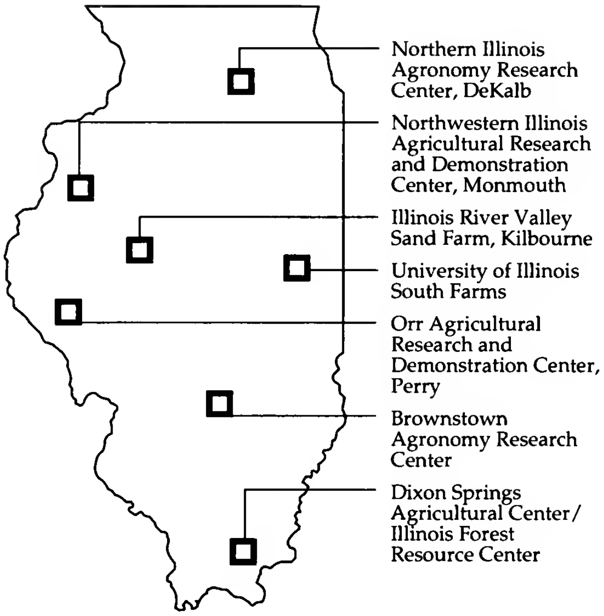
Illinois Agronomy Handbook

1993–1994

University of Illinois at Urbana-Champaign • College of Agriculture
Cooperative Extension Service • Circular 1321

Cover photo: Looking east across the South Farms at the University of Illinois at Urbana-Champaign.

Agricultural Research and Demonstration Centers



☐ Research centers administered by the Department of Agronomy at the University of Illinois. Areas of research include agronomy, agricultural engineering, agricultural entomology, animal sciences, forestry, horticulture, and plant pathology.

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Chapter 1.
Corn

Yield goals

Management decisions are made more easily if the corn producer has set realistic yield goals based on the soil, climate, and available equipment. Usually it is not realistic, for example, to set yield goals of 180 bushels per acre for a soil rated to produce only 100 bushels per acre and from which the highest yield ever produced was 130 bushels per acre. Instead, managing to achieve a realistic yield goal should result in yields greater than the goal in years when conditions are better than average and reduced losses when the weather is unfavorable. The yield goal should be considered an *average;* it will not guarantee high yields when the weather is poor.

The first step in establishing a yield goal is a thorough examination of the soil type. Information for each soil type, such as the productivity ratings given in *Soils of Illinois* (Bulletin 778), can be a useful guideline. This information, however, should be supplemented by 3- to 5-year yield records, county average yields, and the yields on neighboring farms. An attempt should be made to ignore short-term weather and to set a goal based on long-term temperature and rainfall patterns.

Perhaps the simplest way to set a yield goal is to ignore the highest yield and lowest yield for the past 5 or 6 years and average the remaining yields. More than one low yield can be ignored, and more years used, if the average seems too low for a particular field.

Hybrid selection

When tested under uniform conditions, the range in yields among available hybrids is often 30 to 50 bushels per acre. Thus it pays to spend some time choosing the best hybrids. Maturity, yield for that maturity, standability, and disease resistance are the most important factors to consider when making this choice.

Concern exists with what many consider to be a lack of genetic diversity among commercially available hybrids. Although it is true that a limited number of genetic pools, or populations, were used to produce today's hybrids, it is important to realize that these pools contain a tremendous amount of genetic diversity. Even after many years of breeding, there is no evidence that this diversity has been fully exploited. In fact, a number of studies have shown that breeding progress is not slowed even after a large number of cycles of selection. Continued improvements in most desirable traits are evidence that this is true. Many of today's hybrids are substantially better than those that are only a few years old. For this reason, some producers feel that a hybrid "plays out" within a few years. Actually, the performance of a given hybrid remains constant over the years; but comparison with newer and better hybrids may make it appear to have declined in yielding ability.

Despite considerable genetic diversity, it is still possible to buy the same hybrid from several different companies. This happens when different companies buy inbreds from a foundation seed company that has a successful breeding program, or when hybrid seed is purchased on the wholesale market, then resold under a company label. In either case, hybrids are being sold on a nonexclusive basis, and companies simply put their own name and number on the bags of seed.

Many producers, however, would like to avoid planting all of their acres to the same hybrid. One way is to buy from only one company, though this may not be the best strategy if it discourages looking at the whole range of available hybrids. Another way of assuring genetic diversity is to use hybrids with several different maturities. Finally, many dealers have at least some idea of what hybrids are very similar or identical and can provide such information if asked.

It is also important to remember that genetics are only part of the performance potential of any hybrid. The way with which hybrid seed is produced — the care in detasseling, harvesting, drying, grading, testing, and handling — can and does have a substantial effect on its performance. Be certain that the seed being bought was produced in a professional manner.

Maturity is one of the important characteristics used in choosing a hybrid. Hybrids that use most of the growing season to mature generally produce higher yields than those that mature more quickly. The latest-maturing hybrid should reach maturity at least 2 weeks before the average date of the first killing freeze (32°F), which occurs about October 8 in northern Illinois, October 18 in central Illinois, and October 25 in southern Illinois. Physiological maturity is reached when kernel moisture is 30 to 35 percent and is easily identified by the appearance of a black layer on the base of the kernel where it attaches to the cob. The approach to maturity also can be monitored by checking the "milk line," which moves from the crown to the base of the kernel as starch is deposited. The kernel is mature about the time this milk line disappears at the base of the kernel.

Although full-season hybrids generally produce the highest yields, most producers choose hybrids of several different maturities. This practice allows harvest to start earlier and also reduces the risk of stress damage by lengthening the pollination period.

Comparing hybrid maturities may be difficult because there is no uniform way of describing this characteristic. Some companies use days to maturity, whereas others use growing degree days (GDD). Use of growing degree days is becoming more widely accepted, and it is usually possible to obtain a GDD measurement for any hybrid. This is done either directly or by comparing maturity with a hybrid for which GDD is known.

The following formula can be used to calculate GDD accumulated on any given day:

$$\text{GDD} = \frac{\text{H} + \text{L}}{2} - 50°\text{F}$$

where H is the high temperature for the day (but no higher than 86°F) and L is the low temperature (but no lower than 50°F). For example (see the following table), if the daily high temperature were 95°F, calculate at 86°F, the cutoff point for high temperatures. If the daily low temperature were 40°F, calculate at 50°F, the cutoff point for low temperatures. These high and low cutoff temperatures are used because growth rates do not increase above 86°F, and they do not decrease below 50°F.

The following figures are examples of daily high and low temperatures and the resulting GDD, calculated using the GDD formula:

Daily temperature		
High	Low	GDD
80	60	20
60	40	5
95	70	28
50	35	0

It is useful to keep a running total of daily GDD because GDD has been found useful in predicting the rate of development of the corn plant. For a full-season hybrid grown in central Illinois, the following table gives the approximate GDD required to reach certain growth stages:

Stage	GDD
Emergence	120
Two-leaf	200
Six-leaf (tassel initiation)	475
Ten-leaf	740
Fourteen-leaf	1,000
Tassel emergence	1,150
Silking	1,400
Dough stage	1,925
Dented	2,450
Physiological maturity (black layer)	2,700

These GDD numbers will vary with hybrid maturity. The relative proportion of full-season GDD required to reach each growth stage will, however, remain relatively constant. For example, GDD to silking will generally be about one-half of the GDD to physiological maturity.

A full-season hybrid for a particular area will generally mature in several hundred fewer GDD than the number given in Figure 1.1. Thus, a full-season hybrid for northern Illinois would be one that matures in about 2,500 GDD, while for southern Illinois a hybrid that matures in 2,900 to 3,000 GDD would be considered full season. This GDD "cushion" reduces the

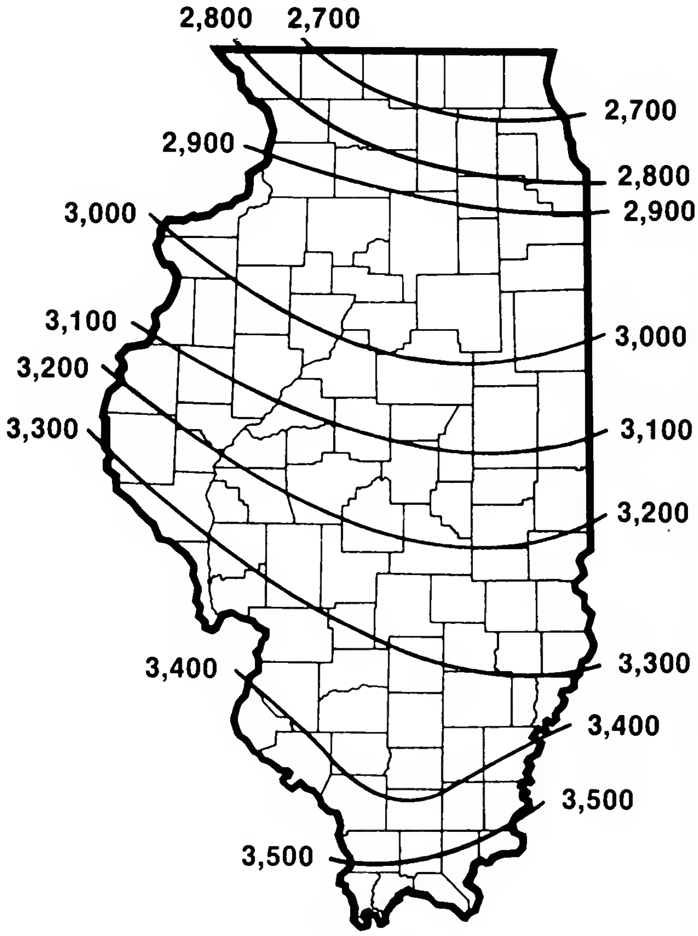

Figure 1.1. Average number of growing degree days from May 1 through September 30, based on temperature data provided by the U.S. Department of Commerce, National Weather Service, 1951-1980.

risk of frost damage and also allows some flexibility in planting time; it may not be necessary to replace a full-season hybrid with one maturing in fewer GDD unless planting is delayed until late May.

After yield and maturity, resistance to lodging is probably the next most important factor in choosing a hybrid. Because large ears tend to draw nutrients from the stalk, some of the highest-yielding hybrids also have a tendency to lodge. Such hybrids may be profitable because of their high yields, but they should be closely watched as they reach maturity. If lodging begins, or if stalks become soft and weak (as determined by pinching or pushing on stalks), then harvesting these fields should begin early.

Resistance to diseases and resistance to insects are important characteristics in a corn hybrid. Leaf diseases are easiest to spot, but stalks also should be checked for diseases. Resistance to insects such as the European corn borer also is being incorporated into modern hybrids. Another useful trait is the ability of the hybrid to emerge under cool soil conditions, a trait that is especially important in reduced- or zero-till planting.

With the large number of hybrids being sold, it is difficult to choose the best one. An important source of information on hybrid performance is the annual report *Performance of Commercial Corn Hybrids in Illinois,* which is available in Extension offices each year following harvest. This summary reports hybrid tests run each year in ten locations and includes information from the previous 2 years. The report gives data on yields, kernel moisture, and lodging of hybrids. Other sources of information include your own tests and tests conducted by seed companies, neighbors, and county Extension personnel.

Producers should see the results of as many tests as possible before choosing a hybrid. Good performance for more than one year is an important criterion. Hybrid choice should not be based on the results of only one "strip test." Such a test uses only one strip of each hybrid; the difference between two hybrids may therefore be due to location in the field rather than to an actual superiority of one over the other.

Planting date

Long-term studies show that the best time to plant corn in Illinois is around May 1, with little or no yield loss when planting is within a week on either side of this date. Weather and soil conditions permitting, planting should begin sometime before this date to allow for bad working days (Table 1.1). Corn that is planted 10 days or 2 weeks before the optimum date may not yield quite as much as that planted on or near the optimum date, but it will usually yield considerably more than that planted 2 weeks or more after the optimum date (Table 1.2).

In general, yields will decline slowly as planting is delayed up to May 10. From May 10 to May 20, the yield will decline about one-half bushel for each day that planting is delayed. This loss will increase to 1 to 1½ bushels per day from May 20 to June 1, with greater reductions in northern Illinois than in the southern part of the state. After June 1, yields decline very sharply with delays in planting. The latest practical date to plant corn ranges from about June 15 in northern Illinois to July 1 in southern Illinois. If you plant this late, expect only 50 percent of the normal yield.

Table 1.1. Days Available and Percent of Calendar Days Available for Field Operations in Illinois[a]

	Northern Illinois		Central Illinois		Southern Illinois	
Period	Days	%	Days	%	Days	%
April 1-20[b]	5.8	(29)	4.2	(21)	2.6	(13)
April 21-30[c]	3.5	(35)	3.1	(31)	2.6	(26)
May 1-10[c]	5.8	(58)	4.3	(43)	3.5	(35)
May 11-20[c]	5.5	(55)	5.0	(50)	4.4	(44)
May 21-30[c]	7.4	(74)	5.8	(58)	5.4	(54)
May 31-June 9[c]	6.0	(60)	5.4	(54)	5.6	(56)
June 10-19[c]	6.0	(60)	5.4	(54)	5.8	(58)

[a] Summary prepared by R.A. Hinton, Department of Agricultural Economics of the University of Illinois Cooperative Crop Reporting Service, unpublished official estimates of Favorable Work Days, 1955-1975. The summary is the mean of favorable days omitting Sundays, less one standard error, representing the days available 5 years out of 6.

[b] 20 days

[c] 10 days

Table 1.2. Effect of Planting Date on Yield[a]

	Northern Illinois	Central Illinois	Southern Illinois
	bushels per acre		
Late April	...	156	102
Early May	151	162	105
Mid-May	150	...	82
Early June	100	133	58

[a] 3-year average at each location.

Early planting results in drier corn in the fall, allows for more control over the planting date, and allows for a greater choice of maturity in hybrids. In addition, if the first crop is damaged, the decision to replant can often be made early enough to allow use of the first-choice hybrid. Of course, early planting has some disadvantages: (1) cold, wet soil may produce a poor stand; (2) weed control may be more difficult; and (3) plants may suffer from frost. Improved seed vigor, seed treatments, and herbicides have greatly reduced the first two hazards; and the fact that the growing point of the corn plant remains below the soil surface for 2 to 3 weeks after emergence minimizes the third hazard. Because it is below the surface, this part of the plant is seldom damaged by cold weather unless the soil freezes. Even when corn is frosted, therefore, the probability of regrowth is excellent. For these reasons, the advantages of early planting outweigh the disadvantages.

The lowest temperature at which corn will germinate is about 50°F. You should know what the soil temperature is, either from your own measurement or from reported measurements that are taken beneath bare soil. Soil temperature, however, is not the only consideration in deciding when to start planting. A more important consideration may be the condition of the soil: it generally is a mistake to till and plant when soils are wet, and the advantages of early planting may well be lost to soil compaction and other problems associated with "mudding in" corn, whether using conventional tillage or no-till techniques. If the weather conditions have been warm and dry enough to result in workable soils by early April, then planting can probably begin by April 10 or 15 with little danger of loss. The weather may change after planting, however, and a return to average temperatures (as happened in 1992) will mean slow growth for corn planted this early. It may be desirable to increase seeding rates by 1,000 to 2,000 seeds per acre if planting in April, mainly to allow for greater losses and to take advantage of the more favorable growing conditions that the crop is likely to encounter. Recent research shows little change in optimum plant population when planting time ranges from mid-April through early May (Figure 1.2).

With typical spring weather, soils can be tilled in preparation for corn planting to begin sometime in the last ten days of April. Delays due to low soil temperature (below 50°F) should be considered only if the weather outlook is for continued cold air temperatures. After April 30, soil temperature should probably be ignored as a factor, and corn should be planted as soon as soil conditions allow. Low-lying areas (such as river bottoms) may be planted last, because they warm up more slowly and are more prone to late freezes.

When planting begins in April, it is generally best to plant very full-season hybrids first, but planting the midseason and early hybrids in sequence tends to "stack" the times of pollination and harvest of the different maturities. It is probably better to alternate between early and midseason hybrids during later planting to help spread both pollination risks and the time of harvest.

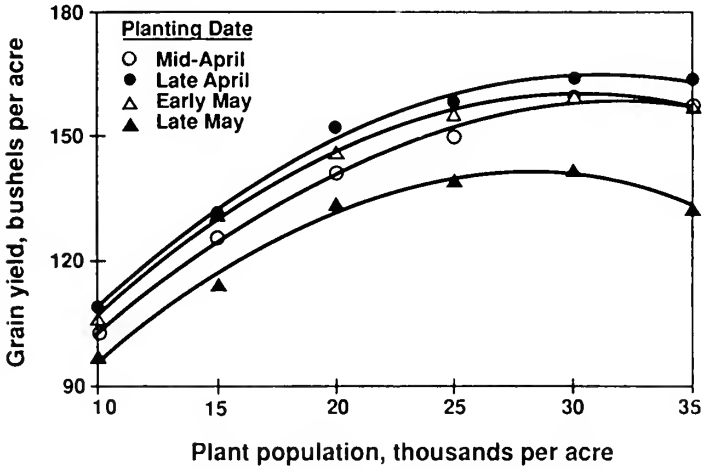

Figure 1.2. Response of corn planted at different times to plant population. Data are averages of two hybrids planted at two locations (Monmouth and DeKalb) for 4 years.

Planting depth

Ideal planting depth varies with soil and weather conditions. Emergence will be more rapid from relatively shallow-planted corn; therefore, early planting should not be as deep as later planting. For normal conditions, an ideal depth is 1½ to 2 inches. Early planted corn should be in the shallower end of this range. Later in the season, when temperatures are higher and evaporation is greater, planting as much as 2½ to 3 inches deep to reach moist soil may be advantageous.

Depth-of-planting studies show not only that fewer plants emerge when planted deep but also that those emerging often take longer to reach the pollinating stage and may have higher moisture in the fall.

Plant population

The goal at planting time is the highest population per acre that can be supported with normal rainfall without excessive lodging, barren plants, or pollination problems. One way to know when the plant population in a field is near the optimum is to check the field for average ear weight. Check at maturity, or estimate by counting kernels (number of rows multiplied by number of kernels per row) once the kernel number is set. Most studies in Illinois suggest that the optimum plant population will produce ears weighing about one-half pound and having about 640 kernels. A half-pound ear should shell out about 0.4 pound of grain at 15 percent moisture.

In the study reported in Table 1.3, ear size reached one-half pound when the plant population was slightly less than 25,000 per acre, at which point ear weight was about 0.5 pound. In the study whose results were given in Figure 1.2, average ear size at the optimum population (just above 30,000 per acre) was only about 0.37 pound, reflecting both the early hybrids and some years with drought stress. At higher populations, the increase in the number of plants was nearly matched by the reduction in ear size.

The optimum population for a particular field is influenced by several factors, some of which can be

Table 1.3. Effect of Plant Population on Corn Yield

Plants per acre	Yield[a]
	bushels per acre
15,000	140
20,000	163
25,000	175
30,000	179
35,000	179

[a] Average of 8 trials (with 2 to 4 hybrids each) conducted at Urbana, Monmouth, and DeKalb over a 3-year period.

controlled and some of which are difficult or impossible to control. Concentrate on those factors that can be controlled. For instance, little will affect the amount of water available to the crop during the growing season. This variable is determined by the soil type and the total amount and distribution of the rainfall between the time the crop is planted and when it is mature. It is possible, however, to influence how efficiently this water is used. The more efficient its use, the higher the population that can be supported with the water that is available. Remember that ear number is generally more important than ear size.

Two very important controllable factors influencing the efficiency of water use are soil fertility and weeds. Keep the fertility level of the soil high and the weed population low.

Other factors that are important include:

1. **Hybrid selection.** Hybrids differ in their tolerance to the stress of high populations. Most modern hybrids can, however, tolerate populations of 20,000 to 24,000 per acre on most Illinois soils. Some need even higher populations — 25,000 to 30,000 per acre — to produce the best yields, especially on more productive soils.
2. **Planting date.** Early planting enables the plant to produce more of its vegetative growth during the long days of summer and to finish pollinating before the hot, dry weather that is normal for late July and early August. Early planting usually produces larger root systems as well.
3. **Row spacing.** The more uniform distribution of plants grown in narrow rows improves the efficiency of water use.
4. **Insect and disease control.**

The harvest population is always less than the number of seeds planted. Insects, diseases, adverse soil conditions, and other hazards take their toll. Expect from 10 to 20 percent fewer plants at harvest than seeds planted (Table 1.4).

Row spacing

Because of the clear yield advantage from using a row spacing of less than 40 inches (Table 1.5), many producers have reduced row spacing; some 40 percent of the corn acres in Illinois are planted in 30-inch rows, and the average row spacing in the state is about 35 inches. A few producers in the Corn Belt use rows less than 30 inches apart. Most studies have shown yield increases of about 5 to 8 percent when rows are narrowed from 30 to 20 inches (Table 1.6). Equipment for harvesting 20-inch rows is not readily available at present, but some harvesting equipment can be modified for this purpose.

Table 1.4. Planting Rate That Allows for a 15 Percent Loss from Planting to Harvest

Plants per acre at harvest	Seeds per acre at planting time
16,000	18,800
18,000	21,200
20,000	23,500
22,000	25,900
24,000	28,200
26,000	30,600
28,000	33,000
30,000	35,300

Replanting

Although it is normal that 10 to 15 percent of planted seeds fail to establish healthy plants, additional stand losses due to insects, frost, hail, flooding, or poor seedbed conditions may call for a decision on whether or not to replant a field. The first rule in such a case is not to make a hasty decision. Corn plants can and often will outgrow leaf damage, especially when the growing point, or tip of the stem, is protected beneath the soil surface or up until about the six-leaf stage. If new leaf growth appears within a few days after the injury, then the plant is likely to survive and produce normal yields.

When deciding whether to replant a field, assemble the following information: (1) original planting date and plant stand, (2) possible replanting date and plant stand, and (3) cost of seed and pest control for replanting.

If the plant stand was not counted before damage occurred, population can be estimated by reducing the dropped seed rate by 10 percent, providing that conditions for emergence were normal. To estimate stand after injury, count the number of living plants in $\frac{1}{1,000}$ of an acre (Table 1.7). Take counts as needed to get a good average, one count for every 2 to 3 acres.

When the necessary information on stands and planting and replanting dates has been assembled, use

Table 1.5. Effect of Row Width on Corn Yield, Urbana

	Row width	
Plants per acre	40 inches	30 inches
	bushels per acre	
16,000	127	132
24,000	133	144
32,000	126	138

Table 1.6. Corn Yields in 20- and 30-Inch Rows at Urbana

	Row width	
Plants per acre	30 inches	20 inches
	bushels per acre	
20,000	165	174
25,000	172	188
30,000	174	187

Table 1.7. Row Length Required to Equal 1/1,000 Acre

Row width	Row length
20″	26′1″
28″	18′8″
30″	17′5″
32″	16′4″
36″	14′6″
38″	13′9″
40″	13′1″

Table 1.8. Yield of Uniformly Spaced Corn Plants with Different Planting Dates and Plant Populations

Planting date	Plants per acre at harvest					
	14,000	16,000	18,000	20,000	22,500	25,000
	percent of maximum yield					
April 25.....	81	86	90	93	96	98
May 6......	83	88	92	95	98	100
May 16.....	81	86	90	93	96	98
May 26.....	75	80	84	87	90	92
June 10.....	58	63	67	70	73	75

Table 1.8 to determine both the loss in yield to be expected from the stand reduction and the yield expected if the field is replanted.

To use Table 1.8, locate the expected yield of the reduced plant stand by reading across from the original planting date to the plant stand after injury. Then locate the expected replant yield by reading across from the expected replanting date to the stand that would be replanted. The difference between these numbers is the percentage yield increase (or decrease) to be expected from replanting. For example, corn that was planted on April 25, but with a plant stand reduced to 18,000 by cutworm injury, would be expected to yield 90 percent of a normal stand. If such a field were replanted on May 16 to establish 25,000 plants per acre, the expected yield would be 98 percent of normal. Whether or not it will pay to replant such a field will depend on whether the yield increase of eight percentage points would repay the replanting costs. In this example, if replanting is delayed until near the end of May, the yield increase to be gained from replanting disappears.

Although uniformity of stand cannot be measured easily, studies have indicated that reduced plant stands will yield better if plants are spaced uniformly than if there are large gaps in the row. As a general guideline, yields will be reduced an additional 5 percent if there are many gaps of 4 to 6 feet in the row and an additional 2 percent for gaps of 1 to 3 feet.

Weather stress in corn

Corn frequently encounters some weather-related problems during the growing season. The effect of such problems differs with the severity and duration of the stress and the stage of crop development at the time of the stress. Some of the possible stress conditions and their effects on corn growth and yield are:

A. **Flooding.** The major stress caused by flooding is simply a lack of oxygen needed for the proper function of the root system. When plants are very small, they will generally be killed after about five or six days of being submerged. Death will occur more quickly if the weather is hot, because high temperatures speed up the biochemical processes that use oxygen, and warm water has less dissolved oxygen. Cool weather, on the other hand, may allow plants to live for more than a week under flooded conditions. When plants reach the 6- to 8-leaf stage, they can tolerate a week or more of standing water, though total submergence may increase disease incidence, and plants will suffer from reduced root growth and function for some days after the water recedes. Tolerance to flooding generally increases with age, but reduced root function due to lack of oxygen is probably more detrimental to yield before and during pollination than during rapid vegetative growth or during grainfill.

B. **Hail.** The most common damage from hail is loss of leaf area, though stalk breakage and bruising of the stalk and ear can be severe. Loss charts based on leaf removal studies generally confirm that defoliation at the time of tasseling causes the greatest yield loss, while loss of leaf area during the first month after planting or when the crop is near maturity generally causes little yield loss. Loss of leaf area in small plants usually delays their development, however, and plants that experience hail may not always grow normally afterward.

C. **Cold injury.** Corn is of tropical origin and is not especially tolerant of cold weather. While the death of leaves from frost is the most obvious type of cold injury, leaves are damaged by temperatures below the low 40s, and photosynthesis can be reduced even if the only symptom is a slight loss of leaf color. The loss of leaves from frost is generally not serious when it happens to small plants, though such loss will delay plant development and could delay pollination to a less favorable (or, rarely, a more favorable) time. Frost injury symptoms may appear on leaves even when nighttime temperatures do not fall below the mid-30s; radiative heat loss can lower leaf temperatures to several degrees below air temperatures on a clear, calm night. If frost kills leaves before physiological maturity (black layer) in the fall, sugars can usually continue to move from the stalk into the ear for some time, although yields will generally be lowered, and harvest moisture may be high due to high grain moisture at the time of frost and slow drying rates that usually follow premature death.

D. **Drought.** Through the late vegetative stage (i.e., the end of June in normal years), corn is fairly tolerant of dry soils, and mild drought during June may even be beneficial, because roots generally grow downward more strongly as surface soils dry, and the crop benefits from the greater amount of sunlight that accompanies dry weather. During the two weeks before and two weeks following pollination, corn is very sensitive to drought, however, and dry soils during this period can cause serious yield losses. Most of these losses are due to failure of pollination, and the most common cause is the failure of silks to emerge from the end of the ear. When this happens, the silks do not receive pollen; thus the kernels are not fertilized and will not develop. Drought later in grainfill has a less serious effect on yield, though root function may decrease and kernels may not fill completely.

E. **Heat.** Because drought and heat usually occur together, many people assume that high temperatures are a serious problem for corn. In fact, corn is a crop of warm regions, and temperatures less than 100°F usually do not cause much injury *if soil moisture is adequate.* Extended periods of hot, dry winds can cause some tassel "blasting" and loss of pollen, but pollen shed usually takes place in the cooler hours of the morning, and conditions severe enough to cause this problem are unusual in Illinois. There is evidence that hybrids vary in their sensitivity to both heat and drought, though very tolerant hybrids usually give up some yield potential. As a result, they may not be good choices for average conditions.

Estimating yields

Making plans for storage and marketing of the corn crop often calls for estimating yields before the crop is harvested. Such estimations are easier to make for corn than for most other crops because the number of plants or ears per acre can be counted fairly accurately.

Estimating corn yields is done by counting the number of ears per acre and the number of kernels per ear, then multiplying these two numbers to get an estimate of the number of kernels per acre. Next, simply divide by an average number of kernels in a normal bushel to get the yield in bushels per acre.

Corn yields can be estimated after the kernel number is fixed — about 2 weeks after the end of pollination. The following steps are suggested:

1. Walk out in the field a predetermined number of rows and paces: For example, go 25 rows from the edge of the field and 85 paces from the end of the field. If this pattern is not determined beforehand, there will be a tendency to stop where the crop looks better than average. Stop *exactly* where planned.
2. Measure $\frac{1}{1,000}$ of an acre (Table 1.7), and count the number of *ears* (not stalks) in that distance. Do not count ears with only a few scattered kernels.
3. Take three ears from the row that was counted. To avoid taking only good ears, take the third, sixth, and tenth ears in the length of row. Do not take ears with so few kernels that they were not included in the ear count.
4. Count the number of rows of kernels and the number of kernels per row on each ear. Multiply these two numbers together for each ear, then average this kernel count for the three ears.
5. Calculate yield using the following formula:

$$\text{bu/acre} = \frac{\text{number of ears per } \frac{1}{1,000} \text{ acre} \times \text{average number of kernels per ear}}{90}$$

6. To get a reliable average, repeat this process at least once for every 5 acres in a field.

In the formula, the number 90 is used based on the assumption that a bushel of normal-sized seed contains about 90,000 kernels. The zeros are dropped because the plant population is given in thousands per acre.

Specialty types of corn

Erratic and generally low world corn prices have resulted in considerable interest among producers in growing various specialty types of corn, either for export or for domestic use. This may mean higher profits if the supply of such types is quite small. Because the total demand might also be quite limited, however, the price advantage may disappear as more producers start growing a particular specialty type. It is therefore important to have other uses for the crop (for example, as livestock feed) and to grow types that do not yield substantially less than normal corn, in the event that the corn cannot be sold for its intended special use.

Many specialty types are grown under contract. The contract buyers often specify what hybrids may or may not be used, and they may specify other production practices to be used. Some contracts also may include pricing information and quality specifications.

Risks associated with growing specialty types of corn vary considerably. Milling companies may buy corn with "food-grade endosperm," requiring only that the grower choose hybrids from a relatively long list of popularly grown hybrids; the risk in this case is small. On the other hand, inbreds used to produce some hybrids are not very vigorous, and seed corn production with such inbreds might be very risky. Production contracts in such cases may shift some of the risk to the buyer. In any case, every grower of specialty types of corn should be aware of risks associated with each type.

White corn

Most of the white corn grown in the United States is used to make cornflakes, cornmeal, and grits. It often sells at a higher price than yellow corn, sometimes as much as double that of yellow corn.

The cultural practices for producing white corn are the same as those for yellow corn except that many of the white hybrids are quite late in maturity when grown in Illinois. Choice of hybrid is therefore important. In addition, kernels fertilized by pollen from yellow hybrids will be light yellow. These yellowish kernels are undesirable. The official standards for corn specify that white corn cannot contain more than 2 percent of corn of other colors; therefore, white corn probably should not be planted on land that produced yellow corn the year before. It may also be desirable to harvest the outside ten or twelve rows separately from the rest of the field. Most of the pollen from adjacent yellow corn will be trapped in those outer rows.

High-lysine corn

Lysine is one of the amino acids essential to animal life. Livestock producers need not be concerned whether or not the protein that ruminant animals eat contains this amino acid because the microflora in rumen can synthesize lysine from lysine-deficient protein. Nonruminants cannot do this, however, so swine, poultry, and humans must have a source of protein that contains sufficient lysine to meet their needs.

Normal dent corn is deficient in lysine. The discovery in 1964 that the level of this essential amino acid is controlled genetically and can be increased by incorporating a gene called *opaque*-2 was exciting news to both the corn geneticist and the animal nutritionist. The potential value of this discovery to the swine farmer was obvious when feeding trials demonstrated that substantially less soybean meal was required when high-lysine corn was fed to swine.

Agronomic research with high-lysine corn indicates that it is slightly lower in yield and higher in moisture than its normal counterpart. Furthermore, the kernel may be softer and more susceptible to damage. Current research involving genes in addition to *opaque*-2, however, has successfully reduced some of these differences.

The *opaque*-2 gene is recessive: high-lysine corn pollinated by normal pollen produces normal low-lysine grain. Although isolation from normal corn is not essential, regular hybrids should not be strip-planted in high-lysine corn, nor should high-lysine corn be planted where the number of volunteer corn plants will be high.

Popcorn

As with several of the other specialty types of corn, most of the popcorn produced in Illinois is under contract to processors. While there are several dozen hybrids from which to choose, the processor may require that a hybrid be grown for its particular kernel characteristics rather than for yield alone. Thus, income per acre should be considered because low-yielding hybrids may often bring a higher price.

Cultural practices for popcorn are much like those for field corn. Popcorn often is attacked by stalk rot; therefore, excessively high plant populations should be avoided, and harvest should begin as soon as the grain is dry enough. Weed control also may be more difficult because of slower emergence and early growth. Rotary hoeing and cultivation may be useful supplements to chemical weed control. Because popcorn yields 30 to 40 percent less than field corn, fertilizer needs should generally be somewhat lower.

Many newer popcorn hybrids are "dent sterile," meaning that field-corn pollen cannot fertilize popcorn kernels. This trait should reduce the need for isolation, but be sure to check with the contractor to verify this. Generally, it is best to avoid planting popcorn in a field where field corn grew the previous season.

High-oil corn

In the summer of 1896, C.G. Hopkins of the University of Illinois started breeding corn for high oil content. With the exception of 3 years during World War II, this research has continued. The oil content of the material that has been under continuous selection has been increased to 17.5 percent from the 4 to 5 percent that is normal for dent corn. Recent research involving new gene pools of high-oil material unrelated to the original Illinois High Oil indicates that varieties containing 7 to 8 percent oil may be produced with little or no sacrifice in yield. Higher-oil hybrids are now being marketed on a limited scale.

Because oil is higher in energy per pound than starch is, a livestock ration containing high-oil corn should have some advantage over one containing normal corn. Feeding trials involving high-oil corn have generally confirmed this assumption. There is also interest in high-oil corn as a source of edible oil. Corn oil has a high ratio of polyunsaturated fatty acids to saturated fatty acids. It is used in salad oils, margarine, and cooking oils.

Waxy maize

Waxy maize is a type of corn that contains 100 percent amylopectin starch instead of the 75 percent typical for ordinary dent hybrids. Amylopectin starch is used in many food and industrial products. Several corn-milling companies annually contract for its production in the central Corn Belt.

The waxy characteristic is controlled by a recessive gene, which means that waxy corn pollinated by pollen from normal corn will develop into normal dent corn. Waxy corn, like high-lysine corn, should not be planted in fields where dent corn is likely to volunteer. The outside six to ten rows may also need to be segregated from the rest of the field to keep the amount of contamination from normal corn at an acceptable level.

Normal dent corn hybrids can be converted to waxy hybrids by the relatively straightforward method of backcrossing, which introduces the waxy characteristic but leaves most of the agronomic traits intact. There are, therefore, a number of good waxy hybrids on the market, and their yields are often comparable to those of normal hybrids. The time required to complete the backcross process, however, will usually mean that the introduction of a waxy type lags a few years behind that of its normal parent hybrid.

High-amylose corn

In high-amylose corn, the amylose starch content has been increased to more than 50 percent. Normal corn contains 25 percent amylose starch and 75 percent amylopectin starch.

The amylose starch content also is controlled by a recessive gene; therefore, isolation of production fields is important, as is selecting production fields that were not planted in normal corn the previous year.

Chapter 2.

Soybeans

Planting date

Soybeans generally yield best when planted in May, with full-season varieties tending to yield best when planted in early May. Earlier varieties, however, often yield more when planted in late May than in early May. When the planting of full-season varieties is delayed until late May, the loss in yield is minor compared with the penalty for planting corn late. Therefore, the practice of planting soybeans after corn has been planted is accepted and wise.

The loss in yield of soybeans becomes more severe when planting is delayed past early June. The penalty, however, for late-planted corn is proportionally greater, and the danger of wet or soft corn becomes such a threat that soybeans are, under most conditions, a better crop for late planting than corn. Table 2.1 illustrates yield losses resulting from delayed planting of soybeans.

Planting date has an effect upon the length of time it takes soybeans to mature. The vegetative stage (planting to the beginning of flowering) is 45 to 60 days for full-season varieties planted at the normal time. This period is shortened as planting is delayed and may be only about 25 days when these varieties are planted in late June or early July.

Soybeans are photoperiod responsive and the length of the night or dark period is the main factor that determines when flowering begins. Also, the vegetative period is influenced by temperatures — with high temperatures shortening and low temperatures lengthening it. But the main effect remains that of the length of the dark period.

As planting is delayed, the length of the flowering period and that of pod filling also are shortened; but the effect of planting time on these periods is minor compared with that on the vegetative period.

As the length of the vegetative period grows shorter, because of delayed planting, soybean plants mature in fewer days (Table 2.2).

Planting rate

Maximum yields for May and very early June plantings of soybeans generally are provided by planting rates that result in 8 to 10 plants per foot of row at harvest in 40-inch rows, 6 to 8 plants in 30-inch rows, 4 to 6 plants in 20-inch rows, or 3 to 4 plants in 10-inch rows. Higher populations will usually result in excessive lodging in all varieties except those that are extremely lodging resistant. With populations that are sufficiently low, yield may be lower because the plants fail to form a complete canopy, which fully utilizes

Table 2.1. Effect of Planting Date on Soybean Yields

Variety	Date of planting			
	May 7	May 21	June 8	June 19
	bushels per acre			
Urbana location				
Corsoy	56	62	49	42
Beeson	57	55	52	47
Calland	56	51	47	40
	May 3	May 17	June 7	July 1
Carbondale location				
Corsoy	27	38	43	28
Cutler	62	46	54	27
Dare	72	45	37	32

Table 2.2. Effect of Planting Date on Days to Maturity, Soybeans

Variety		Date of planting		
		May 1	June 1	June 12
		days to maturity		
Columbia, Missouri (6-year average)				
Hawkeye		122	104	98
Clark		149	115	105
	May 3	May 17	June 7	July 1
Carbondale location				
Corsoy	118	103	107	101
Wayne	131	117	117	105
Cutler	145	133	117	108
Dare	159	153	138	122

available sunlight. Lower population densities also tend to branch more and pod lower, two factors that can lead to increased harvest losses and lower yields.

As row spacing narrows, fewer seeds per foot of row are needed to achieve a given rate of seeds per acre (Table 2.3). Remember that the plant population achieved is always less than the seeding rate used. Some seeds simply are not viable, while others fail to establish a plant because of disease, excessive planting depth, or other problems.

Seeding-rate studies have demonstrated the productive capacity of soybeans at rather low plant densities. At extremely low plant densities, a considerable amount of the production may not be harvestable with a conventional combine because of low podding and excessive branching on the plant. Precipitation during vegetative development will help determine what the "ideal" plant density is for a given year. In a dry year, when vegetative development of plants is restricted, thicker stands of soybeans are desirable so that the smaller plants can develop a full crop canopy. In a year with considerable rain during May and June, which causes plants to grow taller and can lead to lodging by the crop, somewhat lower plant densities are better to avoid excessive lodging. At the time of planting, however, you cannot predict precipitation during vegetative growth, so a compromise in seeding rate offers the most potential.

Seeding-rate trials conducted on numerous varieties across several years suggest that a wide range of seeding rates will produce good yields. Seeding rates of 110,000 to 150,000 seeds per acre tend to produce the best yields (Figure 2.1). For seed of average size, these rates correspond to roughly 40 to 60 pounds per acre. Planting at rates toward the high end of this range helps ensure a full stand, while planting toward the low end of the range helps conserve seed. Virtually all soybean varieties respond to changes in seeding rate in a similar manner. Possible exceptions are varieties with weak stems (which lodge easily) and those with a determinate growth habit (which have reduced capacity to produce vegetative growth after the onset of flowering).

If seeding of soybeans is delayed until late June or early July, vegetative development of the plant will be greatly reduced. The smaller plants that develop will be resistant to lodging. The small stature of the plants limits the amount of sunlight each can intercept; to compensate for this effect, the seeding rate is increased. Increases of 50 to 100 percent over that suggested for May plantings are advisable.

Table 2.3. Number of Seeds Required to Achieve Given Seeding Rates in Various Row Widths

Desired seed rate per acre	Row width, inches					
	36	30	20	15	10	7
	seeds required per row-foot					
100,000	6.9	5.7	3.8	2.9	1.9	1.3
125,000	8.6	7.1	4.7	3.6	2.4	1.6
150,000	10.3	8.6	5.7	4.3	2.9	2.0
175,000	12.1	10.0	6.7	5.0	3.3	2.3
200,000	13.8	11.4	7.6	5.8	3.8	2.6

Planting depth

Emergence will be more rapid and stands will be more uniform if soybeans are planted only 1½ to 2 inches deep. Deeper planting often results in lower emergence and poor stands.

Varieties differ in their ability to emerge when planted more than 2 inches deep. The description of a variety may mention an "emergence score," which reflects the ability of the seedling hypocotyl to elongate sufficiently when planting is deeper than recommended. Scores for emergence are usually given on a 1-to-5 scale, with a score of 1 indicating that the likelihood of emergence is very good and a score of 5 indicating that such probability is very weak. Special attention should be given to the planting depth of varieties that are known to have weaker emergence potentials. Because a variety has a tendency to emerge slowly or weakly from excessively deep planting does not mean it lacks the ability to produce a good crop when planted at a reasonable depth. It simply means that extra attention to depth of planting is needed to ensure a good stand.

Crop rotation

The crop preceding soybeans has an influence on yield potential. If soybeans are planted after soybeans, diseases and other pest problems may be intensified in the second and later years of production. Difficult-

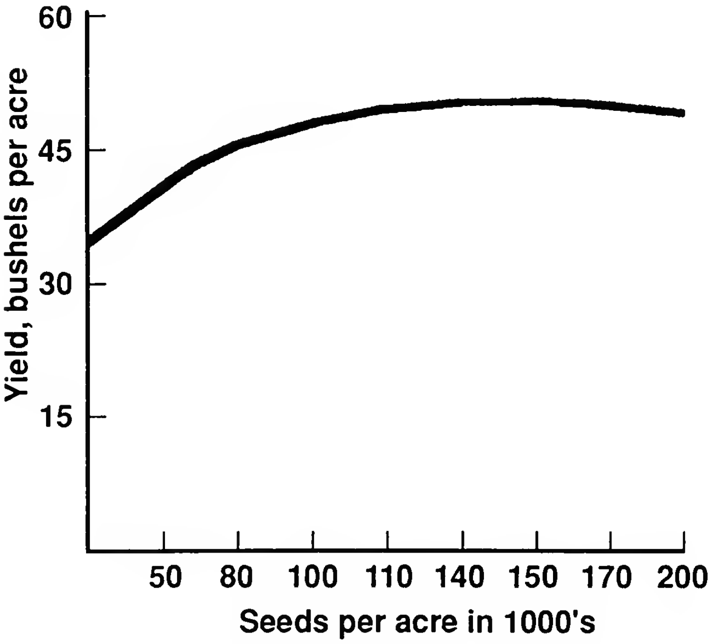

Figure 2.1. Effect of seeding rate on soybean yields.

to-control weed problems will become worse. Research evidence also suggests that growth-inhibiting substances (allelopathic chemicals) are released from soybean residue as it decomposes in the soil. These substances have a negative effect on growth and production of soybeans. To avoid this problem, sufficient time must elapse between one soybean crop and the next to allow decomposition of the soybean crop residue. Planting soybeans after soybeans will not provide a sufficient interval.

Several studies on the rotation benefits for soybean yield have been done. Table 2.4 summarizes these results, which indicate that higher yields tend to result from soybeans grown in rotation, compared to those from soybeans after soybeans.

Row width

If weeds are controlled, soybeans often will yield more in narrow rows than in traditional row spacings of at least 30 inches. The yield advantage for narrow rows is usually greatest for earlier-maturing varieties, with full-season varieties showing smaller gains in yield as row spacing is reduced to less than 30 inches. A multiyear study illustrates that average gains for narrow versus wider row spacings will vary from year to year (Table 2.5).

The following rule of thumb predicts situations in which narrower row spacings will likely be advantageous to yield: If a full canopy of leaves is not developed over the ground by the time that pod development begins, narrower spacings for soybeans can be advantageous to yield.

In addition to row spacing, factors that influence canopy development by the time podding begins are (1) relative maturity of the variety grown, (2) growing conditions during the vegetative period of plant development, and (3) planting date. Varieties that mature relatively early generally have the smallest canopies when podding begins and, consequently, can benefit most from narrow-row spacings. Dry or otherwise undesirable weather early in the season will reduce the amount of canopy developed before the onset of flowering by the soybean. When such weather patterns occur, rows that are more narrow help develop a full canopy by the time podding begins. Delays in planting reduce the amount of canopy that develops before seed formation activity of the plant begins; thus when planting is delayed considerably, soybeans respond to narrower rows with yield increases. Double-crop soybeans planted after the small-grain harvest should be planted in rows no wider than 20 inches (Table 2.6).

For many years, some Illinois farmers have planted their soybeans with a grain drill. Interest in this planting method has increased to the point that about 20 percent of the soybean acres of Illinois are planted this way. The availability of improved herbicides has helped producers to expand the use of this planting method. If the weeds can be kept under control, the small-grain drill is a practical narrow-row planting device for soybeans. Research does not always show an advantage for the 7- or 8-inch rows over 15- or 20-inch spacings, but the drilled beans usually yield better than those planted in rows spaced at least 30 inches apart. A key factor to successful planting with a grain drill is good weed control. Also, with a grain drill, planting depth is more difficult to control. Because of these possible problems, farmers trying this planting method are wise to do so on a small acreage first.

For additional information about planting soybeans with a grain drill, see Illinois Cooperative Extension Service Circular 1161, *Narrow-Row Soybeans: What to Consider.*

Table 2.4. Effect of Crop Rotation on Soybean Yields

Location	Soybeans after Soybeans	Soybeans after Corn
	bushels per acre	
DeKalb	39	44
Dixon	30	35
Urbana	44	50
Brownstown	30	35

Table 2.5. Average Yield of 30 Soybean Lines in Wide- and Narrow-Row Spacings, 1980-83

Year	Row spacings, inches 30	15	10	Narrow-row yield advantage
1980	39.8	41.4	. . .	4%
1981	55.8	. . .	61.6	10%
1982	56.1	. . .	57.9	3%
1983	53.5	. . .	54.4	2%

When to replant

Uniform full stands have been compared to those with irregular deficiencies of varying magnitudes to evaluate yield potentials of stands that are less than perfect (Tables 2.7 and 2.8). Studies strongly suggest that the soybean plant has a tremendous ability to compensate for missing plants. By developing more branches and podding more heavily, the effect of missing plants in the stand is often not detected in yields. Yield reduction that is suffered with very poor stands may still be more profitable to the grower than

Table 2.6. Yield of Double-Crop Soybeans When Planted in 20- and 30-Inch Rows, 1972

Site	Row spacings, inches 20	30
Dixon Springs	53	43
Brownstown	37	32
Urbana	33	24

a replanted field, which has additional costs associated with replanting and a reduced yield potential because of a delayed seeding date.

Data in Table 2.7 illustrate the soybean's ability to compensate for missing plants when randomly placed gaps occur in the stand. The influence of plant density in the remaining row sections is also apparent from the table. For soybeans to exhibit their full capacity to compensate for missing plants, it is necessary to control weed growth in the areas without soybean plants. In a field situation where poor stands are realized, management to control weeds is essential to prevent further yield losses due to the poor stand. The cost of maintaining the necessary weed control must be considered a cost of keeping a less-than-perfect stand.

Growers who replant do so at a later planting date than is the optimum. A penalty to yield due to delayed planting of 2 to 3 weeks is reflected in values presented in Table 2.8. The plant density per foot of row achieved with replanting, along with possible gaps in that stand, will also influence yield potential. It is wise to remember that replanted soybeans are not guaranteed to grow: A perfect stand is not always achieved when a poor stand is destroyed and the field replanted.

At a given level of stand reduction, the impact on yield is minimized if the gaps are small rather than large in size. A gap size of 16 inches has been found to have no influence on yield of soybeans grown in 30-inch row spacing, provided adjacent rows have a full stand. Compensation for gaps in the row has been found to occur not only in the row where the gap is located but also in the rows bordering the gap. The degree of compensation exhibited by soybeans should be enhanced as rows are spaced closer together, for under such planting arrangements the plants are initially more uniformly spaced in the field, making it more likely they can fully compensate for a stand deficiency of a given level. Extension Circular 1317, *Managing Deficient Soybean Stands*, can be useful to growers making a replanting decision.

Table 2.7. Percent of Full-Yield Potential for Timely Planted Soybeans, as Influenced by Plants per Foot of Row and Percent Stand Reduction

Stand reduction	Plants per foot of row[a]		
	8	6	4
	percent of full-yield potential		
0 (full stand)	100	97	95
10 percent	98	96	93
20 percent	96	93	91
30 percent	93	90	88
40 percent	89	86	83
50 percent	84	81	78
60 percent	78	75	73

[a] Plants per foot of row in row sections with no gaps or skips.

Table 2.8. Percent of Full Yield Expected from Replanting Soybeans, as Influenced by Plants per Foot of Row and Stand Deficiency

Stand-deficiency level	Plants per foot of row[a]		
	8	6	4
	percent of full-yield potential		
0 (full stand)	89	86	83
10 percent	88	85	83
20 percent	86	84	81
30 percent	84	81	79
40 percent	81	78	75
50 percent	76	74	71
60 percent	71	69	66

[a] Plants per foot of row in row sections with no gaps or skips.

Double-cropping

See Illinois Cooperative Extension Circular 1106, *Double-Cropping in Illinois.*

Seed source

To ensure a good crop, you must do a good job of selecting seed. When evaluating seed quality, consider the percent germination, percent pure seed, percent inert matter, percent weed seed, and the presence of diseased and damaged seed.

Samples of soybean seed taken from the planter box as farmers were planting showed that homegrown seed was inferior to seed from other sources (Table 2.9). The number of seeds that germinate and the pure seed content of homegrown seeds were lower. Weed seed content, percent inert material (hulls, straw, dirt, and stones), and presence of other crop seeds (particularly corn) in homegrown seed were higher.

This evidence indicates that the Illinois farmer can improve soybean production potential by using higher-quality seed. Homegrown seed is the basic problem. Few producers are equipped to carefully harvest, dry, store, and clean seeds, and to perform laboratory tests that adequately assure high-quality seed. A grower who is not a professional seed producer and processor may be well advised to market the homegrown soybeans and obtain high-quality seed from a reputable professional dealer.

A state seed tag is attached to each legal sale from a seed dealer. Read the analysis and evaluate if the

Table 2.9. Quality Differences in Soybeans from Different Sources

Source	Germination, %	Pure seed, %	Inert matter, %	Seed cleaned, %	Seed germination tested, %
1985 survey					
Certified seed	88.2	99.5	0.42	100	100
Bin-run seed	85.9	98.1	1.19	51	14
1986 survey					
Certified seed	89.0	99.4	0.29	100	100
Bin-run seed	87.7	98.6	1.59	90	10

seed being purchased has the desired germination, purity of seed, and freedom from weeds, inert material, and other crop seeds. The certification tag verifies that an unbiased nonprofit organization (in our state, the Illinois Crop Improvement Association) has inspected the production field and the processing plant. These inspections make certain that the seeds are of a particular variety as named and have met certain minimum quality standards. Because some seed dealers may have higher quality seed than others, it always pays to read the tag.

Seed size

The issue of how the size of seed planted affects soybean growth and the final yield often arises following a year with stress during the seed-fill period, which reduces final seed size. Research suggests little detrimental effect from planting seed that is smaller than normal.

Across a broad range of seed sizes, insignificant effects on emergence have been reported. Seed of extremely small size, which normally do not make their way into the seed market, may be reduced in emergence when planted at a normal seeding depth of 1 to 2 inches. Interestingly, though, at excessive seeding depths (3 inches) the smaller seeds have been reported to enjoy an advantage over large ones. This advantage may be caused by the smaller cross-sectional dimension of their cotyledons, which must be dragged up through the soil.

Final differences in plant size, which might result from planting seed of different sizes, do not suggest any problems with using small seed. Any differences reported on final plant size are so small (less than 4 inches) that they would likely not have a significant effect on yield.

The size of seed produced by soybeans is determined by a combination of genetic factors for the variety and the environment in which the seed develop. Whether soybeans are large or small, seed for a given variety has the same genetic potential. Therefore, the size of the seed produced on a plant established by planting a small seed will be expected to be the same as those from a plant grown from large seed.

Effects of the seed size on final yield, which is the ultimate concern of growers, appears to be minimal. When shopping for soybean seed, seed quality should be a more important consideration than actual seed size. If smaller-than-normal seed will be used to establish soybeans, check your planter calibration to meter the seed at the proper rate. Excessive seeding rates, resulting from misadjusted planting equipment metering small seed, can result in excessively thick stands that will be more prone to lodging.

Varieties

Soybean varieties are divided into maturity groups according to their relative time of maturity (see Tables 2.10, 2.11, and 2.12). Varieties of Maturity Group I are nearly full season in northernmost Illinois but are too early for good growth and yield farther south. In extreme southern Illinois, varieties in Maturity Groups IV and V are best adapted.

Traditionally, soybeans grown in the Midwest had indeterminate growth habits; that is, vegetative growth continues beyond the time when flowering begins, continuing generally until seed filling begins. In recent years, a few varieties with determinate growth habits have been developed and released in the Midwest. The main reason for their introduction was to provide varieties that are highly resistant to lodging, which would be most useful in environments where lodging is a yield-limiting factor. The determinate growth habit, which is a genetically controlled trait, stops vegetative growth on the main stem when flowering begins; this produces a relatively short plant that is quite resistant to lodging. With this growth pattern, determinate soybeans must develop adequate leaf material before flowering.

While determinate varieties can be very productive in a favorable environment, they can also disappoint growers when production is attempted in a low-yield environment. Determinate varieties will be most useful and profitable to growers in environments where conditions favor rapid early-season vegetative growth, the same conditions that can possibly lead to lodging problems with indeterminate varieties. Lacking such an environment for soybean production, growers would be wise to use only indeterminate varieties.

The following is a list of public varieties of soybeans that are available in Illinois. If a variety is determinate, the description so notes — all others are indeterminate. Varietal names marked with an asterisk (*) are protected varieties. (See the section titled "Plant Variety Protection Act" in Chapter 8.)

Maturity Group I

Archer* provides resistance to brown stem rot and multiple races of Phytophthora root rot in Group I maturity. In addition, it has good lodging resistance.

BSR 101 has more genetic resistance to brown stem rot than does any other public variety in its maturity group. In addition, it has resistance to Phytophthora root rot, race 1. BSR 101 has more lodging resistance and better yield potential than Hardin, which has similar maturity.

Bell* has a late Group I maturity which offers good yield potential along with resistance to races 3 and 4 of the cyst nematode. It does not have resistance to Phytophthora.

Maturity Group II

BSR 201 has resistance to brown stem rot, which makes it particularly useful in fields infested with that disease. In the absence of brown stem rot, BSR 201 is quite competitive in yield with the Century 84 and

Table 2.10. Morphologic Characteristics of Soybean Varieties

Maturity group and variety	Flower color	Pubescence color	Pod color	Seed luster	Hilum color
I					
Archer	purple	gray	tan	dull	imblk[a]
Bell	purple	tawny	tan	shiny	black
BSR 101	purple	gray	tan	intermediate	imblk[a]
II					
BSR 201	white	gray	brown	dull	buff
Burlison	white	tawny	tan	dull	black
Chapman	purple	gray	brown	shiny	imblk[a]
Conrad	purple	tawny	tan	dull	brown
Corsoy 79	purple	gray	brown	dull	yellow
Gnome 85	purple	tawny	tan	shiny	black
Hack	white	gray	tan	shiny	buff
Jack	white	gray	brown	dull	yellow
Preston	purple	gray	brown	intermediate	gray
III					
Cartter	white	tawny	tan	shiny	black
Chamberlain	purple	tawny	brown	shiny	black
Edison	purple	tawny	tan	shiny	black
Fayette	white	tawny	tan	shiny	black
Harper 87	purple	tawny	brown	shiny	black
Hobbit 87	white	tawny	tan	shiny	black
Kunitz	white	brown	tan	shiny	black
Linford	white	tawny	tan	shiny	black
Pella 86	purple	tawny	tan	dull	black
Resnik	purple	tawny	tan	dull	black
Sherman	white	gray	brown	shiny	buff
Williams 82	white	tawny	tan	shiny	black
IV					
Delsoy 4210	white	tawny	tan	shiny	gray
Delsoy 4710	purple	tawny	tan	intermediate	black
Egyptian	white	tawny	tawny	shiny	black
Flyer	purple	tawny	tan	dull	black
Hamilton	white	gray	brown	shiny	buff
Nile	white	tawny	tan	shiny	black
Pharaoh	purple	tawny	tan	shiny	brown
Pyramid	purple	gray	tan	shiny	imblk[a]
Spry	purple	tawny	brown	dull	black
Union	white	tawny	tan	shiny	black
V					
Essex	purple	gray	tan	intermediate	buff

[a] Imperfect black hilum.

Corsoy 79 varieties. Resistance to races 1 and 2 of Phytophthora root rot and fair resistance to lodging are characteristics of BSR 201.

Burlison* has quite good yield potential for northern and central Illinois producers. It carries multiple race resistance to Phytophthora root rot, but is very sensitive to metribuzin herbicide. Maturity is toward the late side of Group II varieties.

Chapman* has Group II maturity that combines multirace resistance to Phytophthora with improved yield potential.

Conrad* has early Group II maturity which offers improved yield potential if Phytophthora and brown stem rot are not a problem. Because of susceptibility to these disease problems, growers should consider likely disease problems.

Corsoy 79 is an improved version of Corsoy, similar to the original, with strong emergence and early Group II maturity. Like the original Corsoy, the Corsoy 79 has poor lodging resistance. Unlike the older Corsoy, however, it has resistance to seven races of Phytophthora root rot.

Gnome 85* is an improved version of Gnome, a previously released short-statured variety of determinate growth habit. It has the same yield potential and lodging resistance as did Gnome. Resistance to Phytophthora, however, is the same as for Williams 82.

Hack* has high yield potential and lodging resistance superior to other varieties of similar maturity. It has resistance to Phytophthora root rot, races 1 and 2, and to bacterial pustule.

Jack* will provide resistance to races 3 and 4 of the cyst nematode with good yield potential in areas where a late Group II variety is adapted. It has moderate resistance to lodging and is susceptible to Phytophthora and brown stem rot disease.

