240	Good	High	30,000 & up	Requires support handling systems. Requires wet holding. Requires sophisticated controls.
Combination low temperature/ high temperature	High	10–125 & 1–2	120–240 & 0–10 above outside air	Excellent	High	15,000 & up	Maximum movement of grain.
High temperature dryer with: Dryeration	High	10–125 & ½ – 1	120–240	Excellent	Medium to high	25,000 & up	Requires extra grain handling. Managing moisture condensation moisture content.
High temperature dryer with: in-storage cooling	High	10–125 & ½–1	120–240	Good	Medium to high	25,000 & up	Managing moisture condensation. Harder to get the desired moisture content. More management for cooling.

Profit Prospects

Total acres of corn harvested for grain in Kansas increased 39.5 percent from 1989 to 1992, with about 8.5 percent of the state's harvested crop acres in corn. In 1992, Kansas ranked tenth in the United States in the production of corn for grain with 259.5 million bushels. Corn for grain produced under irrigation represented 69.7 percent of the total corn acreage in 1992, with 70.5 percent of the irrigated acres in the western region of the state. In comparison, total non-irrigated corn acreage in eastern Kansas was 430,000, or 81.9 percent of the state's non-irrigated corn acreage.

Two questions each producer must answer when selecting crops and the acreage of each crop to produce are: (1) Will this choice be profitable? (2) Will this add more to the total net income of my farm operation than other choices? That is, is this the most profitable choice?

The fixed or overhead costs of land and machinery ownership for corn, grain sorghum, soybeans, and wheat will be basically equal for the production period under consideration. Therefore, the variable costs associated with each crop are the costs that need to be considered when selecting a given crop. Variable costs include: labor, seed, herbicide/insecticide, fertilizer, fuel, oil, repairs, crop insurance, drying, custom work, crop consulting, and miscellaneous.

Variable costs will vary depending on the management practices used, tillage operations, labor efficiency, and type and fertility of the land. Each producer should develop the variable costs of production for corn and any other crop alternatives. Expected yield and selling price need to be determined for each crop alternative.

Budgeted variable costs by item are shown for dryland corn production in central, northeast, and southeast Kansas, and for irrigated corn production. Dryland corn production in the central and western regions of Kansas is not usually considered to be a profitable crop alternative, although it may be for your farm operation. In 1992, 95,000 acres of dryland corn were harvested in these two regions, with approximately 95.7 percent of this acreage produced in the northwest and central regions of the state.

The prices used in these tables are not price forecasts. They are used to indicate the method of computing "expected returns above variable costs." These projections should be considered valid only under the costs, production levels, and prices specified. Individuals or groups using the information provided should substitute costs, production levels, and prices valid for the locality, management level to be adopted, marketing circumstances for the location, and time period involved.

The decision to plant corn or another crop alternative can be made by comparing the "expected returns above variable costs" for each crop. Returns above variable costs will depend on yields and prices. Each producer should use yields that are reasonable for the land, or classes of land operated.

The decision to produce corn will depend primarily on the costs and expected returns for corn in comparison with other crop alternatives. However, the producer should take into account other variables such as previous crop rotation, livestock operation, and the machinery and labor requirements of each crop.

The type and amount of equipment, crop rotations, and farm size all affect the cost of producing crops. The tillage practices used and their timing, also affect yields, and therefore, production costs. Each producer should compute the "expected returns above variable costs" for the farm operation as a means of selecting the crops and acreage of each crop to produce. When computing "expected returns above variable costs," one may want to consider a number of price alternatives.