Preston has high yield potential with a maturity similar to Century and Century 84. Preston is susceptible to both Phytophthora root rot and brown stem rot.

Maturity Group III

Cartter has a relatively early Group III maturity that offers growers resistance to cyst nematode races

Table 2.11. Reactions of Soybean Varieties to Phytophthora Root Rot Disease

Maturity group	Susceptible to Phytophthora root rot	Resistant to races 1 and 2	Resistant to races 1, 2, and others
I	Bell	BSR 101	Archer
II	Conrad Jack Preston	BSR 201 Hack	Burlison Chapman Corsoy 79 Gnome 85
III	Cartter Fayette Linford Sherman	Chamberlain	Edison Harper 87 Hobbit 87 Kunitz Pella 86 Resnik Williams 82
IV	Delsoy 4210 Delsoy 4710 Egyptian Hamilton Nile Pharaoh Pyramid Spry	Union	Flyer
V	Essex		

Table 2.12. Soybean Variety Characteristics, 1990–91

Maturity group and variety	Protected variety[a]	Relative maturity[b]	Lodging	Height	Soybean cyst nematode[c]	
		days	*score*[d]	*inches*	*race 3*	*race 4*
I						
Archer	Yes	−17	1.7	33	S	S
Bell	Yes	−14	1.9	30	R	R
BSR 101	No	−12	1.7	33	S	S
II						
BSR 201	No	−6	1.7	33	S	S
Burlison	Yes	−7	1.7	32	S	S
Chapman	Yes	−8	1.8	32	S	S
Conrad	Yes	−7	1.8	33	S	S
Hack	Yes	−9	1.4	30	S	S
Jack	Yes	−2	2.4	40	R	R
Preston	No	−7	2.0	35	S	S
III						
Cartter	No	−4	1.8	32	R	R
Chamberlain	Yes	−1	2.0	35	S	S
Edison	Yes	−2	1.2	30	S	S
Fayette	No	+1	2.2	35	R	R
Harper 87	Yes	9/21	1.6	33	S	S
Hobbit 87	Yes	−1	1.0	20	S	S
Kunitz	Yes	0	1.7	37	S	S
Linford	No	+2	2.2	36	R	R
Pella 86	No	−1	1.4	32	S	S
Resnik	Yes	−1	1.6	31	S	S
Sherman	Yes	−1	2.1	32	S	S
Williams 82	No	+4	1.6	36	S	S
IV						
Delsoy 4210	Yes	+9	1.7	34	R	R
Delsoy 4710	Yes	+21	2.7	42	R	R
Flyer	Yes	+4	1.4	32	S	S
Hamilton	Yes	+6	1.7	31	S	S
Nile	No?	+2	1.9	37	R	S
Pharaoh	Yes	+18	1.6	29	R	S
Pyramid	No	+12	2.0	37	R	R
Spry	Yes	+16	1.5	28	S	S
Union	No	+7	2.1	39	S	S

[a] U.S. Protected Variety; see the chapter titled "Seed Production."
[b] Relative to Harper 87.
[c] R = resistant, S = susceptible.
[d] 1 = all plants standing; 5 = all plants flat.

3 and 4, but it lacks resistance to Phytophthora root rot. It was developed from the same breeding program that produced Fayette.

Chamberlain* has a mid-Group III maturity and resistance to brown stem rot disease. It also has resistance to bacterial pustule and races 1 and 2 of Phytophthora root rot. It has good resistance to lodging and has good yield potential.

Edison* has an early Group III maturity, which offers improved yield along with multirace resistance to Phytophthora root rot.

Fayette is most useful to growers needing resistance to soybean cyst nematode, races 3 and 4. It matures about the same time as Williams 82. Fayette is susceptible to Phytophthora root rot and is moderately resistant to lodging. In the absence of cyst nematode problems, growers should not use Fayette, for other varieties of similar maturity yield better.

Harper 87 was developed by backcrossing Harper with Williams 82 to incorporate into the variety the resistance to Phytophthora root rot. Harper 87 has a maturity and agronomic character essentially the same as the earlier released Harper variety.

Hobbit 87* is an improved version of Hobbit. Resistance to Phytophthora equal to that found in Williams 82 is the notable improvement in this variety. Determinate growth, short stature, lodging resistance, and good yield potential of the original Hobbit are found in Hobbit 87.

Kunitz* has a Group III maturity with multirace resistance to Phytophthora root rot. It is closely related and similar to Williams 82. It differs from other varieties in that it lacks the Kunitz trypsin inhibitor, which allows it to be used for on-farm feeding to swine during finishing stages of growth.

Linford maturity is toward the late side of Group III varieties. It offers resistance to races 3 and 4 of cyst nematode, good lodging resistance and good yield potential. It lacks resistance to Phytophthora and brown stem rot, however.

Pella 86 is an improved version of Pella. It is a relatively early Group III variety with good lodging resistance and other characteristics of Pella. The improvement in Pella 86 is in Phytophthora resistance, which is equal to that of Williams 82.

Resnik* is a mid-Group III variety, with good yield potential, lodging resistance, and Phytophthora resistance equal to that of Williams 82.

Sherman offers growers an improved yield potential in a variety that matures 2 or 3 days later than Pella. Although Sherman does not have genetic resistance to Phytophthora root rot, it offers yield advantages in environments where that disease is not a problem.

Williams 82 is an improved version of the Williams variety, which was released in the 1970s. It has a late Group III maturity. The Williams 82 has a broad base of resistance to Phytophthora root rot (races 1 to 10, 13 to 15, 17, 18, 21, and 22), allowing it to produce well across a wide range of root-rot infested fields. Plant size and yield potential are the same as in the original Williams variety.

Maturity Group IV

Delsoy 4210* has an early to mid-Group IV maturity and offers protection to soybean cyst nematode races 3 and 4. In addition to good yield potential, it stands well.

Delsoy 4710* has a late Group IV maturity and carries resistance to soybean cyst nematode races 3 and 4. Although it has improved yield, it tends to have a lodging problem in most environments as the plant grows tall.

Egyptian is resistant to races 3 and 4 of soybean cyst nematode. It has determinate growth but, because of the time it takes to reach maturity, will not be very short statured. Maturity is about 2 weeks after the Union variety.

Flyer* offers producers excellent resistance to Phytophthora in a relatively early Group IV maturity. Resistance to lodging is quite good. Producers using Union may find Flyer better yielding.

Hamilton* is an early Group IV with maturity equal to Union. It resists lodging better than Union and has higher yield potential, but lacks resistance to Phytophthora.

Nile carries resistance to race 3 of soybean cyst nematode in an early Group IV maturity. It offers growers good lodging resistance and improved yield potential.

Pharaoh* is a fairly late Group IV with resistance to race 3 of cyst nematode. If race 4 of soybean cyst nematode is a production problem, this variety may not be a good choice. Yield potential in its maturity range appears very good.

Pyramid matures about 10 days after Union. Although susceptible to Phytophthora root rot, Pyramid is resistant to soybean cyst nematode, races 3 and 4.

Spry* is a late Group IV with exceptionally vigorous vegetative growth. It has determinate growth and somewhat shorter plant stature than other varieties of similar maturity. It has excellent resistance to lodging as well.

Union has resistance to Phytophthora, downy mildew, and bacterial pustule. Maturity is early in the Group IV maturity range. Lodging of Union has been a problem in environments that favor abundant vegetative development.

Maturity Group V

Essex has relatively early Group V maturity and is susceptible to soybean cyst nematode. It is resistant, however, to bacterial pustule, downy mildew, and frogeye leaf spot and has field tolerance to Phytophthora root rot. It has very good resistance to lodging.

Private varieties and blends

Well over 500 varieties, blends, and brands of soybeans are available to Illinois growers. Each year the University of Illinois conducts the Commercial Soybean Performance Trials at numerous locations in the state. Each year a report on results of the soybean trials is published and is available from county Extension offices. In addition to yield, maturity, lodging resistance, height, and shatter resistance are provided in the report.

Blends (mixtures) of two or more varieties are sometimes marketed for planting. Usually these are identified by a brand name, such as "John Doe 200 Brand." Although most blends are composed of the same varieties in the same proportions each year, neither the Illinois Seed Law nor the Federal Seed Law requires this consistency; therefore, performance of blends may vary from year to year because of variation in components from which they are made.

Chapter 3.

Small Grains

Winter wheat

Although both soft red and hard red winter wheat can be grown in Illinois, improved soft wheat varieties are widely adapted in the state; nearly all of Illinois wheat is the soft type. The primary reasons for this are the better yields of soft wheat and the sometimes poor quality of hard wheat produced in our warm and humid climate. It may be difficult to find a market for hard wheat in many parts of the state; therefore, it is advisable to line up a market before planting the crop.

Date of seeding

The Hessian-fly-safe dates for each county in Illinois are given in Table 3.1. Wheat planted on or after the fly-safe date is much less likely to be damaged by the insect than wheat planted earlier. Wheat planted on or after the fly-safe date also will be less severely damaged in the fall by diseases such as Septoria leaf spot, which is favored by the excessive fall growth usually associated with early planting. Because the aphids that carry the barley yellow dwarf (BYD) virus and the mites that carry the wheat streak mosaic virus are killed by freezing temperatures, the effects of these viruses will be less severe if wheat is planted shortly before the first killing freeze. Finally, wheat planted on or after the fly-safe date will probably suffer less from soil-borne mosaic; most varieties of soft red winter wheat carry good resistance but may show symptoms if severely infested.

The decreases in yield as planting is delayed past the fly-safe date vary considerably, depending on the year and location within Illinois. In general, studies have shown that yields decline only slowly with planting delays for the first 10 days after the fly-safe date. From 10 to 20 days late, yields decline at the rate of a bushel or so per day. This yield loss accelerates to as much as 2 bushels per day from 20 to 30 days late, with sharper declines in the northern part of the state than in southern Illinois. By one month after the fly-safe date, yield potential is probably only 60 to 70 percent of normal, making this about the latest practical date to plant wheat and still expect a reasonable yield. Wheat may survive even if planted so late that it fails to emerge in the fall, but reduced tillering and marginal winterhardiness will often result in large yield decreases.

Rate of seeding

While seeding rate recommendations for wheat have usually been expressed as pounds of seed per acre, differences in seed size can mean that the number of seeds per acre or per square foot may not be very precisely specified. Recent research in Illinois has measured yield in response to varying the number of seeds per square foot. Results are given in Table 3.2.

The results in Table 3.2 indicate that seed rates within this range affect yield very little, though in northern Illinois, where there was some cold injury in the spring, the extra plants gave a slight yield advantage. On average, though, it appears that about 30 seeds per square foot is adequate for top yields.

Seed size in wheat varies by variety and by weather during seed production but is usually in the range of 13,000 to 17,000 seeds per pound. At 15,000 seeds per pound, a seeding rate of 1½ bushels per acre provides about 31 seeds per square foot. A stand of 25 to 30 plants per square foot is generally considered the optimum, and a minimum of 15 to 20 plants per square foot is needed to justify keeping a field in the spring.

If planting is delayed much past the fly-safe date, then fall growth and spring tillering are likely to be reduced. To compensate, it is suggested that seeding rate be increased by one-half bushel if planting is two to three weeks after the fly-safe date and by one bushel if planting is delayed by more than three weeks.

Seed treatment

Treating wheat seeds with the proper fungicide or mixture of fungicides is a cheap way to help ensure improved stands and better seed quality. Under conditions that favor the development of seedling diseases, the yield from treated seed usually will be 3 to 5 bushels higher than that from untreated seed.

Table 3.1. Best Date for Seeding Wheat

County	Average date of seeding wheat for highest yield	County	Average date of seeding wheat for highest yield	County	Average date of seeding wheat for highest yield	County	Average date of seeding wheat for highest yield
Adams	Sept. 30-Oct. 3	Ford	Sept. 23-29	Livingston	Sept. 23-25	Randolph	Oct. 9-11
Alexander	Oct. 12	Franklin	Oct. 10-12	Logan	Sept. 29-Oct. 3	Richland	Oct. 8-10
Bond	Oct. 7-9	Fulton	Sept. 27-30	Macon	Oct. 1-3	Rock Island	Sept. 20-22
Boone	Sept. 17-19	Gallatin	Oct. 11-12	Macoupin	Oct. 4-7	St. Clair	Oct. 9-11
Brown	Sept. 30-Oct. 2	Greene	Oct. 4-7	Madison	Oct. 7-9	Saline	Oct. 11-12
Bureau	Sept. 21-24	Grundy	Sept. 22-24	Marion	Oct. 8-10	Sangamon	Oct. 1-5
Calhoun	Oct. 4-8	Hamilton	Oct. 10-11	Marshall-Putnam	Sept. 23-26	Schuyler	Sept. 29-Oct. 1
Carroll	Sept. 19-21	Hancock	Sept. 27-30			Scott	Oct. 2-4
Cass	Sept. 30-Oct. 2	Hardin	Oct. 11-12	Mason	Sept. 29-Oct. 1	Shelby	Oct. 3-5
Champaign	Sept. 29-Oct. 2	Henderson	Sept. 23-28	Massac	Oct. 11-12	Stark	Sept. 23-25
Christian	Oct. 2-4	Henry	Sept. 21-23	McDonough	Sept. 29-Oct. 1	Stephenson	Sept. 17-20
Clark	Oct. 4-6	Iroquois	Sept. 24-29	McHenry	Sept. 17-20	Tazewell	Sept. 27-Oct. 1
Clay	Oct. 7-10	Jackson	Oct. 11-12	McLean	Sept. 27-Oct. 1	Union	Oct. 11-12
Clinton	Oct. 8-10	Jasper	Oct. 6-8	Menard	Sept. 30-Oct. 2	Vermilion	Sept. 28-Oct. 2
Coles	Oct. 3-5	Jefferson	Oct. 9-11	Mercer	Sept. 22-25	Wabash	Oct. 9-11
Cook	Sept. 19-22	Jersey	Oct. 6-8	Monroe	Oct. 9-11	Warren	Sept. 23-27
Crawford	Oct. 6-8	Jo Daviess	Sept. 17-20	Montgomery	Oct. 4-7	Washington	Oct. 9-11
Cumberland	Oct. 4-5	Johnson	Oct. 10-12	Morgan	Oct. 2-4	Wayne	Oct. 9-11
DeKalb	Sept. 19-21	Kane	Sept. 19-21	Moultrie	Oct. 2-4	White	Oct. 9-11
DeWitt	Sept. 29-Oct. 1	Kankakee	Sept. 22-25	Ogle	Sept. 19-21	Whiteside	Sept. 20-22
Douglas	Oct. 2-3	Kendall	Sept. 20-22	Peoria	Sept. 23-28	Will	Sept. 21-24
DuPage	Sept. 19-21	Knox	Sept. 23-27	Perry	Oct. 10-11	Williamson	Oct. 11-12
Edgar	Oct. 2-4	Lake	Sept. 17-20	Piatt	Sept. 29-Oct. 2	Winnebago	Sept. 17-20
Edwards	Oct. 9-10	LaSalle	Sept. 19-24	Pike	Oct. 2-4	Woodford	Sept. 26-28
Effingham	Oct. 5-8	Lawrence	Oct. 8-10	Pope	Oct. 11-12		
Fayette	Oct. 4-8	Lee	Sept. 19-21	Pulaski	Oct. 11-12		

The Department of Plant Pathology suggests that carboxin (Vitavax) or a combination of carboxin with captan, maneb, or thiram be used to treat wheat seed. Vitavax controls loose smut in wheat and barley and should be used if this disease was present in the field where the seed was produced. Because Vitavax is not effective on some other seed-borne diseases that cause seedling blight (such as Septoria), another fungicide should be used along with Vitavax. Should additional information about wheat diseases or seed treatment methods and materials be desired, contact the University of Illinois Department of Plant Pathology or the local Extension office.

Seedbed preparation

Wheat requires good seed-soil contact and moderate soil moisture for germination and emergence. Generally, one or two trips with a disk harrow or field cultivator will produce an adequate seedbed if the soil is not too wet. It is better to wait until the soil dries adequately before preparing it for wheat, even if planting is delayed.

No-till drills may be used for wheat, but the soil must be reasonably dry. Do not reduce seeding rates for no-till. It is also important that crop residue be spread uniformly before no-tilling wheat. Heavy residue cover may cause disease, nutrient, and winter survival problems. Fertilizer materials may be placed on the surface; the drilling action will incorporate them adequately for wheat.

Depth of seeding

Wheat should not be planted more than 1 to 2 inches deep. Deeper planting may result in poor emergence, particularly with semidwarf varieties because coleoptile length is positively correlated with plant height. Drilling is the best way to ensure proper depth of placement.

Table 3.2. Effect of Seed Rate on Wheat Yield

Seeds per square foot	Southern Illinois[a]	Northern Illinois[b]
	bushels per acre	
24	77.2	71.8
36	77.6	74.0
48	77.8	75.9

[a] Average of 4 trials conducted at Belleville and Brownstown.
[b] Average of 4 trials conducted at Urbana and DeKalb.

Though a drill is best for placing seed at the right depth, a number of growers use a fertilizer spreader to seed wheat. This practice is somewhat risky but often works well, especially if rain falls after planting. The air-flow fertilizer spreaders will usually give a better distribution than the spinner type. If seed is broadcast, the seeding rate should be increased to 2 to 3 bushels per acre to compensate for uneven placement. After broadcast seeding, the field may be rolled with a cultipacker or cultimulcher (with the tines set shallow), or it may be tilled very lightly with a disk or tine harrow to improve seed-soil contact.

Row spacing

Research on row spacing generally shows little advantage for planting wheat in rows that are more narrow than 7 or 8 inches. Yield is usually reduced by wider rows, with a reduction of about 1 to 2 bushels in 10-inch rows. Wisconsin data show greater yield reductions in 10-inch rows, probably due to slower early growth than is common in Illinois.

Varieties

The genetic improvement of wheat has continued with the involvement of both the private sector and public institutions. As a result, there are now some 50 varieties sold in Illinois, with over half of this number provided by private companies.

Both public and private varieties are tested at six locations in Illinois each year, and the results are assembled in a report titled *Wheat Performance in Illinois Trials.* This report also contains descriptions of varieties, including both agronomic characteristics and resistance to diseases. Copies of this report are available in Extension offices by mid-August, thus allowing the use of this information before planting.

Intensive management

Close examination of the methods used to produce very high wheat yields in Europe has increased interest in application of similar "intensive" management practices in the United States. Such practices generally include narrow row spacing (4 to 5 inches); high seeding rates (3 to 4 bushels per acre); high nitrogen rates, split into three or more applications; and heavy use of foliar fungicides for disease control and plant growth regulators to reduce height and lodging.

From research conducted in Illinois, it has become apparent that responses to these inputs are much less predictable in Illinois than in Europe, primarily because of the very different climatic conditions. Following is a summary of research findings to date:

1. Research in Indiana and other states shows that the response to rows narrower than 7 or 8 inches is quite erratic, with little evidence to suggest that the narrow rows will pay added equipment costs.
2. Seeding rates of around 1½ bushels per acre (30 to 35 seeds per square foot) generally produce maximum yields (Table 3.2).
3. Increasing nitrogen rates beyond the recommended rates of 50 to 110 pounds per acre has not increased yields. Splitting the spring nitrogen into two or more applications has not increased yields.
4. Although foliar fungicides are useful if diseases are found, routine use has resulted in yield increases of only 3 to 5 bushels per acre (Table 3.3) and is probably not economically justified.
5. The response to the plant growth regulator Cerone, which is labeled for use on wheat, has not been consistent. While there has been an occasional yield increase from the use of this chemical, especially where the yield levels were above 80 bushels per acre, the results from a number of Illinois trials show no average yield increase (Table 3.3). Where yields are poor due to soil and weather problems, the use of Cerone can result in further yield decreases and should not be considered. The use of this chemical where high yields are expected, and where lodging is likely to be a problem, may be justified.

Table 3.3. Response of Caldwell Wheat to Cerone Growth Regulator and Tilt Fungicide

Treatment	Southern Illinois[a]	Northern Illinois[b]
	bushels per acre	
−Cerone	55.6	69.0
+Cerone	55.1	69.3
−Tilt	55.2	64.3
+Tilt	57.7	69.5

[a] Average of 7 Cerone trials and 4 Tilt trials at Brownstown and Belleville.
[b] Average of 8 Cerone trials and 4 Tilt trials at Urbana and DeKalb.

In summary, although more experiments will be needed to optimize production practices in winter wheat in Illinois, the management recommendations in this section appear to be fairly well matched to the soils and climate of Illinois.

Spring wheat

Spring wheat is not well adapted to Illinois. Because it matures more than 2 weeks later than winter wheat, it is in the process of filling kernels during the hot weather typical of late June and the first half of July. Consequently, yields average only about 50 to 60 percent of those of winter wheat.

With the exception of planting time, production practices for spring wheat are similar to those for winter wheat. Because of the lower yield potential, nitrogen rates should be 20 to 30 pounds less than those for winter wheat. Spring wheat should be planted in early spring, as soon as a seedbed can be prepared. If planting is delayed beyond April 10, yields are likely to be very low, and another crop should be considered.

The acreage of spring wheat in Illinois is extremely small, and variety testing has not been extensive. Table 3.4 lists some of the more recent varieties, most of which were developed in Minnesota or other northern states. These have not been tested extensively in Illinois, and as the table shows, yields are likely to vary substantially depending on the year. Any of these

Table 3.4. Yield of Spring Wheat Varieties, 1991 and 1992, DeKalb

Variety	1991	1992	Average yield 1991–92
Butte 86	14.9	44.6	29.8
Prospect	21.8	43.3	32.6
Wheaton	18.6	43.7	31.2
Sharp	16.1	46.0	31.1
Gus	19.8	35.6	27.7
Grandin	13.1	42.0	27.6
Marshall	17.8	45.6	31.7
Guard	19.8	42.0	30.9

varieties is likely to do reasonably well if weather favors spring wheat production, but all will yield quite poorly if the weather is unfavorable.

Rye

Both winter and spring varieties of rye are available, but only the winter type is suitable for use in Illinois. Winter rye is often used as a cover crop to prevent wind erosion of sandy soils. The crop is very winter-hardy, grows late into the fall, and is quite tolerant to drought. Rye generally matures 1 or 2 weeks before wheat. The major drawbacks to raising rye are the low yield potential and the very limited market for the crop. It is less desirable than other small grains as a feed grain.

The cultural practices for rye are the same as for wheat. Planting can be somewhat earlier, and the nitrogen rate should be 20 to 30 pounds less than that for wheat because of lower yield potential. Watch for shattering as grain nears maturity. Watch also for the ergot fungus, which replaces grains in the head and is poisonous to livestock.

There has been very little development of varieties specifically for the Corn Belt area, and no yield testing has been done recently in Illinois. Much of the rye seed available in Illinois is simply called common rye; some of this probably descended from Balbo, a variety released in 1933 and widely grown many years ago in Illinois. More recently developed varieties that may do reasonably well in Illinois include **Hancock**, released by Wisconsin in 1979, and **Rymin**, released by Minnesota in 1973.

Triticale

Triticale is a crop that resulted from the crossing of wheat and rye in the 1800s. The varieties currently available are not well adapted to Illinois and are usually deficient in some characteristic such as winterhardiness, seed set, or seed quality. In addition, they are of feed quality only. They do not possess the milling and baking qualities needed for use in human food.

Cultural practices for triticale are much the same as those for wheat and rye. The crop should be planted on time to help winter survival. As with rye, the nitrogen rate should be reduced to reflect the lower yield potential. With essentially no commercial market for this crop, growers should make certain they have a use for the crop before it is grown. Generally when triticale is fed to livestock, it must be blended with other feed grains.

A limited testing program at Urbana indicates that the crop is generally lower yielding than winter wheat and spring oats. Both spring and winter types of triticale are available, but only the winter type is suitable for Illinois. Caution must be used in selecting a variety because most winter varieties available are adapted to the South and may not be winter-hardy in Illinois. Yields of breeding lines tested at Urbana have generally ranged from 30 to 70 bushels per acre.

Spring oats

To obtain high yields of spring oats, plant the crop as soon as you can prepare a seedbed. Yield reductions become quite severe if planting is delayed beyond April 1 in central Illinois and beyond April 15 in northern Illinois. After May 1, another crop should be considered, unless the oats are being used as a companion crop for forage crop establishment and yield of the oats is not important.

When planting oats after corn, it will probably be desirable to disk the stalks; plowing will produce the highest yields but is usually impractical. When planting oats after soybeans, disking is usually the only preparation needed, and it may be unnecessary if the soybean residue is evenly distributed. Make certain that the labels of the herbicides used on the previous crop allow oats to be planted; oats are quite sensitive to a number of common herbicides.

Before planting, treat the seed with a fungicide or a combination such as captan plus Vitavax. Several other fungicides and combinations can be used. For more information, see the local Extension office or contact the Department of Plant Pathology, University of Illinois, Urbana, Illinois. Seed treatment protects the seed during the germination process from seed- and soil-borne fungi.

Oats may be broadcast and disked in but will yield 7 to 10 bushels more per acre if drilled. When drilling, plant at a rate of 2 to 2½ bushels per acre. If the oats are broadcast and disked in, increase the rate by one-half to one bushel per acre.

For suggestions on fertilizing oats, see the chapter titled "Soil Testing and Fertility."

Varieties

In recent years, Illinois has been a leading state in the development of oat varieties. Excellent progress has been made in selecting varieties with high yield, good standability, and resistance to barley yellow dwarf mosaic virus (also called redleaf disease), which is the most serious disease of oats in Illinois.

Table 3.5 lists the characteristics of oat varieties that are suitable for production in Illinois. Yields of these varieties in Illinois tests are given in Table 3.6.

Winter oats

Winter oats are not as winter-hardy as wheat and are adapted to only the southern third or quarter of the state; U.S. Highway 50 is about the northern limit for winter oats. Because winter oats are somewhat winter-tender and are not attacked by Hessian fly,

Table 3.5. Characteristics of Spring Oat Varieties Adapted to Illinois Conditions

						Resistance[b]		
Name	State, year released	Kernel color	Maturity[a]	Height	Stand-ability	Barley yellow dwarf	Stem rust	Smut
Don	Illinois, 1985	white	0	short	fair	I	S	R
Hazel	Illinois, 1985	grayish	4	medium to short	very good	R	S	S
Larry	Illinois, 1981	yellow	. . .	short	very good	MR	S	S
Newdak	N. Dakota, 1990	white	1	medium	good	MR	MR	R
Ogle	Illinois, 1981	yellow	4	medium	very good	R	S	S
Prairie	Wisconsin, 1992	tan	5	medium	very good	R	MR	I

[a] Days later than Larry.
[b] R = resistant; MR = moderately resistant; MS = moderately susceptible; S = susceptible; I = intermediate.

planting in early September is highly desirable. Experience has shown that oats planted before September 15 are more likely to survive the winter than those planted after September 15.

The same type of seedbed is needed for winter oats as for winter wheat. The fertility program should be similar to that for spring oats. Seeding rate is 2 to 3 bushels per acre when drilled.

Development of winter oat varieties has virtually stopped in the Midwest because of the frequent winter kill. Of the older varieties, **Norline, Compact,** and **Walken** are sufficiently winter-hardy to survive some winters in the southern third of the state.

Norline was released by Purdue University in 1960. It tends to lodge more than Walken and Compact. Compact was released by the University of Kentucky in 1968. It is short and more lodging resistant than Norline. Walken was released by the University of Kentucky in 1970. It is more lodging resistant than Norline and Compact but grows a little taller than those varieties.

Spring barley

Spring barley is damaged by hot, dry weather, and therefore is adapted only to the northern part of Illinois. Good yields are possible, especially if the crop is planted in March or early April, but yields tend to be erratic. Markets for malting barley are not established in Illinois, and malting quality may be a problem. Barley can, however, be fed to livestock.

Plant spring barley early — about the same time as spring oats. Drill 1½ to 2 bushels of seed per acre. To avoid excessive lodging, harvest the crop as soon as it is ripe. Fertility requirements for spring barley are essentially the same as for spring oats.

The situation with spring barley varieties is similar to that in spring wheat: most varieties originate in Minnesota or North Dakota and have not been widely tested or grown for seed in Illinois. Table 3.7 lists results of limited testing with some of the newer varieties at DeKalb, Illinois. Seed for any of these will likely need to be brought in from Minnesota or the Dakotas.

Table 3.6. Yields and Test Weights of Spring Oat Varieties in Illinois Trials, 1989–92

	Urbana, 1989–92		DeKalb, 1989–92	
Variety	Yield	Test weight	Yield	Test weight
Don	95.9	32.5	80.2	33.4
Hazel	100.9	32.9	86.6	33.1
Larry	95.7	31.5	78.7	32.5
Newdak	103.4	31.2	93.2	31.4
Ogle	103.6	30.6	92.3	31.1
Prairie	106.9	30.7	115.7	31.4

Table 3.7. Yields of Spring Barley Varieties, 1991–92, DeKalb

Variety	Average yield 1989–92
Azure	63.2
Hazen	57.8
Manker	54.8
Morex	50.4
Norbert	57.6
Robust	55.1
Excel	49.1

Winter barley

Winter barley is not as winter-hardy as the commonly grown varieties of winter wheat and should be planted 1 to 2 weeks earlier than winter wheat. Sow with a drill and plant 2 bushels of seed per acre.

The fertility requirements for winter barley are similar to those for winter wheat except that less nitrogen is required. Most winter barley varieties are less resistant to lodging than are winter wheat varieties. Winter barley cannot stand "wet feet"; therefore, it should not be planted on land that tends to be low and wet. The barley yellow dwarf virus is a serious threat to winter barley production.

Varieties

The acreage of winter barley is quite small in Illinois, and variety testing has not been extensive. Based on that limited testing, the following varieties appear to have the best chance of producing a good crop under Illinois conditions. There has been little or no certified seed of these varieties produced in Illinois, but the higher yields make it worthwhile to find seed in another state.

Pennco, released in 1985 by Pennsylvania, is a high-yielding variety with good disease resistance and standability. It is a few days earlier and slightly more winter-hardy than Wysor, and even more winter-hardy (though later in maturity) than Barsoy, an old variety that was once common in Illinois.

Wysor, released in 1985 by Virginia, is a high-yielding variety with good disease resistance and winterhardiness.

Chapter 4.
Grain Sorghum

Although grain sorghum can be grown successfully throughout Illinois, its greatest potential, in comparison with other crops, is in the southern third of the state. It is adapted to almost all soils, from sand to heavy clay. Its greatest advantage over corn is tolerance of moisture extremes. Grain sorghum usually yields more than corn when moisture is in short supply, but often yields less than corn under optimum conditions. Grain sorghum is also less affected by late planting and high temperatures during the growing season, but the crop is very sensitive to cool weather and will be killed by even light frost.

Fertilization

The phosphorus and potassium requirements of grain sorghum are similar to those of corn. The response to nitrogen is somewhat erratic, due largely to the extensive root system's efficiency in taking up soil nutrients. For this reason, and because of the lower yield potential, the maximum rate of nitrogen suggested is about 125 pounds per acre. For sorghum following a legume such as soybeans or clover, this rate may be reduced by 20 to 40 pounds.

Hybrids

The criteria for selecting grain sorghum hybrids are very similar to those for selecting corn hybrids. Yield, maturity, standability, and disease resistance are all important. Consideration should also be given to the market class (endosperm color) and bird resistance, which may be associated with palatability to livestock. Performance tests of commercial grain sorghum hybrids are conducted at three locations in southern Illinois, and results are available (usually in the same report as the commercial corn hybrid yields) in Extension offices in December or January. Because of the limited acreage of grain sorghum in the eastern United States, most hybrids are developed for the Great Plains and may not have been extensively tested under Midwest conditions.

Planting

Sorghum should not be planted until soil temperature is at least 65°F. In the southern half of the state, mid-May is considered the starting date; late May to June 15 is the planting date in the northern half of the state. Such late planting — along with a shorter, cooler growing season — means that hybrids used in northern Illinois must be early-maturing.

Sorghum emerges more slowly than corn and requires a relatively fine and firm seedbed. Planting depth should not exceed 1½ inches, and ¾ to 1 inch is considered best. Because sorghum seedlings are slow to emerge, growers should use caution when using reduced- or no-till planting methods. Surface residue usually keeps the soil cooler and may harbor insects that can attack the crop, causing serious stand losses, especially when the crop is planted early in the season.

Row spacing

Row-spacing experiments have shown that narrow rows produce far better than wide rows (Table 4.1). Drilling in 7- to 10-inch rows works well if weeds can be controlled without cultivation.

Plant population

Because grain sorghum seed is small and some planters do not handle it well, there is a tendency to

Table 4.1. Yield of Grain Sorghum as Affected by Row Spacing in a Missouri Trial

Row spacing	Yield
inches	*bu/A*
7	121
14	118
21	103
28	98
35	89

NOTE: Data are 3-year averages.

plant based on pounds of seed per acre, rather than by number of seeds. This usually results in overly dense plant populations that can cause lodging and yield loss. Aim for a plant stand of 50,000 to 100,000 plants per acre, with the lower population on droughtier soils. Four to 6 plants per foot of row in 30-inch rows at harvest and 2 to 4 plants per foot in 20-inch rows are adequate. Plant 30 to 50 percent more seeds than the intended stand. Sorghum may also be drilled using 6 to 8 pounds of seed per acre. When drilling, be sure not to use excessive seed rates; plant stands when drilled should not be much larger than those in rows.

Weed control

Because emergence of sorghum is slow, controlling weeds presents special problems. Suggestions for chemical control of weeds are given in the back of this handbook. As with corn, a rotary hoe is useful before weeds become permanently established.

Harvesting and storage

Timely harvest is important. Rainy weather after sorghum grain reaches physiological maturity may cause sprouting in the head, weathering (soft and mealy grain), or both. Harvest may begin when grain moisture is 20 percent or greater, if drying facilities are available. Sorghum dries very slowly in the field. Because sorghum does not die until frost, the use of a desiccant (sodium chlorate) can reduce the amount of green plant material going through the combine, making harvest easier.

Marketing

Before planting, check on local markets. Because the acreage in Illinois is limited, many elevators do not purchase grain sorghum.

Grazing

After harvest, sorghum stubble may be used for pasture. Livestock should not be allowed to graze for one week after frost because the danger of prussic acid or hydrocyanic acid (HCN) poisoning is especially high. Newly frosted plants sometimes develop tillers high in prussic acid.

Chapter 5.

Cover Crops and Cropping Systems

Cover crops

Rye, wheat, ryegrass, hairy vetch, and other grasses and legumes are sometimes used as winter cover crops in the Midwest. The primary purpose for using cover crops is to provide plant cover for the soil to help reduce soil erosion during the winter and spring. Winter cover crops plowed under in the spring have been shown to reduce total water runoff and soil loss by 50 percent or more, although the actual effect on any one field will depend on soil type and slope, the amount of cover, the planting and tillage methods, and intensity of rainfall. The use of winter cover crops in combination with no-till corn may reduce soil loss by more than 90 percent. A cover crop can only protect the soil while it or its residue is present, however, and a field planted after a cover crop has been plowed under may lose a great deal of soil if there is intense rainfall after planting. Cover crops can also help to improve soil tilth and they can often contribute nitrogen to the following crop.

The advantages of grasses such as rye that are used as cover crops include rapid establishment of ground cover in the fall, vigorous growth, effective recovery of residual nitrogen from the soil, and good winter survival. Most research has shown, however, that corn planted into a grass cover crop often yields less than when grown without a cover crop. There are several reasons for this. Residue from grass crops, including corn, has a high carbon-to-nitrogen ratio, so nitrogen from the soil is often tied up by microbes as they break down the residue. Secondly, a vigorously growing grass crop such as rye can dry out the surface soil rapidly, thereby causing problems with stand establishment under dry planting conditions. When the weather at planting is wet, heavy surface vegetation from a cover crop can also cause soils to stay wet and cool, thus reducing emergence. Finally, chemical substances released during the breakdown of some grass crops have been shown to inhibit the growth of a following grass crop or of grass weeds.

There are several benefits associated with the use of legumes as cover crops. Legumes are capable of nitrogen fixation; so, providing that they have enough time to develop this capability, they may provide some "free" nitrogen — fixed from the nitrogen in the air — to the following crop. Most leguminous plants have a lower carbon-to-nitrogen ratio than grasses, and soil nitrogen will not be tied up as much when legume plant material breaks down. On the negative side, early growth by legumes may be somewhat slower than that of grass cover crops; many of the legumes too are not as winter-hardy as grasses such as rye. Legumes seeded after the harvest of a corn or soybean crop, therefore, often grow little before winter, resulting in low winter survivability, limited nitrogen fixation before spring, and ground cover that is inadequate to protect the soil.

Hairy vetch, at least in the southern Midwest, has usually worked well as a winter cover crop. It offers the advantages of fairly good establishment, good fall growth and vigorous spring growth, especially if it is planted early — during the late summer. When allowed to make considerable spring growth, hairy vetch has provided as much as 80 to 90 pounds of nitrogen per acre to the corn crop that follows. One disadvantage to hairy vetch is its lack of sufficient winterhardiness; severe cold without snow cover will often kill this crop in the northern half of Illinois, especially if it has not made at least 4 to 6 inches of growth in the fall. The 20 to 40 pound per acre seed rate, with seed costs ranging up to $1.00 per pound, can make use of this crop quite expensive; some farmers in the Midwest are growing their own seed to reduce this expense. This crop can also produce a considerable amount of hard seed, which may not germinate for 2 or 3 years, at which time it may be a serious weed, especially in a crop such as winter wheat. Other legume species that may be used as winter cover crops include mammoth and medium red clovers, alfalfa, and ladino clover.

To get the maximum benefit from a legume cover crop, such crops must be planted early enough to grow considerably before the onset of cold weather in the late fall. The last half of August is probably the best time for planting these cover crops. They can be aerially seeded into a standing crop of corn or soybeans, although dry weather after seeding may result in poor stands of the legume. Some attempts have been made to seed legumes such as hairy vetch into corn at the time of the last cultivation. This may work occasionally, but a very good corn crop will shade the soil surface enough to prevent growth of a crop underneath its canopy, and cover crops seeded in this way will often by injured by periods of dry weather during the summer. All things considered, the chances for successfully establishing legume cover crops are best when they are seeded into small grains during the spring or after small grain harvest, or when they are planted on set-aside or other idle fields.

There is some debate as to the best management of cover crops before planting a field crop in the spring. There is usually a trade-off of benefits: planting delays will allow the cover crop to make more growth and to fix more nitrogen in the case of legume cover crops, but this extra growth may be more difficult to kill, and it will sometimes result in depletion of soil moisture. Most indications are that killing a grass cover crop several weeks before planting is preferable to killing it with herbicide at the time of planting. Legumes can also produce some of the same problems as grass cover crops, especially if they are allowed to grow past the middle of May.

Recent research at Dixon Springs in southern Illinois has illustrated both the potential benefits and possible problems associated with the use of hairy vetch. In these studies, hairy vetch accumulated almost 100 pounds of dry matter and about 2.6 pounds of nitrogen per acre *per day* from late April to mid-May (Table 5.1). The best time to kill the cover crop with chemicals and to plant corn, however, varied considerably among the three years of the study. On average, corn planted following vetch yielded slightly more when the vetch was killed one or two weeks before planting. (Table 5.2). Also, corn planted in mid-May yielded more than corn planted in early May, primarily due to a very wet spring in one of the three years, in which vetch helped to dry out the soil. Vetch also dried out the soil in the other two years, but in those years this proved to be a disadvantage because moisture was short at planting. The conclusions from this study were that vetch should normally be killed at least a week before planting, and that planting should not be delayed much past early May because yield decreases due to late planting can quickly overcome the benefits of additional vetch growth.

Table 5.1. Dry Matter and Nitrogen Content of Hairy Vetch Killed by Herbicide at Different Dates at Dixon Springs, 1989-91

Kill date	Dry matter	Nitrogen
	pounds per acre	
Late April	1300	55
Early May	2509	85
Mid-May	3501	115

Table 5.2. Effect of Vetch Kill Date and Corn Planting Time on Corn Yield at Dixon Springs, 1989-91

	Vetch kill date	
Planting time	1 to 2 weeks before corn planting	At corn planting
Early May	116	114
Mid-May	129	125
Late May	85	. . .

Whether or not to incorporate cover-crop residue is also debatable, with some research showing no advantages to incorporation and other results showing some benefit. Incorporation may enhance the recovery of nutrients such as nitrogen under some weather conditions; it may offer more weed control options; and it will help in stand establishment, both by reducing competition from the cover crop and by providing a better seedbed. Incorporating cover-crop residue, on the other hand, removes most or all of the soil-retaining benefit of the cover crop during the time between planting and crop canopy development, which is a period of high risk for soil erosion caused by rainfall. Tilling to incorporate residue can also stimulate the emergence of weed seedlings. One alternative to tillage for residue management is to have livestock graze off most of the top growth before planting.

Cropping systems

The term "cropping system" refers to the crops and crop sequences and to management techniques used on a particular field over a period of years. This term is not a new one, but it has been used more often in recent years in discussions about sustainability of our agricultural production systems. Several other terms have also been used during these discussions, and following are working definitions of some of these terms:

- **Allelopathy** is the release of a chemical substance by one plant species that inhibits the growth of another crop.
- **Doublecropping** is the practice, also known as sequential cropping, of planting a second crop immediately following the harvest of a first crop, thus harvesting two crops from the same field in one year. This is a case of **multiple cropping.**
- **Intercropping** is the presence of two or more crops in the same field at the same time, planted in an arrangement that results in the crops competing with one another.
- **Monocropping** refers to the presence of a single crop in a field. This term is often used incorrectly to refer to growing the same crop year after year in the same field.
- **Relay intercropping** is a form of intercropping in which one crop is planted at a different time than

the other. An example would be dropping cover crop seed into a standing soybean crop.

- **Strip cropping** is defined as two or more crops growing in the same field, but planted in strips such that most plant competition is within each crop, rather than between the two crops. This practice has elements of both intercropping and monocropping, with the width of the strips determining the degree of each.

Crop rotations, as a primary aspect of cropping systems, have received a great deal of attention in recent years, with many people contending that most current rotations are unstable and (at least indirectly) harmful to the environment, and are therefore not sustainable. During the past 50 years, the number and complexity of crop rotations used in Illinois have decreased as the number of farms producing forages and small grains has declined. The corn-soybean rotation (with only one year of each crop) is now by far the most common one in the state. Although some consider that this crop sequence barely qualifies as a rotation, it offers several advantages to growing either crop continuously. These benefits include more weed control options and, often, fewer difficult weed problems, less insect and disease buildups, and less nitrogen fertilizer use than with continuous corn. Primarily because of these (and other, some poorly understood) reasons, both corn and soybeans grown in rotation yield about 10 percent more than if they were grown continuously. Growing these two crops in rotation also allows for more flexibility in marketing and it offers some protection against weather- or pest-related problems in either crop.

The specific effects of a corn-soybean rotation on nitrogen requirements are discussed in Chapter 10 of this handbook. Figure 10.6 provides data on the effect of the previous crop on corn yields and on the nitrogen requirements of the corn crop. These data show that, except in the case of alfalfa, most of the effect of the previous crop on corn yields could be overcome with the use of additional nitrogen. Other studies also have shown that the yield differential due to crop rotation can be overcome partially by additional nitrogen, but the differential usually cannot be eliminated.

One frequent question is whether input costs can be reduced by using longer-term, more diverse crop rotations. Studies into this question have compared continuous corn and soybean and the corn-soybean rotation with rotations lasting four or five years that contain small grains and legumes, either as cover crops or as forage feed sources. Like the corn-soybean rotation, certain longer rotations can reduce pest control costs, while including an established forage legume can provide a considerable amount of nitrogen to a succeeding corn crop (Figure 10.6). At the same time, it should be noted that most of the longer-term rotations include forage crops or other crops with smaller, and perhaps more volatile, markets than corn and soybeans. Lengthening rotations to include forages will be difficult unless the demand for livestock products increases. Such considerations will continue to favor production of crops such as corn and soybeans.

Chapter 6.
Miscellaneous Crops

A large number of crops that will grow in Illinois have not been produced commercially. A few others have been produced on a limited scale. This section provides a brief introduction to these crops. Production information is given for a few crops that have been tested and grown in the state.

Sunflowers

Two kinds of sunflowers are produced in Illinois, the oilseed sunflower and the nonoil, or confectionary, sunflower. The oilseed sunflower bears a relatively small seed with an oil content of 38 to 50 percent. The hull is thin and dark and adheres closely to the kernel. The oil is highly regarded as a salad oil and because of its high smoke point is unusually good for frying food and popping corn. The meal is used as a protein supplement in livestock rations; because sunflower meal is deficient in lysine, however, it cannot be used as the only source of protein in rations for nonruminant animals. The protein and crude fiber content vary with the method of processing. The confectionary (nonoil) sunflower bears a larger seed with a lower oil content. The hull is also lighter in color, is usually striped, and separates easily from the kernel. Confectionary sunflowers are used for human food and bird feed.

Planting. Sunflowers should be planted at the same time as corn. Because many of the hybrids offered for sale in Illinois reach physiological maturity (25 to 30 percent moisture) in 90 to 100 days, they may also follow small grain plantings as second crops. Because sunflowers do not host the soybean cyst nematode, they are a possible substitute for soybeans as a double crop.

Oilseed sunflowers should be planted at a population rate that will establish 20,000 to 25,000 plants per acre on soils with good water-holding capacity and 16,000 to 20,000 plants per acre on more coarsely textured soils with relatively low water-holding capacity. Confectionary sunflowers should be planted at a lower population rate to ensure larger seed size.

The recommended planting depth is 1½ to 2 inches, or about the same as that recommended for corn. Sunflowers perform best when planted in 20- to 30-inch rows, but planting in wider rows will also produce good yields.

Harvesting. Agronomists in North Dakota recommend harvesting after seed moisture has dropped to 18 or 20 percent. Losses are greatly reduced when sunflower attachments are used on the conventional combine head. These attachments are long panlike guards extending from the cutter bar.

Problems. Because sunflowers are not commonly grown in Illinois, it is important to locate a market before planting a crop.

Feeding by birds can become a serious problem in any sunflower field and is most likely to occur near farmsteads and wooded areas. Insects and diseases can also damage sunflower crops. The severity of the damage will increase as the acreage of sunflowers increases in a community and will vary from season to season.

Oilseed rape (Canola)

Rape, a member of the mustard family, is grown as a traditional oilseed crop in a number of other countries but has not been grown widely in the United States. Both spring and winter types exist, but the poor performance of this crop in hot weather suggests that the winter type will be most likely to succeed in Illinois. Most varieties of this type are currently of European origin. Their winterhardiness under Illinois conditions could be a problem.

Unimproved varieties and landraces of rapeseed contain erucic acid as part of the oil and high levels of toxic glucosinolates in the meal. Both of these antinutritional factors have been reduced or eliminated in some varieties (double-low or double-zero varieties). Canadian workers designated this group of improved varieties as Canola. Such varieties have better commercial potential than those containing one or both of the antinutritional factors because both the oil and meal from double-low varieties can be used. Rapeseed oil is of high quality, and the meal can be used as a livestock feed supplement.

Winter rapeseed has been grown only on a limited scale in Illinois, and cultural practices are not well established. Limited experience with the crop strongly suggests that site selection is critical to success. Only fields with good drainage should be used because excessive moisture (ponding) will kill Canola. The crop is generally seeded 3 to 4 weeks before the optimum time to sow wheat. The seed is very small, and 5 to 6 pounds per acre seeded shallowly with a drill or forage seeder should be sufficient to establish a stand. Fertility requirements are much the same as for winter wheat, except that the per-acre nitrogen rate should be 20 to 40 pounds higher than for wheat. The crop normally will be ready for harvest the same time as winter wheat and should be harvested in a timely and careful manner to avoid shatter loss. With the limited acreage, it is not yet known what insects and diseases will attack this crop in Illinois.

A few elevators in central and southern Illinois have accepted Canola in recent years. Compared with corn and soybeans, however, there are limited marketing opportunities. Limited markets for the crop should be considered before planting.

Buckwheat

Buckwheat may mature in 75 to 90 days. It can be planted as late as July 10 to 15 in the northern part of the state and in late July in southern Illinois. The crop is sensitive to both cold and hot weather. It will be killed by the first frost in the fall. Yields will be disappointingly low if it blooms during hot weather.

The market for buckwheat is limited unless you plan to use it for livestock feed. Be sure of a market before you plant it.

Grain amaranth

This crop, which is a type of pigweed selected for seed production, was a traditional crop of Central and South America before the Spanish Conquest. The seeds are usually ground into flour, which is sold mainly in health-food outlets. The nutritional quality of the seeds is quite good compared to that of cereal grains. While efforts are under way to improve this crop genetically, limited experience in Illinois has shown most of the existing varietal types to be somewhat poorly adapted to field-scale production; standability and seed shatter can be problems. At the present time, amaranth, which is generally produced as a row crop, has a very limited market.

Other crops

Many other crops can grow in Illinois, but markets for them are not established or are very small. Some of these crops require a considerable amount of hand labor, and competing with areas of the world where labor is very cheap will be difficult.

Crops that remain undeveloped in Illinois include industrial crops such as meadowfoam and cuphea (specialty oil crops) and kenaf, a possible source of paper pulp. Other possibilities include medicinal crops such as belladonna and evening primrose and spice crops such as ginseng and sesame. A number of grain legumes such as mungbean, various edible dry beans, and lupines could also be produced, though pest problems could be serious if any of these were grown on a commercial scale.

While there is plenty of opportunity for individuals or small groups of entrepreneurs to explore production and marketing of the crops mentioned in this section, it is difficult to foresee a substantial move away from corn, soybeans, and wheat in favor of any of these crops. Nutrients required in very large amounts by people and livestock include carbohydrates, protein, and oil, and a good balance of these is provided by the crops now grown in this state.

Alternative Field Crops Manual, a reference publication, contains production information on more than 30 miscellaneous crops. It is available from the University of Minnesota, Center for Alternative Plant and Animal Products, (612)625-5747.

Chapter 7.

Hay, Pasture, and Silage

High yields

Thick, vigorous stands of grasses and legumes are needed for high yields. A thick stand of grass will cover nearly all the ground. A thick stand of alfalfa is about 30 plants per square foot at the end of the seeding year, 10 to 15 plants per square foot the second year, and 5 to 7 plants per square foot for the succeeding years.

Vigorous stands are created and maintained by choosing disease- and insect-resistant varieties that grow and recover quickly after harvest, by following good seeding practices, by fertilizing adequately, by harvesting at the optimum time, and by protecting the stand from insects.

Establishment

Spring seeding date for hay and pasture species in Illinois is late March or early April — as soon as a seedbed can be prepared. Exceptions are seedings that are made in a fall-seeded, winter annual companion crop; for such seedings, seed hay and pasture species about the time of the last snow.

Sowing hay and pasture species into spring oats in the spring should be done when the oats are seeded, as early as a seedbed can be prepared.

Spring seedings are more successful in the northern half of Illinois than in the southern half. The frequency of success in the southern one-quarter to one-third of the state indicates that late-summer seedings may be more desirable than spring seedings.

Late-summer seeding date is August 10 in the northern quarter of Illinois, August 30 in central Illinois, and September 15 in the southern quarter of Illinois. Seedings should be made close to these dates, and no more than 5 days later, to assure that the plants become well established before winter. Late-summer seedings that are made extremely early may suffer from drought following germination.

Seeding rates for hay and pasture mixtures are shown in Table 7.6. These rates are for seedings made under average conditions, either with a companion crop in the spring or without a companion crop in late summer. Higher rates may be used to obtain high yields from alfalfa seeded without a companion crop in the spring. Seeding rates higher than described in Table 7.6 have proven economical in northern and central Illinois when alfalfa was seeded as a pure stand in early spring and two or three harvests were taken in the seeding year. In northern and central Illinois, but not in south-central Illinois, seeding alfalfa at 18 pounds per acre has produced yields 0.2 to 0.4 ton higher than seeding at 12 pounds per acre.

The two basic methods of seeding are band seeding and broadcast seeding. With band seeding, a band of phosphate fertilizer (0-45-0) is placed about 2 inches deep in the soil with a grain drill; then the forage seed is placed on the soil surface directly above the fertilizer band (Figure 7.1). Before the forage seeds are dropped, the fertilizer should be covered with soil, which occurs naturally when soils are in good working condition. A presswheel should roll over the forage seed to firm the seed into the soil surface. Many seeds will be placed one-eighth to one-fourth inch deep with this seeding method.

With broadcast seeding, the seed is spread uniformly over a firm, prepared seedbed; then the seed is pressed into the seedbed surface with a corrugated roller. The fertilizer is applied at the early stages of seedbed

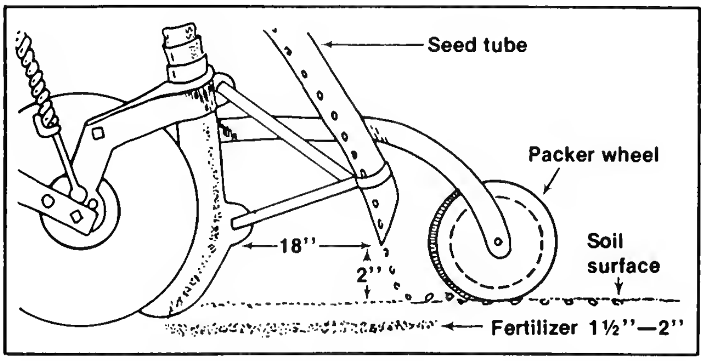

Figure 7.1. Placement of seed and high-phosphate fertilizer with grain drill.

preparation. The seedbed is usually disked and smoothed with a harrow. Most soil conditions are too loose after these tillage operations and should be firmed with a corrugated roller before seeding. The best seeding tool for broadcast seeding is the double corrugated roller seeder.

Which is the better seeding method? Illinois studies have shown that band seeding often results in higher alfalfa yields than broadcast seedings for August and spring seedings. Seedings on soils that are low in phosphorus yield more from band seeding than from broadcast seeding. Early seeding on cold, wet soils is favored by banded phosphorus fertilization. The greater yield from band seeding may be a response to abundant, readily available phosphorus from the banded fertilizer. Broadcast seedings may yield as high as band seedings when the soils are medium to high in phosphorus-supplying capacity and are well drained, so that they warm up quickly in the spring.

Forage crop seeds are small and should be seeded no deeper than one-eighth to one-fourth inch. The seeds should be in close contact with soil particles. The double corrugated roller seeder and the band seeder with press-wheels roll the seed into contact with the soil and are the best known methods of seeding forages.

Fertilizing and liming before or at seeding

Lime. Apply lime at rates suggested in Figure 10.5. If rate requirements are in excess of 5 tons, apply half before the primary tillage (in most cases, plowing) and half before the secondary tillage (harrowing or disking). For rates of less than 5 tons, make a single application, preferably after plowing, although applying either before or after plowing is acceptable.

Nitrogen (N). No nitrogen should be applied for legume seedings on soils with an organic-matter content above 2.5 percent. Applying as much as 20 pounds of nitrogen per acre may help assure rapid seedling growth of legume-grass mixtures on soils with less than 2.5 percent organic matter. When seeding a pure grass stand, 50 to 100 pounds of nitrogen per acre in the seedbed are suggested. If band seeding, apply nitrogen with phosphorus through the grain drill. For broadcast seedings, apply broadcast with phosphorus and potassium.

Phosphorus (P). Apply all phosphorus at seeding time (Tables 10.19 and 10.20) or broadcast part of it with potassium. For band seeding, reserve at least 30 pounds of phosphate (P_2O_5) per acre to be applied at seeding time. For broadcast seeding, broadcast all the phosphorus with the potassium, preferably after primary tillage and before final seedbed preparation.

Potassium (K). Fertilize before or at seeding. Broadcast application of potassium is preferred (Tables 10.20 and 10.21). For band seeding, you can safely apply a maximum of 30 to 40 pounds of potash (K_2O) per acre in the band with phosphorus. The response to band fertilizer will be mainly from phosphorus unless the K soil test is very low (perhaps 100 pounds per acre or less). For broadcast seeding, apply all the potassium after the primary tillage. You can apply up to 600 pounds of K_2O per acre in the seedbed without damaging seedlings if the fertilizer is incorporated.

Fertilization

Nitrogen. See the chapter titled "Soil Testing and Fertility," the subsection about nitrogen.

Phosphorus. This nutrient may be applied in large amounts, adequate for 2 to 4 years. The annual needs of a hay or pasture crop are determined from yield and nutrient content of the forage harvested (Table 10.20). Grasses, legumes, and grass-legume mixtures contain about 12 pounds of P_2O_5 (4.8 pounds of P) per ton of dry matter. Total annual fertilization needs include the maintenance rate (Table 10.20) and any needed build-up rate (Table 10.19).

Potassium. Because potassium helps the plant convert nitrogen to protein, grasses need large amounts of potassium to balance high rates of nitrogen fertilization. As nitrogen rates are increased, the nitrogen percent in the plant tissue also increases. If potassium is deficient, however, some nitrogen may remain in the plant as nonprotein nitrogen.

Legumes feed heavily on potassium. Potassium, a key element in maintaining legumes in grass-legume stands, is credited with improving winter survival.

Annual potassium needs are determined from yield, nutrient content in the forage that is harvested, and nutrient build-up requirements of a particular soil (Tables 10.20 and 10.21). Grasses, legumes, and grass-legume mixtures contain about 50 pounds of K_2O (41.5 pounds of K) per ton of dry matter.

Boron (B). Symptoms of boron deficiency appear on second and third cuttings of alfalfa during droughty periods in some areas of Illinois. But yield increases from boron fertilization have been infrequent. Application of boron on soils with less than 2 percent organic matter is recommended for high-yielding alfalfa production in Illinois. If you suspect a boron deficiency, topdress a test strip in your alfalfa fields with 30 pounds per acre of household borax (3.3 pounds of boron). For general application, have boron added to the phosphorus-potassium fertilizer.

Management

Seeding year. Hay and pasture crops seeded into a companion crop in the spring will benefit by early removal of the companion crop. Oats, wheat, or barley should be removed when the grain is in the milk stage. If these small grains are harvested for grain, it is important to remove the straw and stubble as soon as possible. As small-grain yields increase, the underseeded legumes and grasses face greater competition, and fewer satisfactory stands are established by the companion-crop method. Forage seedings established with a companion crop may have one harvest taken by late August in northern Illinois and, occasionally, two harvests by September 10 in central Illinois and by September 25 in southern Illinois.

Spring-seeded hay crops and pastures without a companion crop should be ready for harvest 65 to 70 days after an early April seeding. Weeds very likely must be controlled about 30 days after seeding unless a preemergence herbicide was used. Postemergence herbicides 2,4-DB and Buctril are effective against most broadleaf weeds. Grassy weeds are effectively controlled by Poast. Follow label directions. Leafhoppers often become a problem between 30 to 45 days after an early April seeding and must be controlled to obtain a vigorous, high-yielding stand.

Second and third harvests may follow the first harvest at 35- to 40-day intervals. The last harvest of the season should be in late August for the northern quarter of Illinois, by September 10 for the central section, and by September 20 for the southern quarter.

Established stands. Maximum dry-matter yield from alfalfa and most forages is obtained by harvesting or grazing the first cutting at nearly full bloom and harvesting every 40 to 42 days thereafter until September. This management produces a forage that is relatively low in digestibility. Such forage is suitable for livestock on maintenance, will produce slow weight gain, and can be used in low-performance feeding programs. In contrast, high-performance feeding programs require a highly digestible forage. The optimum compromise between high digestibility and dry-matter yield of alfalfa is to harvest or graze the first cutting at the late-bud to first-flower stage and to make subsequent cuttings or grazings at 32- to 35-day intervals. Rotational grazing is essential to maintaining legumes in pastures. A rotational grazing program should provide for 5 to 7 days of grazing and 30 to 35 days of rest. More intensive grazing, using 8 to 11 pastures, 3 to 4 days of grazing, and 30 to 33 days of rest, increases meat or milk production per acre but may not increase individual animal performance. Intensive grazing management is being adopted by many livestock producers in Illinois.

Because high levels of root reserves (sugars and starches) are needed for winter survival and vigorous spring growth, the timing of the fall harvest is critical. Following a harvest, root reserves decline as new growth begins. About 3 weeks after harvesting, root reserves are depleted to a low level, and the top growth is adequate for photosynthesis to support the plant's needs for sugars. From this point, root reserves are replenished gradually until harvest or until the plant becomes dormant in early winter. Harvests made in September and October affect late-fall root reserves of alfalfa more than do summer harvests. After the September harvest, alfalfa needs a recovery period until late October to restore root reserves. On well-drained soils in central and southern Illinois, a "late" harvest may be taken after plants have become dormant in late October or early November.

Pasture establishment

Many pastures can be established through a hay crop program. Seedings are made on a well-prepared, properly fertilized seedbed. If it is intended that the hay crop becomes a pasture, the desired legume and grass mixture should be seeded. When grasses and legumes are seeded together, 2,4-DB or Buctril is a herbicide that can be used for broadleaf weed control. Apply 2,4-DB or Buctril about 30 days after seeding, when the legumes are 2 to 4 inches tall and the weeds less than 4 inches tall.

Pasture renovation

Pasture renovation usually means changing the plant species in a pasture to increase the pasture's quality and productivity. Improving the fertility of the soil is basic to this effort. A soil test helps identify the need for lime, phosphorus, and potassium — the major nutrients important to establishing new forage plants.

Before seeding new legumes or grasses into a pasture, reduce the competition from existing pasture plants. Tilling, overgrazing, and herbicides — used singly or in combination — have proven useful in subduing existing pasture plants.

For many years, tilling (plowing or heavy disking) has been used to renovate pastures; but success has been variable. Major criticisms have been that tilling can cause erosion, that the pasture supply for the year of seeding is usually limited, and that a seeding failure would leave no available permanent vegetation for pasturing or soil protection.

No-till seeding of new pasture plants into existing pastures began when herbicides and suitable seeders were developed. The practice of using a herbicide to subdue existing pasture plants and then seeding with a no-till seeder has proven very successful in many research trials and farm seedings. Following are eight basic steps to no-till pasture renovation.

1. Graze the pasture intensively for 20 to 30 days before the seeding date to reduce the vigor of existing pasture plants.
2. Lime and fertilize, using a soil test as a guide. Soil pH should be between 6.5 and 7.0. Desirable test levels of phosphorus and potassium vary with soil type; phosphorus should be in the range of 40 to 50 pounds per acre, and potassium in the range of 260 to 300 pounds per acre. For more information, see the chapter titled "Soil Testing and Fertility."
3. One or 2 days before seeding, apply a herbicide to subdue the vegetation. Gramoxone Super (paraquat)

and Roundup (glyphosate) are approved for this purpose.

4. Seed the desired species, using high-yielding varieties. Alfalfa and red clover are the legumes with higher yields and are often the only species seeded into a pasture that has a desirable grass species and in which Gramoxone Super is going to be used in preference to Roundup. To seed, use a no-till drill that places the seed in contact with the soil.
5. Seedings may be made in early spring throughout the northern two-thirds of Illinois and in late August throughout the southern three-fourths of Illinois.
6. Apply insecticides as needed. Soil insects that eat germinating seedlings are more prevalent in southern Illinois than in northern Illinois, and a soil insecticide may be needed. Furadan has been approved for this use. Leafhoppers will be present throughout Illinois in early summer and during most of the growing season. They must be controlled where alfalfa is seeded, especially in spring-seeded pastures, because they are devastating to new alfalfa seedlings. Several insecticides are approved; for more information, see the *1993 Illinois Pest Control Handbook* chapter on *Insect Pest Management for Field and Forage Crops.* Well-established alfalfa plants are injured but not killed by leafhoppers; red clover and grass plants are not attacked by leafhoppers.
7. Initiate grazing 60 to 70 days after spring seedings and not until the next spring for late-August seedings. Spring-seeded alfalfa and red clover should be at about 50 percent bloom at the first grazing. Alfalfa and red clover that are seeded in late August should be in the late-bud to first-flower stage of growth when grazing begins. Use rotational grazing. Graze 5 to 7 days and rest 28 to 30 days; for slightly lower-quality and lower-yielding pastures, graze 10 days and rest 30 days; for greater animal product yield per acre, graze 3 to 4 days and rest 32 to 33 days.
8. Fertilize pastures annually on the basis of estimated crop removal. Each ton of dry matter from a pasture contains about 12 pounds of phosphate (P_2O_5) and 50 to 60 pounds of potash (K_2O). Do not use nitrogen on established pastures in which at least 30 percent of the vegetation is alfalfa, red clover, or both. Because much of the nutrients grazed are returned to the pasture in urine and manure, you should soil test thoroughly every 4 years and adjust your fertilization program according to soil tests. Usually less phosphate and potash are needed on pastures than hay fields.

Selection of pasture seeding mixture

Alfalfa is the single best species for increasing yield and improving the quality of pastures in Illinois. Red clover produces very well in the first 2 years after seeding but contributes very little after that. Birdsfoot trefoil establishes slowly and increases to 40 to 50 percent of the yield potential of alfalfa. Mixtures of alfalfa at 8 pounds and red clover at 4 pounds per acre or of birdsfoot trefoil at 4 pounds and red clover at 4 pounds per acre have demonstrated high yield. Red clover diminishes from the stand about the third year; and the more persistent species, alfalfa or birdsfoot trefoil, increases to maintain a high yield level for the third and subsequent years.

Pasture fertilization

The yield and quality of many pastures can be improved by fertilization. The soil pH is basic to any fertilization program. Pasture grasses tolerate a lower soil pH than do hay and pasture legumes. For pastures that are primarily grass, a minimal pH should be 6.0. A pH of 6.2 to 6.5 is more desirable because nutrients are more efficiently utilized in this pH range than at lower pH values. Lime should be applied to correct the soil acidity to one-half plow depth. This liming is effective half as long as when a full rate is applied and plowed into the plow layer. Consequently, pastures will usually require liming more often (but at lower rates) than will cultivated fields.

Phosphorus and potassium needs are assessed by a soil test. Without a soil test, the best guess is to apply what the crop removes. Pasture crops remove about 12 pounds of phosphate (P_2O_5) and 50 pounds of potash (K_2O) per ton of dry matter. Very productive pastures yield 5 to 6 tons of dry matter per acre; moderately productive pastures yield 3 to 5 tons; and less productive pastures, 1 to 3 tons. Recycling of nutrients from urine and manure reduces the total nutrients removed from a pasture. Soil test every 4 years to monitor changes in fertility status of pastures.

Pasture management

Rotational grazing of grass pastures results in greater production (animal product yield per acre) than does continuous grazing, except for Kentucky bluegrass pastures. Pastures that include legumes need rotational grazing to maintain the legumes. A rotational grazing plan that works well is 5 to 7 days' grazing with 28 to 30 days' rest, which requires five to six fields. This plan provides the high-quality pasture needed by growing animals and dairy cows. A more intense grazing system for high performance livestock and for high animal product per acre is a rotational grazing system of 8 to 11 fields, 3 to 4 days' grazing and 30 to 33 days' rest per pasture field. A less intense grazing plan for beef cow herds, dry cows, and stocker animals is 10 days' grazing with 30 days' rest, which requires four fields.

Weed control is usually needed in pastures. Clipping pastures after each grazing cycle helps in weed control, but herbicides may be needed for problem areas. Banvel and 2,4-D are effective on most broadleaf weeds. Banvel is more effective than 2,4-D for most conditions but also has more restrictions. Do not graze dairy animals or feed harvested forage from these fields until 60 days after treatment with Banvel. Remove meat animals from Banvel-treated pastures 30 days before slaughter. Restrictions for 2,4-D apply to milk cows, which should not be grazed on treated pasture for 7 days after treatment. Thistles can usually be controlled by 2,4-D or Banvel, although repeated applications of the herbicide may be necessary. Multiflora rose may be controlled with Banvel applied in early spring, when the plant is actively growing, but before flower bud formation.

Species and varieties

Alfalfa is the highest-yielding perennial forage crop suited to Illinois, and its nutritional qualities are nearly unsurpassed. Alfalfa is an excellent hay crop species and, with proper management, may be used in pastures, as already mentioned.

Bloat in ruminant animals often is associated with alfalfa pastures. Balancing soil fertility, including grasses in mixtures with alfalfa, maintaining animals at good nutritional levels, and using bloat-inhibiting feed amendments are methods to reduce or essentially eliminate the bloat hazard.

Many varieties of alfalfa are available. Some have been privately developed, some developed at public institutions. Private varieties usually are marketed through a few specific dealers. Not all varieties are available in Illinois.

An extensive testing program has been under way at the University of Illinois for many years. The performance of alfalfa varieties listed in Table 7.1 is based on test data compiled since 1961. Some varieties have been tested every year since then; others have been tested only 3 or 4 years. Each variety in this list, however, has been in tests at least 3 years.

Bacterial wilt is one of the major diseases of alfalfa in Illinois. Stands of susceptible varieties usually decline severely in the third year of production and may die out in the second year under intensive harvesting schedules. Moderate resistance to bacterial wilt enables alfalfa to persist as long as 4 or 5 years. Varieties listed as resistant usually persist beyond 5 years.

Phytophthora root rot is a major disease of alfalfa grown on poorly drained soils, primarily in the northern half of Illinois. This disease attacks both seedlings and mature plants. The root develops a black lesion, which progresses and rots the entire root. In mature stands, shortened taproots are a symptom of this disease. Many alfalfa varieties with high-yield performance have resistance or moderate resistance to phytophthora root rot.

Anthracnose is an important disease in the southern half of Illinois and may be important in northern Illinois during warm, humid weather. The disease causes the stem and leaves to brown, with the tip of the stem turning over like a hook. The fungus causes a stem lesion, usually diamond-shaped in the early stages, which enlarges to completely encircle the stem. Many alfalfa varieties with high-yield performance have resistance or moderate resistance to anthracnose.

Table 7.1. Leading Alfalfa Varieties Tested at Least 3 Years in Illinois

Brand or variety	Bacterial wilt resistance[a]	Percent of yield of check varieties[b]		
		Northern	Central	Southern
Aggressor	HR	110.19	104.17	...
AgriBoss	HR	112.88	...	...
Allegiance	R	98.95	...	107.29
Apollo II	R	109.11	103.69	...
Arrow	R	107.38	103.70	102.07
Blazer	R	111.50	104.20	110.29
Chief	HR	103.71	104.84	103.53
Cimarron VR	HR	105.57	105.44	...
Clipper	HR	106.82	102.22	114.60
Comet	R	103.15	107.05	...
Commandor	R	100.11	110.04	93.59
Dart	HR	105.24	106.02	98.80
Dawn	R	109.78	110.33	...
Decathlon	HT	101.01	...	108.66
DeKalb Br 120	HR	105.56	104.52	...
Echo	R	102.31	...	110.33
Edge	R	115.12	...	...
Elevation	R	107.50	110.91	...
Embro A-54	R	105.08	105.76	104.50
Epic	R	107.38	109.13	101.09
Fortress	R	106.04	105.68	103.57
Funk's G-2852	HR	104.95	106.19	...
Garst 629	MR	105.76	103.23	100.57
Garst 630	HR	102.35	104.45	106.30
Garst 636	R	105.52	106.94	105.94
Magnum III	R	106.38	103.53	...
Magnum +	R	101.37	100.59	109.54
Mercury	R	116.10	110.10	...
Milkmaker	R	104.56	108.43	95.69
Perry	R	100.54	103.46	100.03
Pioneer BR 5262	HR	111.21	...	106.32
Pioneer BR 5373	HR	105.42	105.39	...
Pioneer BR 5432	HR	103.42	101.65	102.16
PRO-CUT 2	HR	105.32	107.05	99.53
Renegade	R	...	107.20	...
Riley	HR	100.55	102.18	101.14
Saranac AR	MR	100.33	103.73	102.00
Shenandoah	R	103.60	100.12	103.01
Sure	HR	...	110.86	...
Vancor	R	104.02	104.36	108.49
Vector	R	98.52	108.02	104.76
Vernal	R	100.41	100.05	103.37
Verta +	HR	...	111.80	...
WL 225	HR	101.76	101.54	107.20
WL 317	HR	104.57	105.86	101.03
Wrangler	R	105.76	100.96	105.73

[a] HR = highly resistant; R = resistant; MR = moderately resistant; HT = highly tolerant.

[b] Check varieties are Baker, Riley, Saranac AR, and Vernal. The average yield of check varieties equals 100.

Verticillium wilt is a root-rot disease that is similar to bacterial wilt. Verticillium wilt develops slowly, requiring about 3 years before plant loss becomes noticeable. Associated with cool climates and moist soils, this fungus is gradually spreading southward in Illinois. Producers in the northern quarter of Illinois should seek resistant varieties; and producers in the rest of the northern half of the state should observe their fields and consider using resistant varieties when seeding alfalfa. Many alfalfa varieties with high-yield performance have resistance or moderate resistance to verticillium wilt.

Other diseases and insects are problems for alfalfa, and some varieties of alfalfa have particular resistance to these problems. You should question your seed supplier about these attributes of the varieties being offered to you.

Red clover (medium red clover) is the second most important hay and pasture legume in Illinois. Although it does not have the yield potential of alfalfa under good production conditions, red clover can persist in more acidic soils and under more shade competition than can alfalfa. And, although red clover is a perennial physiologically, root and crown diseases limit the life of red clover to 2 to 3 years. Many new varieties have an increased resistance to root and crown diseases and are expected to be productive for at least 3 years. (See Table 7.2.)

Red clover does not have as much seedling vigor or as rapid a seedling growth rate as alfalfa. Therefore, red clover does not fit into a spring seeding program without a companion crop as well as does alfalfa.

Red clover has more shade tolerance at the seedling stage than does alfalfa; therefore, red clover is recommended for most pasture renovation mixtures where shading by existing grasses occurs. The shade tolerance of red clover enables it to establish well in companion crops such as spring oats and winter wheat.

There are fewer varieties of red clover than of alfalfa. Private breeders are active in developing more varieties of red clover.

Fewer acres are dedicated to mammoth red clover because its yields have been lower than most of the improved varieties of medium red clover.

Ladino clover is an important legume in pastures, but it is a short-lived species. The very leafy nature of ladino makes it an excellent legume for swine. It is also a very high-quality forage for ruminant animals, but problems of bloat are frequent.

Ladino lacks drought tolerance because its root system is shallower than that of red clover or alfalfa.

Birdsfoot trefoil has been popular in permanent pastures in northern Illinois. It has a long life but becomes established very slowly. Seedling growth rate is much slower than that of alfalfa or red clover.

A root rot has made birdsfoot trefoil a short-lived crop throughout southern Illinois. The variety Dawn may have adequate resistance to persist throughout the state (see Table 7.3 for variety yields).

Rooting depth of birdsfoot trefoil is shallower than that of alfalfa, thus birdsfoot trefoil is not as productive during drought.

Crownvetch is well known for protecting very erosive soil areas. As a forage crop, crownvetch is much slower than alfalfa or red clover in seedling emergence, seedling growth rate, early-season growth, and recovery growth. Growth rate is similar to that of birdsfoot trefoil. The potential of crownvetch as a hay or pasture plant seems restricted to very rough sites and soils of low productivity. Crownvetch does not tolerate defoliation (grazing or hay harvesting) as well as alfalfa, red clover, or birdsfoot trefoil.

Sainfoin is a legume that was introduced into the western United States from Russia. In Illinois tests, this species has failed to become established well enough to allow valid comparisons with alfalfa, red clover, and others. Observations indicate that sainfoin has a slow growth and recovery growth rate and is not well suited to the humid conditions in Illinois.

Hairy vetch is a winter annual legume that has limited value as a hay or pasture species. Low production and its vinelike nature have discouraged much use. Hairy vetch may reseed itself and become a weedy species in small grain fields. Hairy vetch seeded with winter wheat at 22 to 25 pounds per acre has increased the protein yield of wheat-vetch silage. Hairy vetch is a popular cover crop, providing approximately 60 pounds of available nitrogen to a following crop. Hairy vetch should be seeded in September and not killed until mid-May to obtain high nitrogen contributions.

Table 7.2. Leading Red Clover Varieties Tested at Least 2 Years in Illinois

Variety	Anthracnose resistance[a]		Powdery mildew resistance	Percent of check yield[b]		
	Northern	Southern		Northern	Central	Southern
Arlington	R	. . .[c]	R	100.00	100.00	100.00
Atlas	R	HR	R	. . .	101.87	96.74
E 688	T	R	R	. . .	94.76	98.38
Florie	R	R	R	99.64	101.45	101.45
Kenland	S	R	. . .	83.45	100.84	100.88
Kenstar	S	R	. . .	85.91	106.36	91.40
Marathon	R	MR	. . .	102.79	110.72	. . .
Mega	R	R	R	. . .	98.58	95.25
Mor Red	HR	MR	HR	102.74	95.77	. . .
Redland	MR	R	R	101.19	100.01	102.21
Redland II	R	R	R	108.88	106.81	104.86
Redland III	R	R	R	. . .	99.50	. . .
Redman	R	MR	R	109.40	97.42	97.42
Ruby	R	R	. . .	109.05	105.05	99.87

[a] HR = highly resistant; R = resistant; MR = moderately resistant; S = susceptible.
[b] The check variety is Arlington. The check variety yield equals 100.
[c] Data not available.

Table 7.3. Leading Birdsfoot Trefoil Varieties Tested at Least 3 years in Illinois

Variety	Winter-hardiness[a]	Percent of check yield[b]		
		Northern	Central	Southern
Au Dewey	SH	. . .	101.54	100.45
Bonnie	MH	. . .	105.61	107.39
Carroll	H	112.28	97.19	95.43
Dawn	MH	109.48	102.31	96.16
Empire	MH	102.66	92.86	87.23
Fergus	H	. . .	111.00	104.76
Georgia I	SH	. . .	98.28	91.72
KO-4	. . .	103.35	95.88	. . .
Leo	MH	101.14	98.62	98.90
Mackinac	H	102.91	94.91	. . .
Maitland	H	99.48	106.56	. . .
Norcen	H	110.19	107.07	108.33
Viking	H	90.46	100.32	103.89

[a] Winterhardiness ratings: H = hardy; MH = moderately hardy; SH = slightly hardy; . . . = information not available.
[b] Check varieties are Dawn and Viking. The average yield of check varieties equals 100.

Lespedeza is a popular annual legume in the southern third of Illinois. It flourishes in midsummer when most other forage plants are at low levels of productivity. It survives on soils of low productivity and is low yielding. Even in midsummer, it does not produce as well as a good stand of alfalfa, nor will it encroach on a good alfalfa stand. As alfalfa or other vigorous pasture plants fade out of a pasture, lespedeza may enter it.

Inoculation

Legumes — such as alfalfa, red clover, crownvetch, hairy vetch, ladino, and birdsfoot trefoil — can meet their nitrogen needs from the soil atmosphere if the roots of the legume have the correct Rhizobium species and favorable conditions of soil pH, drainage, and temperature. Rhizobium bacteria are numerous in most soils; however, the species needed by a particular legume species may be lacking.

There are seven general groups and some other specific strains of Rhizobium, with each group specifically infecting roots of plants within its corresponding legume group and some specific strains infecting only a single legume species. The legume groups are (1) alfalfa and sweet clover; (2) true clovers (such as red, ladino, white, and alsike); (3) peas and vetch (such as field pea, garden pea, and hairy vetch); (4) beans (such as garden and pinto); (5) cowpeas and lespedeza; (6) soybeans; and (7) lupines. Some of the individual Rhizobium strains are specific to (1) birdsfoot trefoil; (2) crownvetch; or (3) sainfoin.

Grasses

Cool-season perennials

Timothy is the most popular hay and pasture grass in Illinois, although it is not as high yielding and has less midsummer production than smooth bromegrass. A cool-season species, it is best suited to the northern half of Illinois. There are promising new varieties (Table 7.4).

Smooth bromegrass is probably the most widely adapted high-yielding grass species for northern and central Illinois. Smooth bromegrass combines well with alfalfa or red clover. It is productive but has limited summer production when moisture is lacking and temperatures are high. It produces well in spring and fall and can utilize high-fertility programs. There are a few improved varieties, and breeding work continues (Table 7.4).

Orchardgrass is one of the most valuable grasses used for hay and pasture in Illinois. It is adapted throughout the state, being marginally winter-hardy for the northern quarter of the state. Orchardgrass heads out relatively early in the spring and thus should be combined with alfalfa varieties that flower early. One of the more productive grasses in midsummer, it is a high-yielding species and several varieties are available (Table 7.4).

Reed canarygrass is not widely used, but it has growth attributes that deserve consideration. Reed canarygrass is the most productive of the tall, cool-season perennial grasses that are well suited to Illinois hay and pasture lands. Tolerant of wet soils, it also is one of the most drought-resistant grasses and can utilize high fertility. It is coarser than orchardgrass or bromegrass but not as coarse as tall fescue. Grazing studies indicate that, under proper management, reed canarygrass can produce good weight gains on cattle equal to those produced by bromegrass, orchardgrass, or tall fescue. Reed canarygrass should be considered for grazing during spring, summer, and early fall. Cool temperatures and frost retard growth and induce dormancy earlier than with tall fescue, smooth bromegrass, or orchardgrass. New low-alkaloid varieties have improved animal performance (Table 7.4).

Tall fescue is a high-yielding grass (Table 7.4). It is outstanding in performance when used properly and is a popular grass for beef cattle in southern Illinois. Because it grows well in cool weather, tall fescue is especially useful for winter pasture; and it is also most palatable during the cool seasons of spring and late fall. A fungus living within the plant tissue (endophyte) has a major influence on the lower palatability and digestibility of this grass during the warm summer months. Varieties are available that are fungus-free or low in fungus. Forager, Johnstone, and Kenhy are productive varieties in Illinois that are low in endophyte fungus. Tall fescue is marginally winter-hardy when used in pastures or hay crops in the northern quarter of the state. A more extensive list of hay, pasture, and silage crop varieties is given in Table 7.5.

Warm-season annuals

Sudangrass, sudangrass hybrids, and sorghum-sudangrass hybrids are annual grasses that are very

Table 7.4. Leading Grass Varieties Tested at Least 2 Years in Illinois

Species variety	Percent of check yield[a]		
	Northern	Central	Southern
Kentucky bluegrass			
Dormie	71.30	86.45	. . .
Orchardgrass			
Benchmark	. . .	102.42	101.80
Crown	110.10	99.80	97.40
Dart	107.50	105.21	95.44
Dawn	. . .	102.10	94.38
Hawk	100.20	106.40	. . .
Hera	. . .	. . .	105.30
Ina	108.00	112.05	. . .
Juno	105.00	96.50	97.60
Justus	. . .	100.30	109.70
Pacific	107.00	. . .	. . .
Phyllox	. . .	96.80	94.20
Potomac	95.20	100.20	98.80
Rancho	97.50	108.70	100.80
Rapido	. . .	104.60	95.70
Perennial ryegrass and ryegrass-fescue hybrids			
Bison	102.90	107.50	. . .
Gladiator	. . .	100.80	. . .
Grimalda Tetraploid	91.90	51.20	. . .
Tandem Festulolium	. . .	101.80	105.00
Reed canarygrass			
Flare	106.20	123.00	103.40
Palaton	115.50	122.40	105.00
Vantage	93.00	. . .	110.10
Venture	109.30	127.70	105.60
Rescuegrass			
Matua	. . .	99.20	98.10
Smooth bromegrass			
Barton	102.10	104.20	116.30
Blair	86.40	105.20	. . .
Bravo	97.00	98.70	101.20
Fox	66.70	. . .	96.28
FS Beacon	107.30	102.90	114.00
Lincoln	92.30	95.10	101.80
Rebound	90.70	104.60	100.20
Sac	95.50	. . .	107.10
Tall fescue			
AU-Triumph	. . .	121.30	94.30
FA-293	. . .	116.40	103.40
Forager	117.70	111.40	100.61
Johnstone	113.80	114.70	100.70
Kenhy	108.00	122.60	110.50
Ky-31	107.30	119.50	104.10
Martin	115.70	121.70	109.40
Mozark	109.30	128.20	104.50
Mustang	99.80	104.50	. . .
Phyter (Syn W)	. . .	122.40	101.30
Timothy			
Itasca	75.50	92.50	94.60
Mariposa	. . .	103.80	113.40
Mohawk	95.60	112.80	. . .
Pronto	78.10	. . .	86.20
Richmond	103.50	95.80	101.40
Timfor	. . .	111.20	98.50

[a] Check varieties are Potomac orchardgrass and Lincoln smooth bromegrass. The average yield for check varieties equals 100.

productive during the summer. These grasses must be seeded each year on a prepared seedbed. Although the total-season production from these grasses may be less than that from perennial grasses with equal fertility and management, these annual grasses fill a need for quick, supplemental pastures or green feed. These tall, juicy grasses are difficult to make into high-quality hay. Sudangrass and sudangrass hybrids have finer stems than the sorghum-sudan hybrids and thus will dry more rapidly; they should be chosen for hay over the sorghum-sudan hybrids. Crushing the stems with a hay conditioner will help speed drying. These crops may be used for silage, green chop, or pasture more effectively than for hay.

Sudangrass, sudangrass hybrids, and sorghum-sudangrass hybrids produce prussic acid, a compound that is toxic to livestock. Prussic acid is the common name for hydrogen cyanide (HCN). The compound in sorghum plants that produces HCN is dhurrin. Two enzymes are required to hydrolyze dhurrin to HCN. The microflora in the rumen of ruminant animals are capable of enzymatic breakdown of dhurrin, producing HCN. The concentration of dhurrin is highest in young tissue, with more found in leaves than in stems. There is more dhurrin in the forage of grain or forage sorghums than in sorghum-sudangrass hybrids, and more in sorghum-sudangrass hybrids than in sudangrass hybrids or sudangrass.

Sudangrass and sudangrass hybrids are considered safe for grazing when they are 18 inches tall. The sorghum-sudangrass hybrids should be 24 inches tall before grazing is permitted. Very hungry cattle or sheep should be fed other feeds that are low in prussic-acid potential before turning them onto a lush sudangrass or sorghum-sudangrass pasture. This prefeeding will prevent rapid grazing and a sudden influx of forage that contains prussic acid. These animals can tolerate low levels of prussic acid because they can metabolize and excrete the HCN.

Frost on the crops of the sorghum family breaks cell walls and permits the plant enzymes to come into contact with dhurrin and HCN to be released rapidly. For this reason, it is advisable to remove grazing ruminant livestock from freshly frosted sudangrasses and sorghums. When the frosted plant material is thoroughly dry, usually after 3 to 5 days, grazing can resume. Grazing after this time should be observed closely for new tiller growth, which will be high in dhurrin; and livestock should be removed when there is new tiller growth that is being grazed.

The sorghums can be ensiled. The fermentation of ensiling reduces the prussic acid potential very substantially. This method is the safest for using feed that has a questionably high prussic acid potential.

Harvesting these crops as hay is also a safe way of using a crop with questionably high levels of prussic acid potential.

Toxic levels of prussic acid (HCN) vary. Some workers report toxicity at 200 ppm HCN of tissue dry weight, while others report moderate toxicity at 500 to 750 ppm HCN of tissue dry weight. Laboratory diagnostic procedures can determine relative HCN potential. An alkaline picrate solution is commonly used to detect HCN in plant tissue.

Millets are warm-season annual grasses that are drought tolerant. Four commonly known millets are

Table 7.5. Hay, Pasture, and Silage Crop Varieties

Crop	Variety	Origin	Use
Ladino clover	Merit	Iowa	Pasture
Birdsfoot trefoil	Carroll	Iowa	Hay and pasture
	Dawn	Missouri	Pasture
	Empire	New York	Pasture
	Fargo	North Dakota	Hay and pasture
	Fergus	Kentucky	Hay and pasture
	Leo	Canada	Hay and pasture
	Mackinaw	Michigan	Hay and pasture
	Maitland	Europe	Hay and pasture
	Norcen	Universities of North-Central States	Hay and pasture
	Viking	New York	Hay and pasture
Crownvetch	Chemung	New York	Erosion and pasture
	Emerald	Iowa	Erosion and pasture
	Penngift	Pennsylvania	Erosion and pasture
Smooth bromegrass	Barton	Land O'Lakes, Inc.	Hay and pasture
	Baylor	AgriPro	Hay and pasture
	Blair	AgriPro	Hay and pasture
	Bravo	Otto Pick & Sons Seed, Inc.	Hay and pasture
	FS Beacon	Land O'Lakes, Inc.	Hay and pasture
	Jubilee	Otto Pick & Sons Seed, Inc.	Hay and pasture
	Lincoln	Nebraska	Hay and pasture
	Sac	Wisconsin	Hay and pasture
Orchardgrass	Benchmark	Farm Forage Research Cooperative	Hay and pasture
	Boone	Kentucky	Hay and pasture
	Crown	AgriPro	Hay and pasture
	Dart	Land O'Lakes, Inc.	Hay and pasture
	Dayton	AgriPro	Hay and pasture
	Hawk	AgriPro	Hay and pasture
	Ina	Northrup, King and Co.	Hay and pasture
	Juno	Ottawa Research Station	Hay and pasture
	Napier	AgriPro	Hay and pasture
	Pennlate	Pennsylvania	Hay and pasture
	Potomac	Maryland	Hay and pasture
	Rancho	Farm Forage Research Cooperative	Hay and pasture
	Sterling	Iowa	Hay and pasture
Tall fescue	Alta	Oregon	Pasture
	Fawn	Oregon	Pasture
	Forager	Farm Forage Research Cooperative	Pasture (low endophyte fungus)
	Johnstone	Kentucky	Pasture (low endophyte fungus)
	Kenhy	Kentucky	Pasture (more palatable; low endophyte fungus)
	Kenwell	Kentucky	Pasture (more palatable)
	Ky-31	Kentucky	Pasture
	Martin	Missouri	Pasture (higher magnesium; low endophyte fungus)
	Mozark	Missouri	Pasture (low endophyte fungus)
	Mustang	New Jersey	Pasture
Timothy	Clair	Kentucky	Hay
	Climax	Indiana	Hay
	Itasca	Minnesota	Hay
	Mariposa	Otto Pick & Sons Seed, Inc.	Hay
	Mohawk	Farm Forage Research Cooperative	Hay
	Pronto	Pride Company, Inc.	Hay
	Richmond	Otto Pick & Sons Seed, Inc.	Hay
	Timfor	Northrup, King and Company	Hay
	Toro	AgriPro	Hay
	Verdant	Wisconsin	Hay
Switchgrass	Blackwell	—	Hay and pasture
	Caddo	Oklahoma	Hay and pasture
	Cave-in-Rock	Soil Conservation Service (Illinois)	Hay and pasture
	Kanlow	—	Hay and pasture
	Nebraska 28	Nebraska	Hay and pasture
	Pathfinder	—	Hay and pasture
	Trailblazer	—	Hay and pasture
Eastern gamagrass	Pete	Soil Conservation Service	Hay and pasture
Big bluestem	Champ	—	Hay and pasture
	Kaw	Kansas	Hay and pasture
	Pawnee	Nebraska	Hay and pasture
	Roundtree	Soil Conservation Service	Hay and pasture
Caucasian bluestem	Caucasian	—	Hay and pasture
Indiangrass	Holt	Nebraska	Hay and pasture
	Osage	Kansas	Hay and pasture
	Oto	Nebraska	Hay and pasture
	Rumsey	Soil Convervation Service	Hay and pasture

pearlmillet (*Pennisetum typhoides*), browntop millet (*Panicum ramosum*), foxtail or Italian millet (*Setaria italica*), and Japanese millet (*Echinochloa crusgalli*). Pearlmillet has been evaluated in grazing trials and is a suitable alternative for summer annual pastures.

Pearlmillet requires a warmer soil for rapid establishment than does sudangrass. Seedings should be delayed until the seedbed averages 70°F.

Pearlmillet does not have a prussic acid potential as does sudangrass, nor is pearlmillet as susceptible to leaf diseases. Pearlmillet is more drought tolerant than is sudangrass, thus producing more pasture during the hot, dry periods of late summer.

Forage mixtures

Mixtures (Table 7.6) of legumes and grasses usually are desirable. Yields tend to be greater than with either the legume or the grass alone. Grasses are desirable additions to legume seedings to fill in where the legume ceases to grow, to reduce soil erosion, to increase the drying rate, to reduce legume bloat, and perhaps to improve animal acceptance. Mixtures of two or three well-chosen species usually yield more than mixtures that contain five or six species, some of which are not particularly well suited to the soil, climate, or use.

Warm-season perennials

Warm-season perennial grasses also are known as native prairie grasses. These prairie grasses normally provide ample quantities of good- to high-quality pasture during midsummer when cool-season perennials are low yielding and often of low quality. Switchgrass, big bluestem, and indiangrass have been the more popular prairie grasses for use in Illinois.

Switchgrass (*Panicum virgatum L.*) is a tall, coarse-stemmed grass with long, broad leaves that grows 3 to 5 feet tall, with short rhizomes. It is not as palatable as smooth bromegrass. It is native to the Great Plains.

In Illinois, switchgrass starts growing in May but makes most of its growth in June to August. Switchgrass is one of the earliest maturing prairie grasses. Grazing or harvesting should leave a minimum of a 4- to 6-inch stubble. Close grazing or harvesting quickly diminishes the stand.

Switchgrass needs abundant moisture and fertility for maximum growth. Because switchgrass is tolerant of moist soils, it is often used in grass waterways.

Varieties. Blackwell, Caddo, Kanlow, Nebraska 28, Pathfinder, and Trailblazer were selected in the southern and central Great Plains. Trailblazer, released in 1985, is more digestible than the other varieties. Cave-in-Rock was selected from southern Illinois in 1958 and released by the Soil Conservation Service, Elsberry, Missouri, in 1972. Cave-in-Rock has yielded well in Illinois trials.

Switchgrass should be seeded in mid-April to early May. A continuous supply of soil moisture is needed for germination and early seedling development. Precipitation during the first 10 days following seeding has beeen more important for the establishment of switchgrass than the seeding date.

A seeding rate of 6 pounds of pure live seed (PLS) per acre of switchgrass is adequate if weeds are controlled and precipitation is favorable. Increasing the seeding rate increases the number of seedlings established but has little effect on forage yield or forage quality of established stands.

Frequent grazing or hay harvesting — more often than every 6 weeks — reduces the yield and vigor of switchgrass. A harvest may be taken after frost without reducing yield and vigor the following year.

Crude protein and digestible dry matter of switchgrass decline with maturity. Animal gains on switchgrass may be less than on big bluestem or indiangrass.

Switchgrass, indiangrass, and big bluestem yield well as pasture plants. A major portion of the growth occurs after July 1, and nearly all growth from these grasses is completed by August 1 in southern Illinois. The dry matter yield of switchgrass is greater than that of indiangrass and big bluestem.

The crude protein content of switchgrass is higher than indiangrass or big bluestem at comparable maturities during the pasture season. The crude protein values range from 3.4 to 6.4 percent for the major yield of the season. These values are very low if these forages are the only protein source for cattle, sheep, or horses. Big bluestem tends to have a higher crude protein content than indiangrass.

The digestible dry matter of warm-season perennial grasses tends to be below 50 percent, which is below the maintenance level for pregnant beef cows. They may need supplemental feed when pasturing on switchgrass. Indiangrass and big bluestem tend to be a little higher in digestibility than switchgrass, but they are marginal for maintenance of pregnant beef cows. Dry-matter digestibility may be underestimated by *in vitro* analysis methods.

Warm-season perennial grasses may yield 5.5 to 7.5 tons of hay dry matter per acre throughout Illinois.

Big bluestem (*Andropogon gerardii*) grows to 4 to 7 feet tall and is a sod-forming, warm-season perennial grass. It was a major contributor to the development of the deep, dark, prairie soils of Illinois. This perennial has short rhizomes, but it makes a very tough sod. Big bluestem thrives on moist, well-drained loam soils of relatively high fertility. It is one of the dominant grasses of the eastern Great Plains and is found in association with little bluestem, switchgrass, and indiangrass. Big bluestem establishes slowly from seed.

Big bluestem begins growth in May and makes a large part of its growth in late July through August. Grazing should leave a 6-inch stubble to prevent loss of stand.

This grass is palatable and nutritious in its early stages of growth. It withstands close grazing late in the season if it is protected from close grazing early in the season. Good hay may be made if harvested

Table 7.6. Forage Seed Mixture Recommendations, All Entries Given in Pounds per Acre

For hay crops

Northern, Central Illinois		**Southern Illinois**	
Moderately to well-drained soils			
Alfalfa	12	Alfalfa Orchardgrass	8 4
Alfalfa Bromegrass	8 6	Alfalfa Tall fescue	8 6
Alfalfa Bromegrass Timothy	8 4 2		
Alfalfa Timothy	8 4		
Poorly drained soils			
Red clover Timothy	8 4	Red clover Bromegrass	8 6
Red clover Bromegrass	8 6	Reed canarygrass Alsike clover	8 4
Alsike clover Timothy	5 4	Tall fescue Alsike clover	6 4
Reed canarygrass Alsike clover	8 3	Redtop Alsike clover	4 4
Birdsfoot trefoil Timothy	5 2		
Droughty soils			
Alfalfa Bromegrass	8 6	Alfalfa Orchardgrass	8 4
Alfalfa Tall fescue[a]	8 6	Alfalfa Tall fescue	8 6
		Alfalfa Bromegrass	8 6

For horse pastures

Northern, Central Illinois		**Southern Illinois**	
Moderately to well-drained soils			
Alfalfa Smooth bromegrass Kentucky bluegrass	8 6 2	Alfalfa Orchardgrass Kentucky bluegrass	8 3 5
Poorly drained soils			
Ladino clover Smooth bromegrass Kentucky bluegrass Timothy	½ 6 2 2	Ladino clover Orchardgrass Kentucky bluegrass	½ 6 5

Central Illinois

Moderately to well-drained soils		*Poorly drained soils*	
Alfalfa Orchardgrass Kentucky bluegrass	8 3 2	Ladino clover Orchardgrass Kentucky bluegrass	½ 6 2

For hog pastures

All soil types, anywhere in Illinois

Alfalfa	8
Ladino clover	2

For warm-season perennial grasses

Moderately to well-drained and droughty soils,[b] anywhere in Illinois

Switchgrass	6	Big bluestem Indiangrass	5 5
Eastern gamagrass	12	Switchgrass Big bluestem Indiangrass	2 4 4
Big bluestem	10		
Caucasian bluestem	3		
Indiangrass	10		

For rotation and permanent pastures

Northern, Central Illinois		**Southern Illinois**	
Moderately to well-drained soils			
Alfalfa Bromegrass Timothy	8 5 2	Alfalfa Orchardgrass	8 4
Alfalfa Orchardgrass[a]	8 4	Alfalfa Tall fescue	8 6
Alfalfa Orchardgrass[a] Timothy	8 4 2	Tall fescue Ladino clover	8 ½
Orchardgrass[a] Ladino clover	6 ½	Alfalfa Bromegrass Timothy	8 6 2
Red clover Ladino clover Orchardgrass[a]	8 ½ 4	Orchardgrass Ladino clover	6 ½
Red clover Ladino clover Tall fescue	8 ½ 6-8	Tall fescue	10
Birdsfoot trefoil Timothy	5 2	Orchardgrass	8
Ladino clover Bromegrass	½ 8	Red clover Ladino clover Orchardgrass	8 ½ 4
Tall fescue	10	Red clover Ladino clover Tall fescue	8 ½ 6-8
Orchardgrass[a]	8		
Poorly drained soils			
Alsike clover Ladino clover Timothy	3 ¼ 4	Alsike clover Ladino clover Tall fescue	2 ½ 8
Birdsfoot trefoil Timothy	5 2	Alsike clover Ladino clover Reed canarygrass	3 ½ 8
Reed canarygrass Alsike clover Ladino clover	8 3 ¼-½		
Alsike clover Ladino clover Tall fescue	2 ½ 8		
Droughty soils			
Alfalfa Bromegrass	8 5	Alfalfa Orchardgrass	8 4
Alfalfa Orchardgrass[a]	8 4	Alfalfa Tall fescue	8 6
Alfalfa Tall fescue	8 6	Red clover Ladino clover Orchardgrass[a]	8 ½ 4
Red clover Ladino clover Orchardgrass	8 ½ 4	Red clover Ladino clover Tall fescue	8 ½ 6-8
Red clover Ladino clover Tall fescue	8 ½ 6-8		

For pasture renovation

Northern, Central Illinois		**Southern Illinois**	
Moderately to well-drained soils			
Alfalfa Red clover	8 4	Alfalfa Red clover	8 4
Poorly drained soils			
Birdsfoot trefoil Red clover	4 4	Alsike Ladino clover Red clover	2 ½ 4

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[a] Central Illinois only.
[b] Not recommended for poorly drained soils.

before seed heads emerge. Seed matures in late September and October.

Roundtree big bluestem was released by the Soil Conservation Service and the Missouri Agricultural Experiment Station in 1983. Other varieties of big bluestem are Champ, Kaw, and Pawnee. Other bluestem varieties include Plains (Yellow Bluestem), released by the Oklahoma Agricultural Experiment Station in 1970, and King Ranch.

Seedings should be made from mid-May to mid-June at 10 pounds of pure live seed (PLS) per acre. Seed at one-fourth inch deep, on a prepared seedbed that has been firmed with a corrugated roller. Use no nitrogen during the seeding year. See Table 7.5 for a list of varieties and Table 7.7 for yield information.

Indiangrass (*Sorghastrum nutans*) is a sod-forming grass with a deep, extensive root system with short rhizomes. It is adapted to deep, well-drained soils.

Indiangrass produces fair- to good-quality forage during the summer months. Grazing months are July through mid-September. Harvest indiangrass for hay at the early boot stage. Begin grazing after the plant reaches 18 inches in height. Graze to a minimum of a 10-inch stubble.

Varieties are Holt, from the Nebraska Agricultural Experiment Station; Osage, from the Kansas Agricultural Experiment Station; Oto, from the Nebraska Agricultural Experiment Station; and Rumsey, from a native stand in south-central Illinois.

Seedings should be made from mid-May to mid-June at 10 pounds of pure live seed (PLS) per acre. Seed at one-fourth inch deep, on a prepared seedbed that has been firmed with a corrugated roller. Use no nitrogen during the seeding year. See Table 7.5 for a list of varieties and Table 7.7 for yield information.

Eastern gamagrass (*Tripsacum dactyloides* [*L*]. *L*) is related to corn. The seed heads have the female flowers on the lower portion and the male flowers above. It grows in large clumps in low areas, is quite palatable, and often is destroyed by close grazing. Eastern gamagrass produces a large tonnage of forage and can be used for hay or silage.

Seedings should be made from mid-May to mid-June at 12 pounds of pure live seed (PLS) per acre. Seed at one-fourth inch deep, on a prepared seedbed that has been firmed with a corrugated roller. Use no nitrogen during the seeding year. See Table 7.5 for a list of varieties and Table 7.7 for yield information.

Caucasian bluestem or Old Word bluestems (*Bothriochloa caucasica C.E. Hubb.*), a perennial bunchgrass, is an introduction from Russia that shows promise as a pasture and hay grass in Illinois. It is easily established from seed and makes good growth even if moisture supplies are low. It bears an abundance of small, viable seed that shatter readily.

Seedings should be made from mid-May to mid-June at 3 pounds of pure live seed (PLS) per acre. Seed at one-fourth inch deep, on a prepared seedbed that has been firmed with a corrugated roller. Use no nitrogen during the seeding year. See Table 7.5 for a list of varieties and Table 7.7 for yield information.

Table 7.7. Species and Varieties of Warm-Season Perennial Grasses at Dixon Springs

Species/variety[a]	1981	1990	Average
	dry matter, tons per acre		
Switchgrass/ Cave-in-Rock	4.50	6.43	5.47
Eastern gamagrass/ Pete	8.25	6.14	7.20
Big bluestem/ Roundtree	5.44	4.23	4.84
Caucasian bluestem	3.73	3.42	3.58
Indiangrass/ Rumsey	5.95	6.11	6.03

[a] Each variety is harvested twice a year.

Establishment of warm-season perennial grasses

Establishment of warm-season perennial grasses is slow. Seedings need to be made early in the season, from April through June, to allow adequate time for the seedlings to become well established. Atrazine (at 2 pounds of active ingredients per acre) may be applied to the surface after seeding big bluestem. Switchgrass and indiangrass seedlings are damaged by atrazine.

Suggested seeding rates are 6 pounds of PLS per acre of switchgrass and 10 pounds of PLS per acre of big bluestem and indiangrass. Do not graze until plants are well established, at least one year old. Weeds may be reduced during seeding year by clipping. The first clipping should occur about 60 days after seeding at a height of 3 inches. Later clippings should be at no less than 6-inch stubble height. Do not clip after August 1.

Seedings should be made on prepared seedbeds that are very firm. The drill or seeder must be able to handle the seed, because seeds of indiangrass and big bluestem are light and feathery. Debearding will help to get the seed through the seeders.

Seedings may be made into existing grass sods, but the grass must be destroyed. Roundup will remove most grasses when applied according to label instructions. Atrazine also may be used for seeding big bluestem into a grass sod. A no-till drill is needed to place seeds into soil surface for good soil-seed contact.

Fertilization

Warm-season perennial grasses prefer fertile soils but grow well in moderate fertility conditions. Warm-season perennials do not respond to nitrogen fertilization as much as cool-season perennials. Warm-season perennial grasses use minerals and moisture more efficiently than cool-season perennial grasses.

For establishment, fertilize with 30 to 40 pounds of nitrogen, 24 to 30 pounds of phosphate, and 40 to 60 pounds of potash per acre.

For pasture or hay production of established stands, fertilize with 100 to 120 pounds of nitrogen, 50 to 60 pounds of phosphate, and 100 to 120 pounds of potash per acre.

Chapter 8.

Seed Production

Seed production of forage legumes

Illinois is an important producer of red clover seed, but very little seed is produced of other forage legumes. Red clover seed yields vary widely from year to year. Warm, dry summers favor seed production. In part, low yields are caused by inadequate pollination by bees. Only during the clover's second growth period do honey bees visit red clover in numbers high enough to pollinate for high seed yields while they collect pollen and nectar. In Urbana, studies showed that honey bees collected 54 to 99 percent of their daily pollen intake from red clover between July 12 and August 3.

Bumblebees also pollinate red clover but are not reliable pollinators because they are not always present in sufficient numbers. The presence of honey bees in the vicinity of red clover fields can be assured by placing hives in or around red clover seed production fields.

To produce red clover seed, use the second growth period crop and at least two colonies of honey bees per acre within or beside the field. On large fields, place the hives in two or more groups. Do not rely on bees present in the neighborhood, because pollination and seed set decrease rapidly as distance between the hives and the crop becomes greater than 800 feet. Bring a sufficient number of hives to the field as soon as it comes into bloom. When all factors for seed production are favorable, proper pollination of red clover by honey bees has the potential of doubling or tripling seed yields.

White and yellow sweet clovers are highly attractive to bees and other insects. Still, probably because of the large number of blossoms, their seed yields increase when colonies of honey bees are placed nearby. Yields up to 1,400 pounds per acre have been produced in the Midwest when using six colonies of bees per acre. One or two hives per acre will give reasonably good pollination.

Crownvetch does not attract bees and requires special techniques to produce a commercial crop of seed. Best yields have been obtained by bringing strong, new hives of bees to the fields every 8 to 10 days. Instead of such special provisions, one or more hives of honey bees per acre of crownvetch are of value.

The effects of insect pollination on annual lespedeza, such as Korean, have not been investigated; but the perennial lespedezas require insect pollination to produce a crop of seed, and honey bees can be used.

Many legumes grown in Illinois for pasture or for purposes other than seed production are visited by honey bees and other bee pollinators. Alfalfa and birdsfoot trefoil — as well as alsike, white, and ladino clovers — all provide some pollen and nectar and, in turn, are pollinated to varying degrees.

During their bloom in July and August, soybeans are visited by honey bees. Soybeans are a major source of honey in the state. In tests at Urbana, honey bee visits to soybeans did not increase seed yield over that of plants caged to exclude bees. Other studies have indicated that some varieties increase yields as a result of increasing honey bee visits during flowering.

Plant Variety Protection Act

Congress passed the Plant Variety Protection Act in 1970. This law provides the inventor or owner of a new variety of certain seed-propagated crops the right to exclude others from selling, offering for sale, reproducing, exporting, or using the variety to produce a hybrid, different variety, or blend.

These rights are not automatic. The owner must apply for a certificate of protection. If the owner does not choose to protect the variety, it is public property and anyone may legally reproduce it and sell the seed.

Many varieties of the self-pollinated crops commonly grown in Illinois — such as soybeans and wheat — that were developed by private industry since 1970 are protected varieties. Many varieties developed at state experiment stations also are protected.

Farmers who purchase a protected variety may use their production for seed on their own farm or market it as grain. An exemption has permitted limited marketing of seeds of protected varieties between farmers. This exemption may be changed in the future. Farmers should verify the legal marketing privileges of protected varieties to avoid infringing the legal rights of the holder of the Plant Variety Protection Certificate.

Under one provision of the act, the owner may stipulate that the variety be sold by variety name only as a class of Certified Seed. Seeds of a certified variety are produced according to the standards and procedures of an official Seed Certification Agency in the United States or Canada. In Illinois, this is the Illinois Crop Improvement Association. Selling uncertified seed by variety name of varieties protected in this manner is a violation of Seed Certification rules, the Federal Seed Act, and the State Seed Law. Violators are subject to prosecution.

If the owner of a protected variety does not choose the Certified Seed provision of the act, a farmer whose primary occupation is producing food or feed may sell seed of the protected variety to another farmer whose primary occupation is producing grain for food or feed. The second farmer, however, may not sell as seed any of the crop that is produced.

Even if the protected variety is not covered by the act's Certified Seed provision, any advertising of the sale of seed of that variety — including farm sale bills — usually is considered an infringement of the owner's rights. Therefore, any person who desires to sell the uncertified seed of a protected variety must also obtain permission from the variety's owner. Violators are subject to civil lawsuits.

The container in which seed of a protected variety is sold should carry a label identifying the seed as that of a protected variety. All seeds offered for sale in Illinois must be labeled according to the Illinois Seed Law. Requirements for labeling vary among the crop seeds. For current information, consult an Illinois Seed Law publication, available from the Illinois Department of Agriculture.

Plant variety protection has greatly benefited U.S. agriculture. Many improved varieties of various crops have been developed that would not have been developed without this protection. Farmers should not be reluctant to use "protected varieties" since many of these will be top performers, but they must be aware of the limitation of use of these crops for seed purposes.

Chapter 9.
Water Quality

The protection of water quality is an important part of any crop production system. Illinois farmers have a great stake in protecting drinking water quality because they often consume the water that lies directly under their farming operation. Their domestic water wells are often in proximity to agricultural operations or fields and, therefore, must be safeguarded against contamination. The great majority of crop protection chemicals never reach groundwater. In Illinois, favorable soil and geologic conditions help degrade or retard movement of pesticides. Vulnerable site conditions are found in some parts of Illinois, however. In these areas (described in detail later) appropriate chemical selection and management decisions need to be made to ensure good water quality.

New federal drinking-water standards for 18 pesticides and pesticide break-down products went into effect on July 30, 1992. This regulation will require public-water-supply monitoring for these compounds at least four times annually. The most commonly used herbicides on the list are atrazine and alachlor. Many other commonly used herbicides are currently unregulated but will be monitored in the drinking-water samples. Initially, only surface-water supplies (lakes, reservoirs) will be monitored, and groundwater sources will be phased in over the next three years.

Compliance with the federal standards will be based on the average of the samples taken consecutively over a 1-year period. For example, atrazine has a standard of 3 parts per billion (ppb), so if the sum of four quarterly samples is equal to 12 ppb or more, the water is out of compliance. A single detection of over 12 ppb would therefore immediately put a water supply out of compliance.

If standards are exceeded, water customers will be notified by local media and subsequently on their water bill. If a water source is in violation, water blending with an uncontaminated supply or extensive decontamination treatment will be required. The additional water-treatment expense can be prohibitive to small communities; this underlines the importance of agricultural management practices that reduce the entry of herbicides into the aquatic system.

The Illinois Environmental Protection Agency has analyzed finished drinking water at 129 surface-water supplies in 1991 and 1992. The study provides a look at the potential for noncompliant water supplies in the coming years (Table 9.1). About 13 percent of the surface water samples exceeded the 3-ppb drinking water standard for atrazine. Detections of atrazine exceeded 50 percent for both years of the study. The drop-in detections in 1992 may be related to a drier spring that resulted in less cropland runoff directly following herbicide application. Trifluralin is a herbicide that is tightly held to soil particles. Trifluralin's presence in 23 percent of the samples in 1991 suggests that erosion of soil with attached herbicide may be responsible for some of the detections.

A statewide study of rural private water supplies involving 337 wells was conducted cooperatively by the Illinois Department of Agriculture, the UI Cooperative Extension Service, and the state Geological Survey. The study was completed in 1992 (Table 9.2). Results of the study offer the first statistically valid estimate of the condition of well water in Illinois. About 12 percent of the 360,000 rural private wells in the state contained detectable concentrations of at least one herbicide, and 10.5 percent of the wells had nitrate nitrogen above the drinking-water standard of 10 ppm. Preliminary interpretation of the data suggests that shallow wells and dug wells were more likely to be contaminated than deep-drilled wells. Wells drawing water from aquifers within 20 feet of land surface were more likely to contain high levels of nitrate. The

Table 9.1. Herbicide Detections in Selected Community Water Supplies in Illinois

Pesticide	Percent supply detections 1991	1992	Maximum concentration	Minimum concentration detected	Percent exceeding MCL
			-------- *ug/1*	--------	
Atrazine	78	55	13.0	.03	13
Alachlor	52	17	2.0	.02	<1
Metolachlor ..	49	30	30.0	.02	
Trifluralin	23	5	0.36	.02	
Cyanazine....	11	38	16.0	.06	

SOURCE: Illinois EPA.

Table 9.2. Statewide Estimates for Percent and Number of Rural, Private Wells Containing Pesticides and Nitrate

	Estimated percentage of wells	Confidence interval	Estimated number of wells in Illinois
Pesticides	12.1	7.5 to 16.7	43,600
Pesticides (>MCL/HAL)	2.1	0.6 to 3.6	7,560
Nitrate nitrogen (>10 ppm)	10.5	6.7 to 14.3	37,800

2.1 percent of wells containing pesticide concentrations above the drinking-water standards were fully accounted for by three compounds: alachlor (Lasso), dieldrin (a pesticide whose registration has been canceled), and heptachlor epoxide (a degradation product of a discontinued insecticide).

No interpretation of contamination source is possible with the study, so it is impossible to determine whether the compounds were point-source (spill) or non-point-source (leached into water from regular farm practices) in origin. Pesticides detected in greater than 1 percent of the wells include: aciflurofen (1.4 percent, Blazer), atrazine (2.1 percent, AAtrex); bentazon (1.4 percent, Basagran); dieldrin (1.6 percent); dinoseb (3.7 percent, Dyanap); and prometon (1.2 percent, Pramitol). The following pesticides were detected in 0.1 to 1.0 percent of the wells: alachlor (0.7 percent, Lasso); aldrin (0.3 percent); bromacil (0.3 percent, Hyvar-X); chloramben (0.2 percent, Amiben); 2,4-D (0.1 percent); endrin (0.8 percent); metolachlor (0.3 percent, Dual); metribuzin (0.1 percent, Lexone, Sencor); simazine (0.2 percent, Princep); and trifluralin (1.0 percent, Treflan). Atrazine was not found in any well at concentrations above the drinking-water standard of 3 ppb. Additionally, 19 of the pesticides (or their break-down products) were not detected in any of the wells. These include: butylate (Sutan +); cyanazine (Bladex); 2,4-DB; dicamba (Banvel); and EPTC (Eptam).

Results from surface- and well-water samples suggest that atrazine is the most likely herbicide to appear in surface water but does not appear to be widely found in well water at levels above drinking-water standards. Alachlor and several discontinued insecticides are the predominant organic pesticide contaminants in rural well water. Nitrate nitrogen contamination is often associated with shallow wells and surface water and my be an indication of movement of fertilizers, manures, and other wastes into these water supplies. The greatest challenge facing Illinois producers may be to keep herbicides out of the surface-water supplies. Management practices that reduce runoff may be helpful in this regard.

In other studies, the highest levels of detection are often from wells that are in proximity to chemical handling sites, or wells that are known to have been contaminated by an accidental point source introduction of the chemical directly to the well, such as back-siphoning.

Protection of groundwater drinking sources is a critical and achievable task that can be accomplished by (1) preventing point source contamination of the well, (2) evaluating the groundwater contamination susceptibility as determined by soil and geologic conditions and the water management system, (3) selecting appropriate chemicals and chemical application strategies, and (4) practicing sound agronomy that uses integrated pest management principles and appropriate yield goals.