Expected Returns Above Variable Costs for Corn

	Southeast	Northeast	Central	Irrigated*	My Farm
Yield per acre	85	100	60	150	___________
Returns:					
Yield per acre x $2.10	178.50	210.00	126.00	315.00	___________
Net Government Payments	44.50	52.00	31.00	78.00	___________
GROSS RETURNS	$223.00	$262.00	$157.00	$393.00	___________
Variable Costs:					
Labor	24.00	24.00	17.60	22.60	___________
Seed	22.80	22.80	18.75	32.00	___________
Herbicide–Insecticide	27.30	32.70	27.30	75.30	___________
Fertilizer–Lime	26.15	24.80	17.30	33.45	___________
Fuel and Oil-Crop	8.80	9.80	8.60	8.40	___________
Fuel and Oil-Pumping	0.00	0.00	0.00	35.40	___________
Machinery Repairs	16.50	20.65	14.65	21.50	___________
Irrigation Equip. Repairs	0.00	0.00	0.00	5.40	___________
Crop Insurance	6.15	6.95	4.40	29.80	___________
Drying	8.50	10.00	6.00	15.00	___________
Custom Hire	0.00	0.00	0.00	0.00	___________
Crop Consulting	0.00	0.00	0.00	6.00	___________
Miscellaneous	5.25	5.25	5.00	7.00	___________
Interest on ½ Variable Costs (9%)	6.55	7.05	5.40	13.15	___________
TOTAL VARIABLE COSTS	$152.00	$164.00	$125.00	$305.00	___________
EXPECTED RETURNS ABOVE VARIABLE COSTS	$71.00	$98.00	$32.00	$88.00	___________

*The irrigated corn budget represents an average of the variable costs for flood and center pivot irrigation practices.

Estimated Variable Costs of Production

	Southeast Kansas	Northeast Kansas	Central Kansas	Western Kansas	irrigated*	**My Farm**
Corn	$152	$164	$125	—	$305	________
Grain Sorghum	102	127	95	68	167	________
Soybeans	98	109	89	—	151	________
Wheat	83	78	68	56	111	________

* For each crop, the values represent an average of the variable costs for flood and center pivot irrigation practices.

Southeast Kansas

	Yield	Price	Net Govn't Payments	Gross/ Acre	Variable Costs	Return Above Var. Costs	Fixed Costs*	Return Above All Costs
Corn	85	$2.10	$44.50	$223	$152	$71	$74	($3)
Grain Sorghum	70	1.70	51.00	170	102	68	74	(6)
Soybeans	25	5.60	0.00	140	98	42	74	(32)
Wheat	35	2.65	40.25	133	83	50	74	(24)

* Based on $525 per acre land at 6 percent; $5.25 per acre taxes. Depreciation, interest, and insurance on $255 per acre machinery investment equals $37.

Northeast Kansas

Corn	100	$2.10	$52.00	$262	$164	$98	$83*	$15
Grain Sorghum	80	1.70	58.00	194	127	67	83	(16)
Soybeans	35	5.60	0.00	196	109	87	83	4
Wheat	40	2.65	46.00	152	78	74	83	(9)

* Based on $655 per acre land at 6 percent; $6.55 per acre taxes. Depreciation, interest, and insurance on $255 per acre machinery investment equals $37.

Central Kansas

Corn	60	$2.10	$31.00	$157	$125	$32	$74*	($42)
Grain Sorghum	55	1.70	40.50	134	95	39	74	(35)
Soybeans	25	5.60	0.00	140	89	51	74	(23)
Wheat	35	2.65	40.25	133	68	65	74	(9)

* Based on $575 per acre land at 6 percent; $5.75 per acre taxes. Depreciation, interest, and insurance on $230 per acre machinery investment equals $34.

Western Kansas

Grain Sorghum	45	$1.70	$32.50	$109	$68	$41	$71*	($30)
Wheat	35	2.65	40.25	133	56	77	71	6

* Based on 1.5 acres of land for each acre harvested. $435 per acre land at 6 percent; $4.35 per acre taxes. Depreciation, interest, and insurance on $165 per acre machinery investment equals $25.