Drinking water contaminants

Many substances in the environment, whether related to industry, agriculture, or of natural derivation, have been associated with health problems in humans and livestock. The scope of this chapter does not warrant a full discussion of all pollutants but rather focuses on the contaminants that are associated with agriculture and the rural farmer. The most frequent contaminant of rural wells is coliform bacteria, which are associated with livestock or human waste. These bacteria can enter wells laterally through a septic tank leach field or overland into a wellhead as runoff from livestock impoundments. Nitrate-nitrogen is the second most common substance that can occur in levels exceeding health advisories. Although the presence of nitrates (NO_3) in drinking water is frequently blamed on agriculture, nitrates come from many sources, including septic tanks, livestock waste, and decaying organic matter. Bacteria and nitrates are often the "first to arrive" in a well with high potential for contamination. Together their presence suggests a possible pathway from a contaminating source to the well that has been established.

A variety of herbicides have been detected in trace amounts in potable water supplies. A recently completed nationwide survey found detectable levels of herbicides in 13 percent of the wells surveyed. Atrazine was detected in 12 percent of the wells surveyed and, therefore, constituted over 90 percent of the total detections. Although the herbicides were detected in a significant percentage of the wells, only 0.11 percent of the wells had herbicide concentrations above the health advisory levels.

Point source prevention

Control of point source contamination is the most important measure a farmer can take to protect a groundwater drinking source. A point source is a well-defined and traceable source of contamination such as a leaking pesticide container, a pesticide spill, or back-siphoning from spray tanks directly into a well. Because point sources involve high concentrations or direct movement of contaminants to the water source, the purifying ability of the soil is bypassed. The following handling practices, based largely on common sense, will minimize the potential for groundwater contamination:

- Never mix chemicals near (within 200 feet of) wells, ditches, streams, or other water sources.
- Prevent back-siphoning of mixed pesticides from the spray tank to the well by always keeping the fill hose above the overflow of the spray tank.
- Store pesticides downslope from well-water sources and a safe distance from both wells and surface waters.
- Triple-rinse pesticide containers, and put rinsate back into the spray tank to make up the final spray mixture.
- Avoid introducing pesticides or fertilizers into sinkholes or abandoned wells. Lateral movement of contaminants in the groundwater to a drinking water well may be more rapid than vertical movement through the soil.
- Seal abandoned wells to prevent connection between agricultural practices and the groundwater.

Groundwater vulnerability

Site characteristics, including the soil and geologic properties, water table depth, and depth of the well, will determine the potential of nonpoint contamination of the groundwater. Nonpoint sources of contamination are difficult to pinpoint, originate from a variety of sources, and are affected by many processes. Contaminants moving into groundwater from routine agricultural use are an example of a nonpoint source. Producers applying pesticides in vulnerable areas should pay strict attention to chemical selection and management practices.

Soil characteristics

Water-holding capacity, permeability, and organic matter content are important soil properties that determine a soil's ability to detain surface-applied pesticides in the crop root zone. Fine-textured, dark prairie soils have large water-holding capacities, low permeabilities, and large organic matter contents, all attributes that reduce pesticide leaching due to reduced water flow or increased binding of pesticides. The forest soils that dominate the landscape in western and southern Illinois are slightly lower in organic matter and, therefore, may be less effective at binding pesticides.

The most vulnerable soils for groundwater contamination are the sandy soils that lie along the major river valleys of Illinois. Sandy soils are highly permeable, have low organic matter contents, and often are irrigated. All of these factors represent increased risks to groundwater quality. Extra precautions in chemical selection and application method should be taken in these vulnerable soils. Irrigators in particular should pay attention to groundwater advisory warnings that restrict the use of some herbicides on sandy soils.

Geology

The geologic strata beneath a farming operation may be important in determining the risk of nonpoint contamination. In Illinois the most hazardous geology for groundwater pollution is the karst or limestone region that occurs along the margins of the Mississippi River and in the northwestern part of the state. Sinkholes and fractures that occur in the bedrock in these areas may extend to the soil surface, providing access for runoff directly to the groundwater. Water moving into these access points bypasses the natural treatment that is provided by percolation through soil. Karst areas should be farmed carefully with due attention to buffer zones around sinkholes to prevent runoff entry to the groundwater. Agronomic practices that minimize runoff are effective ways to reduce the potential for pesticide movement to the groundwater.

Groundwater and well depths

Deep aquifers that lie under impermeable geologic formations are the most protected from contamination by surface activities. Shallow water-table aquifers are more vulnerable to contamination because of their proximity to the surface. Shallow dug wells in water-table or shallow aquifers are also more vulnerable because of typically inadequate wellhead protection.

Surface water contamination

Although groundwater protection receives the majority of media attention, surface water quality is generally at greater risk. Surface waters have a greater capacity for breaking down pesticides, because biological breakdown processes operate at a faster rate than in groundwater. A recent survey of surface waters in Illinois by the U.S. Geological Survey found detectable herbicide levels in 90 percent of the samples taken in May and June of 1989. Control of surface water contamination is best achieved by controlling runoff movement of water and sediment. Soil conservation practices and prudent use of buffer strips near stream banks generally reduce the probability of surface water contamination.

Management practices

Many effective management practices outlined in other sections of this handbook have been recommended with due consideration to water quality. Management is most critical in areas that are the most vulnerable to contamination.

Nutrient management

Soil testing is a basic foundation for fertilizer recommendations. Testing manures for nutrient content allows accurate crediting for fertilizer replacement. A sound nitrogen management program for grain crops that emphasizes appropriate yield goals and credit for prior legumes will optimize the amount of fertilizer nitrogen introduced to the field. Splitting nitrogen applications on sandy irrigated soils is wise because it reduces the chances for excessive leaching that might occur if a single nitrogen application is used.

Integrated pest management

It is generally assumed that reduced pesticide use results in a reduced probability of groundwater contamination. The use of integrated pest management strategies reduces unnecessary use of pesticides. Two examples are the recommended practice of crop rotation that reduces the need for corn rootworm insecticides in continuous corn, and the use of crop rotation and tolerant varieties to control plant diseases.

Conservation tillage

Reducing tillage and retaining crop residues on the soil surface limits the runoff and overland flow that carries pesticides and nutrients out of the field. The effect of conservation tillage and no-till on groundwater quality is controversial and the subject of much research. Reduction of runoff and erosion is accomplished by increasing infiltration of water. Increased infiltration, particularly through earthworm-formed macropores, offers a transport system to the subsoil that soil-applied pesticides can follow. Conversely, the macropores are not the primary routes of water flow unless heavy rainfall or flooding occurs and allows rapid movement of "clean" rainwater past the soil layers that contain pesticides. Conservation tillage methods are most important in controlling soil erosion on sloping land. Adopting more severe tillage to protect groundwater quality is not warranted based on our current knowledge.

Cover crops

A cover crop such as a small grain or legume may provide water quality benefits from several standpoints. The effectiveness of cover crops in controlling erosion is well documented, and controlling erosion is an important component of surface water quality protection. Small-grain cover crops have shown some efficiency at retrieving residual nitrogen from the soil following fertilized corn or vegetable crops. This feature may be important on sandy irrigated soils where winter rainfall leaches much of the residual nitrogen.

Legumes may provide a source of nitrogen to subsequent crops. Refer to the chapter on cover crops in this handbook for further information.

Chemical properties and selection

The selection of agricultural chemicals is most critical for producers on vulnerable soils and geologic sites. Herbicide selection is a complex task that must take into account the crop, tillage system, target species, and a host of other variables. Chemical properties of the herbicide are important to consider when evaluating their potential to leach to the groundwater. The three most important characteristics of a pesticide that influence leaching potential are solubility in water, ability to bind with the soil (adsorption), and the rate at which it breaks down in the soil. High solubility (dissolves readily), low binding ability, and slow breakdown all increase a pesticide's ability to move to the groundwater. Among the frequently used herbicides that have a greater potential to leach and are labeled with groundwater advisories are those that contain alachlor, atrazine, clopyralid, cyanazine, metribuzin, metolachlor, or simazine (Table 9.3).

Precautions for irrigators

Chemigation refers to the application of fertilizers and pesticides through an irrigation system and is a management tool that has benefits and potential drawbacks for groundwater protection. The greatest benefit of chemigation is for fertigation, which is the application of fertilizers, particularly nitrogen, through the irrigation system. Nitrogen application can be more carefully spread out in the vegetative growth period of grain crops, thereby minimizing the susceptibility of leaching.

Chemigation systems should be equipped with backflow prevention devices. These greatly reduce the

Table 9.3. Herbicide and Herbicide Premixes with Groundwater Advisories

Trade name	Common (generic) name
AAtrex, Atrazine	atrazine
Bicep	metolachlor + atrazine
Bladex	cyanazine
Bronco	alachlor + glyphosate
Buctril/atrazine	bromoxynil + atrazine
Bullet	alachlor + atrazine
Cannon	alachlor + trifluralin
Canopy	metribuzin + chlorimuron
Dual	metolachlor
Extrazine	cyanazine + atrazine
Freedom	alachlor + trifluralin
Laddok	bentazon + atrazine
Lariat	alachlor + atrazine
Lasso EC, MT*	alachlor
Lexone	metribuzin
Marksman	dicamba + atrazine
Preview	metribuzin + chlorimuron
Princep, Simazine	simazine
Salute	metribuzin + trifluralin
Sencor	metribuzin
Stinger	clopyralid
Sutazine	butylate + atrazine
Turbo	metribuzin + metolachlor

* Lasso MT has shown reduced leaching tendency in initial experiments.

threat of back-siphoning undiluted chemicals into the irrigation well. Back-flow prevention devices will likely become mandatory on irrigation systems by 1994 but should already be on every irrigation system that injects chemicals. Reputable irrigation dealers do not sell irrigation systems without this important feature.

Well water testing

The most important step in well water testing is to contact the local health department and determine the procedure for sampling and submitting water for nitrate and bacteria determinations. The service is provided at no cost or a nominal fee in most counties. The presence of coliform bacteria with or without elevated nitrates is a sign that a well is contaminated by runoff or a septic system. Faulty well construction or improper wellhead protection is a major cause of contamination. Pesticide testing is expensive and requires sensitive analytical equipment. Several private water testing laboratories, certified by the Illinois Environmental Protection Agency, will perform water analyses for citizens. Contact a local Extension adviser for information on nearby laboratories.

Chapter 10.

Soil Testing and Fertility

Soil testing

Soil testing is the single most important guide to the profitable application of fertilizer and lime. When soil test results are combined with information about the nutrients that are available to the various crops from the soil profile, the farmer has a reliable basis for planning the fertility program on each field.

Traditionally, soil testing has been used to decide how much lime and fertilizer to apply. Today, with increased emphasis on the environment, soil tests are also a logical tool to determine areas where adequate or excessive fertilization has taken place.

How to sample. A soil tube is the best implement to use for taking soil samples, but a spade or auger also can be used (Figure 10.1). One composite sample from every 2½ acres is suggested. Five soil cores taken with a tube will give a satisfactory composite sample of about 1 to 2 cups in size. You may follow a regular pattern as indicated in Figure 10.2. The objective is to map nutrient patterns in the field. This will provide information for fertilizing areas of the field differently, if that option is chosen.

The most common mistake is taking too few samples to represent the fields adequately. Taking shortcuts in sampling may produce unreliable results and lead to higher fertilizer costs, lower returns, or both.

It is important to collect soil samples to the proper depth — 7 inches. For fields in which reduced tillage systems have been used, proper sampling depth is especially important, as these systems result in less thorough mixing of lime and fertilizer than does a tillage system that includes a moldboard plow. This stratification of nutrients has not adversely affected crop yields, but misleading soil test results may be obtained if samples are not taken to the proper depth.

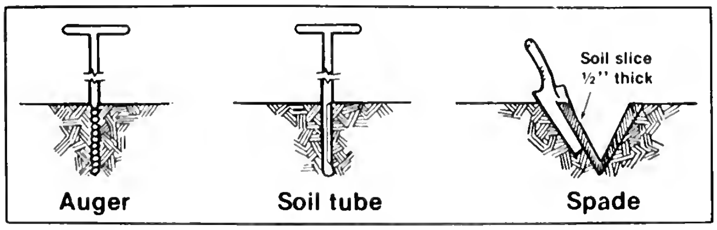


Figure 10.1. How to take soil samples with an auger, soil tube, and spade.

Under reduced-tillage systems, it is of interest to monitor surface soil pH by collecting samples to a depth of 2 inches from 3 separate areas in a 40-acre field. These areas should represent the low, intermediate, and high ground of the field. If surface soil pH is either too high or too low, the efficacy of herbicides and other chemical reactions may be affected.

When to sample. Sampling every 4 years is strongly suggested. To improve the consistency of results, it is

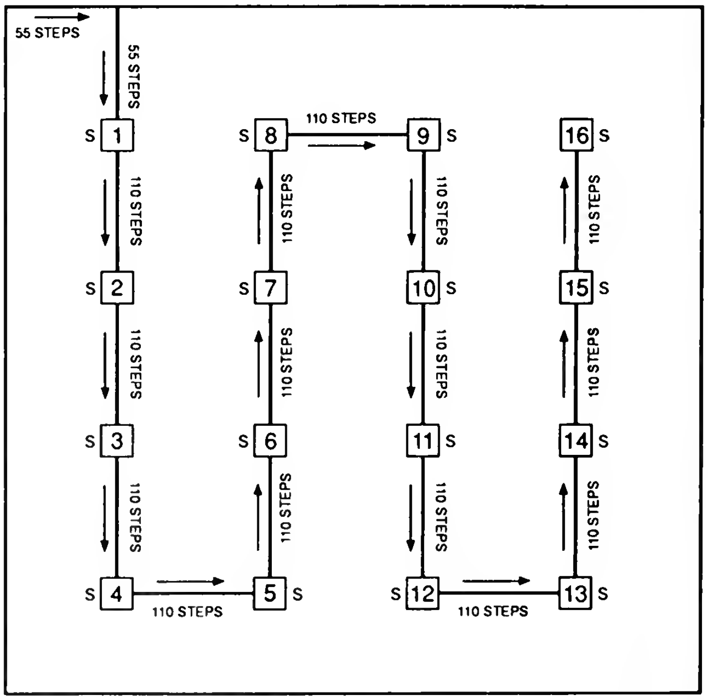


Figure 10.2. Directions for collecting soil samples from a 40-acre field. Each step is a 3-foot distance. Each numbered area is a soil sample location 1 rod square. Five core samples 1 inch in diameter are collected from each square to a depth of 7 inches and mixed.

suggested that samples be collected at the same time following the same crop. Therefore, for a 3-year rotation, collect samples every 3 years instead of every 4 years.

Late summer and fall are the best seasons for collecting soil samples from the field because potassium test results are most reliable during these times. The K soil test tends to be cyclic, with low test levels in late summer and early fall and high test levels in late January and early February.

Where to have soil tested. Illinois has about 40 commercial soil-testing services. Your local Extension office or fertilizer dealer can provide advice about availability of soil testing in your area.

Information to accompany soil samples. The best fertilizer recommendations are those based on both soil test results and a knowledge of the field conditions that will affect nutrient availability. Because the person making the recommendation does not know the conditions in each field, it is important to provide adequate information with each sample.

This information includes cropping intentions for the next 4 years; name of the soil type, or if not known, then the nature of the soil (clay, silty, or sandy; light or dark color; level or hilly; eroded; well drained or wet; tiled or not; deep or shallow); fertilizer used (amount and grade); lime applied in the past 2 years; and proven yields or yield goals for all proposed crops.

What tests to have made. Soil fertility problems in Illinois are largely associated with acidity, phosphorus, potassium, and nitrogen. Recommended soil tests for making decisions about lime and fertilizer use are as follows: water pH test, which will show soil reaction as pH units; Bray P_1 test for plant-available soil phosphorus, which will commonly be reported as pounds of phosphorus per acre (elemental basis); and the potassium (K) test, which will commonly be reported as pounds of potassium per acre (elemental basis). Guides for interpreting these tests are included in this section. An organic-matter test made by some laboratories is particularly useful in selecting the proper rate of herbicide and agricultural limestone.

Because nitrogen (N) can change forms or be lost from the soil, the use of soil testing to determine nitrogen fertilizer needs for Illinois field crops is not recommended in the same sense as testing for the need for lime, phosphorus, or potassium fertilizer. Testing the soil to predict the need for nitrogen fertilizer is complicated by the fact that nitrogen availability — both the release from soil organic matter and the loss by leaching and denitrification — is regulated by unpredictable climatic conditions. Under excessively wet conditions, both soil and fertilizer nitrogen may be lost by denitrification or leaching. Under dry conditions, the amount of nitrogen released from organic matter is low, but under ideal moisture conditions, it is high. Use of the organic-matter test as a nitrogen soil test, however, may be misleading and result in underfertilization.

Scientists in Vermont and Wisconsin have identified nitrogen soil tests that work well under their conditions. Specifics of the tests, along with an evaluation of their potential and limitations for Illinois, are discussed in the nitrogen section of this chapter. Guides for planning nitrogen fertilizer use are also provided.

Tests are available for most of the secondary nutrients and micronutrients, but interpretation of these tests is less reliable than the interpretation of tests for lime, phosphorus, or potassium. Complete field history and soil information are especially important in interpreting the results. Even though these tests are less reliable, they may be useful in two ways:

1. *Troubleshooting.* Diagnosing symptoms of abnormal growth. Paired samples representing areas of good and poor growth are needed for analyses.
2. *"Hidden-hunger checkup."* Identifying deficiencies before symptoms appear. Soil tests are of little value in indicating marginal levels of secondary nutrients and micronutrients when crop growth is apparently normal. For this purpose, plant analysis may yield more information.

Soil test ratings (given in Table 10.1) have been developed to put into perspective the reliability, usefulness, and cost effectiveness of soil tests as a basis for planning a soil fertility and liming program for Illinois field crops. These subjective ratings are on a scale from 0 to 100, for which a score of 100 is deemed very reliable, useful, and cost effective, and a score of zero is deemed of little value. Additional research will undoubtedly improve some test ratings.

Cation-exchange capacity. Chemical elements exist in solution as cations (positively charged ions) or anions (negatively charged ions). In the soil solution, the plant nutrients calcium (Ca), magnesium (Mg), potassium (K), ammonium (NH_4), iron (Fe), manganese (Mn), zinc (Zn), and copper (Cu) — as well as non-plant nutrients such as hydrogen (H), sodium (Na), barium (Ba), and metals of environmental concern such as mercury (Hg), cadmium (Cd), chromium (Cr), and others — exist as cations. Cation-exchange capacity is a measure of the amount of attraction for these chemical elements.

In soil, a high cation-exchange capacity is desirable but not necessary for high crop yields, as it is not a direct crop yield determining factor. Cation-exchange capacity in soil arises from negatively charged electrostatic charges in minerals and organic matter. Depending on the amount of clay and humus, soil types have a characteristic amount of cation exchange. Sandy soils will have up to 4 milliequivalent (me) per 100 grams of soil; light-colored silt loam soils will be 8 to 12 me; dark-colored silt loam soils will be 15 to 22 me; and clay soils will have 18 to 30 me.

Cation-exchange capacity facilitates retention of positively charged chemical elements from leaching, yet gives nutrients to a growing plant root by an exchange of hydrogen (H). Farming practices that reduce soil erosion and maintain soil humus favor the maintenance of cation-exchange capacity. The cation-exchange capacity of organic residues is low but increases as the residues convert to humus, which requires from 5 years to centuries.

Plant analyses

Plant analyses can be useful in diagnosing problems, in identifying hidden hunger, and also in determining whether current fertility programs are adequate. For example, they often provide more reliable measures of micronutrient and secondary nutrient problems than do soil tests.

How to sample. When making a plant analysis to diagnose a problem, select paired samples of comparable plant parts representing the abnormal and normal plants. Abnormal plants selected should represent the first stages of a problem.

When using the technique to diagnose hidden hunger in corn, sample several of the leaves opposite and below the ear at early tassel time. For soybeans, sample the most recent fully developed leaves and petioles at early podding. Samples taken later will not indicate the nutritional status of the plant. After collecting the samples, deliver them immediately to the laboratory. They should be air-dried if they cannot be delivered immediately or if they are going to be shipped to a laboratory.

Environmental factors may complicate the interpretation of plant analysis data. The more information concerning a particular field, the more reliable the interpretation will be. Suggested critical nutrient levels are provided in Table 10.2. Lower levels may indicate a nutrient deficiency.

Fertilizer management related to tillage systems

Fertilizer management will be affected by tillage systems because immobile materials such as limestone, phosphorus, and potassium move slowly in most soils unless they are physically mixed by tillage operations. Such "stratification" of nutrients, with higher concentrations developing near the surface, has been well documented in a number of studies during the past 30 years but has not been shown to reduce yields of corn or soybeans in Illinois. Limited research indicates that plants develop more roots near the soil surface in conservation-tillage systems, apparently due to both the improved moisture conditions caused by the surface mulch of crop residues and the higher levels of available nutrients.

Soil tests are important for phosphorus, potassium, and limestone management under any tillage system. Consult the section above titled "How to sample," and make sure the samples are taken from the full 7-inch depth. If either limestone (which raises pH) or nitrogen fertilizer (which lowers pH) is applied to the surface and not incorporated with tillage, pH tests of the upper 2 inches of soil are needed to aid in the management of some herbicides.

See guidelines for adjusting limestone application rates under different tillage systems. For any tillage system, the information contained in the section on "Phosphorus and potassium" is valid.

Nitrogen fertilizer management may be affected to a limited extent by changing tillage systems. The information contained in the section on "Nitrogen"

Table 10.1. Ratings of Soil Tests[a]

Soil test	Rating	Soil test	Rating
Water pH	100	Organic matter	75
Salt pH	30	Calcium	40
Buffer pH	30	Magnesium	40
Exchangeable H	10	Cation-exchange capacity	60
Phosphorus	85	Sulfur	40
Potassium	80	Zinc	45
Boron (alfalfa)	60	Manganese (pH > 7.5)	40
Boron (corn and soybeans)	10	Manganese (pH < 7.5)	10
Iron (pH > 7.5)	30	Copper (organic soils)	20
Iron (pH < 7.5)	10	Copper (mineral soils)	5

[a] On a scale of 0 to 100, for which a score of 100 rates the test as very reliable, useful, and cost effective, and a score of zero rates the test as having little value.

Table 10.2. Suggested Critical Plant Nutrient Levels

Crop	Plant part	N	P	K	Ca	Mg	S	Zn	Fe	Mn	Cu	B
		percent						*ppm*				
Corn	Leaf opposite and below the ear at tasseling	2.9	0.25	1.90	0.40	0.15	0.15	15	25	15	5	10
Soybeans	Fully developed leaf and petiole at early podding	...	0.25	2.00	0.40	0.25	0.15	15	30	20	5	25

will be valid in all tillage systems, with only the following exceptions:

- Where crop residue is present, a coulter may be needed in front of an applicator knife to properly inject anhydrous ammonia or liquid nitrogen fertilizers.
- In no-till systems, where the surface soil may be firm, special care is needed to make sure that the slit left by an ammonia applicator knife is completely closed to prevent nitrogen loss through the escape of gaseous ammonia.
- Because crop residue in reduced-tillage systems may inhibit urea or urea-containing fertilizers from making direct contact with the soil and thus increase the possibility of nitrogen loss through volatilization, these materials should be mechanically incorporated. Urease inhibitors may aid in preventing this loss, according to preliminary research on this developing technology.
- The higher moisture conditions under a residue mulch may also cause a higher rate of nitrogen loss through denitrification. Judicious management — including time of application and the use of nitrification inhibitors — may help avoid significant denitrification losses.
- A risk of occasional anhydrous ammonia damage to corn seed and seedlings exists in fields with any tillage system, especially when the soil is dry, the ammonia is placed shallow, or when corn is planted immediately after ammonia application. Corn in no-till fields seems to be particularly vulnerable to such damage in spring preplant ammonia applications whenever the seed is placed directly over the ammonia band. Keeping the anhydrous ammonia and the corn separated in either distance or time will reduce the potential for this problem.

Lime

Soil acidity is one of the most serious limitations to crop production. Acidity is created by a removal of bases by harvested crops, leaching, and an acid residual that is left in the soil from nitrogen fertilizers. During the last several years, limestone use has tended to decrease while crop yields and nitrogen fertilizer use have increased markedly (Figure 10.3).

At the present rate of limestone use, no lime is being added to correct the acidity that is created by the removal of bases nor the acidity created in prior years that had not been corrected. A soil test every 4 years is the best way to check on soil acidity levels.

The effect of soil acidity on plant growth. Soil acidity affects plant growth in several ways. Whenever soil pH is low (that is, acidity is high), several situations may exist:

A. The concentration of soluble metals may be toxic. Damage from excess solubility of aluminum and manganese due to soil acidity has been shown in field research.

B. Populations and the activity of the organisms responsible for transformations involving nitrogen, sulfur, and phosphorus may be altered.

C. Calcium may be deficient. This usually occurs only when the cation-exchange capacity of the soil is extremely low.

D. Symbiotic nitrogen fixation in legume crops is impaired greatly. The symbiotic relationship requires a narrower range of soil reaction than does the growth of plants not relying on nitrogen fixation.

E. Acidic soils are poorly aggregated and have poor tilth. This is particularly true for soils that are low in organic matter.

F. The availability of mineral elements to plants may

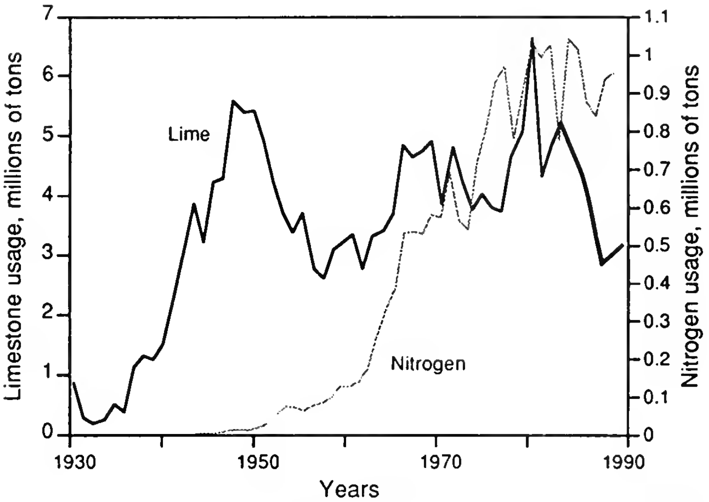


Figure 10.3. Use of agricultural lime and commercial nitrogen fertilizer, 1930–1989.

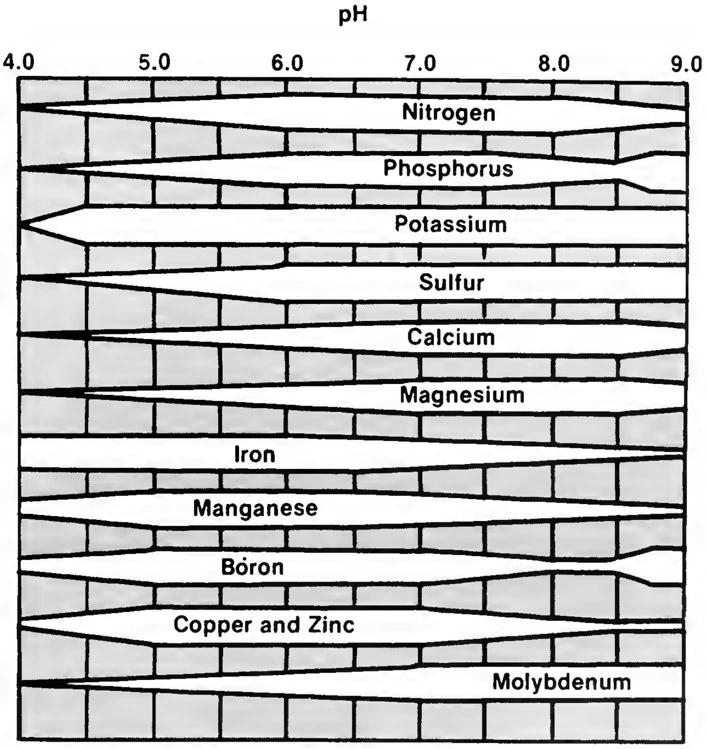


Figure 10.4. Available nutrients in relation to pH.

be affected. Figure 10.4 shows the relationship between soil pH and nutrient availability. The wider the white bar, the greater the nutrient availability. For example, the availability of phosphorus is greatest in the pH range between 6.0 and 7.5, dropping off below 6.0. Because the availability of molybdenum is increased greatly as soil acidity is decreased, molybdenum deficiencies usually can be corrected by liming.

Suggested pH goals. For cash-grain systems (no alfalfa or clover), maintaining a pH of at least 6.0 is a realistic goal. If the soil test shows that the pH is 6.0 or less, apply limestone. After the initial investment, it costs little more to maintain a pH at 6.5 than it does at 6.0. The profit over a 10-year period will be little affected because the increased yield will approximately offset the cost of the extra limestone plus interest.

Research indicates that a profitable yield response from raising the pH above 6.5 in cash-grain systems is unlikely.

For cropping systems with alfalfa and clover, aim for a pH of 6.5 or higher unless the soils have a pH of 6.2 or higher without ever being limed. In those soils, neutral soil is just below plow depth; and it will probably not be necessary to apply limestone.

Liming treatments based on soil tests. The limestone requirements in Figure 10.5 assume:

A. A 9-inch plowing depth. If plowing is less than 9 inches, reduce the amount of limestone; if more than 9 inches, increase the lime rate proportionately. In zero-tillage systems, use a 3-inch depth for calculations (one-third the amount suggested for soil moldboard-plowed 9 inches deep).

B. Typical fineness of limestone. Ten percent of the particles are greater than 8-mesh; 30 percent pass an 8-mesh and are held on 30-mesh; 30 percent pass a 30-mesh and are held on 60-mesh; and 30 percent pass a 60-mesh.

C. A calcium carbonate equivalent (total neutralizing power) of 90 percent. The rate of application may be adjusted according to the deviation from 90.

Instructions for using Figure 10.5 are as follows:

1. Use Chart I for grain systems and Chart II for alfalfa, clover, or lespedeza.
2. Decide which classification fits the soil:
   a. Dark-colored silty clays and silty clay loams.
   b. Light- and medium-colored silty clays and silty clay loams; dark-colored silt and clay loams.
   c. Light- and medium-colored silt and clay loams; dark- and medium-colored loams; dark-colored sandy loams.
   d. Light-colored loams; light- and medium-colored sandy loams; sands.
   e. Muck and peat.

Soil color is related to organic-matter level. Light-colored soils usually have less than 2.5 percent organic matter; medium-colored soils have 2.5 to 4.5 percent organic matter; dark-colored soils have more than 4.5 percent organic matter; sands are excluded.

Limestone quality. Limestone quality is measured by the neutralizing value and the fineness of grind. The neutralizing value of limestone is measured by its calcium carbonate equivalent: the higher this value, the greater the limestone's ability to neutralize soil acidity. Rate of reaction is affected by particle size; the finer that limestone is ground, the faster it will neutralize soil acidity. Relative efficiency factors have been determined for various particle sizes (Table 10.3).

The quality of limestone is defined as its effective neutralizing value (ENV). This value can be calculated for any liming material by using the efficiency factors in Table 10.3 and the calcium carbonate equivalent for the limestone in question. The "typical" limestone on which Figure 10.5 is based has an ENV of 46.35 for 1 year and 67.5 for 4 years.

The Illinois Department of Agriculture, in cooperation with the Illinois Department of Transportation, collects and analyzes limestone samples from quarries that wish to participate in the Illinois Voluntary Limestone Program. These analyses, along with the calculated correction factors, are available from the Illinois Department of Agriculture, Division of Plant Industries and Consumer Services, P.O. Box 19281, Springfield, IL 62794-9281, in an annual publication titled *Illinois Voluntary Limestone Program Producer Information.* To calculate the ENV for materials not reported in that publication, obtain the analysis of the material in question from the supplier and use the worksheet provided for making calculations.

As an example, consider a limestone that has a calcium carbonate equivalent of 86.88 percent, that the sample has 13.1 percent of the particles greater than 8-mesh, 40.4 percent that pass 8-mesh and are held on 30-mesh, 14.9 percent that pass 30-mesh and are held on 60-mesh, and 31.6 percent that pass 60-mesh. Assume that 3 tons of typical limestone are needed per acre (according to Figure 10.5).

At rates up to 6 tons per acre, if high initial cost is not a deterrent, then the entire amount may be applied at one time. If cost is a factor and the amount of limestone needed is 6 tons or more per acre, apply it in split applications of about two-thirds the first time and the remainder 3 or 4 years later.

Fluid lime suspensions (liquid lime). These products are obtained by suspending very finely ground

Table 10.3. Efficiency Factors for Various Limestone Particle Sizes

	Efficiency factor	
Particle sizes	1 year after application	4 years after application
Greater than 8-mesh	5	15
8- to 30-mesh	20	45
30- to 60-mesh	50	100
Passing 60-mesh	100	100

Worksheet

Evaluation for 1 year after application

Efficiency factor

% of particles greater than 8-mesh = ____/100 × 5 =

% of particles that pass 8-mesh and are held on 30-mesh = ____/100 × 20 =

% of particles that pass 30-mesh and are held on 60-mesh = ____/100 × 50 =

% of particles that pass 60-mesh = ____/100 × 100 =

Total fineness efficiency ____

$$\text{ENV} = \text{total fineness efficiency} \times \frac{\%\ \text{calcium carbonate equivalent}}{100}$$

$$\text{Correction factor} = \frac{\text{ENV of typical limestone (46.35)}}{\text{ENV of sampled limestone (\_\_\_)}}$$

Correction factor × limestone requirement (from Figure 10.5) = ____ tons of sampled limestone needed per acre

Evaluation for 4 years after application

Efficiency factor

% of particles greater than 8-mesh = ____/100 × 15 =

% of particles that pass 8-mesh and are held on 30-mesh = ____/100 × 45 =

% of particles that pass 30-mesh and are held on 60-mesh = ____/100 × 100 =

% of particles that pass 60-mesh = ____/100 × 100 =

Total fineness efficiency ____

$$\text{ENV} = \text{total fineness efficiency} \times \frac{\%\ \text{calcium carbonate equivalent}}{100}$$

$$\text{Correction factor} = \frac{\text{ENV of typical limestone (67.5)}}{\text{ENV of sampled limestone (\_\_\_)}}$$

Correction factor × limestone requirement (from Figure 10.5) = ____ tons of sampled limestone needed per acre

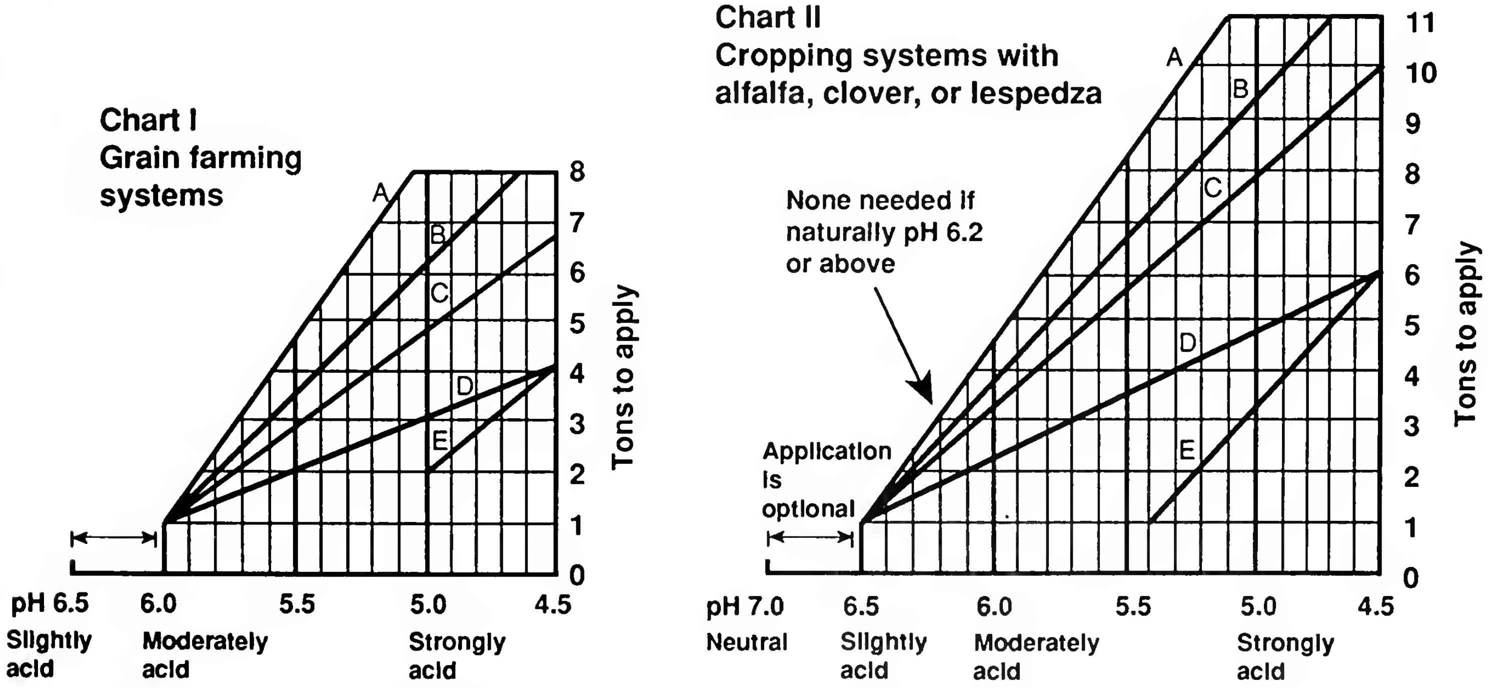


Figure 10.5. Suggested limestone rates based on soil type, pH, and cropping system.

limestone in water. Several industrial by-products that have liming properties also are being land-applied as suspensions, either because they are too fine to be spread dry or they are already in suspension. These by-product materials include residue from water treatment plants, cement plant stack dusts, paper mill sludge, and other waste products. These materials may contain as much as 50 percent water. In some cases, a small amount of attapulgite clay is added as a suspending agent.

The chemistry of liquid liming materials is the same as that of dry materials. Research results have confirmed that the rate of reaction and neutralizing power for liquid lime are the same as for dry materials when particle sizes are the same.

Results collected from one research study indicate that application of liquid lime at the rate of material calculated by the following equation is adequate to maintain soil pH for at least a 4-year period at the same level as typical lime.

$$\frac{\text{ENV of typical limestone (use 46.35)}}{\begin{matrix}\text{100 (fineness}\\ \text{efficiency}\\ \text{factor)}\end{matrix} \times \frac{\begin{matrix}\text{\% calcium carbonate}\\ \text{equivalent, dry}\\ \text{matter basis}\end{matrix}}{100} \times \frac{\begin{matrix}\text{\% dry}\\ \text{matter}\end{matrix}}{100}}$$

$$\times \text{ tons of limestone needed per acre} = \text{tons of liquid lime needed per acre}$$

During the first few months after application, the liquid material will provide a more rapid increase in pH than will typical lime, but after that the two materials will provide equivalent pH levels in the soil.

As an example, assume a lime need of 3 tons per acre (based on Figure 10.5) and liquid lime that is 50 percent dry matter and has a calcium carbonate equivalent of 97 percent on a dry matter basis. The rate of liquid lime needed would be calculated as follows:

$$\frac{46.35}{100 \times \frac{97}{100} \times \frac{50}{100}} \times 3 = 2.87 \text{ tons of liquid lime per acre}$$

Lime incorporation. Lime does not react with acidic soil very far from the particle; but special tillage operations to mix lime with soil usually are not necessary in systems that use a moldboard plow. Systems of tillage that use a chisel plow, disk, or field cultivator rather than a moldboard plow, however, may not mix limestone deeper than 4 to 5 inches.

1 Year

$$\frac{13.1\%}{100} \times 5 = 0.65$$

$$\frac{40.4\%}{100} \times 20 = 8.08$$

$$\frac{14.9\%}{100} \times 50 = 7.45$$

$$\frac{31.6\%}{100} \times 100 = 31.60$$

Total fineness efficiency 47.78

$$\text{ENV} = 47.78 \times \frac{86.88}{100} = 41.51$$

$$\frac{46.35}{41.51} \times 3 = 3.35 \text{ tons per acre}$$

4 Years

$$\frac{13.1\%}{100} \times 15 = 1.96$$

$$\frac{40.4\%}{100} \times 45 = 18.18$$

$$\frac{14.9\%}{100} \times 100 = 14.90$$

$$\frac{31.6\%}{100} \times 100 = 31.60$$

Total fineness efficiency 66.64

$$\text{ENV} = 66.64 \times \frac{86.88}{100} = 57.9$$

$$\frac{67.5}{57.9} \times 3 = 3.5 \text{ tons per acre}$$

Calcium-magnesium balance in Illinois soils

Soils in northern Illinois usually contain more magnesium than those in central and southern Illinois because of the high magnesium content in the rock from which the soils developed and because northern soils are geologically younger. This relatively high level of magnesium has caused some speculation as to whether the level is too high. Although there have been reports of suggestions that either gypsum or low-magnesium limestone should be applied, no research data has been put forth to justify concern over a too-narrow ratio of calcium to magnesium.

On the other hand, concern is justified over a soil magnesium level that is low — because of its relationship with hypomagnesemia, a prime factor in grass tetany or milk fever in cattle. This concern is more relevant to forage production than to grain production. Very high potassium levels (more than 500 pounds per acre) combined with low soil magnesium levels contribute to low-magnesium grass forages. Research data to establish critical magnesium levels are very limited. However, levels of soil magnesium less than 60 pounds per acre on sands and 150 pounds per acre on silt loams are regarded as low.

Calcium and magnesium levels of agricultural limestone vary among quarries in the state. Dolomitic limestone (material with an appreciable magnesium content as high as 21.7 percent MgO or 46.5 percent $MgCO_3$) occurs predominantly in the northern three tiers of Illinois counties, in Kankakee County, and in

Calhoun County. Limestone occurring in the remainder of the state is predominantly calcitic (high calcium), although it is not uncommon for it to contain 1 to 3 percent $MgCO_3$.

For grain farmers, there are no agronomic reasons to recommend either that farmers in northern Illinois bypass local limestone sources, which are medium to high in magnesium, and pay a premium for low-magnesium limestone from southern Illinois or that farmers in southern Illinois order limestone from northern Illinois quarries because of magnesium content.

For farmers with a livestock program or who produce forages in the claypan and fragipan regions of the south, where soil magnesium levels may be marginal, it is appropriate to use a soil test to verify conditions and to use dolomitic limestone or magnesium fertilization or to add magnesium to the feed.

Nitrogen

About 40 percent of the original nitrogen and organic-matter content has been lost from typical Illinois soils since farming began, by erosion and from increased oxidation of organic matter. Erosion reduces the nitrogen content of soils because the surface soil is richest in nitrogen and this erodes first. Farming practices that improved aeration of the soil, including improved drainage and tillage, have increased the rate of organic matter degradation. Further nitrogen losses occur as a result of denitrification and leaching.

Because harvested crops remove more nitrogen than any other nutrient from Illinois soils, the use of nitrogen fertilizer is necessary if Illinois agriculture is to be competitive in the world market. Low grain prices, along with concern for the environment, make it imperative that all nitrogen fertilizers be used in the most efficient manner possible. Factors that influence efficiency of fertilizer use are discussed in the following sections.

Nitrogen recommendation systems

Nitrogen recommendations in the humid regions of the Corn Belt have been based in large part on expected yield with an adjustment for previous crop and management programs. Although this system has worked well, there are documented reports of near-optimal corn yields with little or no supplemental nitrogen. Such results have encouraged researchers to develop a reliable and practical soil nitrogen test that would give farmers and their advisers the opportunity to identify those conditions where the nitrogen application rate could likely be modified to enhance crop profits without harming the environment.

Total soil nitrogen. Because 5 percent of soil organic matter is nitrogen, some have theorized that organic matter content of a soil could be used as an estimate of the amount of supplemental nitrogen that would be needed for a crop. Attempts to use this procedure have been unsuccessful because mineralization of organic matter varies significantly over time due to variation in available soil moisture. Additionally, soils high in organic matter usually have a higher yield potential due to their ability to provide a better environment for crop growth.

Early spring nitrate nitrogen. This procedure has been used for several years in the more arid parts of the Corn Belt (west of the Missouri River) with reasonable success. It involves the collection of soil samples in 1-foot increments to a 2- to 3-foot depth in early spring for analysis of nitrate nitrogen. Although the use of the information varies somewhat from state to state, the consensus is to reduce the normal nitrogen recommendation by the amount found in the soil profile sampled. Results obtained by scientists in both Wisconsin and Michigan in the late 1980s have found this procedure to work well, but work in Iowa indicated that the procedure did not accurately predict nitrogen needs.

Since samples are collected in early spring, this procedure measures potential for nitrogen carryover from the previous crop. Therefore, it will have the greatest potential for success on continuous corn, especially in fields where adverse growing conditions have limited yields the previous year. Additional work is needed to ascertain the sampling procedure that will best characterize the field conditions, especially when nitrogen has been injected in prior years. When excessive precipitation is received in late spring or early summer, this procedure will not likely be successful because most of the nitrogen that is detected early may be leached or denitrified before the plant has an opportunity to absorb it from the soil.

Late-spring nitrate nitrogen. Success with this procedure was first observed with work in Vermont. Follow-up work in Iowa in the late 1980s also indicated that the procedure accurately characterized nitrogen needs. Soil samples are collected to a 1-foot depth when corn plants are 6 to 12 inches tall and analyzed for nitrate nitrogen. Several university agronomists suggest that no additional nitrogen be applied when soil test levels exceed 26 parts per million (52 pounds per acre) and that full rate be applied if nitrate nitrogen levels are less than 10 parts per million. They suggest proportional adjustments in nitrogen rates when test levels are between 10 and 26 parts per million. To minimize the potential for decreased yield that might be caused by delayed nitrogen application, agronomists at Iowa State University suggest that 50 to 70 percent of the normal nitrogen application be applied preplant. If the fertilizer was broadcast, they suggest collecting 16 to 24 core samples within an area not exceeding 10 acres. If the fields have been fertilized with anhydrous ammonia, they suggest a modified soil test. The modified test can be used under the following conditions: (a) the rate of ammonia application did not exceed 125 pounds of nitrogen per acre; (b) the soil sample is derived from at least 24 cores collected without regard to location of ammonia injection bands;

and (c) fertilizer nitrogen recommendations are adjusted to reflect that one-third of the nitrogen applied was not revealed by the soil test.

If sampling is done later in the season, testing provides a measure of the mineralization of organic nitrogen that has occurred and the amount of residual carryover that is still present in the soil. Obvious limitations of this procedure include: (a) its use only on fields that receive sidedress application of nitrogen; (b) the short time available between sampling and the need to apply fertilizer — this could be especially critical in wet years and could result in corn plants becoming too large to use conventional application equipment; and (c) no existing correlation for use of the procedure on fields that have received a banded nitrogen application.

Because none of the nitrogen soil procedures have received adequate research to determine their reliability and usefulness under Illinois conditions, it is suggested that nitrogen rates be determined using the following materials as a guide.

Yield potential

Corn. Proven yield potential is one of the major considerations to use in determining the optimum rate of nitrogen application for corn. These potentials should be established for each field, taking into account the soil type and management level under which the crop will be grown. If yield records are available, use the 5-year average yield as the basis. When figuring the average, eliminate years of abnormally low yields that resulted from drought or other weather-related conditions.

If yield records are not available for a particular field, suggested productivity-index values are given in Illinois Cooperative Extension Service Bulletin 778, *Soils of Illinois*. Yield goals are presented for both basic and high levels of management. For fields that will be under exceptionally high management, a 15 to 20 percent increase in the values given for high levels of management would be reasonable. Annual variations in yield of 20 percent above or below the productivity-index values are common because of variations in weather conditions. However, applying nitrogen fertilizer for yields possible in the most favorable year will not result in maximum net return when averaged over all years.

The University of Illinois Department of Agronomy has conducted research trials designed to determine the optimum nitrogen rate for corn under varying soil and climatic conditions.

The results of these experiments show that average economic optimum nitrogen rates varied from 1.22 to 1.32 pounds of nitrogen per bushel of corn produced when nitrogen was applied in the spring (Table 10.4). The lower rate of application (1.22 pounds) would be recommended at a corn-nitrogen price ratio (corn price per bushel to nitrogen price per pound) between 10:1 and 20:1, and the higher rate (1.32 pounds) at a price ratio of 20:1 or greater.

As would be expected, the nitrogen requirement was lower at sites having a corn-soybean rotation than at sites with continuous corn. (See the subsection about rate adjustments on page 61.)

With the exception of Dixon, which was based on limited data, Brownstown and DeKalb had the highest nitrogen requirement per bushel of corn produced. In part, this higher requirement may be the result of the higher denitrification losses that frequently have been observed at Brownstown and DeKalb.

Based on these results, Table 6 gives examples of the recommended rate of nitrogen application for selected Illinois soils under a high level of management.

Evaluation of nitrogen recommendation systems for corn. Over a two-year period, experiments were conducted at 47 locations around Illinois to evaluate the potential for using the nitrate nitrogen soil test systems to improve nitrogen recommendations. Use of the nitrate nitrogen soil test systems was compared to use of yield potential, times a factor, minus adjustments for previous crops and legumes. Considering only those locations exhibiting a significant response to applied fertilizer nitrogen, all three systems — those based on yield potential with an adjustment for previous crop or manure application, and those based on yield potential with an adjustment for the amount of nitrate nitrogen observed in the soil at early spring or at presidedress time — gave recommendations that were within 3 pounds of the amount needed for the fields on the average (Table 10.5a). Adjustments based on the early spring nitrate nitrogen test resulted in recommendations about 25 pounds less than needed to obtain the most return per acre.

None of the three systems provided accurate recommendations for fields where adverse weather conditions limited yield potential far below expectation and limited yield response to applied nitrogen (Table 10.5b). At most locations where manure had been applied prior to planting, both the preplant and presidedress nitrate nitrogen tests predicted a need for no supplemental fertilization.

Based on results so far, none of the nitrogen soil test procedures now available offer enough improved accuracy or reliability over the yield potential system described earlier to justify their use on Illinois fields. The exception appears to be on fields that have received a broadcast application of manure or other organic nitrogen-containing materials. In those cases, if the nitrate nitrogen test exceeds 25 parts per million at the time the corn is 6 to 12 inches tall, there is no need for additional nitrogen fertilizer.

Soybeans. Based on average Illinois corn and soybean yields from 1984 to 1985 and average nitrogen content of the grain for these two crops, the total nitrogen removed per acre by soybeans was greater than that removed by corn (soybeans, 148 pounds of nitrogen per acre; corn, 96 pounds of nitrogen per acre). Research results from the University of Illinois,

Table 10.4. Economic Optimum Nitrogen Rate Experimentally Determined for Eight Locations as Affected by Corn-Nitrogen Price Ratios

	Corn-nitrogen price ratio			
	10:1		20:1	
Location and rotation	Optimum yield, bu/acre	Optimum N rate, lb/bu	Optimum yield, bu/acre	Optimum N rate, lb/bu
Brownstown (continuous corn)	83	1.30	86	1.47
Carthage (continuous corn)	144	1.22	147	1.29
DeKalb (continuous corn)	141	1.28	143	1.31
Urbana (continuous corn)	171	1.17	173	1.24
Average of continuous corn		1.24		1.33
Dixon (corn-soybeans)	131	1.37	134	1.58
Hartsburg (corn-soybeans)	156	1.19	157	1.27
Oblong (corn-soybeans)	123	1.11	126	1.23
Toledo (corn-soybeans)	123	1.12	124	1.20
Average of corn-soybeans		1.20		1.32
Average of all locations		1.22		1.32

Table 10.5a. Relationship Between Experimentally Derived, Economically Optimum Nitrogen Rates and Nitrogen Recommendations from Three Recommendation Systems

Number of locations	Yield goal	Optimum yield	Optimum N rate	Recommendation system		
				PY[a]	PPNT[b]	PSNT[c]
	bushel/acre		*lb N/acre*			
Responding sites						
27	141	143	141	137	109	130
Nonresponding sites						
20	140	129	0	123	81	100

Table 10.5b. Relationship Between Experimentally Derived, Economically Optimum Nitrogen Rates and Nitrogen Recommendations from Three Recommendation Systems as Influenced by Manure Application, Environmental Factors, and Previous Crop

Number of locations	Yield goal	Optimum yield	Optimum N rate	Recommendation system		
				PY[a]	PPNT[b]	PSNT[c]
	bushel/acre		*lb N/acre*			
Manured sites						
4	146	172	0	38	22	31
Drought-affected sites						
6	152	98	0	162	111	125
Forage legume sites						
2	160	133	0	111	83	90

[a] Proven yield. University of Illinois Department of Agronomy recommendations using proven yield.
[b] Preplant nitrogen test. UI Department of Agronomy recommendations, minus nitrate content in top 2 feet of surface soil in early spring.
[c] Pre-sidedress nitrogen test. Iowa State University Department of Agronomy nitrogen recommendations.

however, indicate that when properly nodulated soybeans were grown at the proper soil pH, the symbiotic fixation was equivalent to 63 percent of the nitrogen removed in harvested grain. Thus, the net nitrogen removal by soybeans was less than that of corn (corn, 96; soybeans, 55).

This net removal of nitrogen by soybeans in 1984–85 was equivalent to 24 percent of the amount of fertilizer nitrogen used in Illinois. On the other hand, symbiotic fixation of nitrogen by soybeans in Illinois (420,000 tons of nitrogen) was equivalent to 55 percent of the fertilizer nitrogen used in Illinois.

Even though there is a rather large net nitrogen removal from soil by soybeans (55 pounds of nitrogen per acre), research at the University of Illinois has generally indicated no soybean yield increase caused by either residual nitrogen in the soil or nitrogen fertilizer applied for the soybean crop.

1. *Residual from nitrogen applied to corn (Table 10.7).* Soybean yields at four locations were not increased

Table 10.6. Nitrogen Recommendations for Selected Illinois Soils Under High Level of Management

Soil type	Corn-nitrogen price ratio 10:1	20:1
	nitrogen recommendation, lb/acre	
Muscatine silt loam	205	220
Ipava silt loam	200	215
Sable silty clay loam	190	205
Drummer silty clay loam	185	200
Plano silt loam	185	200
Hartsburg silty clay loam	175	190
Fayette silt loam	155	170
Clinton silt loam	155	170
Cowden silt loam	145	160
Cisne silt loam	140	150
Bluford silt loam	125	135
Grantsburg silt loam	115	125
Huey silt loam	80	85

Table 10.7. Soybean Yields at Four Locations as Affected by Nitrogen Applied to Corn the Preceding Year (Four-Year Average)

N applied to corn, lb/acre	Soybean yield Aledo	Dixon	Elwood	Kewanee	Average
	bushels per acre				
0	48	40	37	40	41
80	49	40	36	38	41
160	48	39	36	40	41
240	48	42	36	40	41
320	48	42	36	37	41

by residual nitrogen in the soil, even when nitrogen rates as high as 320 pounds per acre had been applied to corn the previous year.

2. *Nitrogen on continuous soybeans (Table 10.8).* After 18 years of continuous soybeans at Hartsburg, yields were unaffected by applications of nitrogen fertilizer.
3. *High rates of added nitrogen (Table 10.9).* In 1968 a study was started at Urbana using moderate rates of nitrogen. Rates were increased in 1969 so that the higher rates would furnish more than the total nitrogen needs of soybeans. Yields were not affected by nitrogen in 1968; but with 400 pounds per acre of nitrogen, a tendency toward a yield increase occurred in 1969 and 1970. However, the yield increase would not pay for the added nitrogen at current prices.

Table 10.8. Yield of Continuous Soybeans with Rates of Added Nitrogen at Hartsburg

Nitrogen, lb/acre/year	Soybean yield 1968-71	1954-71
	bushels per acre	
0	43	37
40	42	36
120	43	37

Table 10.9. Soybean Yields at Urbana as Affected by High Rates of Nitrogen

Nitrogen, lb/acre 1968	1969	1970	Soybean yield, bu/acre 1968	1969	1970
0	0	0	54	53	40
40	200	200	54	57	41
80	400	400	56	57	45
120	800	800	53	55	42
160	1,600	1,600	55	34	36

Wheat, oats, and barley. The rate of nitrogen to apply on wheat, oats, and barley is dependent on soil type, crop and variety to be grown, and future cropping intentions (Table 10.10). Light-colored soils (low in organic matter) require the highest rate of nitrogen application because they have a low capacity to supply nitrogen. Deep, dark-colored soils require lower rates of nitrogen application for maximum yields. Estimates of organic-matter content for soils of Illinois may be obtained from Agronomy Fact Sheet SP-36, *Average Organic Matter Content in Illinois Soil Types,* or by using University of Illinois publication AG-1941, *Color Chart for Estimating Organic Matter in Mineral Soils.*

Nearly all modern varieties of wheat have been selected for improved standability; thus concern about nitrogen-induced lodging has decreased considerably. Varieties of oats, though substantially improved with regard to standability, will still lodge occasionally; and nitrogen should be used carefully. Barley varieties, especially varieties of spring barley, are prone to lodging; thus rates of nitrogen application shown in Table 10.10 should not be exceeded.

Some wheat and oats in Illinois serve as a companion crop for legume or legume-grass seedings. On those fields, it is best to apply nitrogen fertilizer at well below the optimum rate because unusually heavy vegetative growth of wheat or oats competes unfavorably with the young forage seedlings (Table 10.10). Seeding rates for small grains should also be somewhat lower if used as companion seedings.

The introduction of nitrification inhibitors and improved application equipment now provide two options for applying nitrogen to wheat. Research has shown that when the entire amount of nitrogen needed is applied in the fall with a nitrification inhibitor, the resulting yields are equivalent to that obtained when a small portion of the total need was fall-applied and the remainder was applied in early spring. Producers who are frequently delayed in applying nitrogen in the spring because of muddy fields may wish to consider fall application with a nitrification inhibitor. For fields that are not usually wet in the spring, either system of application will provide equivalent yields.

The amount of nitrogen needed for good fall growth is not large because the total uptake in roots and tops before cold weather is not likely to exceed 30 to 40 pounds per acre.

Hay and pasture grasses. The species grown, period of use, and yield goal determine optimum nitrogen

Table 10.10. Recommended Nitrogen Application Rates for Wheat, Oats, and Barley

Soil situation	Organic-matter content	Fields with alfalfa or clover seeding		Fields with no alfalfa or clover seeding	
		Wheat	Oats and barley	Wheat	Oats and barley
		nitrogen, pounds per acre			
Soils low in capacity to supply nitrogen: inherently low in organic matter (forested soils)	<2%	70-90	60-80	90-110	70-90
Soils medium in capacity to supply nitrogen: moderately dark-colored soils	2-3%	50-70	40-60	70-90	50-70
Soils high in capacity to supply nitrogen: all deep, dark-colored soils	>3%	30-50	20-40	50-70	30-50

fertilization (Table 10.11). The lower rate of application is recommended on fields where inadequate stands or moisture limits production.

Kentucky bluegrass is shallow-rooted and susceptible to drought. Consequently, the most efficient use of nitrogen by bluegrass is from an early spring application, with September application a second choice. September fertilization stimulates both fall and early spring growth.

Orchardgrass, smooth bromegrass, tall fescue, and reed canarygrass are more drought-tolerant than bluegrass and can use higher rates of nitrogen more effectively. Because more uniform pasture production is obtained by splitting high rates of nitrogen, two or more applications are suggested.

If extra spring growth can be utilized, make the first nitrogen application in March in southern Illinois, early April in central Illinois, and mid-April in northern Illinois. If spring growth is adequate without extra nitrogen, the first application may be delayed until after the first harvest or grazing cycle to distribute production more uniformly throughout the summer. Total production likely will be less, however, if nitrogen is applied after first harvest rather than in early spring. Usually the second application of nitrogen is made after the first harvest or first grazing cycle; to stimulate fall growth, however, this application may be deferred until August or early September.

Legume-grass mixtures should not receive nitrogen if legumes make up at least 30 percent of the mixture. Because the main objective is to maintain the legume, the emphasis should be on applying phosphorus and potassium rather than nitrogen.

After the legume has declined to less than 30 percent of the mixture, the objective of fertilizing is to increase the yield of grass. The suggested rate of nitrogen is about 50 pounds per acre when legumes make up 20 to 30 percent of the mixture.

Rate adjustments

In addition to determining nitrogen rates, consideration should be given to other agronomic factors that influence available nitrogen. These factors include past cropping history and the use of manure (Table 10.12), as well as the date of planting.

Corn following another crop consistently yields better than continuous corn. This is especially true for corn following a legume such as soybeans or alfalfa (Figure 10.6). This is due in part to residual nitrogen from the legumes as the differences in yield between rotations become smaller with increasing nitrogen rates. When no nitrogen was applied, the data indicate that soybeans and alfalfa contributed the equivalent of 65 and 108 pounds of nitrogen per acre, respectively. At the optimum production level, soybeans contributed the equivalent of about 30 pounds of nitrogen per acre. The contribution of legumes, either soybeans or alfalfa, to wheat will be less than the contribution to corn because the oxidation of the organic nitrogen from these legumes will not be as rapid in early spring, when nitrogen needs of small grain are greatest, as it is in the summer, when nitrogen needs of corn are greatest.

Table 10.11. Nitrogen Fertilization of Hay and Pasture Grasses

Species	Time of application			
	Early spring	After first harvest	After second harvest	Early September
	nitrogen, pounds per acre			
Kentucky bluegrass	60-80			(see text)
Orchardgrass	75-125	75-125		
Smooth bromegrass	75-125	75-125		50[a]
Reed canarygrass	75-125	75-125		50[a]
Tall fescue for winter use		100-125	100-125	50[a]

[a] Optional if extra fall growth is needed.

Table 10.12. Adjustments in Nitrogen Recommendations

Crop to be grown	Factors resulting in reduced nitrogen requirement						
	After soybeans	1st year after alfalfa or clover			2nd year after alfalfa or clover		Manure
		Plants/sq ft			Plants/sq ft		
		5	2-4	<2	5	<5	
	nitrogen reduction, lb/acre						
Corn	40	100	50	0	30	0	5[a]
Wheat	10	30	10	0	0	0	5[a]

[a] Nitrogen contribution in pounds per ton of manure.

Corn following oats had a higher yield than continuous corn (Figure 10.6). Although oats are not a

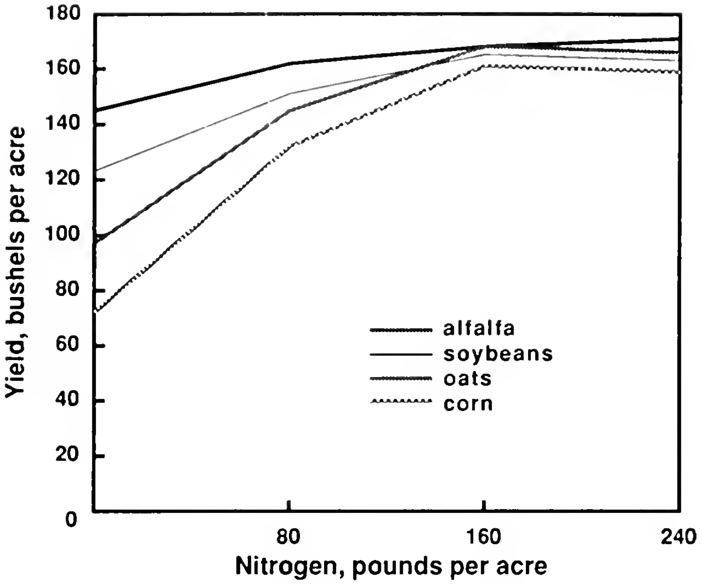


Figure 10.6. Effect of crop rotation and applied nitrogen on corn yield, DeKalb, 1980–83.

legume, a part of this yield differential may be due to nitrogen released from the soil after the oat crop had completed its nitrogen uptake, and thus it was carried over to the next year's corn crop.

Depending on the crop grown, the nitrogen credit from idled acres may be positive or negative. Plowing under a good stand of a legume that had good growth will result in a contribution of 60 to 80 pounds of nitrogen per acre. If either stand or growth of the legume was poor or if corn was zero-tilled into a good legume stand that had good growth, the legume nitrogen contribution could be reduced to 40 to 60 pounds per acre. Because most of the net nitrogen gained from first-year legumes will be in the herbage, fall grazing will reduce the nitrogen contribution to 30 to 50 pounds per acre. If sorghum residues are incorporated into the soil, an additional 30 to 40 pounds of nitrogen should be applied per acre.

Nutrient content of manure will vary, depending on source and method of handling (Table 10.13). Additionally, the availability of the total nitrogen content will vary, depending on method of application. When incorporated during or immediately after application, about 50 percent of the total nitrogen in dry manure and 50 to 60 percent of the total nitrogen in liquid manure will be available for the crop that is grown during the year following manure application.

Research at the Northern Illinois Research Center for several years showed that as planting was delayed, less nitrogen fertilizer was required for most profitable yield. Based upon that research, Illinois agronomists suggest that for each week of delay in planting after the optimum date for the area, the nitrogen rate can be reduced 20 pounds per acre down to 80 to 90 pounds per acre as the minimum for very late planting in a corn-soybean cropping system. Suggested reference dates are April 10 to 15 in southern Illinois, April 20 to May 1 in central Illinois, and May 1 to 10 in northern Illinois. This adjustment is, of course, possible only if the nitrogen is sidedressed.

Because of the importance of the planting date, farmers are encouraged not to delay planting just to apply nitrogen fertilizer: Plant, then sidedress.

Table 10.13. Average Composition of Manure

	Nutrients (lb/ton)		
Kind of animal	Nitrogen (N)	Phosphorus (P_2O_5)	Potassium (K_2O)
Dairy cattle.................	11	5	11
Beef cattle..................	14	9	11
Hogs......................	10	7	8
Chicken....................	20	16	8
Dairy cattle (liquid)..........	5(26)[a]	2(11)	4(23)
Beef cattle (liquid)...........	4(21)	1(7)	3(18)
Hogs (liquid)	10(56)	5(30)	4(22)
Chicken (liquid).............	13(74)	12(68)	5(27)

[a] Parenthetical numbers are pounds of nutrients per 1,000 gallons.

Reactions in the soil

Efficient use of nitrogen fertilizer requires an understanding of how nitrogen behaves in the soil. Key points to consider are the change from ammonium (NH_4^+) to nitrate (NO_3^-) and the movements and transformations of nitrate.

A high percentage of the nitrogen applied in Illinois is in the ammonium form or converts to ammonium (anhydrous ammonia and urea, for example) soon after application. Ammonium nitrogen is held by the soil clay and organic matter and cannot move very far until it nitrifies (changes from ammonium to nitrate). In the nitrate form, nitrogen can be lost by either denitrification or leaching (Figure 10.7).

Denitrification. Denitrification is believed to be the main process by which nitrate and nitrite nitrogen are lost, except on sandy soils, where leaching is the major pathway. Denitrification involves only nitrogen that is in the form of either nitrate (NO_3^-) or nitrite (NO_2^-).

The amount of denitrification depends mainly on (a) how long the surface soil is saturated; (b) the temperature of the soil and water; (c) the pH of the soil; and (d) the amount of energy material available to denitrifying organisms.

When water stands on the soil or when the surface is completely saturated in late fall or early spring, nitrogen loss is likely to be small because (a) much nitrogen is still in the ammonium rather than nitrate form; and (b) the soil is cool, and denitrifying organisms are not very active.

Many fields in east-central Illinois and, to a lesser extent, in other areas have low spots where surface water collects at some time during the spring or early summer. The flat claypan soils also are likely to be saturated, though not flooded, during that time. Sidedressing would avoid the risk of spring loss on these soils but would not affect midseason loss. Unfortunately, these are the soils on which sidedressing is difficult in wet years.

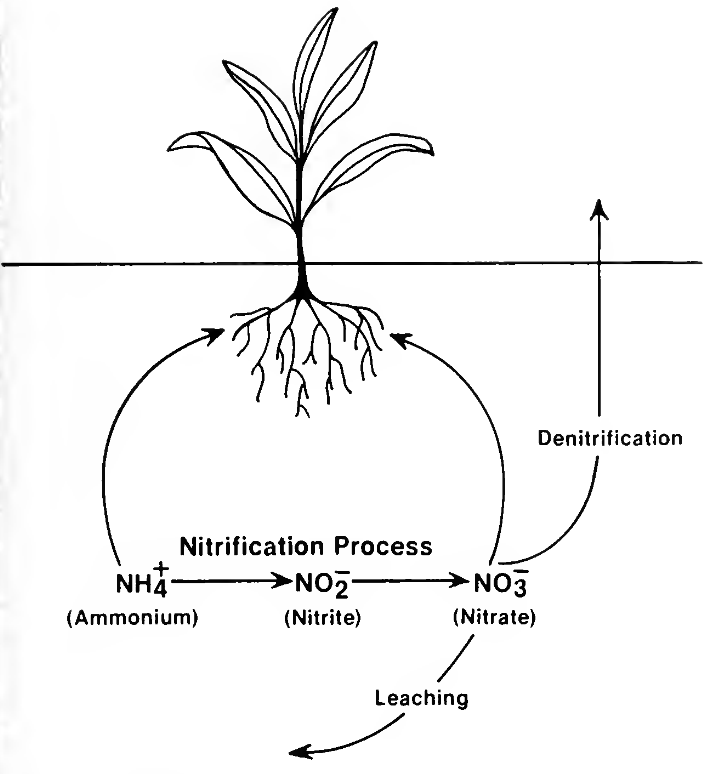


Figure 10.7. Nitrogen reactions in the soil.

New scientific procedures now make it possible to directly measure denitrification losses. Results collected over the past few years indicate that when soils were saturated for 3 to 4 days, losses of 25 to 40 percent of the nitrogen present as nitrate occurred even though water was ponded for only a few hours. These losses resulted in a yield loss of 10 to 20 bushels per acre. Increasing the time that soils were saturated to 6 days resulted in losses of 50 to 60 percent of the nitrogen present as nitrate. As more results are collected, agronomists will be able to predict more accurately the nitrogen loss under specific conditions and, more importantly, to predict the response to added nitrogen.

Leaching. In silt loams and clay loams, 1 inch of rainfall moves down about 5 to 6 inches, though some of the water moves in large pores farther through the profile and carries nitrates with it.

In sandy soils, each inch of rainfall moves nitrates down about one foot. If the total rainfall at one time is more than 6 inches, little nitrate will be left within the rooting depth on sands.

Between rains, some upward movement of nitrates occurs in moisture that moves toward the surface as the surface soil dries. The result is that it is difficult to predict how deep the nitrate has moved based only on cumulative rainfall.

When trying to estimate the depth of leaching of nitrates in periods of very intensive rainfall, two points need to be considered. First, the rate at which water can enter the surface of silt and clay loams may be less than the rate of rainfall, which means that much of the water runs off the surface either into low spots or into creeks and ditches. Second, the soil may be saturated already. In either of these cases, the nitrates will not move down the 5 to 6 inches per inch of rain as suggested above.

Corn roots usually penetrate to 6 feet in Illinois soils. Thus, nitrates that leach only to 3 to 4 feet are well within normal rooting depth unless they reach tile lines and are drained from the field.

Nitrification inhibitors

As Figure 10.7 shows, nitrification converts ammonium nitrogen into the nitrate form of nitrogen and thereby increases the potential for loss of soil nitrogen. Use of nitrification inhibitors can retard this conversion. When inhibitors were properly applied in one experiment, as much as 42 percent of soil-applied ammonia remained in the ammonium form through the early part of the growing season, in contrast with only 4 percent that remained when inhibitors were not used. Inhibitors can therefore have a significant effect on crop yields. The benefit from using an inhibitor will vary, however, with the soil condition, time of year, type of soil, geographic location, rate of nitrogen application, and weather conditions that occur after the nitrogen is applied and before it is absorbed by the crop.

Considerable research throughout the Midwest has shown that only under wet soil conditions will inhibitors significantly increase yields. When inhibitors were applied in years of excessive rainfall, increases in corn yield ranged from 10 to 30 bushels per acre; when moisture conditions were not as conducive to denitrification or leaching, inhibitors produced no increase.

For the first 4 years of one experiment conducted by the University of Illinois, nitrification inhibitors produced no effect on grain yields because soil moisture levels were not sufficiently high. In early May of the fifth year, however, when soils were saturated with water for a long time, the application of an inhibitor in the preceding fall significantly increased corn yields (Figure 10.8). Furthermore, at a nitrogen application rate of 150 pounds per acre, the addition of an inhibitor increased grain yields more than did the addition of another 40 pounds of nitrogen (Figure 10.8). Under the conditions of that experiment, therefore, it was more economical to use an inhibitor than to apply more nitrogen.

Because soils normally do not remain saturated with water for very long during the growing season after a sidedressing operation, the probability of benefiting from the use of a nitrification inhibitor with sidedressed nitrogen is less than from their use with either fall- or spring-applied nitrogen. Moreover, the short time between application and absorption by the crop greatly reduces the potential for nitrogen loss.

The longer the period between nitrogen application and absorption by the crop, the greater the probability that nitrification inhibitors will contribute to higher yields. The length of time, however, that fall-applied inhibitors will remain in the soil is partly dependent on soil temperature. On one plot, a Drummer soil that had received an inhibitor application when soil temperatures were 55°F retained nearly 50 percent of the applied ammonia in ammonium form for about 5 months. When soil temperatures were 70°F, it retained the same amount of ammonia for only 2 months. Fall application of nitrogen with inhibitors should therefore be delayed until soil temperatures are no higher than 60°F; and though temperatures may decrease to 60°F in early September, it is advisable to delay applications until the last week in September in northern Illinois and the first week in October in central Illinois.

In general, poorly or imperfectly drained soils will probably benefit the most from nitrification inhibitors. Moderately well-drained soils that undergo frequent periods of 3 or more days of flooding in the spring will also benefit. Coarse-textured soils (sands) are likely to benefit more than soils with finer textures because the coarse-textured soils have a higher potential for leaching.

Time of application and geographic location must be considered along with soil type when determining whether to use a nitrification inhibitor. Employing nitrification inhibitors can significantly improve the efficiency of fall-applied nitrogen on the loams, silts, and clays of central and northern Illinois in years when the soil is very wet in the spring. At the same time, currently available inhibitors will not adequately reduce the rate of nitrification in the low organic-matter soils of southern Illinois when nitrogen is applied in the fall for the following year's corn. The lower organic-matter content and the warmer temperatures of southern Illinois soils, both in late fall and early spring, will cause the inhibitor to degrade too rapidly. Futhermore, applying an inhibitor on sandy soils in the fall will not adequately reduce nitrogen loss because the potential for leaching is too high. Therefore, fall applications of nitrogen with inhibitors are not recommended for sandy soils or for soil with low organic-matter content, especially for those soils found south of Interstate Highway 70.

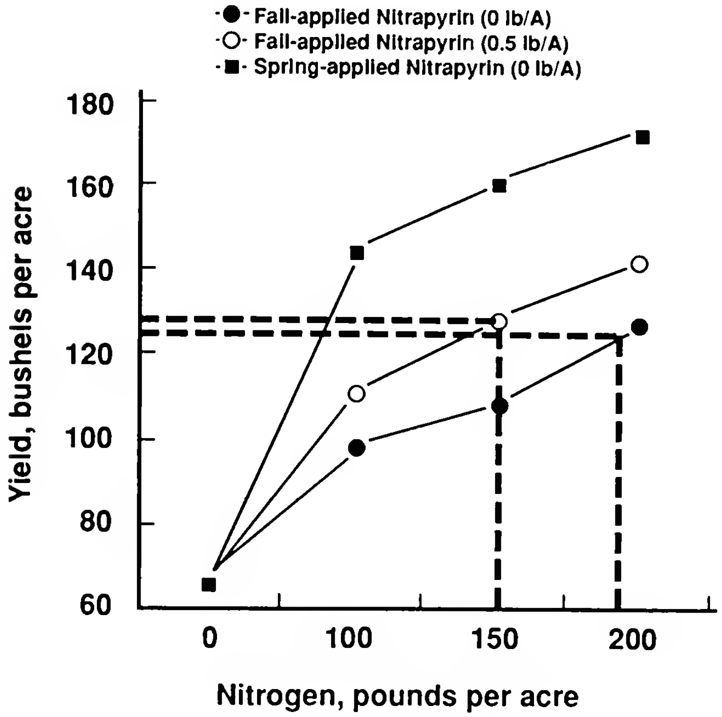


Figure 10.8. Effect of nitrification inhibitors on corn yields at varying nitrogen application rates, DeKalb, 1979.

In the spring, preplant applications of inhibitors may be beneficial on nearly all types of soil from which nitrogen loss frequently occurs, especially on sandy and poorly drained soils. Again, inhibitors are more likely to have an effect when subsoils are recharged with water than when subsoils are dry at the beginning of spring.

Nitrification inhibitors are most likely to increase yields when nitrogen is applied at or below the optimum rate. When nitrogen is applied at a rate greater than that required for optimum yields, benefits from an inhibitor are unlikely, even when moisture in the soil is excessive.

Inhibitors should be viewed as soil management tools that can be used to reduce nitrogen loss. It is not safe to assume, however, that the use of a nitrification inhibitor will make it possible to reduce nitrogen rates below those currently recommended, because those rates were developed with the assumption that no significant amount of nitrogen would be lost.

Time of nitrogen application

In recent years, farmers in central and northern Illinois have been encouraged to apply nitrogen in non-nitrate form in the late fall any time after the soil temperature at 4 inches was below 50°F, except on sandy, organic, or very poorly drained soils.

The 50°F level for fall application is believed to be a realistic guideline for farmers. Applying nitrogen earlier involves risking too much loss (Figure 10.9). Later application involves risking wet or frozen fields,

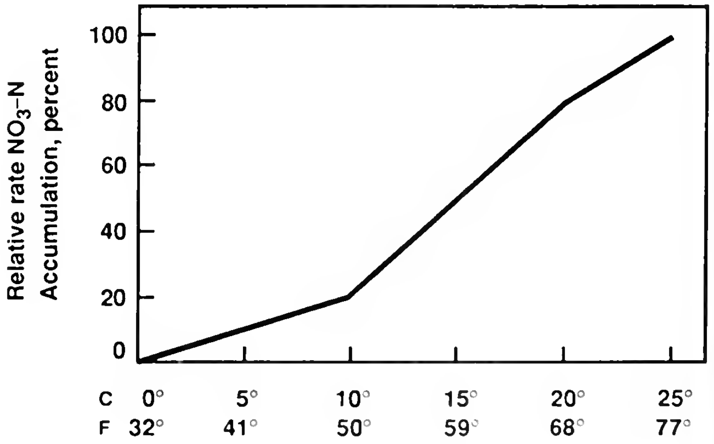


Figure 10.9. Influence of soil temperature on the relative rate of NO_3 accumulation in soils.

which would prevent application and fall tillage. Average dates on which these temperatures are reached are not satisfactory guides because of the great variability from year to year. Soil thermometers should be used to guide fall applications of nitrogen.

In Illinois, most of the nitrogen applied in late fall or very early spring will be converted to nitrate by corn-planting time. Though the rate of nitrification is slow (Figure 10.9), the soil temperature is between 32°F and 40° to 45°F for a long period.

In consideration of the date at which nitrates are formed and the conditions that prevail thereafter, the difference in susceptibility to denitrification and leaching loss between late fall and early spring applications of ammonium sources is probably small. Both are, however, more susceptible to loss than is nitrogen applied at planting time or as a sidedressing.

Anhydrous ammonia nitrifies more slowly than other forms and is slightly preferred for fall applications. It is well suited to early spring application, provided the soil is dry enough for good dispersion of ammonia and closure of the applicator slit.

Sidedress application. Results collected from studies in Illinois indicated that nitrogen injected between every other row was comparable in yield to injection between every row. This finding was true irrespective of tillage system (Table 10.14) or nitrogen rate (Table 10.15). This outcome should be expected, as even with every-other-row injection, each row will have nitrogen applied on one side or the other (Figure 10.10). Although all of the results to date were obtained with anhydrous ammonia, there is no reason to believe that the same results would not be obtained with injected nitrogen solutions.

Use of wider injection spacing at sidedressing allows for a reduction in power requirement for a given applicator width or use of a wider applicator with the same power requirement. From a practical standpoint, the lower power requirement will frequently mean a smaller tractor and associated smaller tire, making it easier to maneuver between the rows and also giving less compaction next to the row. With this system, injector positions can be adjusted to avoid placing an injector in the wheel track. When matching the driving pattern for planters of 8, 12, 16, or 24 rows, the outside two injectors must be adjusted to half-rate application, as the injector will go between those two rows twice if one avoids the wheel track. To avoid problems of back pressure that might be created when applying at relatively high rates of speed, use a double-tube knife, with two hoses going to each knife; the outside knives would require only one hose to give the half-rate application.

Table 10.14. Effect on Corn Yield of Ammonia Knife Spacing with Different Tillage Systems at Two Locations in Illinois

Injector spacing, inches	Yield, bushels per acre Plow	Chisel	Disk	No-Till
	DeKalb			
30	159	157	163	146
60	158	157	157	143
	Elwood			
30	...	119	121	118
60	...	117	125	121

Table 10.15. Effect on Corn Yield of Injector Spacing of Ammonia Applied at Different Rates of Nitrogen, DeKalb

Injector spacing, inches	Nitrogen, lb/acre 120	180	240
	yield, bu/acre		
30	171	176	181
60	170	171	182

Winter application. Based on observations, the risk of nitrogen loss through volatilization associated with winter application of urea for corn on frozen soils is too great to consider the practice unless one is assured of at least one-half inch of precipitation occurring within 4 to 5 days after application. In most years, application of urea on frozen soils has been an effective practice for wheat.

Aerial application. Recent research at the University of Illinois has indicated that an aerial application of dry urea will result in increased yield. This practice should not be considered a replacement for normal nitrogen application but rather an emergency treatment in situations where corn is too tall for normal applicator equipment. Aerial application of nitrogen solutions on growing corn is not recommended, as extensive leaf damage will likely result if the rate of application is greater than 10 pounds of nitrogen per acre.

Which nitrogen fertilizer?

Most of the nitrogen fertilizer materials available for use in Illinois provide nitrogen in the combined form of ammonia, ammonium, urea, and nitrate (Table 10.16). For many uses on a wide variety of soils, all forms are likely to produce about the same yield — provided that they are properly applied.

Ammonia. Nitrogen materials that contain free ammonia (NH_3), such as anhydrous ammonia or low-pressure solutions, must be injected into the soil to avoid loss of ammonia in gaseous form. Upon injection into the soil, ammonia quickly reacts with water to form ammonium (NH_4^+). In this positively charged form, the ion is not susceptible to gaseous loss because it is temporarily attached to the negative charges on clay and organic matter. Some of the ammonia reacts with organic matter to become a part of the soil humus.

On silt loam or soils with finer textures, ammonia will move about 4 inches from the point of injection. On more coarsely textured soils such as sands, ammonia may move 5 to 6 inches from the point of injection. If the depth of application is shallower than the distance of movement, some ammonia may move

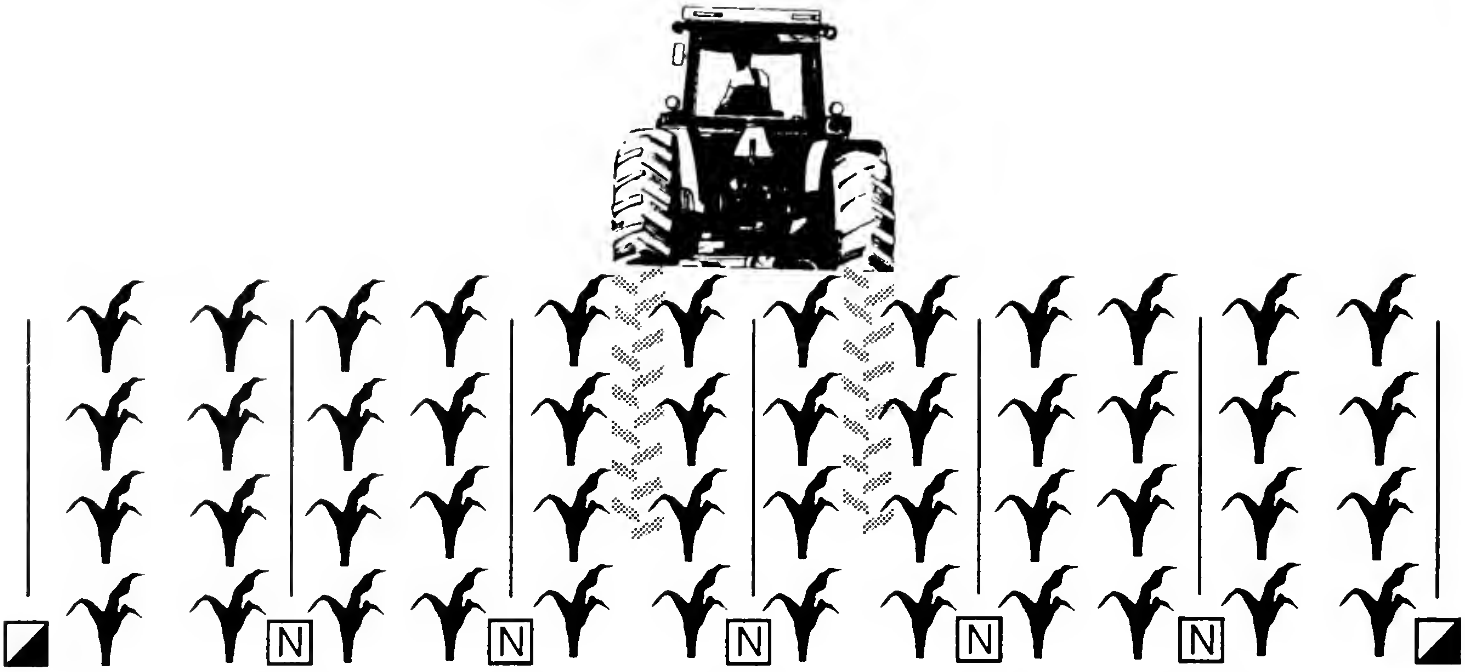


Figure 10.10. Schematic of every-other-row, sidedress nitrogen injection. Note that the outside two injectors are set at one-half rate because the injector will run between those two rows twice.

Table 10.16. Composition of Various Nitrogen Fertilizers

Material	Total nitrogen %	Percent of total nitrogen as				Salting out temperature	Weight of solution per gallon
		Ammonia	Ammonium	Nitrate	Urea		
Anhydrous ammonia	82	100	—	—	—	—	5.90
Ammonium nitrate	34	—	50	50	—	—	—
Ammonium sulfate	21	—	100	—	—	—	—
Urea	46	—	—	—	100	—	—
Urea-ammonium nitrate	28	—	25	25	50	-1	10.70
Urea-ammonium nitrate	32	—	25	25	50	32	11.05

slowly to the soil surface and escape as a gas over a period of several days. On coarse-textured (sandy) soils, anhydrous ammonia should be placed 8 to 10 inches deep, whereas on silt-loam soils, the depth of application should be 6 to 8 inches. Anhydrous ammonia is lost more easily from shallow placement than is ammonia in low-pressure solutions. Nevertheless, low-pressure solutions contain free ammonia and thus need to be incorporated into the soil at a depth of 2 to 4 inches. Ammonia should not be applied to soils having a physical condition that would prevent closure of the applicator knife track. Ammonia will escape to the atmosphere whenever there is a direct opening from the point of injection to the soil surface.

Seedlings can be damaged if proper precautions are not taken when applying nitrogen materials that contain or form free ammonia. Damage may occur if nitrogen material is injected into soils that are so wet that the knife track does not close properly. If the soil dries rapidly, this track may open. Damage can also result from applying nitrogen material to excessively dry soils, which allow the ammonia to move large distances before being absorbed. Finally, damage to seedlings can be caused by using a shallower application than that suggested in the preceding paragraph. Generally, delaying planting 3 to 5 days after applying fertilizer will cause little, if any, seedling damage. Under extreme conditions, however, seedling damage has been observed even when planting was delayed for 2 weeks after the fertilizer was applied.

Ammonium nitrate. Half of the nitrogen contained in ammonium nitrate is in the ammonium form, and half is in the nitrate form. The part present as ammonium attaches to the negative charges on the clay and organic-matter particles and remains in that state until it is used by the plant or converted to the nitrate ions by microorganisms present in the soil. Because 50 percent of the nitrogen is present in the nitrate form, this product is more susceptible to loss from both leaching and denitrification. Thus, ammonium nitrate should not be applied to sandy soils because of the likelihood of leaching, nor should it be applied far in advance of the time when the crop needs the nitrogen because of possible loss through denitrification.

Urea. The chemical formula for urea is $CO(NH_2)_2$. In this form, it is very soluble and moves freely up and down with soil moisture. After being applied to the soil, urea is converted to ammonia, either chemically or by the enzyme urease. The speed with which this conversion occurs depends largely on temperature. At low temperatures, conversion is slow; but at temperatures of 55°F or higher, conversion is rapid.

If the conversion of urea occurs on the soil surface or on the surface of crop residue or leaves, some of the resulting ammonia will be lost as a gas to the atmosphere. The potential for loss is greatest when:

1. Temperatures are greater than 55°F. Loss is less likely with winter or early spring applications, but results show that the loss may be substantial if the materials remain on the surface of the soil for several days.
2. Considerable crop residue remains on soil surface.
3. Application rates are greater than 100 pounds of nitrogen per acre.
4. The soil surface is moist and rapidly drying.
5. Soils have a low cation-exchange capacity.
6. Soils are neutral or alkaline in reaction.

Research conducted at both the Brownstown and Dixon Springs research centers has shown that surface application of urea for zero-till corn did not yield as well as ammonium nitrate in most years (Table 10.17). In years when a rain was received within 1 or 2 days after application, urea resulted in as good a yield increase as did ammonium nitrate (that is, compared to results from early spring application of ammonium nitrate at Dixon Springs in 1975). In other studies, urea that was incorporated soon after application yielded as well as ammonium nitrate.

Urease inhibitor. Chemical compound N-(n-butyl) thiophosphoric triamide, commonly referred to as NBPT, has been shown to inhibit the urease enzyme that converts urea to ammonia. This material, scheduled for release to the market for the 1993 crop year, will be sold as a product that could be added to urea-ammonium nitrate solutions or to urea in the manufacturing process. Addition of this material will reduce the potential for volatilization of surface-applied, urea-containing products. Experimental results collected around the Corn Belt over the last several years have shown an average increase of 4.3 bushels per acre when applied with urea and 1.6 bushels per acre when applied with urea-ammonium nitrate solutions. Where nonvolatile nitrogen treatments resulted in a higher yield than unamended urea, addition of the urease inhibitor increased yield by 6.6 bushels per acre for urea and by 2.7 bushels per acre for urea-ammonium nitrate solutions.

Table 10.17. Effect of Source of Nitrogen on Yield for Zero-Till Corn

Nitrogen						
Source	Date of application	Method of application	Rate, lb/acre	Brownstown 1974-77 avg.	Dixon Springs 1974	Dixon Springs 1975
				yield, bu/acre		
Control....	...	...	0	52	50	...
Ammonium nitrate...	early spring	surface	120	96	132	160
Urea	early spring	surface	120	80	106	166
Ammonium nitrate...	early June	surface	120	106	151	187
Urea	early June	surface	120	99	125	132

Urease inhibitors have the greatest potential for benefit when urea-containing materials are surface-applied without incorporation at 50°F or higher. The potential is even greater if there is significant residue remaining on the soil surface. In situations where the urea-containing materials can be incorporated within 2 days after application, either with a tillage operation of with adequate rainfall, the potential for benefit from a urease inhibitor is very low.

Ammonium sulfate. The compound ammonium sulfate ($[NH_4]_2SO_4$) supplies all of the nitrogen in the ammonium form. As a result, it theoretically has a slight advantage over products that supply a portion of their nitrogen in the nitrate form, because the ammonium form is not susceptible to leaching or denitrification. However, this advantage is usually short-lived because all ammonium-based materials quickly convert to nitrate once soil temperatures are favorable for activity of soil organisms (soil temperatures above 50°F). With the exception of application on high-pH soils, there is little risk of loss of the ammonium through volatilization.

Ammonium sulfate is an excellent material to use on soils that may be deficient in both nitrogen and sulfur. However, application of the material at a rate sufficient to meet the nitrogen need will cause over-application of sulfur. That is not of concern because sulfur is mobile and will move out of the profile quickly. Fortunately, there is no known environmental problem associated with sulfur in water supplies.

Most of the ammonium sulfate available in the marketplace is a by-product of the steel, textile, or lysine industry and is marketed as either a dry granulated material or as a slurry.

Ammonium sulfate is more acidifying than any of the other nitrogen materials on the market. As a rough rule, ammonium sulfate requires about 9 pounds of lime per pound of nitrogen applied, compared to 4 pounds of lime per pound of nitrogen from ammonia or urea. The extra acidity is of no concern as long as the soil is monitored for pH every 4 years.

In areas where fall application is acceptable, ammonium sulfate could be applied in late fall (after temperatures have fallen below 50°F) or in winter on frozen ground where the slope is less than 5 percent.

Nitrogen solutions. The nonpressure nitrogen solutions that contain 28 to 32 percent nitrogen consist of a mixture of urea and ammonium nitrate. Typically, half of the nitrogen is from urea, and the other half is from ammonium nitrate. The constituents of these compounds will undergo the same reactions as described above for the constituents applied alone.

Experiments at DeKalb have shown a yield difference between incorporated and unincorporated nitrogen solutions that were spring-applied (Table 10.18). This difference associated with method of application is probably caused by volatilization loss of some nitrogen from the surface-applied solution containing urea.

The effect on yield of postemergence application of nitrogen solutions and atrazine when corn plants are in the 3-leaf stage was evaluated in Minnesota. The results there indicated that yields were generally depressed when the nitrogen rate exceeded 60 pounds per acre. Leaf burn was increased by increasing the nitrogen rate, including atrazine with the nitrogen, and by hot, clear weather conditions.

Phosphorus and potassium

Inherent availability

Illinois has been divided into three regions in terms of the inherent phosphorus-supplying power of the soil below the plow layer in dominant soil types (see Figure 10.11).

High phosphorus-supplying power means that the soil test for available phosphorus (P_1 test) is relatively high and conditions are favorable for good root penetration and branching throughout the soil profile.

Low phosphorus-supplying power may be caused by one or more of these factors:

1. A low supply of available phosphorus in the soil profile because (a) the parent material was low in phosphorus; (b) phosphorus was lost in the soil-forming process; or (c) the phosphorus is made unavailable by high pH (calcareous) material.
2. Poor internal drainage that restricts root growth.
3. A dense, compact layer that inhibits root penetration or branching.
4. Shallowness to bedrock, sand, or gravel.
5. Droughtiness, strong acidity, or other conditions that restrict crop growth and reduce rooting depth.

Table 10.18. Effect of Source, Method of Application, and Rate of Spring-Applied Nitrogen on Corn Yield, DeKalb

Carrier and method of application	N, lb/acre	Year		
		1976	1977	Avg.
		yield, bu/acre		
None	0	66	61	64
Ammonia	80	103	138	120
28 percent N solution, incorporated	80	98	132	115
28 percent N solution, unincorporated	80	86	126	106
Ammonia	160	111	164	138
28 percent N solution, incorporated	160	107	157	132
28 percent N solution, unincorporated	160	96	155	126
Ammonia	240	112	164	138
28 percent N solution, incorporated	240	101	164	132
28 percent N solution, unincorporated	240	91	153	122
LSD_{10}[a]		9.1	5.2	

[a] Differences greater than the LSD value are statistically significant.

Regional differences in phosphorus-supplying power are shown in Figure 10.11. Parent material and degree of weathering were the primary factors considered in determining the various regions.

The "high" region is in western Illinois, where the primary parent material was more than 4 to 5 feet of loess that was high in phosphorus content. The soils are leached of carbonates to a depth of more than 3½ feet, and roots can spread easily in the moderately permeable profiles.

The "medium" region is in central Illinois, with arms extending into northern and southern Illinois. The primary parent material was more than 3 feet of loess over glacial till, glacial drift, or outwash. Some sandy areas with low phosphorus-supplying power occur in the region. In comparison with the high-phosphorus region, more of the soils are poorly drained and have less available phosphorus in the subsoil and substratum horizons. Carbonates are likely to occur at shallower depths than in the "high" region. The soils in the northern and central areas are generally free of

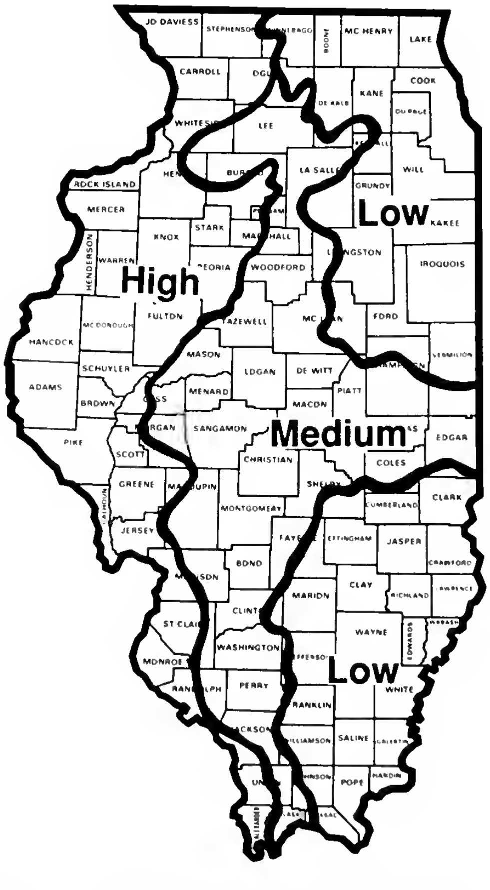


Figure 10.11. Phosphorus-supplying power.

root restrictions, whereas soils in the southern arm are more likely to have root-restricting layers within the profile. The phosphorus-supplying power of soils of the region is likely to vary with natural drainage. Soils with good internal drainage are likely to have higher levels of available phosphorus in the subsoil and substratum. If internal drainage is fair or poor, phosphorus levels in the subsoil and substratum are likely to be low or medium.

In the "low" region in southeastern Illinois, the soils were formed from 2½ to 7 feet of loess over weathered Illinoisan till. The profiles are more highly weathered than in the other regions and are slowly or very slowly permeable. Root development is more restricted than in the "high" or "medium" regions. Subsoil levels of phosphorus may be rather high by soil test in some soils of the region, but this is partially offset by conditions that restrict rooting.

In the "low" region in northeastern Illinois, the soils were formed from thin loess (less than 3 feet) over glacial till. The glacial till, generally low in available phosphorus, ranges in texture from gravelly loam to clay in various soil associations of the region. In addition, shallow carbonates further reduce the phosphorus-supplying power of the soils of the region. Further, high bulk density and slow permeability in the subsoil and substratum restrict rooting in many soils of the region.

The three regions are delineated to show broad differences among them. Parent material, degree of weathering, native vegetation, and natural drainage vary within a region and cause variation in the soil's phosphorus-supplying power. It appears, for example, that soils developed under forest cover have more available subsoil phosphorus than those developed under grass.

Illinois is divided into two general regions for potassium, based on cation-exchange capacity (Figure 10.12). Important differences exist, however, among soils within these general regions because of differences in these factors:

1. The amount of clay and organic matter, which influences the exchange capacity of the soil.
2. The degree of weathering of the soil material, which affects the amount of potassium that has been leached out.
3. The kind of clay mineral.
4. Drainage and aeration, which influence uptake of potassium.
5. The parent material from which the soil was formed.
6. Compactness or other conditions that influence root growth.

Soils that have a cation-exchange capacity less than 12 me/100 gram are classified as having low cation-exchange capacity. These soils include the sandy soils because minerals from which these soils were developed are inherently low in potassium. Sandy soils also have very low cation-exchange capacities and thus do not hold much reserve potassium.

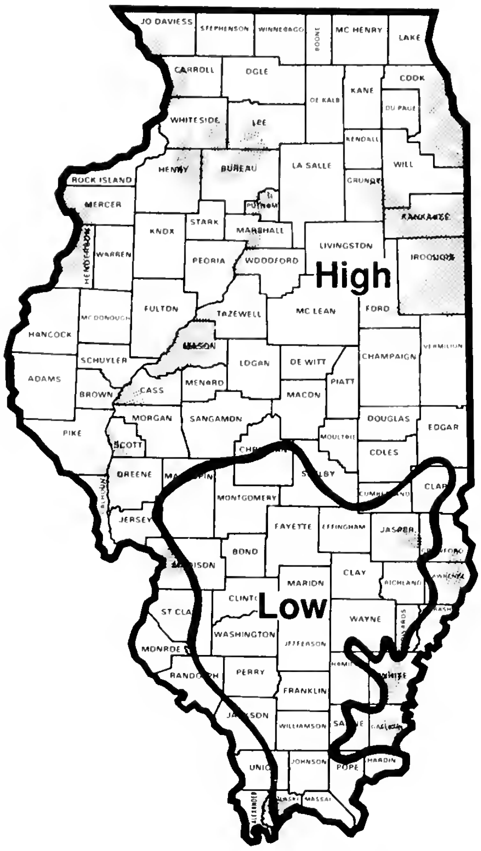


Figure 10.12. Cation-exchange capacity. The shaded areas are sands with low cation-exchange capacity.

Silt-loam soils in the "low" area in southern Illinois (claypans) are relatively older in terms of soil development; consequently, much more of the potassium has been leached out of the rooting zone. Furthermore, wetness and a platy structure between the surface and subsoil may interfere with rooting and with potassium uptake early in the growing period, even though roots are present.

Rate of fertilizer application

Minimum soil-test levels required to produce optimum crop yields vary depending on the crop to be grown and the soil type (Figures 10.13 and 10.14). Near-maximum yields of corn and soybeans will be obtained when levels of available phosphorus are maintained at 30, 40, and 45 pounds per acre for soils in the high, medium, and low phosphorus-supplying regions, respectively. Potassium soil-test levels at which optimum yields of these two crops will be attained are 260 and 300 pounds of exchangeable potassium per acre for soils in the low and high cation-exchange capacity regions,· respectively. Because phosphorus, and on most soils also potassium, will not be lost from the soil system other than through crop removal or soil erosion and because these are minimum values required for optimum yields, it is recommended that soil-test levels be built up to 40, 45, and 50 pounds per acre of phosphorus for soils in the high, medium, and low phosphorus-supplying regions, respectively.

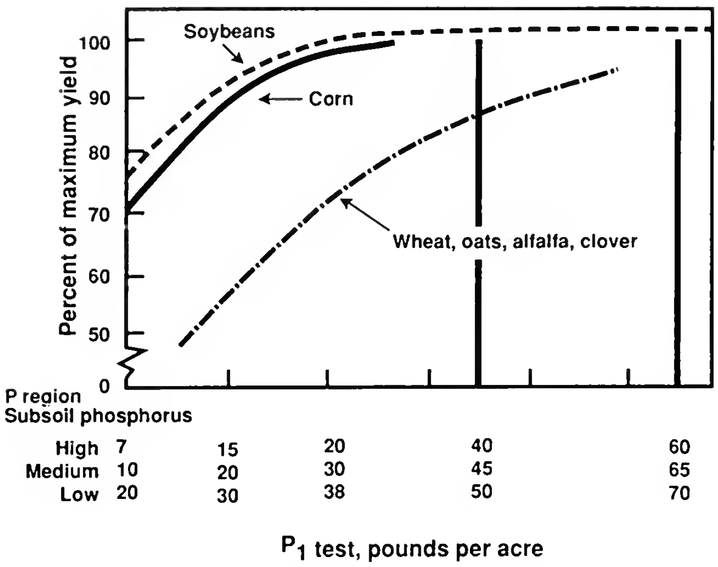


Figure 10.13. Relationship between expected yield and soil-test phosphorus.

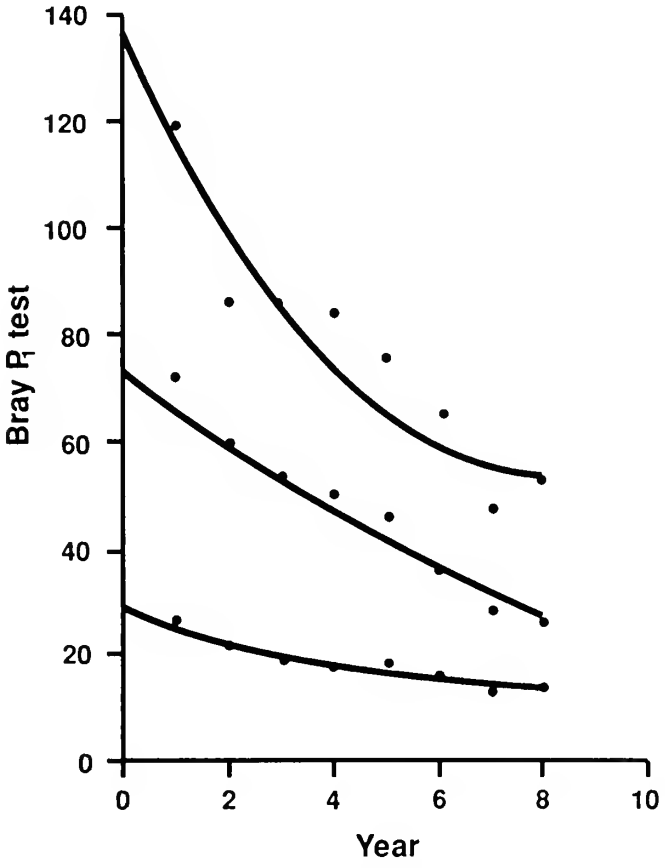


Figure 10.14. Effect of elimination of P fertilizer on P_1 soil test.

Depending on the soil-test level, the amount of fertilizer recommended may consist of a buildup plus maintenance; maintenance; or no fertilizer suggestion. The buildup is the amount of material required to increase the soil test to the desired level. The maintenance addition is the amount required to replace the amount that will be removed by the crop to be grown.

Buildup plus maintenance. When soil-test levels are below the desired values, it is suggested that enough fertilizer be added to build the soil test to the desired goal plus enough to replace what the crop will remove. At these test levels, the yield of the crop to be grown will be affected by the amount of fertilizer applied that year.

Maintenance. When the soil-test levels are between the minimum and 20 pounds above the minimum for phosphorus (that is, 40 to 60, 45 to 65, or 50 to 70) or between the minimum and 100 pounds above the minimum for potassium (that is, 260 to 360 or 300 to 400), apply enough to replace what the crop to be grown is expected to remove. The yield of the current crop may not be affected by the fertilizer addition that year, but the yield of subsequent crops will be adversely affected if the materials are not applied to maintain soil-test levels.

No fertilizer. Although it is recommended that soil-test levels be maintained slightly above the level at which optimum yield would be expected, it would not be economical to attempt to maintain the values at excessively high levels. *Therefore, it is suggested that no phosphorus be applied if P_1 values are higher than 60, 65, or 70, respectively, for soils in the high, medium, and low phosphorus-supplying regions. No potassium is suggested if test levels are above 360 or 400 for the low and high cation-exchange capacity regions, unless crops that remove large amounts of potassium (such as alfalfa or corn silage) are being grown.* When soil-test levels are between 400 and 600 pounds per acre of potassium and corn silage or alfalfa is being grown, the soil should be tested every 2 years instead of 4, or maintenance levels of potassium should be added to ensure that soil-test levels do not fall below the point of optimum yields.

Consequences of omitting fertilizer. The impact of eliminating phosphorus or potassium fertilizer on yield and soil-test level will depend on the initial soil test and the number of years that applications are omitted. In a recent Iowa study, elimination of phosphorus application for 9 years decreased soil-test levels from 136 to 52 pounds per acre, but yields were not adversely affected in any year as compared to plots where soil-test levels were maintained (Figure 10.14). In the same study, elimination of phosphorus for the 9 years when the initial soil test was 29 resulted in a decrease in soil-test level to 14 and a decrease in yield to 70 percent of the yield obtained when adequate fertility was supplied. Elimination of phosphorus at an intermediate soil-test level had little impact on yield but decreased the soil-test level from 67 to 26 pounds per acre over the 9 years. These, as well as similar Illinois results, indicate that there is little if any potential for a yield decrease if phosphorus application was eliminated for 4 years on soils that have a phosphorus test of 60 pounds per acre or higher.

Phosphorus

Buildup. Research has shown that, as an average for Illinois soils, 9 pounds of P_2O_5 per acre are required to increase the P_1 soil test by 1 pound. Therefore, the recommended rate of buildup phosphorus is equal to nine times the difference between the soil-test goal and the actual soil-test value. The amount of phosphorus recommended for buildup over a 4-year period for various soil-test levels is presented in Table 10.19.

Because the rate of 9 pounds of P_2O_5 to increase the soil test by 1 pound is an average for Illinois soils, some soils will fail to reach the desired goal in 4 years with P_2O_5 applied at this rate, and others will exceed the goal. Therefore, it is recommended that each field be retested every 4 years.

In addition to the supplying power of the soil, the optimum soil-test value also is influenced by the crop to be grown. For example, the phosphorus soil-test level required for optimum yields of wheat and oats (Figure 10.13) is considerably higher than that required for corn and soybean yields, partly because wheat and corn have different phosphorus uptake patterns. Wheat requires a large amount of readily available phosphorus in the fall, when the root system is feeding primarily from the upper soil surface. Phosphorus is taken up by corn until the grain is fully developed, so subsoil phosphorus is more important in interpreting the phosphorus test for corn than for wheat. To compensate for the higher phosphorus requirements of wheat and oats, it is suggested that 1.5 times the amount of expected phosphorus removal be applied prior to seeding these crops.

Table 10.19. Amount of Phosphorus (P_2O_5) Required to Build Up the Soil (Based on Buildup Occurring over a 4-Year Period; 9 Pounds of P_2O_5 per Acre Required to Change P_1 Soil Test 1 Pound)

P_1 test, lb/acre	Pounds of P_2O_5 to apply per acre *each year* for soils with supplying power rated		
	Low	Medium	High
4	103	92	81
6	99	88	76
8	94	83	72
10	90	79	68
12	86	74	63
14	81	70	58
16	76	65	54
18	72	61	50
20	68	56	45
22	63	52	40
24	58	47	36
26	54	43	32
28	50	38	27
30	45	34	22
32	40	29	18
34	36	25	14
36	32	20	9
38	27	16	4
40	22	11	0
42	18	7	0
44	14	2	0
45	11	0	0
46	9	0	0
48	4	0	0
50	0	0	0

This correction has already been included in the maintenance values listed for wheat and oats in Table 10.20.

Maintenance. In addition to adding fertilizer to build up the soil test, sufficient fertilizer should be added each year to maintain a specified soil-test level. The amount of fertilizer required to maintain the soil-test value is equal to the amount removed by the harvested portion of the crop (Table 10.20). The only exception to this guideline is that the maintenance value for wheat and oats is equal to 1.5 times the amount of phosphorus (P_2O_5) removed by the grain. This correction has already been accounted for in the maintenance values given in Table 10.20.

Potassium

As indicated, phosphorus will usually remain in the soil unless it is removed by a growing crop or by erosion; thus soil levels can be built up as described. Experience during the past several years indicates that on most soils potassium tends to follow the buildup pattern of phosphorus, but on other soils, soil-test levels do not build up as expected. Because of this, both the buildup-maintenance and the annual application options are provided.

Producers whose soils have one or more of the following conditions should consider the annual application option:

1. Soils for which past records indicate that soil-test potassium does not increase when buildup applications are applied.
2. Sandy soils that do not have a capacity large enough to hold adequate amounts of potassium.
3. Agricultural lands having an unknown or very short tenure arrangement.

On all other fields, use of the buildup-maintenance option is suggested.

Rate of fertilizer application

Buildup. The only significant loss of soil-applied potassium is through crop removal or soil erosion. Therefore, it is recommended that soil-test potassium be built up to values of 260 and 300 pounds of exchangeable potassium, respectively, for soils in the low and high cation-exchange capacity region. These values are slightly higher than that required for maximum yield, but as in the recommendations for phosphorus, this will ensure that potassium availability will not limit crop yields (Figure 10.15).

Research has shown that 4 pounds of K_2O are

Table 10.20. Maintenance Fertilizer Required for Various Yields of Crops

Yield, per acre	P_2O_5	K_2O[a]
	----- *pounds per acre* -----	
Corn grain		
90 bu	39	25
100	43	28
110	47	31
120	52	34
130	56	36
140	60	39
150	64	42
160	69	45
170	73	48
180	77	50
190	82	53
200	86	56
Oats		
50 bu	19[b]	10
60	23	12
70	27	14
80	30	16
90	34	18
100	38	20
110	42	22
120	46	24
130	49	26
140	53	28
150	57	30
Soybeans		
30 bu	26	39
40	34	52
50	42	65
60	51	78
70	60	91
80	68	104
90	76	117
100	85	130
Corn silage		
90 bu; 18 tons	48	126
100; 20	53	140
110; 22	58	154
120; 24	64	168
130; 26	69	182
140; 28	74	196
150; 30	80	210
Wheat		
30 bu	27[b]	9
40	36	12
50	45	15
60	54	18
70	63	21
80	72	24
90	81	27
100	90	30
110	99	33
Alfalfa, grass, or alfalfa-grass mixtures		
2 tons	24	100
3	36	150
4	48	200
5	60	250
6	72	300
7	84	350
8	96	400
9	108	450
10	120	500

[a] If the annual application option is chosen, then K application will be 1.5 times the values shown.

[b] Values given are 1.5 times actual removal.

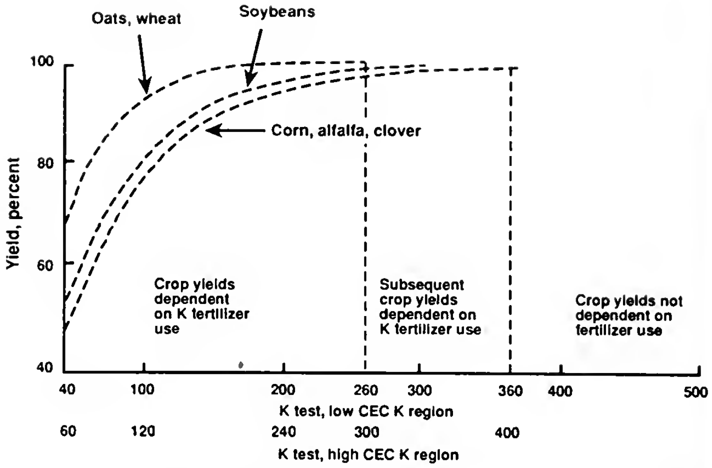


Figure 10.15. Relationship between expected yield and soil-test potassium.

required, on the average, to increase the soil test by 1 pound. Therefore, the recommended rate of potassium application for increasing the soil-test value to the desired goal is equal to four times the difference between the soil-test goal and the actual value of the soil test.

Tests on soil samples that are taken before May 1 or after September 30 should be adjusted downward as follows: subtract 30 for the dark-colored soils in central and northern Illinois; subtract 45 for the light-colored soils in central and northern Illinois, and fine-textured bottomland soils; and subtract 60 for the medium- and light-colored soils in southern Illinois. Annual buildup rates of potassium application recommended for a 4-year period for various soil test values are presented in Table 10.21.

Wheat is not very responsive to potassium unless the soil test value is less than 100. Because wheat is usually grown in rotation with corn and soybeans, it is suggested that the soils be maintained at the optimum available potassium level for corn and for soybeans.

Maintenance. As with phosphorus, the amount of fertilizer required to maintain the soil-test value equals the amount removed by the harvested portion of the crop (Table 10.20).

Annual application option. If soil-test levels are below the desired buildup goal, apply potassium fertilizer annually at an amount equivalent to 1.5 times the potassium content in the harvested portion of the expected yield. If levels are only slightly below desired buildup levels, so that buildup and maintenance are less than 1.5 times removal, add the lesser amount. Continue to monitor the soil-test potassium level every 4 years.

If soil-test levels are within a range from the desired goal to 100 pounds above the desired potassium goal, apply enough potassium fertilizer to replace what the harvested yield will remove.

Each of the proposed options (buildup-maintenance and annual) has advantages and disadvantages. In the

Table 10.21. Amount of Potassium (K_2O) Required to Build Up the Soil (Based on the Buildup Occurring over a 4-Year Period; 4 Pounds of K_2O per Acre Required to Change the K Test 1 Pound)

K test[a], pounds per acre	Amount of K_2O to apply per acre *each year* for soils with cation-exchange capacity: Low[b]	High[b]
50	210	250
60	200	240
70	190	230
80	180	220
90	170	210
100	160	200
110	150	190
120	140	180
130	130	170
140	120	160
150	110	150
160	100	140
170	90	130
180	80	120
190	70	110
200	60	100
210	50	90
220	40	80
230	30	70
240	20	60
250	10	50
260	0	40
270	0	30
280	0	20
290	0	10
300	0	0

[a] Tests on soil samples that are taken before May 1 or after September 30 should be adjusted downward as follows: subtract 30 pounds for dark-colored soils in central and northern Illinois; 45 pounds for light-colored soils in central and northern Illinois, and fine-textured bottomland soils; and 60 pounds for medium- and light-colored soils in southern Illinois.