Irrigated Crops

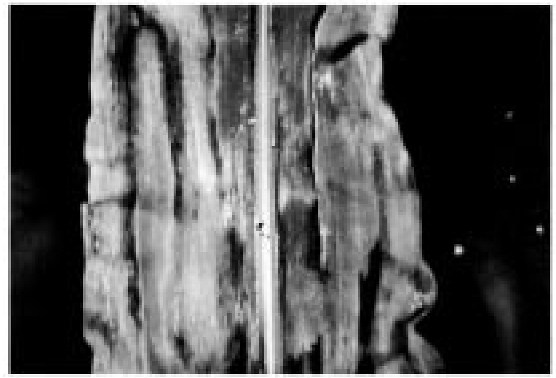
Corn	150	$2.10	$78.00	$393	$305	$88	$134*	($46)
Grain Sorghum	115	1.70	83.50	279	167	112	134	(22)
Soybeans	50	5.60	0.00	280	151	129	134	(5)
Wheat	55	2.65	63.25	209	111	98	134	(36)

* Represents an average of flood and center pivot irrigation practices, and was based on $800 per acre land at 6 percent; $8.00 per acre taxes. Depreciation, interest, and insurance on $660 machinery and irrigation equipment investment equals $78. Center pivot irrigation would have depreciation, interest, and insurance expenses of $103 on a machinery and irrigation equipment investment of $845. Flood irrigation would have depreciation, interest, and insurance expenses of $53 on a machinery and irrigation equipment investment of $475.

My Farm

Corn	________	________	________	________	________	________	________	________
Grain Sorghum	________	________	________	________	________	________	________	________
Soybeans	________	________	________	________	________	________	________	________
Wheat	________	________	________	________	________	________	________	________

Maize Dwarf Mosaic



Stewart's Wilt

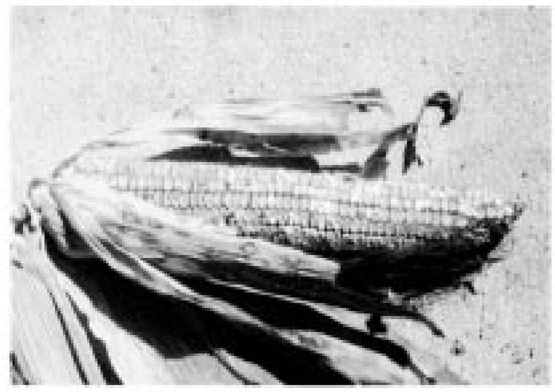
Seedling Blight, Damp-Off

Common Rust

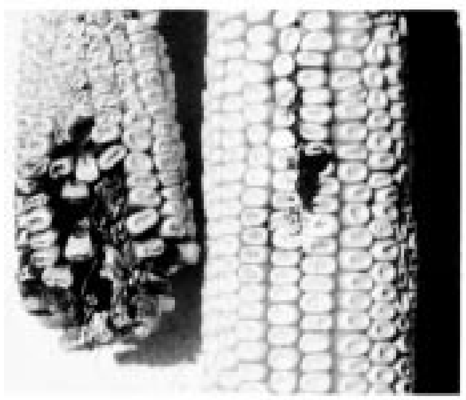
Holcus Spot

Sting Nematode

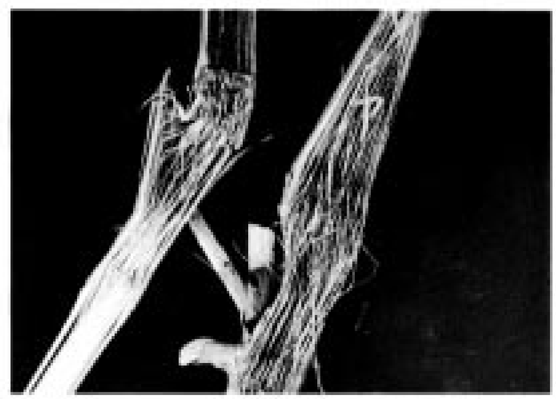
Smut



Fusarium Kernel Rot



Aspergillus Ear Rot



Charcoal Rot

Fusarium Stalk Rot

Kansas State University Agricultural Experiment Station and Cooperative Extension Service

C-560 May 1994

File code: Crops and Soils 1-5