[b] Low cation-exchange capacity soils are those with CEC less than 12 me/100 g soil; high capacity soils are those with CEC at least 12 me/100 g soil.

short run, the annual option will likely be less costly. In the long run, the buildup approach may be more economical. In years of high income, tax benefits may be obtained by applying high rates of fertilizer. Also, in periods of low fertilizer prices, the soil can be built to higher levels that in essence bank the materials in the soil for use at a later date when the economy may not be as good for fertilizer purchases. Producers using the buildup system are insured against yield loss that may occur in years when weather conditions prevent fertilizer application or in years when fertilizer supplies are not adequate. The primary advantage of the buildup concept is the slightly lower risk of potential yield reduction that may result from lower annual fertilizer rates. This is especially true in years of exceptionally favorable growing conditions. The primary disadvantage of the buildup option is the high cost of fertilizer in the initial buildup years.

Examples of how to figure phosphorus and potassium fertilizer recommendations follow.

Example 1. Continuous corn with a yield goal of 140 bushels per acre:

(a)

Soil-test results	*Soil region*
P_1 30	high
K 250	high

(b) *Fertilizer recommendation, pounds per acre per year*

	P_2O_5	K_2O
Buildup	22 (Table 10.19)	50 (Table 10.21)
Maintenance	60 (Table 10.20)	39 (Table 10.20)
Total	82	89

Example 2. Corn-soybean rotation with a yield goal of 140 bushels per acre for corn and 40 bushels per acre for soybeans:

(a)

Soil-test results	*Soil region*
P_1 20	low
K 200	low

(b) *Fertilizer recommendation, pounds per acre per year*

	P_2O_5	K_2O
	Corn	
Buildup	68	60
Maintenance	60	39
Total	128	99
	Soybeans	
Buildup	68	60
Maintenance	34	52
Total	102	112

Note that buildup recommendations are independent of the crop to be grown, but maintenance recommendations are directly related to the crop to be grown and the yield goal for the particular crop.

Example 3. Continuous corn with a yield goal of 150 bushels per acre:

(a)

Soil-test results	*Soil region*
P_1 90	low
K 420	low

(b) *Fertilizer recommendation, pounds per acre per year*

	P_2O_5	K_2O
Buildup	0	0
Maintenance	0	0
Total	0	0

Note that soil-test values are higher than those suggested; thus no fertilizer is recommended. Retest the soil after 4 years to determine fertility needs.

Example 4. Corn-soybean rotation with a yield goal of 120 bushels per acre for corn and 35 bushels per acre for soybeans:

(a)

Soil-test results	*Soil region*
P_1 20	low
K 180	low (soil test does not increase as expected)

(b) *Fertilizer recommendation, pounds per acre per year*

	P_2O_5	K_2O
	Corn	
Buildup........	68	. . .
Maintenance ..	52	. . .
Total...........	120	51 (34 x 1.5)
	Soybeans	
Buildup........	68	. . .
Maintenance ..	30	. . .
Total...........	98	69 (46 x 1.5)

For farmers planning to double-crop soybeans after wheat, it is suggested that phosphorus and potassium fertilizer required for both the wheat and soybeans be applied before seeding the wheat. This practice will reduce the number of field operations necessary at planting time and will hasten the planting operation.

The maintenance recommendations for phosphorus and potassium in a double-crop wheat and soybean system are presented in Tables 10.22 and 10.23, respectively. Assuming a wheat yield of 50 bushels per acre followed by a soybean yield of 30 bushels per acre, the maintenance recommendation would be 71 pounds of P_2O_5 and 54 pounds of K_2O per acre.

Table 10.22. Maintenance Phosphorus Required for Wheat-Soybean Double-Crop System

Wheat yield, bu/acre	Soybean yield, bu/acre				
	20	30	40	50	60
			P_2O_5, *lb/acre*		
30....................	44	53	61	69	78
40....................	53	62	70	78	87
50....................	62	71	79	87	96
60....................	71	80	88	96	105
70....................	80	89	97	105	114
80....................	89	98	106	114	123

Table 10.23. Maintenance Potassium Required for Wheat-Soybean Double-Crop System

Wheat yield, bu/acre	Soybean yield, bu/acre				
	20	30	40	50	60
			K_2O, *lb/acre*		
30....................	35	48	61	74	87
40....................	38	51	64	77	90
50....................	41	54	67	80	93
60....................	44	57	70	83	96
70....................	47	60	73	86	99
80....................	50	63	76	89	102

Computerized recommendations

Soil fertility recommendations have been incorporated into a microcomputer program that utilizes the soil-test information, soil type and characteristics, cropping and management history, cropping plans and yield goals to develop recommendations for lime, nitrogen, phosphorus, and potassium. This program, called *Soil Plan,* groups together similar fertilizer recommendations and provides a map showing where each recommendation should be implemented within the field. Users have the option of altering the map to adjust to the kind of spread pattern desired. Additionally, the user can change the different variables to determine their impact on fertilizer needed.

Further information about this program may be obtained from Illinet Software, 330 Mumford Hall, 1301 West Gregory Drive, Urbana, IL 61801.

Time of application

Although the fertilizer rates for buildup and maintenance in Tables 10.19 through 10.21 are for an annual application, producers may apply enough nutrients in any one year to meet the needs of the crops to be grown in the succeeding 2- to 3-year period.

Phosphorus and potassium fertilizers may be applied in the fall to fields that will not be fall-tilled, provided that the slope is less than 5 percent. Do not fall-apply fertilizer to fields that are subject to rapid runoff. When the probability of runoff loss is low, soybean stubble need not be tilled solely for the purpose of incorporating fertilizer. This statement holds true when ammoniated phosphate materials are used as well because the potential for volatilization of nitrogen from ammoniated phosphate materials is insignificant.

For perennial forage crops, broadcast and incorporate all of the buildup and as much of the maintenance phosphorus as economically feasible before seeding. On soils with low fertility, apply 30 pounds of phosphate (P_2O_5) per acre using a band seeder. If a band seeder is used, you may safely apply a maximum of 30 to 40 pounds of potash (K_2O) per acre in the band with the phosphorus. Up to 600 pounds of K_2O per acre can be safely broadcast in the seedbed without damaging seedlings.

Applications of phosphorus and potassium topdressed on perennial forage crops may be made at any convenient time. Usually this will be after the first harvest or in September.

High water-solubility of phosphorus

The water-solubility of the P_2O_5 listed as available on the fertilizer label is of little importance under typical field crop and soil conditions on soils with medium to high levels of available phosphorus, when recommended rates of application and broadcast placement are used.

For some situations, water-solubility is important. These situations include the following:

1. For band placement of a small amount of fertilizer to stimulate early growth, at least 40 percent of the phosphorus should be water-soluble for application to acidic soils and, preferably, 80 percent for calcareous soils. As shown in Table 10.24, the phosphorus in nearly all fertilizers commonly sold in Illinois is highly water-soluble. Phosphate water-solubility in excess of 80 percent has not been shown to give further yield increases above those that have water-solubility levels of at least 50 percent.
2. For calcareous soils, a high degree of solubility in water is desirable, especially on soils that are shown by soil test to be low in available phosphorus.

Secondary nutrients

The elements that are classified as secondary nutrients include calcium, magnesium, and sulfur. Crop yield response to application of these three nutrients has been observed on a very limited basis in Illinois. Therefore, the data base necessary to correlate and calibrate soil-test procedures is limited, and thus the reliability of the suggested soil-test levels for the secondary nutrients presented in Table 10.25 is low.

Deficiency of calcium has not been recognized in Illinois where soil pH is 5.5 or above. Calcium deficiency associated with acidic soils should be corrected by the use of limestone that is adequate to correct the soil pH.

Table 10.24. Characteristics of Some Common Processed-Phosphate Materials

Material	Percent P_2O_5	Percent water-soluble	Percent citrate-soluble	Total pct. available
Ordinary superphosphate 0-20-0	16-22	78	18	96
Triple superphosphate	44-47	84	13	97
Mono-ammonium phosphate 11-48-0	46-48	100	...	100
Diammonium phosphate 18-46-0	46	100	...	100
Ammonium polyphosphate 10-34-0, 11-37-0	34-37	100	...	100

Table 10.25. Suggested Soil-Test Levels for the Secondary Nutrients

	Levels that are adequate for crop production			
Soil type	Calcium	Magnesium	Rating	Sulfur
	pounds per acre			*lb/acre*
Sandy	400	60-75	Very low	0-12
Silt loam	800	150-200	Low	12-22
			Response unlikely	22

Magnesium deficiency has been recognized in isolated situations in Illinois. Although the deficiency is usually associated with acidic soils, in some instances low magnesium has been reported on sandy soils that were not excessively acidic. The soils most likely to be deficient in magnesium include sandy soils throughout Illinois and low exchange-capacity soils of southern Illinois. Deficiency will be more likely where calcitic rather than dolomitic limestone has been used and where potassium test levels have been high (greater than 400).

Recognition of sulfur deficiency has been reported with increasing frequency throughout the Midwest. These deficiencies probably are occurring because of (1) increased use of S-free fertilizer, (2) decreased use of sulfur as a fungicide and insecticide, (3) increased crop yields, resulting in increased requirements for all of the essential plant nutrients, and (4) decreased atmospheric sulfur supply.

Organic matter is the primary source of sulfur in soils. Thus soils low in organic matter are more likely to be deficient than are soils with a high level of organic matter. Because sulfur is very mobile and can be readily leached, deficiency is more likely to be found on sandy soils than on finer-textured soils.

A yield response to sulfur application was observed at 5 of 85 locations in Illinois (Table 10.26). Two of these responding sites, one an eroded silt loam and one a sandy soil, were found in northwestern Illinois (Whiteside and Lee counties); one site, a silty clay loam, was in central Illinois (Sangamon County); and two sites, one a silt loam and one a sandy loam, were in southern Illinois (Richland and White counties).

At the responding sites, sulfur treatments resulted in corn yields that averaged 11.2 bushels per acre more than yields from the untreated plots. At the nonresponding sites, yields from the sulfur-treated plots averaged only 0.6 bushel per acre more than those from the untreated plots (Table 10.26). If only the responding sites are considered, the sulfur soil test predicts with good reliability which sites will respond to sulfur applications. Of the five responding sites, one had only 12 pounds of sulfur per acre, less than the amount considered necessary for normal plant

Table 10.26. Average Yields at Responding and Nonresponding Zinc and Sulfur Test Sites, 1977-79

	Number of sites	Yield from untreated plots	Yield from zinc-treated plots	Yield from sulfur-treated plots
		bushels per acre		
Responding sites				
Low-sulfur soil	5	140.0	...	151.2
Low-zinc soil	3	150.6	164.7	...
Nonresponding sites	80	147.6	146.2	148.2

growth, and three had marginal sulfur concentration (from 12 to 20 pounds of sulfur per acre). Sulfur tests on the 80 nonresponding sites showed 14 to be deficient and 29 to have a level of sulfur that is considered marginal for normal plant growth. Sulfur applications, however, produced no significant positive response in these plots. The correlation between yield increases and measured sulfur levels in the soil was very low, indicating that the sulfur soil test did not reliably predict sulfur need.

Experiments were conducted over a 2-year period on a Cisne silt loam and a Grantsburg silt loam in southern Illinois to evaluate the effect of sulfur application on wheat production. Even though increasing rates of sulfur application caused an increase in the sulfur concentration of the flag leaf and the whole plant, it did not increase grain yield at either location in either year. Based on these two years of study, routine application of sulfur fertilizer for wheat production does not appear warranted.

In addition to soil-test values, one should also consider organic-matter level, potential atmospheric sulfur contributions, subsoil sulfur content, and moisture conditions just before soil sampling in determining whether a sulfur response is likely. If organic-matter levels are greater than 2.5 percent or if the field in question is located in an area downwind from industrial operations where significant amounts of sulfur are being emitted, use sulfur only on a trial basis even when the soil-test reading is low. Because sulfur is a mobile nutrient supplied principally by organic-matter oxidation, abnormal precipitation (either high or low) could adversely affect the sulfur status of samples taken from the soil surface. If precipitation has been high just before sampling, some samples may have a low reading due to leaching. If precipitation were low and temperatures warm, some soils might have a high reading when, in fact, the soil is not capable of supplying adequate amounts of sulfur throughout the growing season.

Micronutrients

The elements that are classified as essential micronutrients include zinc, iron, manganese, copper, boron, molybdenum, and chlorine. These nutrients are classified as micronutrients because they are required in small (micro) amounts. Confirmed deficiencies of these micronutrients in Illinois have been limited to boron deficiency of alfalfa, zinc deficiency of corn, and iron and manganese deficiencies of soybeans.

Similar to the tests for secondary nutrients, the reliability and usefulness of micronutrient tests are very low because of the limited data base available to correlate and calibrate the tests. Suggested levels for each of the tests are provided in Table 10.27. In most cases, use of plant analysis will probably provide a better estimate of micronutrient needs than will the soil test.

Table 10.27. Suggested Soil-Test Levels for Micronutrients

Micronutrient and procedure	Soil-test level		
	Very low	Low	Adequate
	------------ *pounds per acre* ------------		
Boron (hot-water soluble)	0.5	1	2
Iron (DTPA)	...	<4	>4
Manganese (DTPA)	...	<2	>2
Manganese (H_3PO_4)	...	<10	>10
Zinc (.1N HCl)	...	<7	>7
Zinc (DTPA)	...	<1	>1

Manganese deficiency (stunted plants with green veins in yellow or whitish leaves) is common on high-pH (alkaline), sandy soils, especially during cool, wet weather in late May and June. Suggested treatment is to spray either manganese sulfate or an organic manganese formulation onto the leaves soon after the symptoms first appear; use the rate suggested by the manufacturer. Broadcast application on the soil is ineffective because the manganese becomes unavailable in soils with a high pH.

Wayne and Hark soybean varieties or lines developed from them often show iron deficiency on soils with a very high pH (usually 7.4 to 8.0). The symptoms are similar to those shown with manganese deficiency. Most of the observed deficiencies have been on Harpster, a "shelly" soil that occurs in low spots in some fields in central and northern Illinois. This problem has appeared on Illinois farms only since the Wayne variety was introduced in 1964.

Soybeans often outgrow the stunted, yellow appearance of iron shortage. As a result, it has been difficult to measure yield losses or decide whether or how to treat affected areas. Sampling by U.S. Department of Agriculture scientists in 1967 indicated yield reductions of 30 to 50 percent in the center of severely affected spots. The yield loss may have been caused by other soil factors associated with a very high pH and poor drainage, rather than by iron deficiency itself. Several iron treatments were ineffective in trials near Champaign and DeKalb in 1968.

Research in Minnesota has shown that time of iron application is critical if a response is to be attained. Researchers recommend that a rate of 0.15 pound of iron per acre as iron chelate be applied to leaves within 3 to 7 days after chlorosis symptoms develop (usually in the second-trifoliate stage of growth). Waiting for soybeans to grow to the fourth- or fifth-trifoliate stage before applying iron resulted in no yield increase. Because iron applied to the soil surface between rows does not help, applications directed over the soybean plants were preferred.

A significant yield response to zinc applications was observed at 3 of 85 sites evaluated in Illinois (Table 10.26). The use of zinc at the responding sites produced a corn yield that averaged 14.1 bushels per acre more than the check plots. Two sites were Fayette silt loams in Whiteside County, and one was a Greenriver sand in Lee County.

At two of the three responding sites, tests showed that the soil was low or marginal in available zinc. The soil of the third had a very high zinc level but was deficient in available zinc, probably because of the excessively high phosphorus level also found at that site.

The zinc soil-test procedures accurately predicted results for two-thirds of the responding sites. The same tests, however, incorrectly predicted that 19 other sites would also respond. These results suggest that the soil test for available zinc can indicate where zinc deficiencies are found but does not indicate reliably whether the addition of zinc will increase yields.

To identify areas before micronutrient deficiencies become important, continually observe the most sensitive crops in soil situations in which the elements are likely to be deficient (Table 10.28).

In general, deficiencies of most micronutrients are accentuated by one of five situations: (1) strongly weathered soils, (2) coarse-textured soils, (3) high-pH soils, (4) organic soils, and (5) soils that are inherently low in organic matter or low in organic matter because erosion or land-shaping processes have removed the topsoil.

The use of micronutrient fertilizers should be limited to the application of specific micronutrients to areas of known deficiency. Only the deficient nutrient should be applied. An exception to this guideline would be situations in which farmers already in the highest yield bracket try micronutrients on an experimental basis in fields that are yielding less than would be expected under good management, which includes an adequate nitrogen, phosphorus, and potassium fertility program and a favorable pH.

Method of fertilizer application

With the advent of new equipment, producers have a number of options for placement of fertilizers. These options range from traditional broadcast application to injection of the materials at varying depths in the soil. Selection of the proper application technique for a particular field will depend at least in part upon the inherent fertility level, the crop to be grown, the land tenure, and the tillage system.

On fields where the fertility level is at or above the desired goal, there is little research evidence to show any significant difference in yield that is associated with method of application. In contrast, on low-testing soils and in soils that "fix" phosphorus, placement of the fertilizer within a concentrated band has been shown to result in higher yields, particularly at low rates of application. On higher-testing soils, plant recovery of applied fertilizer in the year of application will usually be greater from a band than a broadcast application, though yield differences are unlikely.

Broadcast fertilization. On highly fertile soils, both maintenance and buildup phosphorus and potassium will be efficiently utilized when broadcast and then plowed or disked in. This system, particularly when the tillage system includes a moldboard plow every few years, distributes nutrients uniformly throughout the entire plow depth. As a result, roots growing within that zone have access to high levels of fertility. Because the nutrients are intimately mixed with a large

Table 10.28. Soil Situations and Crops Susceptible to Micronutrient Deficiency

Micronutrient	Sensitive crop	Susceptible soil situations	Season favoring deficiency
Zinc (Zn)	Young corn	1. Low in organic matter, either inherently or because of erosion or land shaping 2. High pH, that is, >7.3 3. Very high phosphorus 4. Restricted root zone 5. Coarse-textured (sandy) soils 6. Organic soils	Cool, wet
Iron (Fe)	Wayne soybeans, grain sorghum	High pH	Cool, wet
Manganese (Mn)	Soybeans, oats	1. High pH 2. Restricted root zone 3. Organic soils	Cool, wet
Boron (B)	Alfalfa	1. Low organic matter 2. High pH 3. Strongly weathered soils in south-central Illinois 4. Coarse-textured (sandy) soils	Drought
Copper (Cu)	Corn, wheat	1. Infertile sand 2. Organic soils	Unknown
Molybdenum (Mo)	Soybeans	Strongly weathered soils in south-central Illinois	Unknown
Chlorine (Cl)	Unknown	Coarse-textured soils	Excessive leaching by low-Cl water

volume of soil, opportunity exists for increased nutrient fixation on soils having a high fixation ability. Fortunately, most Illinois soils do not have high fixation rates for phosphorus or potassium.

Row fertilization. On soils of low fertility, placement of fertilizer in a concentrated band below and to the side of the seed has been shown to be an efficient method of application, especially in situations for which the rate of application is markedly less than that needed to build the soil to the desired level. Producers who are not assured of having long-term tenure on the land may wish to consider this option. The major disadvantages of this technique are (1) the additional time and labor required at planting time, (2) limited contact between roots and fertilizer, and (3) inadequate rate of application to increase soil levels for future crops.

Strip application. With this technique, phosphorus, potassium, or both are applied in narrow bands on approximately 30-inch centers on the soil surface, in the same direction as the primary tillage. The theory behind this technique is that, after moldboard plowing, the fertilizer will be distributed in a narrow vertical band throughout the plow zone. Use of this system reduces the amount of soil-to-fertilizer contact as compared with a broadcast application, and thus it reduces the potential for nutrient fixation. Because the fertilizer is distributed through a larger soil volume than with a band application, the opportunity for root-fertilizer contact is greater.

Deep fertilizer placement. Several terms have been used to define this technique. They include root-zone banding, dual placement, knife injection, and deep placement. With this system a mixture of nitrogen-phosphorus or nitrogen-phosphorus-potassium is injected at a depth ranging from 4 to 8 inches. The knife spacings used may vary by crop to be grown, but generally they are 15 to 18 inches apart for close-grown crops such as wheat and 30 inches for row crops. Use of this technique provided a significantly higher wheat yield as compared with a broadcast application of the same rate of nutrients in some, but not all, experiments conducted in Kansas. Wisconsin research showed the effect of this technique to be equivalent to that of a band application for corn on a soil testing high in phosphorus but inferior to that of a band application for corn on a soil testing low in phosphorus. If this system is used on low-testing soils, it is advisable to apply a portion of the phosphorus fertilizer in a band with the planter.

Dribble fertilizer. This technique involves the application of urea-ammonium nitrate solutions in concentrated bands on 30-inch spacings on the soil surface. Results from several states have shown that this system reduces the potential for nitrogen loss of these materials, as compared with an unincorporated broadcast application. However, it has not been shown to be superior to an injected or an incorporated application of urea-ammonium nitrate solution.

"Pop-up" fertilization. The term "pop-up" is a misnomer. The corn does not emerge sooner than it does without this kind of application, and it may come up 1 or 2 days later. The corn may, however, grow more rapidly during the first 1 to 2 weeks after emergence. Pop-up fertilizer will make corn look very good early in the season and may aid in early cultivation for weed control. But no substantial difference in yield is likely in most years due to a pop-up application as compared to fertilizer that is placed in a band to the side and below the seed. Seldom will there be a difference of more than a few days in the time the root system intercepts fertilizer placed with the seed as compared to that placed below and to the side of the seed.

If used, pop-up fertilizer should contain all three major nutrients in a ratio of about 1-4-2 of N-P_20_5-K_20 (1-1.7-1.7 of N-P-K). Under normal moisture conditions, the maximum safe amount of N plus K_20 for pop-up placement is about 10 or 12 pounds per acre in 40-inch rows and correspondingly more in 30- and 20-inch rows. In excessively dry springs, even these low rates may result in damage to seedlings, reduction in germination, or both. Pop-up fertilizer is unsafe for soybeans. In research conducted at Dixon Springs, a stand was reduced to one-half by applying 50 pounds of 7-28-14 and reduced to one-fifth with 100 pounds of 7-28-14.

Site-specific application. Equipment has recently been developed that uses computer technology to alter the rate of fertilizer application as the truck passes across the field. Although this technology and the supporting research are still in their infancy, this approach offers the potential to improve yield while minimizing the potential for overfertilization. Yield improvement will result from applying the correct rate (not a rate based on average soil test) to the low-testing portions of the field. Overfertilization will be reduced by applying the correct rate (in many cases this may be zero) to high-testing areas of the field. The combination of improved yield and reduced output will result in improved profit.

Foliar fertilization. Researchers have known for many years that plant leaves absorb and utilize nutrients sprayed on them. Foliar fertilization has been used successfully for certain crops and nutrients. This method of application has had the greatest use with nutrients required in only small amounts by plants. Nutrients required in large amounts, such as nitrogen, phosphorus, and potassium, have usually been applied to the soil rather than the foliage.

The possible benefit of foliar-applied nitrogen fertilizer was researched at the University of Illinois in the 1950s. Foliar-applied nitrogen increased corn and wheat yield, provided that the soil was deficient in nitrogen. Where adequate nitrogen was applied to the soil, additional yield increases were not obtained from foliar fertilization.

Additional research in Illinois was conducted on foliar application of nitrogen to soybeans in the 1960s. This effort was an attempt to supply additional nitrogen to soybeans without decreasing nitrogen that was symbiotically fixed. That is, it was thought that if nitrogen application were delayed until after nodules were well established, then perhaps symbiotic fixation would remain active. Single or multiple applications of nitrogen solution to foliage did not increase soybean yields. Damage to vegetation occurred in some cases because of leaf "burn" caused by the nitrogen fertilizer.

Although considerable research in foliar fertilization had been conducted in Illinois already, new research was conducted in 1976 and 1977. This new research was prompted by a report from a neighboring state indicating that soybean yields had recently been increased by as much as 20 bushels per acre in some trials. Research in that state differed from earlier work on soybeans in that, in addition to nitrogen, the foliar fertilizer increased yield only if phosphorus, potassium, and sulfur were also included. Researchers there thought that soybean leaves become deficient in nutrients as nutrients are translocated from vegetative parts to the grain during grain development. They reasoned that foliar fertilization, which would prevent leaf deficiencies, should result in increased photosynthesis that would be expressed in higher grain yields.

Foliar fertilization research was conducted at several locations in Illinois during 1976 and 1977 — ranging from Dixon Springs in southern Illinois to DeKalb in northern Illinois. None of the experiments gave economical yield increases. In some cases there were yield reductions, which were attributed to leaf damage caused by the fertilizer. Table 10.29 contains data from a study at Urbana in which soybeans were sprayed four times with various fertilizer solutions. Yields were not increased by foliar fertilization.

Table 10.29. Yields of Corsoy and Amsoy Soybeans After Fertilizer Treatments Were Sprayed on the Foliage Four Times, Urbana

Treatment per spraying, lb/acre				Yield, bu/acre	
N	P_2O_5	K_2O	S	Corsoy	Amsoy
0	0	0	0	61	56
20	0	0	0	54	53
0	5	8	1	58	56
10	5	8	1	56	58
20	5	8	1	55	52
30	7.5	12	1.5	52	46

Nontraditional products

In this day of better informed farmers, it seems hard to believe that the number of letters, calls, and promotional leaflets about nontraditional products is increasing. The claim made is usually that "Product X" either replaces fertilizers and costs less, makes nutrients in the soil more available, supplies micronutrients, or is a natural product that does not contain strong acids that kill soil bacteria and earthworms.

The strongest position that legitimate fertilizer dealers, Extension advisers, and agronomists can take is to challenge these peddlers to produce unbiased research results in support of their claims. Testimonials by farmers are no substitute for research.

Extension specialists at the University of Illinois are ready to give unbiased advice when asked about purchasing new products or accepting a sales agency for them.

In addition, each Extension office has the publication *Compendium of Research Reports on the Use of Nontraditional Materials for Crop Production,* which contains data on a number of nontraditional products that have been tested in the Midwest. Check with the nearest Extension office for this information.

Chapter 11.

Soil Management and Tillage Systems

Soils are a natural resource. Mismanagement, neglect, and exploitation can ruin a soil for profitable agricultural production. In Illinois, the greatest concern for soil degradation is soil erosion due to water. The potential for soil erosion for a given slope largely depends on the crops grown and the number and types of tillage operations used to produce the crops.

Tillage is defined as any mechanical manipulation of soil with one of the many types of tillage tools available. A *tillage system* is the sequence of tillage operations performed in producing a crop. Selecting a tillage system for a particular farm situation is an important management decision. The tillage system selected affects virtually every aspect of crop production. The primary objective in selecting a tillage system is usually to maximize profit. Today, effects of tillage on erosion control must also be considered. Thus, there are three major factors to consider when selecting a tillage system: soil erosion, yield, and costs.

Before discussing these factors in detail, several tillage systems must be defined. Because of the number and variations of the tillage systems used by farmers, it is difficult to give each system a meaningful name or a precise definition. To accurately define or describe a tillage system, all the operations that make up the system should be listed. The list should include all the tillage operations, any chopping or shredding of residue, application of fertilizers and pesticides, planting, row cultivating, and harvesting. A few of the more common tillage systems used in Illinois are defined below.

Conservation tillage

Although specific operations or sequences of operations might differ, most would agree that the objective of conservation tillage is to provide a means of profitable crop production while minimizing soil erosion due to wind and water. The emphasis is on soil conservation, but the conservation of soil moisture, energy, labor, and even equipment are sometimes additional benefits. To be considered conservation tillage, the system must produce — on or in the soil — conditions that resist erosion by wind, rain, and flowing water. Such resistance is achieved either by protecting the soil surface with crop residues or growing plants, or by increasing the surface roughness or soil permeability.

Conservation tillage is often defined as any crop production system that provides

- A residue cover of at least 30 percent after planting to reduce soil erosion due to water, or
- At least 1,000 pounds per acre of flat, small-grain residues (or the equivalent) on the soil surface during the critical erosion period to reduce soil erosion due to wind.

Conservation tillage, depending on the preceding crop, may include a broad spectrum of tillage systems, some of which are described below.

Chisel plow and subsoiler systems

A chisel plow or subsoiler is usually used in the fall. In the spring, one or two disk harrowings or field cultivations are done before planting or drilling.

Disk or field cultivate system

A disk harrow or field cultivator may be used in the fall. In the spring, one or more disk harrowings or field cultivations are done before planting or drilling.

A common variation of the chisel plow and disk or field cultivate system is to use a combination tool before planting or drilling instead of a disk harrow or field cultivator.

Ridge-tillage system (till-plant)

The ridge-tillage system includes a one-pass, tillage planting operation. Seed is planted in ridges formed during cultivation of the previous crop. A sweep or double-disks mounted in from each planter unit push the top inch or so of soil and the crop residues off of the existing ridges into the furrows. A special row cultivator is used twice, for weed control and to rebuild the ridges.

No-tillage system (no-till)

Seed is planted or drilled into previously undisturbed soil. The planter or drill is usually equipped with coulters mounted in front of each seed furrow opener. The coulters cut the residue and loosen the soil to seeding depth.

Other tillage systems

Conventional tillage

Conventional tillage is the sequence of tillage operations traditionally or most commonly used in a given geographic area to produce a given crop. The operations used vary considerably for different crops and from one region to another. In the past, conventional tillage in Illinois included moldboard plowing, usually in the fall. Spring operations included one or more disk harrowings or field cultivations before planting or drilling. The soil surface with conventional tillage was essentially free of plant residues and provided a high potential for soil erosion. The term *clean tillage* is also used for systems that provide a residue-free soil surface. A soil surface essentially free of residues can also be achieved with other implements, especially following a crop such as soybeans that produces fragile, easy-to-cover residues.

Minimum tillage

The term *minimum tillage* is not very meaningful, but a definition for it is: "The minimum soil manipulation necessary for crop production, or meeting tillage requirements under existing conditions." The way most people use the term *minimum tillage,* they mean reduced tillage as defined below.

Reduced tillage

Reduced tillage refers to any system that is less intensive and aggressive than conventional tillage. Compared to conventional tillage, the number of operations is decreased, or a tillage implement that requires less energy per unit area is used to replace an implement typically used in the conventional tillage system. Because it is not specific, the term *reduced tillage* is also somewhat vague.

Mulch-till systems

Mulch-till systems include any conservation tillage system other than no-till and ridge-till. Prior to planting, implements such as a chisel plow, disk harrow, field cultivator, or combination tool may be used. At least 30 percent of the soil surface must remain covered with residue after planting.

Rotary-till system

For the rotary-till system, a powered rotary tiller is used in the fall or spring before planting.

Effects of tillage on soil erosion

A primary advantage of conservation tillage systems, particularly the no-till system, is less soil erosion due to water on sloping soils. Although wind erosion in Illinois is not as great a problem as water erosion, conservation tillage systems also essentially eliminate wind erosion. A bare, smooth soil surface is extremely susceptible to erosion. Many Illinois soils have subsurface layers that are not favorable for root growth and development. Soil erosion slowly but constantly removes the surface soil that is most favorable for root development, resulting in gradually decreasing soil productivity and value. Even on soils without root-restricting subsoils, erosion removes nutrients that must be replaced with additional fertilizers to maintain yields.

An additional problem related to soil erosion is sedimentation. Sediment from eroding fields increases water pollution, reduces storage capacity of lakes and reservoirs, and decreases the effectiveness of drainage systems.

A recent dramatic step taken to encourage control of soil erosion was the passage of the 1985 Food Security Act, included in the 1985 Farm Bill. Conservation requirements were also included in the 1990 Farm Bill. For farmers to remain eligible for many USDA programs, Conservation Compliance Provisions of the laws require farmers to develop and apply an approved conservation plan on their highly erodible fields. Conservation plans must meet specifications of the local Soil Conservation Service and be approved by the local conservation district.

In addition to the Conservation Compliance Provisions, the Food Security Act includes the Conservation Reserve Program, Sodbuster Provisions, and Swampbuster Provisions. For details of these programs and provisions, contact your local Soil Conservation Service office. Most conservation plans for compliance include use of conservation tillage, which requires that at least 30 percent of the soil surface be covered with residue after planting. Some plans call for higher percentages of residue cover.

Surface residues effectively reduce soil erosion. A residue cover after planting of 20 to 30 percent reduces soil erosion by approximately 50 percent compared to a cleanly tilled field (Figure 11.1). A residue cover of 70 percent after planting reduces soil erosion more than 90 percent compared to a cleanly tilled field.

On steeply sloping soils, conservation tillage will not adequately control soil erosion. Therefore, other practices will be required, including contouring, grass waterways, terraces, or structures. For technical assistance in developing erosion control systems, consult your district conservationist or the Soil Conservation Service.

Residue cover

The percentage of the soil surface covered with residues after planting is affected by the previous crop

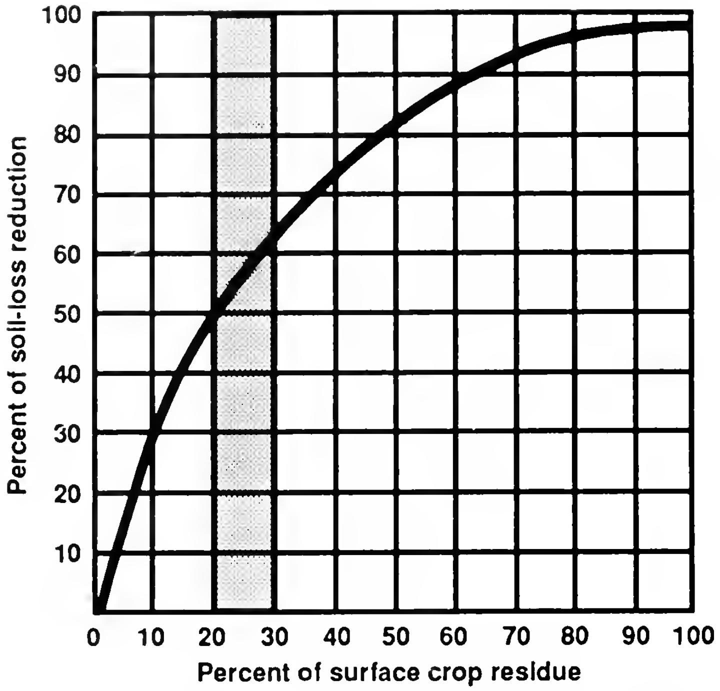


Figure 11.1. Percent of soil-loss reduction for various amounts of surface crop residue.

grown and the tillage system used. In general, the higher the crop yield, the greater the amount of residue produced. More important, however, is the type of residue a crop produces. Types of residue produced by various crops have been classified as nonfragile or fragile (Table 11.1). The classification is subjective and based on the ease with which the residues are decomposed by the elements or buried by tillage operations. Plant characteristics such as composition and size of leaves and stems, density of the residues, and relative quantities produced were considered. The residues of a crop such as soybeans are considered fragile because essentially all of the residues are damaged in passing through the combine, the stems and stubble are small in diameter, and the leaves are small and fall from the plants well before harvest. In contrast, corn residues are classified as nonfragile. Cornstalks, leaves, and cobs are individually large in size and quite durable, and the total mass of residue produced is greater.

The method used by the Soil Conservation Service to measure residue cover is the line-transect method. For the line-transect method, a light rope or tape with 100 equally spaced knots or marks is stretched diagonally across the crop rows. Residue cover is measured by counting each knot or mark that is directly over a piece of residue. The percent residue cover is equal to the number of knots counted.

Often there is a desire to predict the amount of residue that will be remaining on the soil surface using a particular tillage system. The prediction requires knowledge of the amount of residue cover remaining on the soil surface after each field operation included in the tillage system. Typical percentages of the residue cover remaining after various field operations are given in Table 11.2. The percentages can be used to obtain an estimate of the residue cover after each field operation in a tillage system.

Table 11.1. Types of Residue Produced by Various Crops

Nonfragile	Fragile
Alfalfa or legume hay	Canola/rapeseed
Barley*	Dry beans
Buckwheat	Dry peas
Corn	Fall-seeded cover crops
Flaxseed	Flower seed
Forage seed	Green peas
Forage silage	Potatoes
Grass hay	Soybeans
Millet	Vegetables
Oats*	
Pasture	
Popcorn	
Rye	
Sorghum	
Triticale*	
Wheat*	

NOTE: From *Estimates of Residue Cover Remaining After Single Operation of Selected Tillage Machines*, developed jointly by the Soil Conservation Service, U.S. Department of Agriculture, and the Equipment Manufacturers Institute. First edition, February 1992.

* If a combine is equipped with a straw chipper or the straw is otherwise cut into small pieces, small grain residue should be considered as being fragile.

A corn crop of 150 bushels per acre will usually provide a residue cover of 95 percent after harvest. Grain sorghum, most small grains, and lower yielding corn will generally provide a cover of 80 to 90 percent. Following soybean harvest, 70 to 80 percent cover typically remains. In all cases, the residue must be uniformly spread behind the combine. For a tillage system, a rough approximation of the residue cover remaining after planting can be obtained by multiplying the initial percent residue cover by the values in Table 11.2 of percent cover remaining after each operation. To leave 30 percent or more residue cover following corn, only one or two tillage operations can be performed. To leave 30 percent cover following soybeans essentially requires that the no-tillage system be used.

Crop production with conservation tillage

Crop germination, emergence, and growth are largely regulated by soil temperature, moisture content, and nutrient placement. Tillage practices influence each of these components of the soil environment. Conservation tillage systems differ from conventional clean tillage in several respects.

Soil temperature

Crop residue on the soil surface insulates the soil from the sun's energy. In the spring, higher-than-normal soil temperatures are desirable for plant growth. Later in the season, cooler-than-normal temperatures are often desirable, but a complete crop canopy at that

Table 11.2. Percent Residue Cover Remaining on the Soil Surface After Weathering or Specific Field Operations

	Type of residue	
	Nonfragile	Fragile
	percent of residue remaining	
Climatic effects		
Over winter weathering:*		
Following summer harvest	70 to 90	65 to 85
Following fall harvest	80 to 95	70 to 80
Field operations		
Moldboard plow	0 to 10	0 to 5
V ripper/subsoiler	70 to 90	60 to 80
Disk-subsoiler	30 to 50	10 to 20
Chisel plow with:		
Straight spike points	60 to 80	40 to 60
Twisted points or shovels	50 to 70	30 to 40
Coulter-chisel plow with:		
Straight spike points	50 to 70	30 to 40
Twisted points or shovels	40 to 60	20 to 30
Offset disk harrow — heavy plowing >10" spacing	25 to 50	10 to 25
Tandem disk harrow		
Primary cutting >9" spacing	30 to 60	20 to 40
Finishing 7" to 9" spacing	40 to 70	25 to 40
Light disking after harvest	70 to 80	40 to 50
Field cultivator		
As primary tillage operation:		
Sweeps 12" to 20"	60 to 80	55 to 75
Sweeps or shovels 6" to 12"	35 to 75	50 to 70
As secondary tillage operation:		
Sweeps 12" to 20" (30 to 50 cm) wide	80 to 90	60 to 75
Sweeps or shovels 6" to 12" (15 to 30 cm)	70 to 80	50 to 60
Combination finishing tool with:		
Disks, shanks, and leveling attachments	50 to 70	30 to 50
Spring teeth and rolling baskets	70 to 90	50 to 70
Anhydrous ammonia applicator	75 to 85	45 to 70
Drill		
Conventional	80 to 100	60 to 80
No-till	55 to 80	40 to 80
Conventional planter	85 to 95	75 to 85
No-till planters with:		
Ripple coulters	75 to 90	70 to 85
Fluted coulters	65 to 85	55 to 80
Ridge-till planter	40 to 60	20 to 40

NOTE: From *Estimates of Residue Cover Remaining After Single Operation of Selected Tillage Machines,* developed jointly by the Soil Conservation Service, U.S. Department of Agriculture, and the Equipment Manufacturers Institute. First edition, February 1992.

* With long periods of snow cover and frozen conditions, weathering may reduce residue levels only slightly, while in warmer climates, weathering losses may reduce residue levels significantly.

time restricts the influence of crop residue on soil temperature.

Minimum soil temperatures occur between 6 and 8 a.m., and they are affected very little by tillage or crop residue. Maximum soil temperatures at a depth of 4 inches occur between 3 and 5 p.m. During May, fields tilled by the fall-plow method have soil temperatures 3° to 5°F warmer than those with a corn or residue mulch.

During May and early June, the reduced soil temperatures caused by a mulch are accompanied by slower growth of corn and soybeans. Whether the lower soil temperature and subsequent slower early growth result in reduced yields depends largely on weather conditions during the summer, particularly during the tasseling and silking stages. Slower growth may delay this process until weather conditions are better, but best yields normally occur when corn tassels and silks early.

Soil moisture

Surface mulch reduces evaporation. Wetter soil is advantageous in dry summer periods, but it is usually disadvantageous at planting time and during early growth, especially on soils with poor internal drainage.

Soil compaction

Interest in soil compaction has increased, probably because larger equipment is now being used and reduced-tillage systems are more commonly used. Greater soil density or compaction restricts and slows root development and may cause yield declines. However, a complete understanding of the effects of soil compaction on plant growth is not available.

Wet soils compact much more easily and to a greater extent than dry soils. If at all possible, wheel traffic and tillage operations should be restricted to times when the soil is dry.

Measurements indicate decreased soil compaction when tillage tools such as the moldboard plow, chisel plow, or subsoiler are used. The moldboard plow loosens soil uniformly to the plow's operating depth. The chisel plow and subsoiler loosen the soil where the points operate; but between points, just the upper few inches of soil are loosened. The disk loosens the soil to the depth it operates. With no-till, of course, the soil is not loosened.

Secondary tillage implements such as disk harrows and field cultivators tend to increase the soil density when used on loose, tilled soil. These tools also break up soil aggregates, making the soil more susceptible to compaction when it is wetted and then dried.

Wheel traffic increases compaction when the soil strength is insufficient to support the load of the tire. The pressure applied to the soil is approximately equal to the pressure of the tire. If the load on a tire is increased, the tire deflects to maintain a constant pressure. Compaction due to traffic is most severe when the soil is wet.

Stand establishment

Uniform planting depth, good contact between the seed and moist soil, and enough loose soil to cover the seed are necessary to produce uniform stands. Shallower-than-normal planting in the cool, moist soil common to many conservation tillage seedbeds may partially offset the disadvantage of lower temperatures. However, if dry, windy weather follows planting, shallow-planted seedlings may be stressed for moisture. Therefore, a normal planting depth is suggested for all tillage systems.

For most conservation-tillage systems, planters and drills are equipped with coulters in front of each seed furrow opener to cut the surface residues and penetrate the soil. Row cleaners can also be mounted in front of each seed opener. Generally, coulters should be operated at seeding depth. Row cleaners should be set to move the residue from the row area and as little soil as possible. Extra weight may be needed on planters and drills for no-till so that the soil-engaging components function properly and to ensure sufficient weight on the drive wheels. Also, heavy-duty down-pressure springs on each planter unit may be necessary to penetrate firm, undistrubed soil.

Fertilizer placement

See section titled "Fertilizer management related to tillage systems" in Chapter 10.

Weed control

Weed control is essential for profitable production with any tillage system. With less tillage, weed control becomes more dependent on herbicides. Herbicide selection and application rate, accuracy, and timing become more important. Application accuracy is especially important with drilled soybeans because row cultivation is impractical. (For specific herbicide recommendations, see Chapter 13.)

Problem weeds

Perennial weeds such as milkweed and hemp dogbane may be a greater problem with conservation tillage systems. Current programs for control of weeds such as johnsongrass and yellow nutsedge call for recommended rates of preplant herbicides that should be thoroughly incorporated. Wild cane is also best controlled by preplant incorporated herbicides. Volunteer corn is often a problem with tillage systems that leave the corn relatively shallow. Unless control programs are monitored closely, surface-germinating weeds, such as fall panicum and crabgrass, may also increase with reduced-tillage systems.

Herbicide application

Surface-applied and incorporated herbicides may not give optimum performance under tillage systems that leave large amounts of crop residue and clods on the soil surface. These problems interfere with herbicide distribution and thorough herbicide incorporation.

Herbicide incorporation is impossible in no-till systems. Residual or postemergence herbicides are effective, and mechanical cultivation is usually not done.

Cultivation

Heavy-duty cultivators are available to cultivate with high amounts of surface residues and hard soil. High amounts of crop residues may interfere with some rotary hoes and cultivators with multiple sweeps per row. Cultivators equipped with a single coulter and sweep plus two weeding disks per row are effective across a wide range of soil and crop residue conditions.

With the ridge-tillage system, special cultivation equipment is necessary to form a sufficiently high ridge and to operate through the inter-row residue. Weed control is also accomplished as ridges are rebuilt.

Herbicide carryover

The potential for herbicide carryover is greater in conservation-tillage systems because herbicides are diluted less in the soil when moldboard plowing is not done. Herbicide carryover is affected by climatic factors and soil conditions. Breakdown is faster in warm, wet soils than in cool, dry conditions. Soils with a pH above 7.4 tend to have greater problems with atrazine carryover than soils with pH values from 6.0 to 7.3.

The carryover problem can be reduced by using lower rates of the more persistent herbicides in combination with other herbicides or by using less persistent herbicides altogether. Early application of herbicides reduces the potential for carryover.

To detect harmful levels of persistent herbicide carryover, a sensitive species (bioassay) can be grown in soil samples from suspect fields. Carryover is not a problem if the same crop or a tolerant species is to be grown the next cropping season.

No-till weed control

In conventional and most conservation-tillage systems, existing weeds are destroyed by tillage before planting. No-till systems may require a knockdown herbicide like paraquat or Roundup to control existing vegetation. The vegetation may be a grass or legume sod or early germinating annual and perennial weeds. Alfalfa, marestail, and certain perennial broadleaf weeds will not be controlled by paraquat or Roundup. It may be necessary to treat these weeds with Banvel or 2,4-D.

Insect management

Although insect problems and insect management practices may be affected by reduced tillage, concern about insect problems should not prevent a farmer from adopting conservation-tillage practices. With few exceptions, effective insect-management guidelines and tactics are available, regardless of the tillage system used. Extension entomologists throughout the north-central region seldom alter insect-management recommendations for different tillage systems.

Insect development rates are closely related to temperature. Insects that spend a portion of their life cycle in the soil may develop more slowly in conservation-tillage systems. For instance, initial emergence of corn rootworm adults is delayed in no-till cornfields. The type of tillage system may also influence insect survival during the winter. Research has shown that survival of corn rootworm eggs during the winter is greater in no-till systems than in more conventional systems, especially if snow cover is deficient and temperatures remain very cold for an extended period of time.

Conservation-tillage systems may also directly affect other components that will influence insect populations. Examples of indirect effects of tillage on insect pest survival and development include changes in weed densities and changes in populations of beneficial insects in response to a particular tillage practice. Poor weed management in some tillage systems is responsible for increasing the densities of certain insects. On the other hand, some weeds attract predators and parasitoids, thereby increasing the likelihood that natural control will suppress some insect pest populations.

The effects of tillage on insects are most prominent in corn. The insects most directly affected by changes in tillage practices are those that overwinter in the soil and become active during the early stages of crop growth. Increases in grassy weed populations, reduced distrubance of soil, and delayed germination caused by cooler soil temperatures may favor buildup of white grubs and wireworms. Seedcorn maggot flies prefer to lay eggs where crop residue has been partially incorporated into the soil. No-till corn stubble may be less attractive to egg-laying flies, but cooler, wetter soils shaded by crop residues slow germination and increase the period of vulnerability to seedcorn maggot injury. On the other hand, corn rootworms are little affected by conservation tillage. (See Table 11.3.)

Although soil-dwelling insects are usually affected more than the foliage-feeding insects, some species respond to certain weeds. Black cutworm moths prefer to lay eggs in weedy fields and in fields with unincorporated crop residues. Ryegrass and other grass cover crops, hay crops, and grassy weeds are especially attractive to egg-laying armyworm moths. In no-till fields, serious damage by stalk borers is most likely where grasses were present to attract egg-laying moths the previous August and September.

Table 11.3. Potential Effects of Conservation-Tillage Systems on Pests in Corn

Insect	Potential effect*
Armyworm	0 to +++
Black cutworm	+ to +++
Corn earworm	0 to +
Corn leaf aphid	0
Corn rootworms	0
European corn borer	0 to +
Hop vine borer	0 to +++
Seedcorn maggot	+
Slugs	+++
Stalk borer	0 to +++
Stink bugs	+
White grubs	+
Wireworms	+

* Potential effects depend on cropping sequence, weather conditions, and presence or absence of weeds. +++ = substantial increase in pest population; + = some increase; 0 = no effect.

Conservation tillage favors greater survival of European corn borers in crop residue, but effects in specific fields are minor because moths disperse from emergence sites to lay eggs in suitable fields throughout the local area. Where reduced tillage leads to delayed planting or slower germination, corn may be less susceptible to attack by first-generation corn borers and more susceptible to second-generation damage.

Although the potential for insect problems is slightly greater in reduced-tillage and no-till corn than it is in plowed fields, adequate management guidelines are generally available. An efficient and economic insect-management program must include (1) an understanding of the relationship between crop rotation and insect biology, (2) proper selection and placement of soil insecticides in corn, (3) consideration of insecticide seed treatments, (4) effective weed control, (5) regular monitoring of scouting programs in each field, including detailed records and field histories, (6) an understanding of current economic thresholds and treatment guidelines, and (7) timely insecticide applications when necessary.

No-till pest problems

Insect problems occur more frequently in no-till corn than in other tillage systems and are often more serious. No-till systems give pests a stable environment for survival and development. Soil insecticides may be profitably applied to corn following grass sod or in any rotation where grass and weeds are prevalent before planting. It does not generally pay to apply a soil insecticide to no-till corn following corn, except in rootworm-infested areas; nor will it generally benefit soybeans or small grain following corn. A diazinon planter-box seed treatment should, however, be used to protect against damage by seed-corn beetles and seed-corn maggots.

Disease control

The potential for plant disease is greater when mulch is present than when fields are clear of residue. With clean tillage, residue from the previous crop is buried or otherwise removed. Because buried residue is subject to rapid decomposition, infected residue is likely to disappear though decay.

Volunteer corn may be a problem unless the soil is moldboard-plowed in the fall or the no-till system is used. If the volunteer corn in continuous corn is a hybrid that is susceptible to disease, early infection with diseases such as southern corn leaf blight or grey leaf spot, for instance, will increase.

Although the potential for plant disease is greater with mulch tillage than with clean tillage, disease-resistant hybrids and varieties can help reduce this problem. The erosion-control benefit of reduced tillage must be balanced against the increased potential for disease. Crop rotation or modification of the tillage practice may be justified if a disease problem appears likely.

Crop yields

Tillage research is conducted at the seven University of Illinois Agricultural Research and Demonstration Centers (see figure on inside front cover) to evaluate crop yield response to different tillage systems under a wide variety of soil and climatic conditions. Conservation tillage systems have produced yields comparable to those from moldboard plowing on most Illinois soils when stands are adequate and pests are controlled.

Crop yields vary more due to weather conditions during the growing season than the tillage system used. Corn and soybean yields are generally higher when the crops are rotated compared to either crop grown continuously. Yields of continuous corn have especially decreased as tillage is reduced.

Comparative yields due to tillage system also varies with soil type (Table 11.4). It is important with any tillage system that plant stands be adequate, weeds be controlled, soil compaction not be excessive, and adequate nutrients be available. In general, corn and soybean yields have been found to decrease slightly as tillage is reduced on poorly and somewhat poorly drained, dark soils. An exception is the ridge-till system, which frequently produces higher corn yields on these soils. Flanagan silt loam and drummer silty clay loam are two examples of poorly to somewhat poorly drained soils.

On well- to moderately well-drained, medium-textured, dark- and light-colored soils, expected yields are quite similar for rotation corn and soybeans, but yields with continuous corn are decreased as tillage is reduced. Tama silt loam, which is dark, and Downs-Fayette silt loam, which is light-colored, are both well- to moderately well-drained and medium-textured soils. The low yields in Table 11.4 for no-till on the Downs-Fayette silt loam soil is due to poor weed control during the last 3 years of the 10-year experiment.

On somewhat excessively drained sandy soils, conservation-tillage systems that retain surface residues reduce wind erosion, conserve moisture, and typically produce high yields. Bloomfield fine sand is such a soil.

Soils such as Cisne silt loams, which are very slowly permeable and poorly drained, have a clay pan that restricts root development and water used by the crop. On such soils, yields are frequently higher with less tillage.

Production costs

Will the switch from a conventional system to a conservation-tillage system be profitable? The answer depends on how one weighs the importance of three primary factors: yield, cost, and erosion control. The relation of yield and soil erosion to tillage system was discussed in the preceding sections.

Machinery investment is one of the major production costs affected by the choice of tillage system. If new machinery must be purchased, the capital investment and the depreciation and interest costs of the equipment needed for most conservation-tillage systems will be less than for conventional tillage (Table 11.5). For conservation-tillage, fewer implements and field operations are used, and the necessary power units may be smaller. If conservation tillage is used on only a part of the land farmed, larger equipment will still be needed for the other portions, so savings may be small.

With a conservation-tillage system, labor costs will be reduced because some fall or spring tillage operations are reduced or eliminated. The labor saved in this way has value only if it reduces the cost of hired labor or if the saved labor time is directed into other productive activities, such as raising livestock, off-farm employment, farming more acres, or reducing machinery costs by substituting smaller equipment.

An extra cost of additional or more expensive pesticides may be associated with conservation-tillage systems. For example, contact herbicides may be needed with no-till and ridge-tillage systems. These increases must be weighed against the reduced machinery and labor costs necessary to perform fewer operations. Often, the reduced machinery costs associated with conservation tillage are partially offset by increased herbicide cost. Ridge-till can be cost effective, especially if a contact herbicide is not required and only a band application of herbicide is used. Usually costs for seed, fertilizer, land, and other variables are similiar for various tillage systems.

Drilling soybeans in narrow rows instead of planting soybeans in 28-inch or wider rows is another option for most tillage systems. The narrow rows provide a more uniform plant spacing, resulting in potentially greater yields. Drilled soybeans develop a full canopy earlier, which shades the soil earlier, thus reducing weed pressure and absorbing raindrop energy to reduce erosion. Additional erosion control can be obtained by drilling soybeans no-till with residues of the previous crop on the soil surface.

Several available drills are specifically designed to drill soybeans directly into crop residues without tillage. Because no-till drills are expensive, methods should be considered to reduce costs, especially for small farms. Cost-reduction considerations might include renting or sharing ownership with one or more farmers. Owning both a drill for soybeans and a planter for corn increases the machinery inventory required on a corn-soybean farm. The effects on machinery cost for the farm depend on farm size and the tillage system used. For systems that include row cultivation of planted soybeans, the cost increase of the drill may be offset by less use of the planter, row cultivator, and

Table 11.4. Corn and Soybean Yields with Moldboard Plow, Chisel Plow, Disk, No-Till, and Ridge-Till Systems

	Soil type							
Tillage system	Flanagan silt loam and Drummer silty clay loam		Flanagan silt loam and Drummer silty clay loam	Bloomfield fine sand	Cisne silt loam	Downs-Fayette silt loam	Tama silt loam	
	corn yield, bushels per acre							
Moldboard plow[i]	...	129[b]	178[c]	...	113[e]	131[f]	144[g]	112[h]
Chisel plow	142[a]	...	166	130[d]	122	130	147	109
Disk	142	129	172	145	124	130	166	...
No-till	135	108	168	141	118	121	143	90
Ridge-till	144	115	...	...	...	...	152	...
	soybean yield, bushels per acre							
Moldboard plow[i]	44[j]	44[k]	50	...	32	37	46	...
Chisel plow	...	...	46	32	33	38	45	...
Disk	43	42	44	37	34	37	43	...
No-till	41	41	45	37	36	32	43	...
Ridge-till	...	...	...	...	...	...	43	...

[a] Champaign, corn-soybean rotation.
[b] Champaign, continuous corn.
[c] DeKalb, corn-soybean rotation.
[d] Kilbourne, corn-soybean rotation.
[e] Brownstown, corn-soybean rotation.
[f] Perry, corn-soybean rotation.
[g] Monmouth, corn-soybean rotation.
[h] Monmouth, continuous corn.
[i] Moldboard-plowed in the fall, except Cisne moldboard-plowed in the spring.
[j] Row spacing was 10 inches.
[k] Row spacing was 30 inches.

Table 11.5. Estimated Production Costs with Different Tillage Systems

	Cost					
			Herbicide		Total	
Tillage system After corn/after soybean	Machinery[a]	Labor[b]	Corn	Soybean	Corn	Soybean
	dollars per acre					
Moldboard/chisel	55	8	10 to 15	14 to 28	73 to 78	77 to 91
Chisel/disk	50	7	10 to 15	14 to 28	67 to 72	71 to 85
Disk/field cultivate	48	7	10 to 15	14 to 28	65 to 70	69 to 83
No-till/no-till	37	5	15 to 25[c]	25 to 40[c]	57 to 67	67 to 82
Ridge-till/ridge-till	44	7	5 to 25[d]	7 to 40[d]	56 to 76	58 to 91

[a] Machinery and labor costs calculated for 1,000-acre corn-soybean farm using Farm Machinery Selection Program (Siemens, Hamburg, and Tyrrell, 1990).
[b] Labor assumed to cost $8.50 per hour.
[c] No-till herbicide program options include early preplant, preemergent, postemergent, and knockdown.
[d] Ridge-till herbicide program options include band or broadcast applications.

tractor. In comparing no-till planted soybeans (no row cultivation) with no-till drilled soybeans, the no-till drill increases estimated machinery costs from $37 to $42 per acre for a 1,000-acre corn-soybean farm.

Summary

The major advantage of conservation tillage is significantly less water erosion on sloping soils and less wind erosion on level fields. The greatly reduced soil erosion is an important factor that should be given high priority on sloping soils.

Crop yields due to tillage system vary with soil type. Averaged over several years, corn and soybean yields have been found to decrease slightly as tillage is reduced on poorly and somewhat poorly drained, dark-colored soils. On well-drained, medium-textured soils that are either dark or light-colored, yields are quite similar with various tillage systems. On poorly drained, very low organic matter silt loams with fragipans that restrict plant rooting, corn and soybean yields have been found to increase as tillage is reduced. On all soil types, yields are generally higher when corn and soybeans are rotated than when either crop is grown continuously.

Machinery and labor costs decrease as tillage is reduced because the size or number of machines needed on a farm decreases. The decrease in costs for machinery and labor may be partially offset by higher costs for herbicides as tillage is reduced. The total costs for machinery, labor, and herbicides are usually slightly less as tillage is reduced.

Chapter 12.

Water Management

A superior water management program seeks to provide an optimum balance of water and air in the soil that will allow full expression of genetic potential in plants. The differences among poor, average, and record crop yields generally can be attributed to the amount and timing of soil water supply.

Improving water management is an important way to increase crop yields. By eliminating crop-water stress, you will obtain more benefits from improved cultural practices and realize the full yield of the cultivars now available.

To produce maximum yields, the soil must be able to provide water as it is needed by the crop. But the soil seldom has just the right amount of water for maximum crop production; a deficiency or a surplus usually exists. A good water management program seeks to avoid both extremes through a variety of measures. These measures include draining waterlogged soils; making more effective use of the water-holding capacity of soils so that crops will grow during periods of insufficient rainfall; increasing the soil's ability to absorb moisture and conduct it down through the soil profile; reducing water loss from the soil surface; and irrigating soils with low water-holding capacity.

In Illinois, the most frequent water management need is improved drainage. Initial efforts in the nineteenth century to artificially drain Illinois farmland made our soils among the most productive in the world. Excessive water in the soil limits the amount of oxygen available to plants and thus retards growth. This problem occurs where the water table is high or where water ponds on the soil surface. Removing excess water from the root zone is an important first step toward a good water management program. A drainage system should be able to remove water from the soil surface and lower the water table to about 12 inches beneath the soil surface in 24 hours and to 21 inches in 48 hours.

The benefits of drainage

A well-planned drainage system will provide a number of benefits: better soil aeration, more timely field operations, less flooding in low areas, higher soil temperatures, less surface runoff, better soil structure, better incorporation of herbicides, better root development, higher yields, and improved crop quality.

Soil aeration. Good drainage ensures that roots receive enough oxygen to develop properly. When the soil becomes waterlogged, aeration is impeded and the amount of oxygen available is decreased. Oxygen deficiency reduces root respiration and often the total volume of roots developed. It also impedes the transport of water and nutrients through the roots. The roots of most nonaquatic plants are injured by oxygen deficiency; and prolonged deficiency may result in the death of some cells, entire roots, or in extreme cases the whole plant. Proper soil aeration also will prevent rapid losses of nitrogen to the atmosphere through denitrification.

Timeliness. Because a good drainage system increases the number of days available for planting and harvesting, it can enable you to make more timely field operations. Drainage can reduce planting delays and the risk that good crops will be drowned or left standing in fields that are too wet for harvest. Good drainage may also reduce the need for additional equipment that is sometimes necessary to speed up planting when fields stay wet for long periods.

Soil temperature. Drainage can increase soil surface temperatures during the early months of the growing season by 6° to 12°F. Warmer temperatures assist germination and increase plant growth.

Surface runoff. By enabling the soil to absorb and store rainfall more effectively, drainage reduces runoff from the soil surface and thus reduces soil erosion.

Soil structure. Good drainage is essential in maintaining the structure of the soil. Without adequate drainage the soil remains saturated, precluding the normal wetting and drying cycle and the corresponding shrinking and swelling of the soil. The structure of saturated soil will suffer further damage if tillage or harvesting operations are performed on it.

Herbicide incorporation. Good drainage can help avoid costly delays in applying herbicide, particularly of postemergence herbicides. Because some herbicides must be applied during the short time that weeds are still relatively small, an adequate drainage system may be necessary for timely application. Drainage may also help relieve the cool, wet stress conditions that increase crop injury by some herbicides.

Root development. Good drainage enables plants to send roots deeper into the soil so they can extract moisture and plant nutrients from a larger volume of soil. Plants with deep roots are better able to withstand drought.

Crop yield and quality. All these benefits previously mentioned contribute to greater yields of higher-quality crops. The exact amount of the yield and quality increases depends on the type of soil, the amount of rainfall, the fertility of the soil, crop management practices, and the level of drainage before and after improvements are made. Of the few studies that have been conducted to determine the benefits of drainage, the most extensive in Illinois was initiated at the Agronomy Research Center at Brownstown. This study evaluated drainage and irrigation treatments with Cisne and Hoyleton silt loams.

Drainage methods

A drainage system may consist of surface drainage, subsurface drainage, or some combination of both. The kind of system you need depends in part upon the ability of the soil to transmit water. The selection of a drainage system ultimately should be based on economics. Surface drainage, for example, would be most appropriate where soils are impermeable and would therefore require too many subsurface drains to be economically feasible. Soils of this type are common in southern Illinois.

Surface drainage

A surface drainage system is most appropriate on flat land with slow infiltration and low permeability and on soils with restrictive layers close to the surface. This type of system removes excess water from the soil surface through improved natural channels, man-made ditches, and shaping of the land surface. A properly planned system eliminates ponding, prevents prolonged saturation, and accelerates the flow of water to an outlet without permitting siltation or soil erosion.

A surface drainage system consists of a farm main, field laterals, and field drains. The farm main is the outlet serving the entire farm. Where soil erosion is a problem, a surface drain or waterway covered with vegetation may serve as the farm main. Field laterals are the principal ditches that drain adjacent fields or areas on the farm. The laterals receive water from field drains, or sometimes from the surface of the field, and carry it to the farm main. Field drains are shallow, graded channels (with relatively flat side slopes) that collect water within a field.

A surface drainage system sometimes includes diversions and interceptor drains. Diversions are channels constructed across the slope of the land to intercept surface runoff and prevent it from overflowing bottomlands. Diversions are usually located at the bases of hills. These channels simplify and reduce the cost of drainage for bottomlands.

Interceptor drains collect subsurface flow before it resurfaces. These channels may also collect and remove surface water. They are used on long slopes that have grades of one percent or more and on shallow, permeable soils overlying relatively impermeable subsoils. The location and depth of these drains are determined from soil borings and the topography of the land.

The principal types of surface drainage configurations are the random and parallel systems (Figure 12.1). The **random system** consists of meandering field drains that connect the low spots in a field and provide an outlet for excess water. This system is adapted to slowly permeable soils with depressions too large to be eliminated by smoothing or shaping the land.

The **parallel system** is suitable for flat, poorly drained soils with many shallow depressions. In a field that is cultivated up and down a slope, parallel ditches can be arranged to break the field into shorter lengths. The excess water thus erodes less soil because it flows over a smaller part of the field before reaching a ditch. The side slopes of the parallel ditches should be flat enough to permit farm equipment to cross them. The spacing of the parallel ditches will vary according to the slope of the land.

For either the random or parallel systems to be fully effective, minor depressions and irregularities in the soil surface must be eliminated through land grading or smoothing.

Bedding is another surface drainage method that is used occasionally. The land is plowed to form a series of low, narrow ridges separated by parallel, dead furrows. The ridges are oriented in the direction of the steepest slope in the field. Bedding is adapted to the same conditions as the parallel system, but it may interfere with farm operations and does not drain the land as completely. It is not generally suited for land that is planted in row crops because the rows adjacent to the dead furrows will not drain satisfactorily. Bedding is acceptable for hay and pasture crops, although it will cause some crop loss in and adjacent to the dead furrows.

Subsurface drainage

Many of the deep, poorly drained soils of central and northern Illinois respond favorably to subsurface drainage. A subsurface drainage system is used in soils permeable enough that the drains do not have to be placed too closely together. If the spacing is too narrow, the system will not be economical. By the same token, the soil must be productive enough to justify the investment. Because a subsurface drainage system functions only as well as the outlet, a suitable one

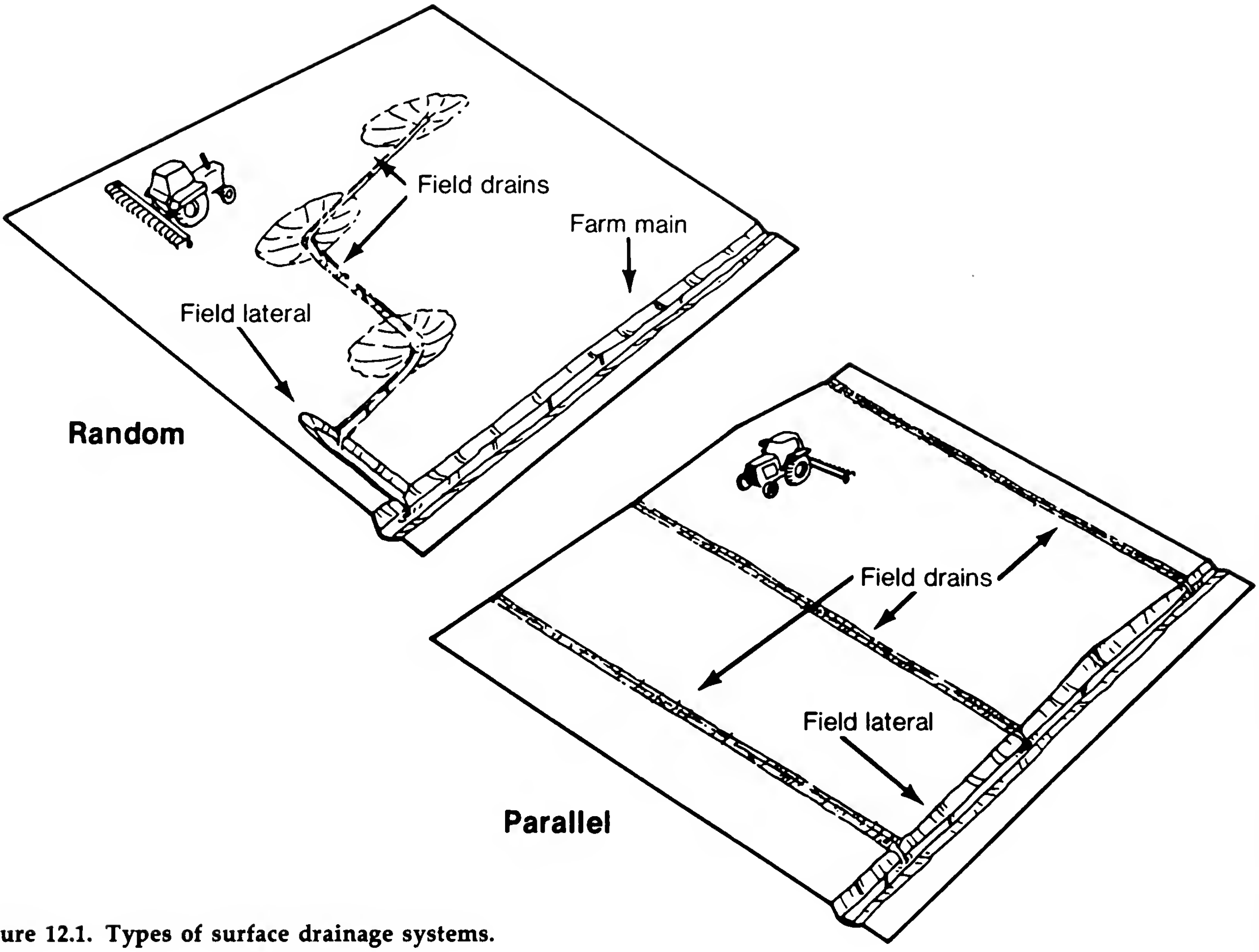


Figure 12.1. Types of surface drainage systems.

must be available or constructed. The topography of the fields also must be considered because the installation equipment has depth limitations and a minimum amount of soil cover is required over the drains.

Subsurface systems are made up of an outlet or main, sometimes a submain, and field laterals. The drains are placed underground, although the outlet is often a surface drainage ditch. Subsurface drainage conduits are constructed of clay, concrete, or plastic.

There are four types of subsurface systems: the random, the herringbone, the parallel, and the double-main (Figure 12.2). A single system or some combination of systems may be chosen according to the topography of the land.

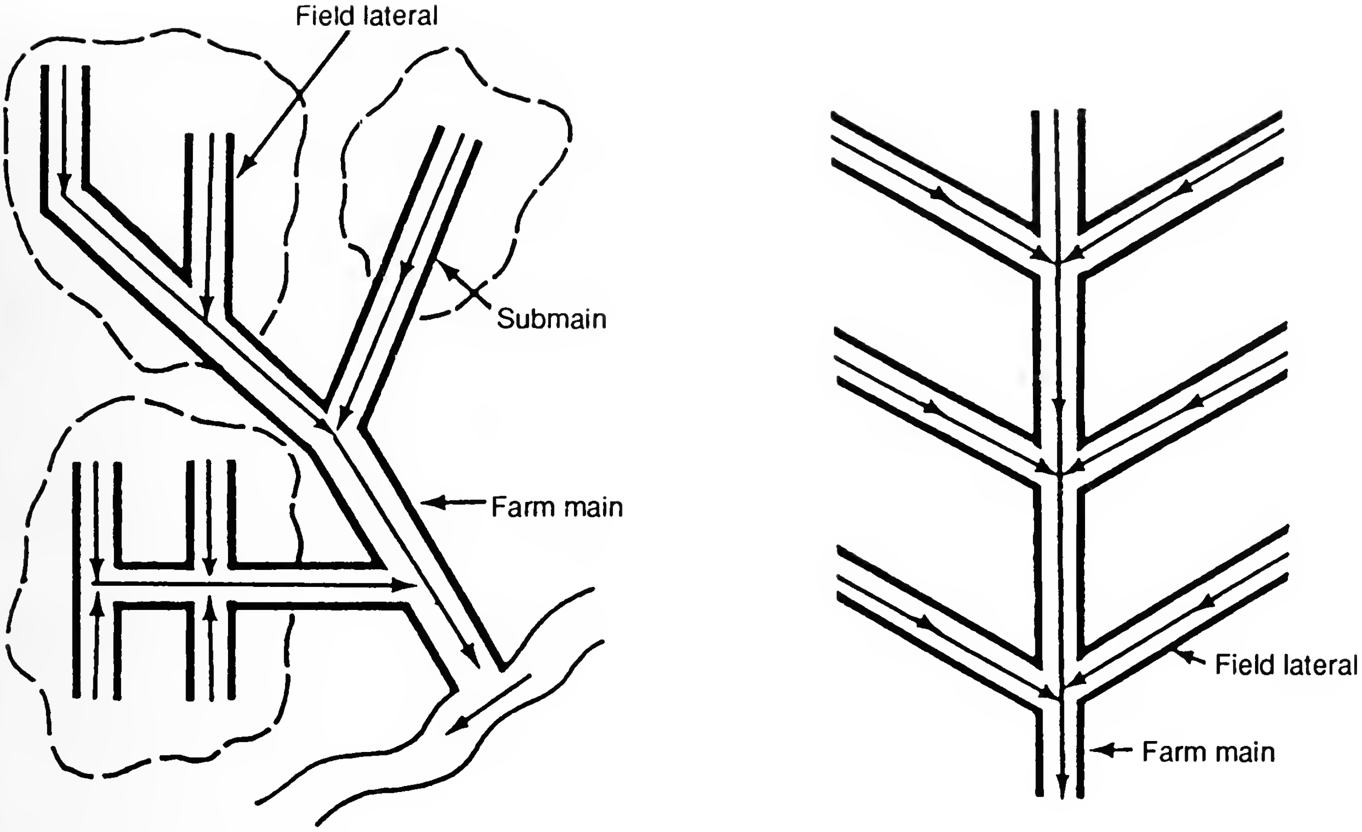
For rolling land, a **random system** is recommended. With this system, the main drain is usually placed in a depression. If the wet areas are large, the submains and lateral drains for each area may be placed in a gridiron or herringbone pattern to achieve the required drainage.

With the **herringbone system**, the main or submain is often placed in a narrow depression or on the major slope of the land. The lateral drains are angled upstream on either side of the main. This system sometimes is combined with others to drain small or irregular areas. Because two laterals intersect the main at the same point, however, more drainage than necessary may occur at that intersection point. The herringbone system may also cost more because it requires more junctions. Nevertheless, it can provide the extra drainage needed for the heavier soils that are found in narrow depressions.

The **parallel system** is similar to the herringbone system, except that the laterals enter the main from only one side. This system is used on flat, regularly shaped fields and on uniform soil. Variations are often used with other patterns.

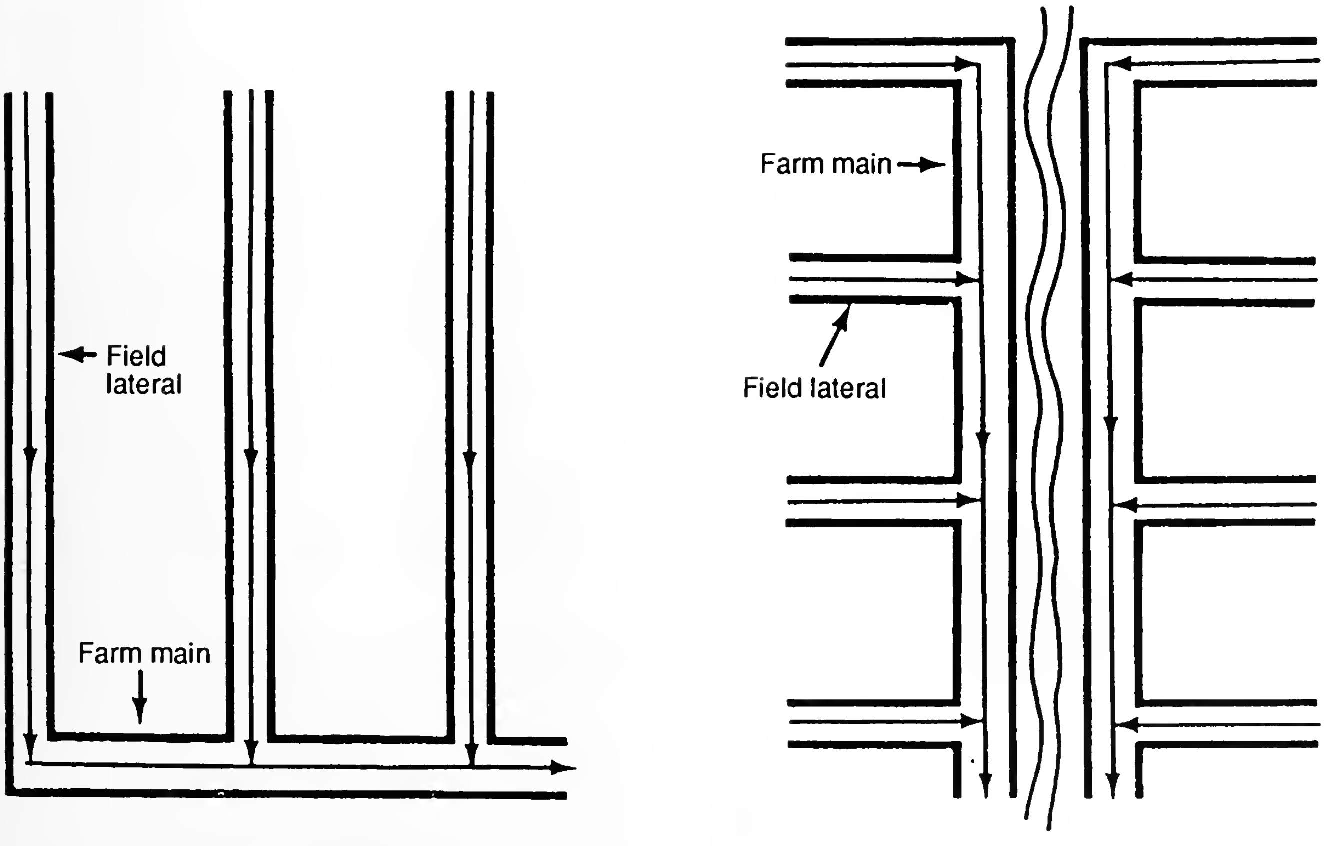
The **double-main system** is a modification of the parallel and herringbone systems. It is used where a depression, frequently a natural watercourse, divides the field in which drains are to be installed. Sometimes the depression may be wet due to seepage from higher ground. A main placed on either side of the depression intercepts the seepage water and provides an outlet for the laterals. If only one main were placed in the center of a deep and unusually wide depression, the grade of each lateral would have to be changed at some point before it reaches the main. A double-main system avoids this situation and keeps the gradelines of the laterals uniform.

The advantage of a subsurface drainage system is that it usually drains soil to a greater depth than



Random

Herringbone



Parallel

Double Main

Figure 12.2. Types of subsurface drainage systems. The arrows indicate the direction of water flow.

surface drainage. Subsurface drains placed 36 to 48 inches deep and 80 to 100 feet apart are suitable for crop production on many medium-textured soils in Illinois. When properly installed, these drains require little maintenance, and because they are underground, they do not obstruct field operations.

For more specific information about surface and subsurface drainage systems, obtain the Extension Circular 1226, *Illinois Drainage Guide*, from your county Extension adviser. This publication discusses the planning, design, installation, and maintenance of drainage systems for a wide variety of soil, topographic, and climate conditions.

The benefits of irrigation

During an average year, most regions of Illinois receive ample rainfall for growing crops; but, as shown in Figure 12.3, rain does not occur when the crops need it the most. From May to early September, growing crops demand more water than is provided by precipitation. For adequate plant growth to continue during this period, the required amount of water must be supplied by stored soil water or by irrigation. During the growing season, crops on deep, fine-textured soils may draw upon moisture stored in the soil, if the normal amount of rainfall is received throughout the year. But if rainfall is seriously deficient or if the soil has little capacity for holding water, crop yield may be reduced. Yield reductions are likely to be most severe on sandy soils or soils with claypans. Claypan soils restrict root growth, and both types of soils often cannot provide adequate water during the growing season.

To prevent crop-water stress during the growing season, more and more producers are using irrigation. It may be appropriate where water stress can substantially reduce crop yields and where a supply of usable water is available at reasonable cost. Irrigation is still most widely used in the arid and semi-arid parts of the United States, but it can be beneficial in more humid states such as Illinois. Almost every year, Illinois corn and soybean yields are limited by drought to some degree, even though the total annual precipitation exceeds the water lost through evaporation and transpiration (ET).

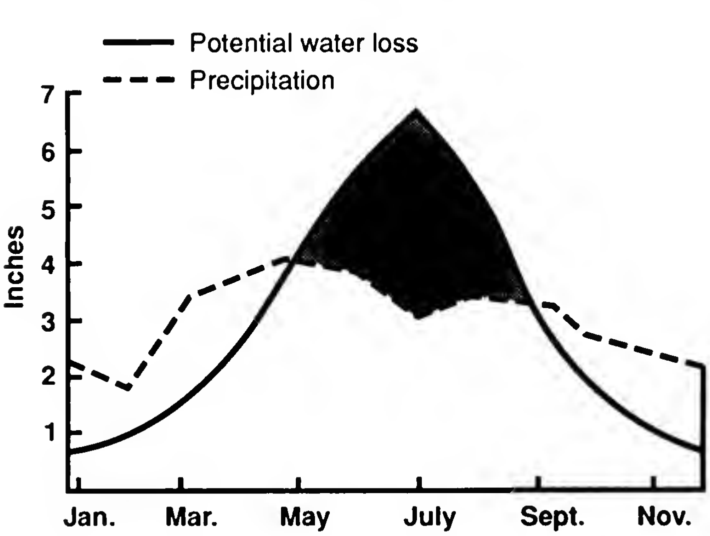


Figure 12.3. Average monthly precipitation and potential moisture loss from a growing crop in central Illinois.

With current cultural practices, a good crop of corn or soybeans in Illinois needs at least 20 inches of water. All sections of the state average at least 15 inches of rain from May through August. Thus satisfactory yields require at least 5 inches of stored subsoil water in a normal year.

Crops growing on deep soil with high water-holding capacity, that is, fine-textured soil with high organic-matter content, may do quite well if precipitation is not appreciably below normal and if the soil is filled with water at the beginning of the season.

Sandy soils and soils with subsoil layers that restrict water movement and root growth cannot store as much as 5 inches of available water. Crops planted on these soils suffer from inadequate water every year. Most of the other soils in the state can hold more than 5 inches of available water in the crop rooting zone. Crops on these soils may suffer from water deficiency when subsoil water is not fully recharged by about May 1 or when summer precipitation is appreciably below normal or poorly distributed throughout the season.

The probability of getting one inch or more of rain in any week is shown in Figure 12.4. One inch of rain per week will not replace ET losses during the summer, but it can keep crop-water stress from severely limiting final grain yields on soils that can hold water reasonably well. This probability is lowest in all sections of Illinois during July, when corn normally is pollinating and soybeans are flowering.

Water stress delays the emergence of corn silks and shortens the period of pollen shedding, thus reducing the time of overlap between the two processes. The result is incomplete kernel formation, which can have disastrous effects on corn yields.

Corn yields may be reduced as much as 40 percent when visible wilting occurs on four consecutive days at the time of silk emergence. Studies have also shown that severe drought during the pod-filling stage causes similar yield reductions in soybeans.

Increasing numbers of farmers are installing irrigation systems to prevent the detrimental effects of water deficiency. Some years of below-normal summer rainfall and other years of erratic rainfall distribution throughout the season have contributed to the increase. As other yield-limiting factors are eliminated, adequate water becomes increasingly important to assure top yields.

Most of the development of irrigation systems has occurred on sandy soils or other soils with correspondingly low levels of available water. Some installations have been made on deeper, fine-textured soils, and other farmers are considering irrigation of such soils.

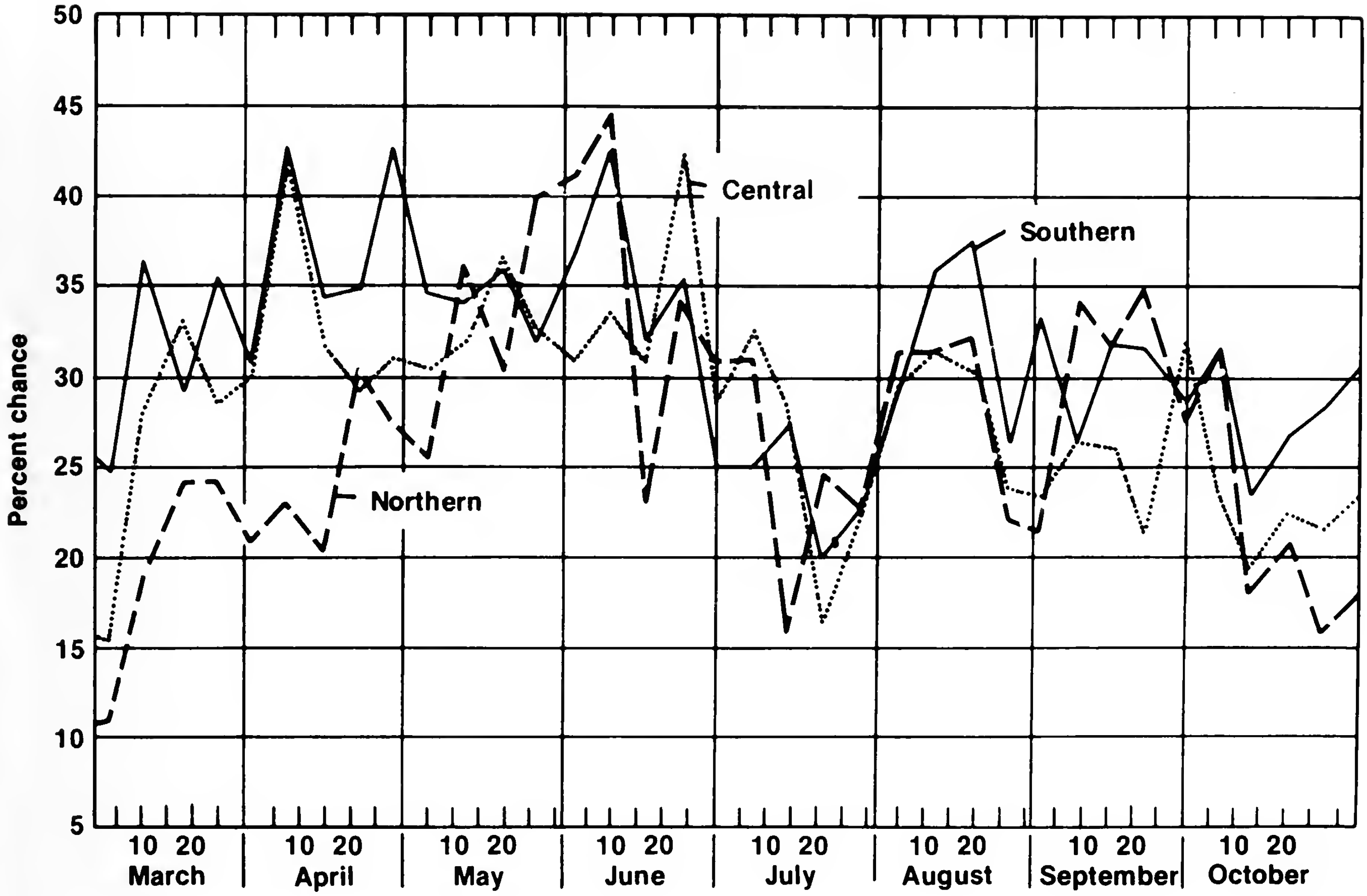


Figure 12.4. Chance of at least one inch of rain in one week.

The decision to irrigate

The need for an adequate water source cannot be overemphasized when one is considering irrigation. If a producer is convinced that an irrigation system will be profitable, an adequate source of water is necessary. Such sources do not now exist in many parts of the state. Fortunately, underground water resources are generally good in the sandy areas where irrigation is most likely to be needed. A relatively shallow well in some of these areas may provide enough water to irrigate a quarter section of land. In some areas of Illinois, particularly the northern third, deeper wells may provide a relatively adequate source of irrigation water.

Some farmers pump their irrigation water from streams, which can be a relatively good and economical source, providing the stream does not dry up in a droughty year. Impounding surface water on an individual farm is also possible in some areas of the state, but this water source is practical only for small acreages. However, an appreciable loss may occur both from evaporation and from seepage into the substrata. Generally, 2 acre-inches of water should be stored for each acre-inch actually applied to the land.

To make a one-inch application on one acre (one acre-inch), 27,000 gallons of water are required. A flow of 450 gallons per minute will give one acre-inch per hour. Thus a 130-acre, center-pivot system with a flow of 900 gallons per minute can apply one inch of water over the entire field in 65 hours of operation. Because some of the water is lost to evaporation and some may be lost from deep percolation or runoff, the net amount added will be less than one inch.

The Illinois State Water Survey and the Illinois State Geological Survey at Urbana can provide information about the availability of irrigation water. Submit a legal description of the site planned for development of a well and request information regarding its suitability for irrigation well development. Once you decide to drill a well, the Water Use Act of 1983 requires you to notify the local Soil and Water Conservation District office if the well is planned for an expected or potential withdrawal rate of 100,000 gallons or more per day. There are no permit requirements or regulatory provisions.

An amendment passed in 1987 allows Soil and Water Conservation districts to limit the withdrawals from large wells if domestic wells meeting state standards are affected by localized drawdown. The legislation currently affects Kankakee, Iroquois, Tazewell, and McLean counties.

The Riparian Doctrine, which governs the use of surface waters, states that one is entitled to a reasonable use of the water that flows over or adjacent to his or her land as long as one does not interfere with someone else's right to use the water. No problem results as long as water is available for everybody. But when the amount of water becomes limited, legal determinations become necessary as to whether one's water use interferes with someone else's rights. It may be important to establish a legal record to verify the date on which the irrigation water use began.

Assuming that it will be profitable to irrigate and that an assured supply of water is available, how do you find out what type of equipment is available and what is best for your situation? University representatives have discussed this question in various meetings around the state, although they cannot design a system for each individual farm. Your county Extension adviser can provide lists of dealers located in and serving Illinois. This list includes the kinds of equipment each dealer sells, but it will not supply information about the characteristics of those systems.

We suggest that you contact as many dealers as you wish to discuss your individual needs in relation to the type of equipment they sell. You will then be in a much better position to determine what equipment to purchase.

Subsurface irrigation

Subirrigation can offer the advantages of good drainage and irrigation using the same system. During wet periods, the system provides drainage to remove excess water. For irrigation, water is forced back into the drains and then into the soil.

This method is most suitable for land areas where the slope is less than 2 percent, with either a relatively high water table or an impermeable layer at 3 to 10 feet below the surface. The impermeable layer ensures that applied water will remain where needed and that a minimum quantity of water will be sufficient to raise the water table.

The free water table should be maintained at 20 to 30 inches below the surface. This level is controlled and maintained at the head control stands, and water is pumped accordingly. In the event of a heavy rainfall, pumps must be turned off quickly and the drains opened. As a general rule, to irrigate during the growing season, you must deliver a minimum of 5 gallons per minute per acre.

The soil should be permeable enough to allow rapid water movement, so that plants are well supplied in peak consumption periods. Tile spacing is a major factor in the cost of the total system and perhaps the most important single variable in its design and effectiveness. Where subirrigation is suitable, the optimum system will have closer drain spacings than a traditional drainage system.

Irrigation for double-cropping

Proper irrigation can eliminate the most serious problem in double-cropping: inadequate water to get the second crop off to a good start. No part of Illinois has better than a 30 percent chance of getting an inch or more of rain during any week in July and most weeks in August. With irrigation equipment available, double-crop irrigation should be a high priority. If one is considering irrigating, the possibility of double-cropping should be taken into account in making the decision about irrigation. Soybeans planted at Urbana on July 6 following a wheat harvest have yielded as much as 38 bushels per acre with irrigation. In Mason County, soybeans planted the first week in July have yielded as much as 30 bushels per acre with irrigation.

While it may be difficult to justify investing in an irrigation system for double-cropping soybeans alone, the potential benefits from irrigating other crops may make the investment worthwhile. Some farmers report that double-cropping is a top priority in their irrigation programs.

Fertigation

The method of irrigation most common in Illinois, the overhead sprinkler, is the one best adapted to applying fertilizer along with water. Fertigation permits nutrients to be applied to the crop as they are needed. Several applications can be made during the growing season with little if any additional application cost. Nitrogen can be applied in periods when the crop has a heavy demand for both nitrogen and water. Corn uses nitrogen and water most rapidly during the 3 weeks before tasseling. About 60 percent of the nitrogen needs of corn must be met by silking time. Generally, nearly all the nitrogen for the crop should be applied by the time it is pollinating, even though some uptake occurs after this time. Fertilization through irrigation can be a convenient and timely method of supplying part of the plant's nutrient needs.

In Illinois, fertigation appears to be best adapted to sandy areas where irrigation is likely to be needed even in the wettest years. On finer-textured soils with high water-holding capacity, nitrogen might be needed even though water is adequate. Neither irrigating just to supply nitrogen nor allowing the crop to suffer for lack of nitrogen is an attractive alternative. Even on sandy soils, only part of the nitrogen should be applied with irrigation water; preplant and sidedress applications should provide the rest of it.

Other problems associated with fertigation can only be mentioned here. These include (1) possible lack of uniformity in application, (2) loss of ammonium nitrogen by volatilization in sprinkling, (3) loss of nitrogen and resultant groundwater contamination by leaching if overirrigation occurs, (4) corrosion of equipment, and (5) incompatibility and low solubility of some fertilizer materials.

Cost and return

The annual cost of irrigating field corn with a center-pivot system in Mason County was estimated in 1987 to vary from $95 to $140 per acre. The lower figure is for a leased low-pressure system with a 50-horsepower electric motor driving the pump. The higher figure is for a purchased high-pressure system with a 130-horsepower diesel engine. Additional costs associated with obtaining a yield large enough to offset the cost of irrigation were estimated to be about $30 per acre per year, for a total irrigation cost of $125 to $170 per acre per year. The total investment for the purchased high-pressure irrigation system, including pivot, pump and gear head, diesel engine, and a 100-foot well, amounted to $450 per acre. If the low-pressure system were purchased, the total investment for the system, including pivot, pump, electric motor, and a 100-foot well, would be $400.

Irrigation purchases should be based on sound economics. The natural soil-water storage capacity for some soils in Illinois is too good to warrant supplemental irrigation. Based on the assumed fixed and variable costs of about $110 per acre per year, it would require an annual yield differential of about 50 bushels of corn ($2.20 a bushel) or 18 bushels of soybeans ($6.00 a bushel) to break even (Table 12.1). For irrigation to pay off, these yield differentials would have to be met on the average, over the 10- to 15-year life of the irrigation system. Some of the deep, fine-textured soils in Illinois simply would not regularly support these yield increases.

Irrigation scheduling

Experienced irrigators have developed their own procedures for scheduling applications, whereas beginners may have to determine timing and rates of application before they feel prepared to do so. Irrigators generally follow one of two basic scheduling methods, each of which has many variations.

The first method involves measuring soil water and plant stress by (1) taking soil samples at various depths with a soil probe, auger, or shovel and then measuring or estimating the amount of water available to the plant roots; or (2) inserting instruments such as tensiometers or electrical resistance blocks into the soil to desired depths and then taking readings at intervals; or (3) measuring or observing some plant characteristics and then relating them to water stress.

Table 12.1. Break-Even Yield Increase Needed to Cover Fixed and Variable Irrigation Costs

Corn price per bushel	Yield increase in bushels	Soybean price per bushel	Yield increase in bushels
$1.50.........	67	$4.75	21
1.70.........	59	5.00	20
1.90.........	53	5.25	19
2.10.........	48	5.50	18
2.30.........	43	5.75	17
2.50.........	40	6.00	17
2.70.........	37	6.25	16
2.90.........	34	6.50	15

Although in theory the crop can utilize 100 percent of the water that is available, the last portion of that water is not actually as available as the first water that the crop takes from the soil. Much like a half-wrung-out sponge, the remaining water in the soil following 50 percent depletion is more difficult to remove than the first half of the plant-available water.

The 50 percent depletion figure is often used to schedule irrigation. For example, if a soil holds 3 inches of plant-available water in the root zone, then we could allow 1½ inches to be used by the crop before replenishing the soil water with irrigation.

Soil samples

Estimating when the 1½ inches is used, or when 50 percent depletion occurs, can be done by a number of methods. One of the simplest is to estimate the amount of depletion by the "feel" method, which involves taking a sample from various depths in the active root zone with a spade, soil auger, or soil probe. It is important to dig a shallow hole to see how the soil looks at 6 to 12 inches early in the irrigation season. As the rooting depth extends to 3 feet, it may be wise to inspect a soil sample from the 9- to 18-inch level and another from the 24- to 30-inch level. Observing only the surface can be misleading on sandy soils because the top portion dries fairly quickly in the summer. To use this method of sampling, follow the guidelines shown in Table 12.2 to identify the depletion range you are in.

Tensiometers

Tensiometers are most suitable for sandy or loamy soils because the changes in soil-water content can be adequately described by the range of soil moisture tension (SMT) in which they operate. As plant roots dry the soil, SMT increases and water is pulled from the tensiometer into the surrounding soil, thereby increasing the reading on the vacuum gauge. After irrigation or rainfall, water replenishes the dry soil and SMT decreases. The vacuum developed in the tensiometer pulls water back through the porous ceramic tip, and the dial gauge reading decreases. By responding to both wetting and drying, a tensiometer can yield information on the effect of crop transpiration or water additions to soil-water status.

A tensiometer must be installed carefully to ensure meaningful readings. Improper use may be worse than not using a tensiometer — because false readings can result in poorly timed irrigation. Before use, each tensiometer assembly must be soaked in water overnight; then the bubbles and dissolved gases must be removed from the water within the tube and ceramic cup. This procedure can be done by using boiled water

Table 12.2. Behavior of Soil at Selected Soil-Water Depletion Amounts

Available water remaining in the soil	Soil type	
	Sands	Loamy sand/sandy loam
Saturated, wetter than field capacity	Free water appears when soil ball is squeezed	Free water appears when soil ball is squeezed
100% available (field capacity)	When soil ball is squeezed, wet outline on hand, but no free water	When soil ball is squeezed, wet outline on hand, but no free water
75 to 100%	Sticks together slightly	Forms a ball that breaks easily
50 to 75%	Appears dry; will not form a ball	Appears dry; will not form a ball
Less than 50%	Flows freely as single grains	Flows freely as grains with some small aggregates

and a small suction pump that is available from tensiometer manufacturers.

The tensiometer should be installed by creating a hole with a soil probe to within 3 to 4 inches of the desired depth, then pounding a rod with a rounded end to the final depth. The rod tip should be shaped like the tensiometer tip to ensure a good, porous cup-to-soil contact. Placement of tensiometers should be made according to two principles: (1) the tensiometer should be readily accessible if it is to be used; and (2) field placement of tensiometers should be made to stagger the readings throughout the irrigation cycle.

Tensiometers are available in lengths ranging from 6 inches to 4 feet. The length required depends on the crop grown, with lengths chosen to gain accurate information in the active root zone. For shallow-rooted vegetable crops, a single tensiometer per station, at a 6- to 9-inch depth, may be sufficient. Multiple-depth stations for corn or soybeans will allow you to track the depletion and recharge of soil water at several depths throughout the season. Because the active root zone shifts as the plant matures, water extraction patterns change as well. If you want to go with a single depth station, refer to Table 12.3 for the proper depths of placement.

Tensiometers may require servicing if SMT increases to more than 80 centibars. At this tension, air enters the porous cup and the vacuum is broken. Tensiometers that have failed in this manner can be put back into service by filling them with deaerated water. Servicing can be done without removing the tensiometer from the soil. If proper irrigation levels are maintained, the SMT should not rise to levels sufficient to break the vacuum.

Moisture blocks

Moisture blocks (sometimes referred to as electrical resistance blocks or gypsum blocks) are small blocks of gypsum with two embedded electrodes. The block operates on the principle that the electrical resistance of the gypsum is affected by water content.

When saturated, the gypsum block has low electrical resistance. As it dries, the electrical resistance increases. The moisture blocks are placed in the soil and electrical leads coming from the embedded electrodes are allowed to protrude from the soil surface. These leads are connected to a portable instrument that includes an electrical resistance meter and a voltage source.

Table 12.3. Tensiometer Placement Depth for Selected Crops

	Depth, inches	Depth, centimeters
Soybeans	18	46
Corn	12	30
Snap beans	9	23
Cucumbers	9	23

When a reading is desired, a voltage is applied and the resulting reading is recorded. The reading is converted to a soil-water content by using a predetermined calibration curve relating resistance to water content. Soil moisture blocks work well in fine- and medium-textured soils and are not recommended for sandy soils. The increase in fine-textured soil irrigation in Illinois, particularly for seed corn, may prompt an increase in the use of moisture blocks. As with tensiometers, a good soil contact is absolutely necessary for meaningful readings. Soil water must be able to move in and out of the blocks as if the blocks were part of the soil. Any gap between the block and the surrounding soil will prevent this movement.

Another method of scheduling, frequently called the "checkbook method," involves keeping a balance of the amount of soil water by measuring the amount of rainfall and then measuring or estimating the amount of water lost from crop use and evaporation. When the water drops to a certain level, the field is irrigated. Computer techniques are also available for estimating water loss, computing the water balance, and predicting when irrigation is necessary.

Management requirements

Irrigation will provide maximum benefit only when it is integrated into a high-level management program. Good seed or plant starts of proper genetic origin planted at the proper time and at an appropriate population, accompanied by optimum fertilization, good pest control, and other recommended cultural practices are necessary to assure the highest benefit from irrigation.

Farmers who invest in irrigation may be disappointed if they do not manage to irrigate properly. Systems are so often overextended that they cannot maintain adequate soil moisture when the crop requires it. For example, a system may be designed to apply 2 inches of water to 100 acres once a week. In two or more successive weeks, soil moisture may be limiting, with potential evapotranspiration equaling 2 inches per week. If the system is used on one 100-acre field one week and another field the next week, neither field may receive much benefit, especially if water stress comes at a critical time, such as during pollination of corn or soybean seed development. Inadequate production of marketable products may result.

Currently we suggest that irrigators follow the cultural practices they would use for the most profitable yield in a year of ideal rainfall. In many parts of the state, 1975, 1981, and 1982 were such years. If a farmer's yield is not already appreciably above the county average for that particular soil type, he or she needs to improve management of other cultural factors before investing in an irrigation system.

The availability of irrigation on the farm permits the use of optimum production practices every year. If rains come as needed, the investment in irrigation equipment will have been unnecessary that year, but no operating costs will be involved. When rainfall is inadequate, however, the yield potential can still be realized with irrigation.

Chapter 13.

1993 Weed Control for Corn, Soybeans, and Sorghum

This guide is based on the results of research conducted by the University of Illinois Agricultural Experiment Station, other experiment stations, and the U.S. Department of Agriculture (USDA). The soils, crops, and weed problems of Illinois have been given primary consideration.

The user should have an understanding of cultural and mechanical weed control. These practices change little from year to year, so this text will focus on making practical, economical, and environmentally sound decisions regarding herbicide use.

Most of the suggestions in this guide are intended primarily for ground applications. For aerial applications, such factors as amount of water and adjuvant may differ.

Precautions

The benefits of chemical weed control must be weighed against the potential risks to crops, people, and the environment. Discriminate use should minimize exposure of humans and livestock, as well as desirable plants. Risks can be reduced by observing current label precautions.

Current label

Precautions and directions for use may change. Herbicides classified as restricted-use pesticides (RUP) must be applied only by certified applicators (Table 13.1). Their use may be restricted because of toxicity or environmental hazards. Toxicity is indicated by the signal word on the label.

Signal word

Heed the accompanying precautions. The signal word for herbicides discussed in this guide is given in Table 13.1. "Danger-Poison" and "Danger" indicate high toxicity hazards, while "Warning" indicates moderate toxicity. Always use protective apparel and equipment for handling and application as specified on the label. Be sure that persons or animals not directly involved in the operation are not in the area. Use special precautions near residential areas.

Environmental hazards

Groundwater advisories (Table 13.1) must be observed, especially on sandy soils with a high water table. The threat of toxicity to fish and wildlife is indicated under "Environmental Hazards" on the label. Hazards to endangered species may be indicated.

Proper herbicide use

Apply only to approved crops at the proper rate and time. Illegal residues can result from overapplication or wrong timing. Observe the recommended harvesting or grazing intervals after treatment.

Proper equipment use

Make sure that spray tanks are clean and free of other pesticide residues. Many herbicide labels provide cleaning suggestions, which are particularly important when spraying different crops with the same sprayer and using postemergence herbicides. Correctly calibrate and adjust the sprayer before adding the herbicide to the tank.

Proper drift precautions

Spray only on calm days or when the wind is very light. Make sure the wind is not moving toward areas of human activity, susceptible crops, or ornamental plants. Nearby residential areas or fields of edible, horticultural crops deserve particular attention. *Use special precautions with Gramoxone Extra, Command, dicamba, and 2,4-D,* as symptoms of injury have occurred far from the application site.

Table 13.1. Herbicide and Herbicide Premix Names and Restrictions

Trade name	Common (generic) name(s)	RUP[a]	GWA[b]	Signal word[c]
AAtrex, atrazine	Atrazine	Yes	Yes	Caution
Accent	Nicosulfuron	—	—	Caution
Assure II	Quizalofop	—	—	Caution
Banvel	Dicamba	—	—	Warning
Basagran	Bentazon	—	—	Caution
Beacon	Primisulfuron	—	—	Caution
Bicep	Metolachlor + atrazine	Yes	Yes	Caution
Bladex	Cyanazine	Yes	Yes	Warning
Blazer	Acifluorfen	—	—	Danger
Bronco	Alachlor + glyphosate	Yes	Yes	Danger
Buctril	Bromoxynil	—	—	Warning
Buctril + Atrazine	Bromoxynil + atrazine	Yes	Yes	Caution
Bullet	Alachlor + atrazine	Yes	Yes	Caution
Butyrac 200	2,4-DB	—	—	Danger
Canopy	Metribuzin + chlorimuron	—	Yes	Caution
Classic	Chlorimuron	—	—	Caution
Cobra	Lactofen	—	—	Danger
Command	Clomazone	—	—	Warning
Commence	Clomazone + trifluralin	—	—	Warning
Cycle	Metolachlor + cyanazine	Yes	Yes	Caution
Dual	Metolachlor	—	Yes	Caution
Eradicane	EPTC + safener	—	—	Caution
Extrazine II	Cyanazine + atrazine	Yes	Yes	Warning
Freedom	Alachlor + trifluralin	Yes	Yes	Warning
Fusilade 2000	Fluazifop	—	—	Caution
Fusion	Fluazifop + fenoxaprop	—	—	Caution
Galaxy	Bentazon + acifluorfen	—	—	Danger
Gramoxone Extra	Paraquat	Yes	—	Danger-Poison
Laddok	Bentazon + atrazine	Yes	Yes	Danger
Lariat	Alachlor + atrazine	Yes	Yes	Warning
Lasso EC	Alachlor	Yes	Yes	Danger
Lexone	Metribuzin	—	Yes	Caution
Lorox	Linuron	—	—	Caution
Lorox Plus	Linuron + chlorimuron	—	—	Warning
Marksman	Dicamba + atrazine	Yes	Yes	Caution
Many trade names	2,4-D dimethylamine	—	—	Danger
Many trade names	2,4-D ester	—	—	Caution
Micro Tech	Alachlor	Yes	Yes	Caution
Option II	Fenoxaprop	Yes	—	Danger
Passport	Trifluralin + imazethapyr	—	—	Danger
Pinnacle	Thifensulfuron	—	—	Caution
Poast Plus	Sethoxydim	—	—	Caution
Preview	Metribuzin + chlorimuron	—	Yes	Caution
Princep, Simazine	Simazine	—	Yes	Caution
Prowl	Pendimethalin	—	—	Warning
Pursuit	Imazethapyr	—	—	Caution
Pursuit Plus	Pendimethalin + imazethapyr	—	—	Caution
Ramrod/atrazine	Propachlor + atrazine	Yes	Yes	Warning
Reflex	Fomesafen	—	—	Warning
Roundup	Glyphosate	—	—	Warning
Salute	Metribuzin + trifluralin	—	Yes	Caution
Scepter	Imazaquin	—	—	Caution
Select	Clethodim	—	—	Warning
Sencor	Metribuzin	—	Yes	Caution
Sonalan	Ethalfluralin	—	—	Warning
Squadron	Imazaquin + pendimethalin	—	—	Danger
Stinger	Clopyralid	—	Yes	Caution
Storm	Bentazon + acifluorfen	—	—	Danger
Sutan+	Butylate + safener	—	—	Caution
Sutazine	Butylate + atrazine	Yes	Yes	Danger
Tornado	Fluazifop + fomesafen	—	—	Warning
Treflan,Tri-4, Trific, Trilin	Trifluralin	—	—	Warning
Tri-Scept	Imazaquin + trifluralin	—	—	Danger
Turbo	Metribuzin + metolachlor	—	Yes	Caution

[a] RUP = Restricted-use pesticide to be applied by licensed applicator.

[b] GWA = Groundwater advisory; special precautions in sandy soils.

[c] Signal word = Toxicity signal; indicates need for extra precautions. The signal words "Danger" and "Warning" often indicate pesticides that can irritate skin and eyes, necessitating protective clothing, gloves, and goggles or face shield.

Precautions to protect the crop

Avoid applying a herbicide to crops under stress or predisposed to injury. Crop sensitivity varies with size of the crop and climatic conditions, as well as previous injury from plant diseases, insects, or chemicals.

Proper recropping interval

Failure to observe the proper recropping intervals may result in carryover injury to the next crop. Soil texture, organic matter, and pH may affect herbicide persistence. Atrazine used in corn or milo can carry over and injure susceptible follow crops. Many soybean herbicides have special recropping restrictions. Check Table 13.2 and current labels for recropping restrictions.

Proper storage

Promptly return unused herbicides to a safe storage place. Pesticides should be stored in their original, labeled containers in a secure place away from unauthorized people (particularly children) or livestock and their food or feed.

Proper container disposal

Liquid containers should be pressure- or triple-rinsed. Properly rinsed containers can be handled at approved sanitary landfills or possibly recycled. Haul paper containers to a sanitary landfill or burn them in an approved manner. If possible, use mini-bulk returnable containers.

Table 13.2. Herbicide Crop Rotation Restrictions — Months

Herbicide	pH	Corn	Milo	Wheat	Oats	Rye	Alfalfa	Clover	Soybeans
Accent	. . .	AT[a]	10[b]	4	8	4	10	10[b]	10
Assure	. . .	4	4	4	4	4	4	4	AT
Atrazine	<7.2	AT	AT	15	21	21	21	21	10[c]
Banvel[d]	. . .	AT	0.5	1	1	1	4	4	0.5
Beacon	. . .	0.5	8	3	8	3	8	18	8
Bicep	. . .	AT	AT•	15	15	15	18	18	10[c]
Buctril/atrazine	. . .	AT	AT	15	21	15	21	21	10[c]
Bullet	. . .	AT	AT•	15	21	15	21	21	10[c]
Canopy[e]	≤6.8	10	12	4	18[f]	18[f]	10	12	AT
Classic	<7.0	9	9[g]	3	3	3	9[g]	9[g]	AT
Command	. . .	9	9	12	16	16	16	16	AT
Commence	. . .	9	12	12	16	16	16	16	AT
Cycle	. . .	AT	AT•	4.5	4.5	4.5	4	9	9
Dual	. . .	AT	AT•	4.5	4.5	4.5	4	9	AT
Extrazine	. . .	AT	AT	15	15	15	18	18	10[c]
Fusion	. . .	2	2	2	2	2	2	2	AT
Laddok	. . .	AT	AT	9	9	9	18	18	10[c]
Lariat	. . .	AT	AT•	15	21	15	21	21	10[c]
Lexone	. . .	4	12	4	12	12	4	12	AT
Lorox Plus	≤6.8	10	10	4	4	4	10	12	AT
Marksman	. . .	AT	AT	10	10	10	18	18	10[c]
Passport	. . .	9.5	18	4	18	18	18	18	AT
Pinnacle	. . .	1.5	1.5	1.5	1.5	1.5	1.5	1.5	AT
Preview	≤6.8	10	12	4	BA[f]	BA[f]	10	12	AT
Princep	. . .	AT	12	15	21	21	21	21	10[c]
Pursuit	. . .	9.5	18	4	18	4	18	18	AT
Pursuit Plus	. . .	9.5	18	4	18	18	18	18	AT
Reflex	. . .	10	18	4	4	4	18	18	AT
Salute	. . .	4	12	4	12	12	4	12	AT
Scepter — Region 3									
1/3 pt/A	. . .	11	11	4[i]	4	18	18	18	AT
2/3 pt/A	. . .	18	11	16	16	18	18	18	AT
Scepter[h]	. . .	11[i]	11	4[i]	11	18	18	18	AT
Sencor	. . .	4	12	4	12	12	4	12	AT
Squadron[h]	. . .	11[i]	11	4[i]	11	18	18	18	AT
Stinger	. . .	AT	AT	AT	AT	AT	12	18	12
Sutazine	. . .	AT	12	15	15	15	18	18	10[c]
Tri-Scept[h]	. . .	11[i]	11	4[i]	11	18	18	18	AT
Turbo	. . .	8	12	4.5	12	12	12	12	AT

The following have no labeled rotational restrictions: Basagran, Bladex, Blazer, Bronco, Butyrac 200, Cobra, Eradicane, 2,4-D, Galaxy, Gramoxone Extra, Lasso, Poast Plus, Roundup, Sonalan, Storm, Sutan, and Treflan except for Eradicane, 2,4-D, and Sutan + that have replanting limits for soybeans.

• Seed protectant is needed.

[a] AT = anytime (no restrictions).

[b] 18 months if pH >6.5.

[c] If applied before June 10.

[d] From the between-cropping label.

[e] Reduced rate label for Midwest states.

[f] BA = bioassay after 10 months.

[g] 15 months if pH >7.

[h] Region 2 on Scepter label (approximately southern two-thirds of Illinois).

[i] 15-inch annual rainfall restriction or use imidazolinone-resistant or tolerant corn hybrids.

Check current labels

This guide has been developed to help you use herbicides effectively and safely. Because no guide can remove all of the risk involved, however, the University of Illinois and its employees assume no responsibility for the results of using herbicides, even if they have been used according to the suggestions, recommendations, or directions of the manufacturer or any governmental agency.

Cultural and mechanical control

Good cultural practices that aid in weed control include adequate seedbed preparation, adequate fertilization, crop rotation, planting on the proper date, use of the optimum row width, and seeding at the rate required for optimum stands.

Planting in relatively warm soil can help the crop emerge quickly and compete better with weeds. Good weed control during the first 3 to 5 weeks is extremely important for both corn and soybeans. If weed control is adequate during that period, corn and soybeans will usually compete quite well with most of the weeds that begin growing later.

Narrow rows will shade the centers faster and help the crop compete better with the weeds. If herbicides alone cannot give adequate weed control, however, then keep rows wide enough to allow for cultivation.

If a preemergence or preplant herbicide does not appear to be controlling weeds adequately, use the rotary hoe while weeds are still small enough to be controlled. Use the rotary hoe after weed seeds have germinated but before most weeds have emerged. Operate it at 8 to 12 miles per hour, and weight it enough to stir the soil and kill the tiny weeds. Rotary hoeing also aids crop emergence if the soil is crusted.

Row cultivators also should be used while weeds are small. Throwing soil into the row can help smother small weeds. Cultivate shallowly to prevent injury to crop roots.

Herbicides can provide a convenient and economical means of early weed control and allow for delayed and faster cultivation. Furthermore, unless the soil is crusted, it may not be necessary to cultivate some fields if herbicides are controlling weeds adequately.

Herbicide incorporation

Sutan+, Eradicane, Command, Treflan, and Sonalan are incorporated after application to minimize surface loss from volatilization and/or photodecomposition. Atrazine, Bladex, Lasso, Dual, Prowl, Pursuit, and Scepter may be incorporated to minimize dependence upon timely rainfall or to improve control of certain weed species.

Incorporation should place the herbicide uniformly throughout the top 1 or 2 inches of soil for the best control of small-seeded annual weeds that germinate at shallow depths. Slightly deeper placement may improve the control of certain weeds from deep-germinating seed under relatively dry conditions. Incorporating too deeply, however, tends to dilute the herbicide and may reduce its effectiveness. The field cultivator and tandem disk place most of the herbicide at about one-half the depth of operation. Thus, for most herbicides, the suggested depth of operation is 3 to 4 inches for most tillage tools.

Thorough incorporation with ground-driven implements usually requires two passes. If the first pass sufficiently covers the herbicide to prevent surface loss, the second pass can be delayed until immediately before planting. Single-pass incorporation may be adequate with some herbicides and some equipment, especially if rotary hoeing, cultivation, or subsequent herbicide treatments are used to improve weed control.

For some herbicides, accurate application and uniform distribution can be very important for avoiding carryover problems.

The depth and thoroughness of incorporation depend upon the type of equipment used, the depth and speed of operation, the texture of the soil, and the amount of soil moisture. Field cultivators and tandem disks are commonly used for incorporation; however, disk-chisels and other combination tools are being used in some areas.

Field cultivators

Field cultivators are frequently used for herbicide incorporation. They should have three or more rows of shanks with an effective shank spacing of no more than 8 to 9 inches (a spacing of 24 to 27 inches on each of three rows). The shanks may be equipped with points or sweeps. Sweeps usually give better incorporation, especially when soil conditions are a little too wet or dry for optimum soil flow and mixing. Sweeps for C-shank cultivators should be at least as wide as the effective shank spacing.

The recommended operating depth for the field cultivator is 3 to 4 inches. It is usually sufficient to operate the field cultivator only deep enough to remove tractor tire depressions. The ground speed should be at least 6 miles per hour. The field cultivator must be operated in a level position so that the back shanks are not operating in untreated soil, which would result in streaked weed control. Two passes are recommended to obtain uniform weed control with most herbicides. However, single-pass incorporation may sometimes be adequate for some herbicides with certain equipment and soil conditions. If single-pass incorporation is preferred, the use of wider sweeps or narrower spacing with a 3- to 5-bar harrow or rolling baskets pulled behind will increase the probability of obtaining adequate weed control.

Tandem disks

Tandem disk harrows invert the soil and usually place the herbicide deeper in the soil than most other incorporation tools. Tandem disks used for herbicide incorporation should have disk blade diameters of 20 inches or less and blade spacings of 7 to 9 inches. Larger disks are considered primary tillage tools and should not be used for incorporating herbicides. Spherical disk blades give better herbicide mixing than do conical disk blades.

Tandem disks usually place most of the herbicide in the top 50 to 60 percent of the operating depth. For most herbicides, the suggested operating depth is from 3 to 4 inches. Two passes are recommended to obtain uniform mixing with a double disk. A leveling device (harrow or rolling baskets) should be used behind the disk to obtain proper mixing. Recommended ground speeds are usually between 4 and 6 miles per hour. The speed should be sufficient to move the soil the full width of the blade spacing. Lower speeds can result in herbicide streaking.

Combination tools

Several new tillage tools combine disk gangs, field cultivator shanks, and leveling devices. Many of these combination tools can handle large amounts of surface residue without clogging and yet leave considerable crop residue on the soil surface for erosion control. Results indicate that these combination tools may provide more uniform one-pass incorporation than a disk or field cultivator, but one pass with them is generally no better than two passes with the disk or field cultivator.

Chemical weed control

Plan your weed-control program to fit your soils, tillage program, crops, weed problems, and farming operations. Good herbicide performance depends on the weather and on wise selection and application. Your decisions about herbicide use should be based on the nature and seriousness of your weed problems. The herbicide selectivity tables in this guide indicate the susceptibility of our most common weed species to herbicides.

Corn or soybeans may occasionally be injured by some of the herbicides registered for use on these crops. To reduce injury to crops, apply the herbicide uniformly, at the time specified on the label, and at the correct rate. (See the section below titled "Herbicide rates.") Crop tolerance ratings for various herbicides are also given in the tables in this guide. Unfavorable conditions such as cool, wet weather; delayed crop emergence; deep planting; seedling diseases; soil in poor physical condition; and poor-quality seed may contribute to crop stress and herbicide injury. Hybrids and varieties also vary in their tolerance to herbicides and environmental stress factors. Once injured by a herbicide, plants are prone to disease.

Crop planting intentions for next season must also be considered. Where atrazine or simazine are used, you should not plant spring-seeded small grains, small-seeded legumes and grasses, or vegetables the following year. Be sure that the application of Treflan or similar herbicides for soybeans is uniform and sufficiently early to reduce the risk of injury to wheat or corn following soybeans. Refer to the herbicide label for information about cropping sequence and appropriate intervals to allow between different crops. Table 13.2 provides a summary of some of the recropping restrictions.

Some herbicides have different formulations and concentrations under the same trade name. *No endorsement of any trade name is implied, nor is discrimination against similar products intended.*

Herbicide combinations

Herbicide combinations can control more weed species, reduce carryover, or reduce crop injury. Numerous combinations of herbicides are sold as premixes, and some are tank-mixed. Registered tank mixes are shown in the tables. Tank-mixing allows you to adjust the ratio of herbicides to fit local weed and soil conditions, while premixes may overcome some of the compatibility problems found with tank-mixing. When using a tank mix, you must follow restrictions on all products used in the combination.

Problems may occur when mixing emulsifiable concentrate (EC) formulations with wettable powder (W), liquid flowable (L), or dry flowable (DF) formulations. These problems can sometimes be prevented by using proper mixing procedures. If using liquid fertilizers, check compatibility in a small lot before mixing a tankful. Fill tanks at least one-fourth full with water or liquid fertilizer before adding herbicides that are suspended. The addition of compatibility agents may be necessary. Wettable powders, dry flowable, or liquid flowable concentrates should be added to the tank and thoroughly mixed before adding emulsifiable concentrates. Emulsify concentrates by mixing with equal volumes of water before adding them to the tank. Empty and clean spray tanks often enough to prevent accumulation of material on the sides and the bottom of the tank.

The user can apply two treatments of the same herbicide (split application) or can use two different herbicides, provided such uses are registered. The use of one herbicide after another is referred to as a sequential or overlay treatment.

Herbicide rates

Herbicide rates vary according to the time of application, soil conditions, the tillage system used, and the seriousness of the weed infestation. Rates of individual components within a combination are usually lower than rates for the same herbicides used alone.

The rates for soil-applied herbicides usually vary with the texture of the soil and the amount of organic matter the soil contains. (See corn and soybean sections under preplant and preemergence herbicides for examples.) For sandy soils, the herbicide label may specify reducing the rate or not to use at all if crop tolerance to the herbicide is marginal. Postemergence rates often vary depending upon the size and species of the weeds and whether or not an adjuvant is specified.

The rates given in this guide are, unless otherwise specified, broadcast rates for the amount of formulated product. If you plan to band or direct herbicides, adjust the amount per crop acre according to the percent of the area actually treated. Herbicides may have several formulations with different concentrations of active ingredient. Be sure to read the label and make necessary adjustments when changing formulations.

Postemergence herbicide principles

Postemergence herbicides applied to growing weeds generally have foliar rather than soil action; however, some may have both. The rates and timing of applications are based on weed size and climatic conditions. (For examples of rates versus weed sizes for soybean postemergence herbicides, see soybean sections titled "Contact herbicides for postemergence control of broadleaf weeds" and "Translocated herbicides for postemergence control of broadleaf weeds.") Weeds can usually be controlled with a lower application rate when they are small and tender. Larger weeds often require a higher herbicide rate. Herbicide penetration and action are usually greater with warm temperature and high relative humidity. Rainfall occurring too soon after application (1 to 8 hours, depending on the herbicide) can cause poor weed control.

Translocated herbicides are most effective at lower spray volumes (5 to 20 gallons per acre), whereas contact herbicides require more complete coverage. Foliar coverage increases as water volume and spray pressure are increased. Spray nozzles that produce small droplets also improve coverage. For contact herbicides, 20 to 40 gallons of water per acre are often recommended for ground application, and a minimum of 5 gallons per acre is recommended for aerial application. Spray pressures of 30 to 60 psi are often suggested with flat-fan or hollow-cone nozzles to produce small droplets and improve canopy penetration. *These small droplets are quite subject to drift.*

The use of an adjuvant such as a surfactant, crop-oil concentrate, or fertilizer solution may be recommended to improve spray coverage and herbicide uptake. These spray additives will usually improve weed control but may increase crop injury. Spray additives may be needed, especially under droughty conditions or on larger weeds.

Crop size limitations may be specified on the label to minimize crop injury and maximize weed control. If weeds are smaller than the crop, basal-directed sprays may minimize crop injury because they place more herbicide on the weeds than on the crop. If the weeds are taller than the crop, rope-wick or sponge-type applicators may be used to place the herbicide on the top of the weeds and minimize contact with the crop. Follow the label directions and precautions for each herbicide.

Conservation tillage and weed control

Conservation tillage allows crop production while it reduces soil erosion by protecting the soil surface with plant residue. Minimum or reduced tillage refers to any tillage system that leaves crop residue on the soil surface. These include primary tillage with chisel plows or disks and the use of field cultivators, disks, or combination tools for secondary tillage. Mulch tillage is reduced tillage that leaves at least 30 percent of the soil surface covered with plant residue.

Ridge tillage and zero tillage are conservation tillage systems with no major tillage prior to planting. In ridge tillage, conditions are often ideal for banding of preemergence herbicides. Cultivation is a part of the system. "No-till" is actually slot tillage for planting with no overall primary tillage. No-till planting conserves moisture, soil, and fuel. It also allows timely planting of soybeans or sorghum after winter wheat harvest.

If tillage before planting is eliminated, undesirable existing vegetation at planting must be controlled with herbicides. The elimination or reduction of herbicide incorporation and row cultivation puts a greater reliance on chemical weed control. Soil conditions must be ideal for single-pass herbicide incorporation to be uniform. Greater emphasis may be placed on preplant or postplant soil-applied herbicides that are not incorporated or on foliar-applied herbicides.

Where primary tillage is minimized, soil residual herbicides applied several weeks before planting may reduce the need for a "knockdown" herbicide. However, early preplant (EPP) application may require additional preemergence or postemergence herbicides or cultivation for satisfactory weed control after planting. See the sections on corn and soybeans under "Preplant not incorporated" for more details.

Corn and soybeans are the primary crops in Illinois, and they are often planted in a corn and soybean rotation. Modern equipment allows successful no-till planting in corn or soybean stubble. The use of a disk or chisel plow on corn stubble may still provide adequate crop residue to allow minimum tillage. Herbicides are also available to allow a "total postemergence" weed control program, especially for soybeans.

Soybean stubble is often ideal for zero or minimum tillage. Primary tillage is rarely needed, and the crop residue should not interfere with herbicide distribution. Early preplant application of preemergence herbicides or the use of postemergence herbicides can often provide adequate weed control.

The existing vegetation in corn and soybean stubble is often annual weeds. If the weeds are small, they can often be controlled before planting with herbicides that have both foliar and soil residual activity (Table 13.3). For corn, these include atrazine or Bladex and their premixes. For soybeans, metribuzin (Sencor or Lexone), linuron (Lorox), and their premixes with chlorimuron (Preview, Canopy, or Lorox Plus), as well as Pursuit can be used. Foliar activity is enhanced with the addition of crop-oil concentrate (COC) or surfactant.

Sod planting requires a different approach. If minimum or zero tillage is to be used in perennial grass or legume sods, *the sod should be controlled prior to planting.* Late control of sod may deplete soil moisture, making crop establishment difficult. Some grass sods may require the use of Roundup *in the fall* when there is adequate foliage and translocation for effective control. Bluegrass or clover may be controlled by atrazine alone or combined with Bladex. Clover sods can be controlled by Roundup, Banvel, or 2,4-D applied in the fall before planting soybeans. Roundup, Banvel, or 2,4-D can be applied in the fall or spring ahead of corn. Alfalfa may be controlled with Banvel or Banvel plus 2,4-D. *Do not plan to take a spring cutting before planting into forage sods.* Regrowth rarely provides sufficient foliage for active herbicide uptake to kill the sod prior to planting corn.

Winter cover crops of wheat or rye can be controlled by Roundup prior to planting corn or soybeans, or Gramoxone plus atrazine may be used prior to planting corn. A winter cover crop of hairy vetch can be controlled with 2,4-D or Banvel before or after planting corn.

Annual vegetation over 2 to 3 inches tall at planting time may require a burndown or translocated herbicide. Gramoxone, Roundup, or Bronco can be used with most preemergence herbicides to control vegetation that is already present.

Gramoxone Extra (paraquat) can be used to control existing vegetation before planting. Gramoxone Extra **2.5S** is used at 1.5 to 3 pints per acre. It should be applied with a nonionic surfactant or crop-oil concentrate in at least 20 gallons of spray per acre. The addition of a photosynthetic inhibitor herbicide can improve control of smartweed, giant ragweed, and "marestail." *Gramoxone Extra is a restricted-use pesticide.*

Roundup (glyphosate) can be used at 3 to 8 pints per acre to control existing vegetation prior to planting. Roundup at the higher rates can translocate to the roots to control some perennials. Spray volume per acre should be 20 to 40 gallons. Small annual weeds can be controlled with 0.75 to 1 pint of Roundup in 5 to 10 gallons of water per acre plus 0.5 percent nonionic surfactant. Micro Tech or Bullet should not be mixed with Roundup unless ammonium sulfate is added at 17 pounds per 100 gallons of water. The ammonium sulfate should be mixed with water first and then the Micro Tech or Bullet added before adding Roundup.

Bronco (glyphosate plus alachlor) contains the equivalent of 2.6 quarts of Lasso EC and 1.4 quarts of Roundup per gallon. Bronco is used at 6 to 10 pints per acre applied in 10 to 30 gallons of water. Application can also be made in urea-ammonium nitrate (UAN) solutions if annual weeds are less than 6 inches tall. *Bronco is a restricted-use pesticide.*

Banvel (dicamba) may be used in the fall or spring before planting corn or only in the fall before planting soybeans. Banvel can control annual and some perennial broadleaf plants including clovers and alfalfa. A combination of Banvel plus 2,4-D can often control more weeds at lower cost.

2,4-D can be used in the fall or spring before planting corn or possibly before no-till soybeans to control broadleaf weeds. *See current 2,4-D label.*

Herbicides for corn

Herbicides mentioned in this section are registered for use on field corn. Some are also registered for silage corn. See Table 13.4 for registered combinations. Herbicide suggestions for sweet corn and popcorn may be found in Chapter 11 of the *Illinois Agricultural Pest Control Handbook,* "Weed Control for Commercial Vegetable Crops." Growers producing hybrid seed corn should check with the contracting company or the

Table 13.3. No-Till Herbicides and Their Knockdown Control of Weeds

Herbicide	DBM	FPN	RYE	MTL	PLC	MTD	LQR	CRW	SWD	HVC	ALF
Roundup	9	9	9	9	8	10	9	9	7	6	6
Gramoxone	7	7	8	7	6	10	8	8	7	7	3
2,4-D ester	0	0	0	8	9	10	9	10	7	10	8
Banvel	0	0	0	9	9	7	10	10	9	10	9
Atrazine	7	5	7	8	9	10	10	9	10	7	4
Bladex	7	8	5	9	9	10	9	10	9	8	4
Extrazine	7	7	6	9	9	10	9	10	9	8	4
Canopy	6	3	3	9	9	10	9	9	9	5	4
Pursuit	6	7	5	6	6	10	6	7	9	2	0

DBM = downy brome, FPN = fall panicum, RYE = rye or wheat, MTL = marestail (also known as horseweed), PLC = prickly lettuce, MTD = mustards, LQR = lambsquarters, CRW = common ragweed, SWD = smartweed, HVC = hairy vetch, ALF = alfalfa sod.

Rating Scale:
10 = 95 to 100 percent, 9 = 85 to 95 percent, 8 = 75 to 85 percent, 7 = 65 to 75 percent, and 6 = 55 to 65 percent. Weed control of 5 or less is rarely significant.

producer of inbred seed about tolerance of the parent lines. Rates for preplant and preemergence herbicides to use on several typical Illinois soils are given in Table 13.5. See Tables 13.6 and 13.7 for weeds controlled by the herbicides used in corn.

Preplant not incorporated (corn)

Early preplant herbicide application is used in no-till programs to minimize existing vegetation problems at planting and reduce the need for a knockdown herbicide. Atrazine, Bladex, and Extrazine have both foliar and soil activity so they may control small annual weeds prior to planting corn, especially if a nonionic surfactant or crop-oil concentrate is added to the spray mix. However, if weeds over 2 to 3 inches tall are present, add Gramoxone Extra, Roundup, 2,4-D ester, Banvel, or Marksman. See Table 13.3 for weeds controlled by these herbicides.

Atrazine, Bicep, Bullet, Dual, Cycle, or Micro Tech can be used within 30 days of corn planting as a single full-rate application or within 45 days if application is split before planting and at planting. *Atrazine, Bicep, Bullet, Cycle, and Micro Tech are restricted-use pesticides.*

Bladex or Extrazine II can be applied 15 to 30 days before planting corn. Apply before weeds germinate or seedlings are more than 3 inches tall. *Bladex and Extrazine II are restricted-use pesticides.*

Banvel or Marksman can be applied before or at planting. On medium- or fine-textured soils with at least 2 percent organic matter, use 1 pint of Banvel or 3.5 pints of Marksman per acre. On other soils *under no-till only,* use 0.5 pint of Banvel or 2 pints of Marksman per acre. To control alfalfa or clover sod, apply after 4 to 6 inches of regrowth. 2,4-D can be added to improve control of dandelions or plantains. *Marksman is a restricted-use pesticide.*

Table 13.4. Registered Herbicide Combinations for Preplant-Incorporated, Preemergence, or Early Postemergence Application in Corn

	Atrazine	Bladex or Extrazine II	Banvel or Marksman	Pursuit[a]
Used alone	1,2,3	1,2,3	2,3	1,2,3
Eradicane	1	1	—	1
Sutan +	1	1	—	1
Dual	1,2,3	1,2	2,3	1,2,3
Micro Tech	1,2,3	1,2	2,3	1,2,3
Prowl	2,3	2[b],3[b]	2,3	2,3

1 = Preplant incorporated; 2 = Preemergence; 3 = Early postemergence; — = Not registered.

[a] Use Pursuit only with tolerant or resistant corn hybrids.

[b] Bladex, not Extrazine.

Table 13.5. Corn Herbicides: Preplant or Preemergence Rates per Acre

		Organic matter:[a]	1%	1-2%	3-4%	5-6%
Herbicide	Unit	Soil texture:[b]	sal	sil	sicl	sic
Atrazine 4L	pt		4.0	4.0	4.0	4.0
Atrazine 90DF	lb		2.2	2.2	2.2	2.2
Bicep 6L	pt		3.0	3.6	4.8	6.0
Bladex 4L	pt		2.5[c]	4-5	7-8	9.5
Bladex 90DF	lb		1.3[c]	2-3	4.4	5.3
Bronco 4L	pt		6.0	8.0	8-10	10.0
Bullet 4L	pt		5.0	6.0	8.0	9.0
Cycle 4L	pt		5.0[c]	6-7	8-9	9-10
Dual 8E	pt		1.5	2.0	2.5	2.5
Dual 25G	lb		6-8	8-10	10.0	12.0
Eradicane 6.7E	pt		4.75	4.75	5.3	5.3
Eradicane Extra 6E	pt		4.0	4.0	5.3	5.3
Extrazine 4L	pt		2.5[c]	4-5	6-7	8-9
Extrazine 90DF	lb		1.5[c]	2-3	4-5	5-5.5
Lariat 4L	pt		5.0	6.0	8.0	9.0
Lasso 4E	pt		3-4	3-4	4-5	5-6
Lasso II 15G	lb		16.0	20.0	22.0	26.0
Marksman 3.3L	pt		—[d]	—[d]	3.5	3.5
Micro Tech 4ME	pt		3-4	3-4	4-5	5-6
Partner 65DF	lb		3-4	4.5	4.5	5.5
Princep 4L	pt		4.0	4.8	6.0	8.0
Princep 90DF	lb		2.2	2.6	3.3	4.4
Prowl 3.3E	pt		2.0	2.4	3.6	4.0
Sutan+ 6.7E	pt		4.75	4.75	4.75	4.75
Sutazine 6L	pt		5.25	5.25	7.0	7.0

[a] Percent organic matter in the soil.

[b] sal = sandy loam, sil = silt loam, sicl = silty clay loam, sic = silty clay.

[c] Questionable due to crop injury or short persistence.

[d] Not recommended on this soil.

Table 13.6. Corn Herbicides: Grass and Nutsedge Control

Herbicide	BYG	CBG	FLP	GFT	YFT	WCG	SBR	SHC	WPM	JHG	QKG	WSM	YNS	CRN
Soil-applied														
Atrazine	8	5	3	7	7	4	7	2	3	0	8	3	6	0
Bladex	7	7	8	8+	8	6	7	2	7	0	3	0	5	2
Dual	8+	9	8+	9	9	7	7	5	7	0	0	0	7+	1+
Eradicane	9	9	9	9	9	8	8	7	7	6	5	2	8	1+
Extrazine	8	7	7	8	8	6	7	2	5	0	4	2	4	2
Micro Tech	8+	9	8	9	9	7	7	5	7	0	0	0	7	1
Princep	8	8	7	7	7	4	5	4	4	0	4	2	2	0
Prowl	8	9	8+	8+	8+	8	7	7	7	2	0	0	0	2
Pursuit[a]	6	7	7	7	6	6	5	7	4	4	2	0	4	1
Sutan+	9	9	9	9	9	8	9	7	7	6	6	5	7	1
Foliar-applied (postemergence)														
Accent	8	5	8	9	8	8	8	9+	8	9	8+	6	6	1
Atrazine/oil	8	5	5	7	7	6	7	2	4	0	7	6	6	1+
Beacon	4	5	7	6	5	2	6	9+	2	8	7	4	6	1+
Bladex	8	7	7	8	8	6	7	2	6	0	3	2	5	2
Pursuit[a]	8	7	7	8	7	5	4	9	3	6	0	2	6	1

BYG = barnyardgrass, CBG = crabgrass, FLP = fall panicum, GFT = giant foxtail, YFT = yellow foxtail, WCG = woolly cupgrass, SBR = sandbur, SHC = shattercane, WPM = wild proso millet, JHG = johnsongrass, QKG = quackgrass, WSM = wirestem muhly, YNS = yellow nutsedge, and CRN = corn response.

[a] Use only on Pursuit-resistant or -tolerant field corn hybrids.

Rating Scale:
10 = 95 to 100 percent, 9 = 85 to 95 percent, 8 = 75 to 85 percent, 7 = 65 to 75 percent, 6 = 55 to 65 percent, and 5 = 45 to 55 percent. Weed control of 5 or less is rarely significant. Corn injury of 1 or less is rarely significant.

Table 13.7. Corn Herbicides: Broadleaf Weed Control

Herbicide	AMG	BCC	CCB	JMW	LBQ	BNS	PGW	CRW	GRW	SMW	SFR	PSI	VLV	CRN
Soil-applied														
Atrazine	9	7	9	10	9	9	9	9	8	9	8	9	8	0
Bladex	8	4	8	8	9	8	6	9	7	9	7	8	7	2
Dual	0	0	0	4	6	7+	8	5	2	4	0	0	0	1+
Eradicane	3	0	2	2	7	4	7	5	3	4	0	0	5	1+
Extrazine	9	7	9	9	9	9	9	9	8	9	8	7	8	2
Marksman	8	6	8	8	8	8	9	9	8	9	8	7	7+	2
Micro Tech	0	0	0	5	7	7+	9	5	2	5	0	0	0	1
Princep	9	6	9	9	9	9	9	9	7	9	8	9	8	0
Prowl	0	0	0	2	8	0	9	2	0	4	0	0	6	2
Pursuit[a]	6	7	7	7	8	8	9	7	6	9	8	7	8	1
Sutan+	3	0	2	2	5	2	7	4	3	3	0	0	4	1
Foliar-applied (postemergence)														
Accent	7	8	4	8	5	0	8+	3	3	8	5	2	6	1
Atrazine/oil	9	8	9	9	9	9	10	9	8	10	9	9	9	1+
Banvel	9	7	9	9	9	8	9	9	9	10	8	7	7	1+
Beacon	5	8	8	8	6	7	8	9	9	8	8	8	7	1+
Bladex	7	5	8	8	9	9	6	9	7	9	7	6	7	2
Buctril	8	8	9	9	9	9	7+	9	7	8+	9	5	8	2
Buctril/atrazine	**9**	**9**	**9**	**10**	**10**	**10**	**10**	**9**	**9**	**10**	**10**	**9**	**9**	**2**
2,4-D	9	3	9	7	9	7	9	9	9	6	8	8	8	2+
Laddok	8	7	9	10	9	9	9	9	9	10	10	8	9	1
Marksman	9	8	9	10	10	10	10	9	9	10	9	9	9	1+
Pursuit[a]	7	8	9	8+	6	9+	9	7	7	8	9	6	8+	1+
Stinger	3	6	9	8	3	7	3	9	9	7	8	3	3	1

AMG = annual morningglory, BCC = burcucumber, CCB = cocklebur, JMW = jimsonweed, LBQ = lambsquarters, BNS = black nightshade, PGW = pigweed, CRW = common ragweed, GRW = giant ragweed, SMW = smartweed, SFR = wild sunflower, PSI = prickly sida, VLV = velvetleaf, and CRN = corn.

[a] Use only on Pursuit-resistant or -tolerant field corn hybrids.

Rating Scale and Approximate Weed Control
10 = 95 to 100 percent, 9 = 85 to 95 percent, 8 = 75 to 85 percent, 7 = 65 to 75 percent, and 6 = 55 to 65 percent.
Weed control of 5 or less is rarely significant. Corn injury of 1 or less is rarely significant.
For ratings on herbicide combinations (tank-mix or premix), see the component parts.

Premix:	Grass	+	Broadleaf	Premix	Broadleaf	+	Broadleaf
Bicep:	Dual	+	atrazine	Buctril + Atrazine:	Buctril	+	atrazine
Bullet:	Micro Tech	+	atrazine	Laddok:	Basagran	+	atrazine
Cycle:	Dual	+	Bladex	Marksman:	Banvel	+	atrazine
Extrazine:	Bladex	+	atrazine				
Lariat:	Lasso	+	atrazine				
Sutazine:	Sutan+	+	atrazine				

2,4-D can be used to control existing vegetation before planting reduced-tillage corn. Some preplant tank-mixes allow 1 to 2 pints of 2,4-D LV ester per acre. See the specific label for instructions on this type of weed control.

Buctril + Atrazine (tank-mix or premix) can control some existing vegetation before planting field corn. *Buctril + Atrazine is a restricted-use pesticide.*

Roundup or Gramoxone Extra has no residual control but can be tank-mixed with most other preplant herbicides to control existing vegetation before planting corn. See the conservation tillage section earlier in this chapter for more information. *Gramoxone Extra is a restricted-use pesticide.*

Preplant-incorporated herbicides (corn)

Sutan+ (butylate) or Eradicane or Eradicane Extra (EPTC) require incorporation because they are volatile. Apply within 2 weeks of the expected planting date. If possible, application and incorporation should be done at the same time. *Do not delay incorporation more than 4 hours.*

Sutan+ and Eradicane control annual grass weeds and are used at 4-3/4 to 7-1/3 pints per acre. The rate for Eradicane Extra 6E is 5-1/3 to 8 pints per acre. Use the higher rates for heavy weed infestations or to suppress certain problem weeds.

Sutan+ or Eradicane may be tank-mixed with atrazine, Bladex, or Extrazine II to improve broadleaf control. **Sutazine,** a premix of butylate (Sutan+) and atrazine, is used at 5.25 to 10.5 pints 6ME or 16.7 to 22.7 pounds 18-6G per acre. *Sutazine is a restricted-use pesticide.*

Preplant or preemergence herbicides (corn)

AAtrex or Atrazine (atrazine) or Princep (simazine) are often incorporated before planting because of low solubility. Atrazine alone is used at 4 pints 4L or 2.2 pounds 90DF per acre. The rate is 2 to 3 pints 4L or 1.1 to 1.8 pounds 90DF per acre for broadleaf control in tank mixes with other herbicides to control grass weeds. *All products containing atrazine are restricted-use pesticides because of the risk of groundwater and surface contamination.*

Required changes in atrazine use

Surface water concerns bring new atrazine restrictions involving rate limits and buffer zones to help protect surface water. Maximum single application is 1.6 to 2 pounds atrazine active ingredient (a.i.) per acre and a total of 2.5 pounds per acre per year. The 1.6-pound rate is for highly erodible land (HEL) with less than 30 percent crop residue.

Required buffer zones (set-backs) are 66 feet between application sites and "points where field surface water can enter streams and rivers" and 200 feet from lakes and reservoirs. On HEL, the 66-foot buffer zone must be planted in crop or seeded in grass. No mixing or loading of atrazine is allowed within 50 feet of streams, rivers, lakes, or reservoirs.

The use of premixes containing atrazine makes calculations of total atrazine use difficult, especially if both soil-applied and postemergence premixes are used. Pounds of active ingredient (a.i.) of atrazine per gallon or pint for liquid premix corn herbicides containing atrazine are listed below:

	Lb atrazine a.i.	
Premix and form	gallon	pint
Atrazine 4L	4.00	0.500
Bicep 6L	2.67	0.333
Bicep Lite 5L	1.67	0.209
Buctril + Atrazine 3L	2.00	0.250
Bullet 4L	1.50	0.189
Extrazine II 4L	1.00	0.125
Laddok 3.3L	1.67	0.209
Lariat 4L	1.50	0.189
Marksman 3.2L	2.10	0.263
Sutazine 6L	1.20	0.150

Example: If you apply 4.8 pints of Bicep (1.602 lb atrazine a.i.) and 3.5 pints of Marksman (0.920 lb atrazine a.i.), you have applied a total of 2.522 pounds of atrazine a.i. per acre, slightly over the 2.5 pounds allowed.

Atrazine and simazine can persist to injure follow crops. The risk of carryover is greater after a cool, dry season and on soils with a pH greater than 7.3. Soybeans planted the next year may show injury from atrazine carryover. If you apply atrazine after June 10, plant only corn or sorghum the next year. *Do not plant small grains, clovers, alfalfa, or vegetables in the fall or the next spring after using atrazine.*

Bladex (cyanazine) controls most annual grass weeds but is weaker than atrazine on some broadleaf weeds. Bladex has shorter persistence than atrazine, but atrazine is less likely to injure corn. **Extrazine II** is a 3:1 premix of cyanazine (Bladex) and atrazine used at rates and times similar to those of Bladex.

Select rates of Bladex or Extrazine accurately on the basis of soil texture and organic matter content to reduce the possibility of corn injury (see Table 13.5). Used alone, Bladex rates are 1.3 to 5.3 pounds of 90DF or 2-1/2 to 9-1/2 pints of 4L per acre, whereas Extrazine rates are 1.4 to 5.8 pounds 90DF or 2-1/2 to 10-1/2 pints 4L per acre. They may be tank-mixed at reduced rates with "grass" herbicides (Table 13.4) for broadleaf weed control. *Bladex and Extrazine II are restricted-use pesticides.*

Cycle 4L, a 1:1 premix of metolachlor (Dual) and cyanazine (Bladex), can be applied up to 14 days prior to planting and incorporated or used preemergence after planting. The rate is 5 to 9 pints per acre. *Cycle is a restricted-use pesticide.*

Lasso (alachlor) or Dual (metolachlor) primarily controls annual grasses and some small-seeded broadleaf weeds (Tables 13.6 and 13.7). To improve broadleaf control, they can be combined with atrazine or Bladex. Dual may be applied and shallowly incorporated within 45 days before planting, or it may be used after planting. The rates are 1-1/2 to 4 pints of Dual 8E or 6 to 16 pounds of Dual 25G per acre.

Alachlor may be applied and shallowly incorporated within 30 days of planting or immediately after planting corn. Use 4 to 8 pints per acre of Lasso 4E or Micro Tech 4ME or equivalent rates of Lasso 15G or Partner 65WDG. Arena, Judge, Stall, Saddle, and Confidence are distributor brands of alachlor. **Cropstar 20G** is intended for mixing and application with dry fertilizer. **Partner and Micro Tech** are encapsulated formulations of alachlor that may have an advantage over Lasso 4E for reduced or no-till systems. *Products containing alachlor are restricted-use pesticides.*

Lasso or Dual plus atrazine may be applied preplant or after planting until corn is 5 inches tall and grass weeds have not passed the two-leaf stage. *Do not use liquid fertilizer as the carrier after corn emergence.*

Bicep 6L and Bicep Lite 5L are 5:4 and 2:1 premixes, respectively, of metolachlor (Dual) plus atrazine used at 3 to 6 pints per acre. **Bullet 4L and Lariat 4L** are 5:3 premixes of alachlor (Micro Tech and Lasso, respectively) plus atrazine used at 5 to 10.5 pints per acre. *Bicep, Bicep Lite, Bullet, and Lariat are restricted-use pesticides.*

Pursuit (imazethapyr) can be used early preplant, preplant incorporated, or preemergence, or early postemergence *on Pursuit-resistant or -tolerant field corn hybrids. Do not use Counter 15G at planting if Pursuit-tolerant hybrids are used.* The Pursuit rate is 4 fluid ounces (0.25 pint) per acre alone or mixed with grass herbicides (see Table 13.4) to improve grass control.

Preemergence herbicides (corn)

Marksman (dicamba + atrazine) or Banvel (dicamba) can be applied after planting corn on medium- to fine-textured soils containing at least 2 percent organic matter. The rate is 3.5 pints of Marksman or 1 pint of Banvel. On other soils, *if the corn is no-till,* Marksman can be applied at 2 pints and Banvel at 0.5 pints per acre. Banvel or Marksman can be tank-mixed with other herbicides (Table 13.4) and applied preemergence or early postemergence. *Do not incorporate Marksman or Banvel. Marksman is a restricted-use pesticide.*

Prowl (pendimethalin) can be used preemergence after planting corn, *but do not incorporate.* Corn should be planted at least 1.5 inches deep. The Prowl 3.3E rate per acre is 1.8 to 4.8 pints alone or 1.8 to 3.6 pints in most tank-mix combinations. Most Prowl tank mixes can also be applied early postemergence, but see the label for corn size limitations.

Postemergence herbicides (corn)

Several preemergence herbicide tank-mixes or premixes may also be applied early postemergence to corn (Table 13.4). Most require the grass weeds to be less than 1.5 to 2 inches tall for effective control. *Do not use liquid fertilizer as the carrier when applying postemergence herbicides.* Some herbicides will control grass weeds; others will control broadleaf weeds (see Tables 13.6 and 13.7). Several combinations of postemergence herbicides are registered (see Table 13.8).

Postemergence grass control in corn

Accent, Beacon, atrazine, Bladex, or Extrazine II can be used to control some grass weeds (see Table 13.6). Atrazine, Bladex, or Extrazine II must be applied before annual grass weeds are over 1.5 inches tall. These herbicides also control several broadleaf weeds.

Accent and Beacon are used for postemergence grass control in field corn. Both can control shattercane and johnsongrass, but Accent is better for giant foxtail and fall panicum control. Check label restrictions on Counter use before applying Accent or Beacon and for tank mixing or sequencing with other herbicides. Accent or Beacon are considered rainfast within 4 to 6 hours.

Accent 75DF (nicosulfuron) can be applied broadcast or with drop nozzles to field corn up to 24 inches tall (free standing). For corn 24 to 36 inches tall, use drop nozzles. Do not use Accent on corn past the 36-inch or ten-leaf collar stage. The rate is 2/3 ounce of product per acre in a minimum of ten gallons of water per acre. A second application may be made 14 to 28 days later if needed.

Weed height limitations when using Accent are 2 to 4 inches for giant foxtail and fall panicum, 4 to 12 inches for shattercane, 8 to 18 inches for rhizome johnsongrass, and 4 to 10 inches for quackgrass.

Accent can be tank-mixed with atrazine, Buctril, Buctril + Atrazine, Banvel, or Marksman, but observe corn height limitations for the tank-mix partner. For Accent plus atrazine, crop-oil concentrate is used. For the other tank mixes, use only a nonionic surfactant. Do not tank-mix Accent with Bladex, Basagran, Laddok, or 2,4-D. Do not apply Accent to corn previously treated (within 7 days) with foliar-applied organophosphate insecticides or with Basagran or Laddok. Do not apply Basagran or Laddok within 3 days after applying Accent.

Beacon 75DF (primisulfuron) can be applied to corn that is 4 to 20 inches tall. A 1.52-ounce packet treats 2 acres. Split applications (50%/50% or 75%/25% will provide better control of johnsongrass and quackgrass, but the second application should be

Table 13.8. Postemergence Herbicide Tank-Mixes for Corn

Herbicide	Buctril	Basagran	Laddok	Banvel	Marksman	2,4-D	Atrazine
Accent	X	–	–	X	X	–	X
Atrazine	X	X	–	X	X	–	–
Beacon	X	–	–	X	–	X	–
Bladex	–	–	X	X	X	–	X
Pursuit	X	–	–	–	–	–	X
2,4-D	X	–	X	X	–	–	–

X = registered; X? = check current label; – = not registered.

made before tassel emergence. Weed height limitations for Beacon are 4 to 12 inches for shattercane, 8 to 16 inches for rhizome johnsongrass, 4 to 8 inches for quackgrass, and less than 2 inches for fall panicum. Beacon can also control several broadleaf weeds (see Table 13.7).

With Beacon, use nonionic surfactant (NIS) at 1 quart per 100 gallons of spray or crop-oil concentrate (COC) at 1 to 4 pints per acre; UAN can also be added, up to 1 gallon per acre. If Beacon is tank-mixed with Buctril, Banvel, or 2,4-D, use nonionic surfactant and not crop-oil concentrate or UAN. Use a minumum of 10 gallons of spray per acre.

If Beacon is to be used, do not use Counter at or before planting corn. Some effect on corn may be noted if other organophosphate insecticides are used at planting. Do not apply any organophosphate insecticide within 10 days before or after Beacon application. Observe label restrictions for preharvest intervals and recropping.

Pursuit (imazethapyr) can be used postemergence *on Pursuit-resistant or -tolerant field corn hybrids. Do not use Counter 15G at planting if Pursuit-tolerant hybrids are used.* The rate is 4 fluid ounces per acre of Pursuit alone or mixed with atrazine or Buctril. Postemergence, Pursuit requires the addition of a surfactant or crop-oil concentrate *and* a fertilizer adjuvant (see label). Pursuit will be used postemergence primarily to control shattercane and giant foxtail, where it is price competitive with Beacon and Accent. *Do not tank-mix Pursuit with Accent or Beacon.*

Atrazine must be applied before corn is 12 inches tall. Use 2.2 pounds 90DF or 4 pints 4L plus 1 quart crop-oil concentrate (COC) per acre to control annual grass weeds less than 1.5 inches tall. Many annual broadleaf weeds up to 4 inches tall are controlled with 1.3 pounds 90DF or 2.4 pints 4L plus 1 quart of COC per acre. *Do not apply more than a total of 2.5 pounds atrazine (a.i.) per acre per year.*

Atrazine plus COC may injure corn that has been under stress from prolonged cold, wet weather or other factors. *Do not add 2,4-D with the atrazine plus COC.* Mix the atrazine with water first and then add the COC. If atrazine is applied after June 10, plant only corn or sorghum the next year. *Atrazine is a restricted-use pesticide.*

Bladex (cyanazine) or Extrazine II (cyanazine + atrazine) may be applied until the five-leaf stage in field corn and before grass weeds exceed 1.5 inches in height. The rate per acre is 1.1 to 2.2 pounds 90DF or 2.2 to 4 pints 4L. Use 4L formulations only under warm, dry, sunny conditions of low humidity. Do not apply Bladex or Extrazine II to corn that is stressed or growing under cold, wet weather. Under dry, arid conditions, a surfactant or vegetable oil may be added to 90DF (not 4L) formulations. Do not use petroleum-based crop oils or apply with liquid fertilizer. *Extrazine II and Bladex are restricted-use pesticides.*

Postemergence broadleaf control (corn)

Banvel, Stinger, and 2,4-D are plant hormone herbicides that control broadleaf weeds in corn (see Table 13.7). Observe drift precautions with these herbicides. Buctril, Buctril + Atrazine, and Laddok are contact herbicides, so good spray coverage is essential.

Banvel (dicamba) or Marksman (dicamba + atrazine) may be applied from spike to five-leaf or 8-inch stage in corn. Use 1 pint of Banvel or 3-1/2 pints of Marksman per acre except on coarse-textured soils, when the rate to use is 1/2 pint of Banvel or 2 pints of Marksman per acre. Banvel may also be applied at 1/2 pint to corn that is 8 to 36 inches tall or 15 days before tassels emerge, whichever comes first. Use drop nozzles on corn over 8 inches tall to reduce the risk of corn injury, improve spray coverage, and reduce drift. *Do not apply Banvel to corn over 24 inches tall or if nearby soybeans are over 10 inches tall or have begun to bloom.*

Observe all label precautions to minimize the risk of Banvel or Marksman drifting to nearby susceptible crop or ornamental plants. The Banvel label calls for directed application if applied with 2,4-D.

Stinger (clopyralid) can be used on field corn up to 24 inches in height. The rate per acre is 1/4 to 1/2 pint for ragweed, cocklebur, sunflower, Jerusalem artichoke, and jimsonweed up to the five-leaf stage, and 1/3 to 2/3 pint for Canada thistle. The interval before planting soybeans is 12 months after application of herbicide.

2,4-D amine or ester can be used from emergence to tasseling of corn. Apply with drop nozzles if corn is more than 8 inches tall. The rate is 1/3 to 1/2 pint of 2,4-D ester or 1 pint of 2,4-D amine if the acid equivalent is 3.8 pounds per gallon. 2,4-D ester can vaporize and injure susceptible plants nearby if temperatures exceed 85°F. Spray particles of either 2,4-D ester or amine can drift and cause injury to susceptible plants.

Corn is often brittle for 1 to 2 weeks after application of 2,4-D and may be susceptible to stalk breakage from high winds or cultivation. Other symptoms of 2,4-D injury are stalk lodging, abnormal brace roots, and failure of leaves to unroll. Corn hybrids differ in their sensitivity to 2,4-D. High humidity and temperature increase the potential for 2,4-D injury to corn.

Buctril (bromoxynil) is used at 1 pint per acre after emergence or up to 1.5 pints per acre after the four-leaf stage of corn up to tassel emergence, but while weeds are in the three- to eight-leaf stage. Larger pigweed and velvetleaf may require the higher rate or a combination with atrazine.

Buctril + Atrazine 3L is used at 1.5 to 3 pints per acre, or Buctril can be tank-mixed with 1 to 2.4 pints atrazine 4L or 0.6 to 1.3 pounds atrazine 90DF. At the higher rate, do not apply until the four-leaf stage of corn. Do not apply to corn over 12 inches tall. Surfactants or crop-oil concentrate can be added, but the potential for corn injury increases. *Buctril + Atrazine is a restricted-use pesticide.*

Laddok (bentazon + atrazine) is used at 2 to 3-1/2 pints per acre until corn is 12 inches tall. Always add 1 gallon of UAN or 1 quart of crop-oil concentrate (COC) or Dash per acre for ground application. Use the COC or Dash for suppression of Canada thistle or yellow nutsedge. *Laddok is a restricted-use pesticide.*

Postemergence soil-applied herbicides (corn)

Some herbicides that are normally applied to the soil may be used postemergence in corn to back up herbicides that had been applied earlier and to keep late-emerging weeds from becoming problems. Drop nozzles should be used if corn foliage prevents uniform application to the soil.

Prowl (pendimethalin) or Treflan (trifluralin) may be applied after *field corn* is 4 inches tall (for Prowl) or from the two-leaf stage (for Treflan) up to last cultivation. Prowl or Treflan plus atrazine can be tank-mixed, but do not apply after corn is 12 inches tall. Apply the herbicide and then incorporate with a sweep or rolling cultivator. Prowl may not require incorporation if rainfall occurs soon after application. These treatments are used to help control late-emerging grasses such as shattercane, wild proso millet, fall panicum, or woolly cupgrass. *Do not use Prowl in corn more than once per crop season.* Observe recropping restrictions, especially for wheat.

Dual (metolachlor) plus atrazine as a tank mix or premix (Bicep) can be used postemergence to control weeds in corn up to 12 inches high, especially in seed corn, where late-emerging weeds become problems. See the current label for rate and timing restrictions.

Directed postemergence herbicides for emergencies (corn)

Directed (not over-the-top) sprays of Lorox, Poast, or Gramoxone Extra can be used for emergencies if weed and crop size limits are met. Early cultivation may allow for the proper height differential between the crop and weeds. Direct the spray to the base of the corn plants to minimize injury to the corn while covering the weeds as much as possible. *Adjust rates for banded application.*

Lorox (linuron) may be used in field corn at least 15 inches tall (freestanding) but before weeds are 5 inches tall. Use Lorox at 1.25 to 3 pounds 50DF or at 1-1/4 to 3 pints 4L per acre, depending upon the weed size and soil type. Add 1 pint of surfactant per 25 gallons of spray.

Gramoxone Extra (paraquat) may be applied after corn is 10 inches tall as a directed spray no higher than the lower 3 inches of cornstalks. Use 12.8 fluid ounces of Gramoxone Extra in 20 to 40 gallons of water per acre. A nonionic surfactant or crop-oil concentrate should be added. A tank mix with atrazine can increase broadleaf control. Observe current label precautions. *Gramoxone Extra is a restricted-use pesticide.*

Poast (sethoxydim) is labeled for use to control some grass weeds in corn. Corn should be at least 30 inches tall with most weed species not over 8 inches. Appropriate equipment should be used so spray is no more than 10 inches high on the cornstalk. Crop-oil concentrate should be added. *Do not add Dash or any fertilizer additive. Do not use Poast Plus.* For broadleaf weeds, 2,4-D may be added with appropriate precautions. Considerable care should be used with this treatment to reduce risk of corn injury.

Corn preharvest treatment

Some labels allow preharvest use of 2,4-D after the hard-dough to dent stage of corn to control or suppress broadleaf weeds that may interfere with harvest. Do not use the corn for forage or fodder for 7 days after treatment.

Herbicides for sorghum

Atrazine, Dual, Banvel, Bicep, 2,4-D, and Marksman are registered for use in grain or "forage" sorghums. Several other corn herbicides can also be used in grain sorghum or milo, although the application rates may be lower. Check the labels for the relevant information.

Gramoxone Extra (paraquat) or Roundup (glyphosate) can be used to control existing vegetation before planting grain sorghum in reduced-tillage systems. **Bronco (glyphosate + alachlor)** can also be used if the seed is treated with Screen. *Gramoxone Extra and Bronco are restricted-use pesticides.*

Atrazine may be applied to medium-textured soils with more than 1 percent organic matter, but the rates are lower than for corn. Atrazine can also be applied postemergence at 4 pints 4L per acre without crop-oil concentrate (COC) or at 2.4 pints per acre with COC for broadleaf control only. Use equivalent rates of atrazine 90DF. *Atrazine is a restricted-use pesticide.*

Ramrod (propachlor) alone or with atrazine or Bladex can be used only preemergence in grain sorghum. Do not graze or feed forage to dairy animals.

Lasso (alachlor) or Lariat (alachlor + atrazine) can be used if grain sorghum seed is treated with Screen. Micro Tech and Bullet are not registered for use in grain sorghum. *Lasso and Lariat are restricted-use pesticides.*

Dual (metolachlor), Bicep (metolachlor + atrazine), or Cycle (metolachlor + cyanazine) can be used if grain sorghum seed has been treated with Concep II. *Bicep and Cycle are restricted-use pesticides.*

2,4-D may be applied for broadleaf control in sorghum that is 4 to 24 inches tall. Use drop nozzles if sorghum is taller than 8 inches.

Banvel (dicamba) or Marksman (dicamba + atrazine) can be applied to grain sorghum after the two-leaf stage. Marksman can be applied at 1-1/2 to 2 pints per acre until sorghum has five leaves or is 8 inches tall; Banvel can be applied at 0.5 pint per acre to sorghum up to 15 inches tall. Do not graze or feed treated forage to animals before the mature grain stage. *Marksman is a restricted-use pesticide.*

Laddok (bentazon + atrazine) can be used postemergence to control broadleaf weeds in grain or forage sorghum if applied before the crop is 12 inches tall. *Laddok is a restricted-use pesticide.*

Buctril (bromoxynil) applied alone can be used from the three-leaf to boot stage, whereas Buctril that has been tank-mixed or premixed with atrazine can only be applied to grain sorghum up to 12 inches in height.

Roundup (glyphosate) may be applied as a spot treatment in grain sorghum prior to heading.

Herbicides for soybeans

Consider the kinds of weeds expected when you plan a herbicide program for soybeans. The herbicide selectivity Tables 13.9, 13.10, and 13.11 list herbicides and their relative weed control ratings for various weeds.

Although soybeans may be injured by some herbicides, they usually outgrow early injury with little or no effect on yield if stands have not been significantly reduced. Significant yield decreases can result when injury occurs during the bloom to pod-fill stages. Excessively shallow planting can increase the risk of injury from some herbicides. Accurate rate selection for soil type is essential for herbicides containing metribuzin (Canopy, Lexone, Preview, Salute, Sencor, or Turbo) or linuron (Linex, Lorox, or Lorox Plus) (see Table 13.8). Do not apply these herbicides after soybeans begin to emerge, or severe injury can result. Always follow label instructions. Rates per acre for preplant or preemergence herbicides for typical Illinois soils are given in Table 13.12. See Table 13.13 for some preplant and preemergence tank-mix combinations.

Preplant herbicides (soybeans)

Early preplant herbicide application is used in minimum tillage programs to minimize existing vegetation problems at planting and reduce the need for a knockdown herbicide. Broadleaf herbicides used for early preplant application in soybeans have both foliar and soil activity (see Table 13.3), so they may control small annual weeds prior to planting, especially if a nonionic surfactant or crop-oil concentrate is added to the spray mix. However, if weeds are over 1 to 2 inches tall, add either Gramoxone Extra, Roundup, or Bronco to the spray mix within label guidelines to control existing vegetation. (See the section on "Conservation tillage and weed control.")

Dual can be applied up to 30 days prior to planting or as a split application within 45 days of planting soybeans. The split application rate is a full rate with two-thirds applied preplant and one-third at planting.

Micro Tech or Partner can be applied early preplant north of Interstate 64. A full rate can be applied up to 30 days before planting soybeans, except on sandy soils where a full rate can be applied no more than two weeks preplant. A split of 60 percent of full rate can be applied up to 45 days preplant with the other 40 percent applied at planting.

Canopy, Lorox Plus, or Preview can be applied early preplant up to 30 days before planting soybeans. However, if applied with Dual, this is reduced to 14 days and with Lasso, to 7 days.

Prowl may be applied up to 60 days before planting soybeans. It should be incorporated if rainfall does not occur within 14 days.

Sencor plus Lasso or Dual may be applied up to 30 days before planting soybeans if applied as a split preplant and at-planting application. **Turbo** is a premix of Sencor and Dual.

Command may be applied early preplant in fields under conservation tillage practices. The rate is 1.5 to 2 pints per acre. *Applications must be made prior to field green-up and in Illinois before: April 1 south of I-70 or April 10 north of I-80.* Field green-up means *before* nearby trees and shrubs are showing green leaf tissue (broken dormancy) and *when* summer annual weeds are emerging at the site. Check a current federal label for drift and setback restrictions from critical housing or agricultural areas.

Pursuit or Pursuit Plus can be applied up to 45 days before planting soybeans. However, if sufficient rain does not occur before planting, then mechanical incorporation is required.

Scepter, or Squadron can be surface-applied up to 30 days before planting soybeans.

Roundup may be used preplant in soybeans to control small annual weeds. The rate is 0.75 to 1 pint per acre in 5 to 20 gallons of water with the addition of a nonionic surfactant.

Poast Plus can be used at 0.75 pint per acre before planting soybeans to control small annual grasses. Always add crop-oil concentrate or Dash with Poast Plus.

Table 13.9. Soybean Soil- and Foliar-Applied Herbicides: Grass and Nutsedge Control

											Perennials			
Herbicide	BYG	CBG	FLP	GFT	YFT	WCG	SBR	SHC	VCN	VCL	JHG	QKG	WSM	YNS
Soil-applied "grass"														
Command	9	9	9	9	9	7	8	6+	5	9	2	0	0	3
Dual	8+	9	8+	9	9	7	7	5	0	3	0	0	0	7+
Micro Tech	8+	9	8	9	9	7	7	5	0	3	0	0	0	7
Prowl	9	9	9	9	9	9	8	7+	4	6	3	2	0	0
Pursuit	6	7	7	7	6	6	5	7	4	4	3	0	0	4
Sonalan	9	8	9	9	9	8	8	7	4	6	2	2	0	0
Trifluralin	9	9	9	9	9	9	8	8	5	6	3	2	0	0
Foliar-applied postemergence														
Assure II	8+	9	9+	9+	8+	9	9	10	10	9	9	9	9	0
Fusilade	8+	8	8	8+	8	9	9	10	10	9	9	9	9	0
Fusion	8+	8	8+	9	8	9	9	10	10	9	9	9	9	0
Option II	8	7	8+	9	8	8	7	9	10	6	8	0	8	0
Poast Plus	9	8	9+	9+	9	9	7	8	8	7	7	7+	8	0
Pursuit	8	7	7	8	6	5	4	9	6	3	3	—	—	6
Select	9	8	9	9+	9	9	8	9	9	8	9	8	—	0

Annual grasses are BYG = barnyardgrass, CBG = crabgrass, FLP = fall panicum, GFT = giant foxtail, YFT = yellow foxtail, WCG = woolly cupgrass, SBR = sandbur, SHC = shattercane, VCN = volunteer corn, VCL = volunteer cereal (wheat, oats, rye), JHG = johnsongrass, QKG = quackgrass, WSM = wirestem muhly, and YNS = yellow nutsedge.

Rating Scale:
10 = 95 to 100 percent, 9 = 85 to 95 percent, 8 = 75 to 85 percent, 7 = 65 to 75 percent, 6 = 55 to 65 percent, and 5 = 45 to 55 percent.

2,4-D application prior to planting soybeans *may have a conditional label in 1993.* 2,4-D is used to control horseweed (marestail), prickly lettuce, and dandelions, but it can also help suppress or control alfalfa, red clover, or hairy vetch. If 1 pint (3.8 lb a.e./gal) is used, apply low volatile ester (LVE) not less than 7 days, or amine salt not less than 15 days, before planting soybeans. If 2 pints (amine or ester) are used, do not plant soybeans for 30 days after application. Plant soybeans at least 1.5 to 2 inches deep and be sure the planted seed is completely covered. Injury is likely on sandy soils with less than 1 percent organic matter. Check current 2,4-D label.

Butyrac 200 (2,4-DB) may be used alone or in combination with Roundup or Gramoxone Extra preplant through preemergence for soybeans. For no-till or reduced tillage systems, 2,4-DB can help to control such weeds as emerged annual morningglories, cocklebur, and marestail (horseweed). The application rate of Butyrac 200 is 0.7 to 0.9 pint per acre.

Soil-applied "grass" herbicides (soybeans)

Treflan, Sonalan, and Command are soil-applied herbicides for grass control which require mechanical incorporation, whereas Prowl, Lasso, Micro Tech, and Dual can be used preemergence or preplant-incorporated. Incorporation improves herbicide performance if rainfall is limited. For more information, see the section titled "Herbicide incorporation" and Tables 13.9 and 13.10 for the weeds controlled.

Treflan, Sonalan, and Prowl are dinitroaniline (DNA) herbicides that control annual grasses, pigweed, and lambsquarters. Control of additional broadleaf weeds requires combinations or sequential treatments with other herbicides.

Soybeans are sometimes injured by DNA herbicides. Symptoms are stunting, swollen hypocotyls, and short, swollen lateral roots. Usually, such injuries are not serious. If incorporation is too shallow or Prowl is applied to the soil surface, soybean stems may be calloused and brittle, leading to lodging or stem breakage.

DNA herbicides can sometimes injure rotational crops of corn or sorghum. Symptoms appear as reduced stands and stunted, purple plants with poor root systems. Under good growing conditions, corn typically recovers from this early season injury. Accurate, uniform incorporation is needed to minimize potential carryover.

Treflan, Tri-4, or Trific (trifluralin) may be applied alone anytime in the spring prior to planting. However, tank mixes may specify application closer to soybean planting. Incorporate trifluralin within 24 hours after application or within 8 hours if the soil is warm and moist. The rate per acre is 1 to 2 pints of 4E or equivalent rates of Treflan Pro-5, 10G, or Trific 60DF. A slightly higher rate and deeper incorporation may be specified for shattercane control.

Sonalan 3E (ethalfluralin) may be applied at 1.5 to 3 pints per acre within 3 weeks before planting and should be incorporated within 2 days after application. There is a greater risk of soybean injury from Sonalan than from trifluralin, so incorporation must be uniform. Sonalan is less likely than trifluralin to carry over and injure corn the following year.

Prowl 3.3E (pendimethalin) may be applied at 1.8 to 4.8 pints per acre up to 60 days (less for some tankmixes) before planting soybeans. Preplant treatments should be incorporated within 7 days unless adequate rainfall occurs to incorporate the herbicide. *South of Interstate 80,* Prowl may be applied preemergence up to 2 days after planting.

Command 4E (clomazone) is used at 1.5 to 2 pints

Table 13.10. Soybean Soil-Applied Herbicides: Broadleaf Control

Herbicide	AMG	BCC	CCB	JMW	LBQ	BNS	PGW	CRW	GRW	SMW	SFR	PSI	VLV	SBN
Soil-applied "grass"														
Command	0	5	6	8	9	6	6	8	6	8	6	8	9+	1
Dual	0	0	0	4	6	7+	8	5	0	4	0	3	0	1
Micro Tech	0	0	0	5	7	7+	9	5	0	5	0	3	0	1
Prowl	4	0	0	2	9	0	9	2	0	4	0	0	6	1
Sonalan	4	0	0	2	9	6	9	2	0	4	0	0	3	2
Trifluralin	4	0	0	2	9	0	9	2	0	4	0	0	2	1
Soil-applied "broadleaf"														
Canopy	6	7	9	9	9	4	9	9	7	9	8	8	9	2
Lexone	3	2	6	7	9	3	9	8	5	9	7	8	8	2
Lorox	4	2	6	5	9	6	9	8	5	8	6	6	6	2
Lorox Plus	6	6	8	7	9	6	9	9	7	9	7	7	7	2
Preview	6	6	8	9	9	4	9	9	7	9	8	8	9	2
Pursuit	6	7	7	7	8	8	9	7	6	9	8	8	8	1
Scepter	6+	8	9	8	9	8+	9	8+	7	9	9	8	7	1+
Sencor	3	2	6	7	9	3	9	8	5	9	7	8	8	2

AMG = annual morningglory, BCC = burcucumber, CCB = cocklebur, JMW = jimsonweed, LBQ = lambsquarters, BNS = black nightshade, PGW = pigweed, CRW = common ragweed, GRW = giant ragweed, SMW = smartweed, SFR = wild sunflower, PSI = prickly sida, VLV = velvetleaf, and SBN = soybean tolerance.

Rating Scale and Approximate Weed Control
10 = 95 to 100 percent, 9 = 85 to 95 percent, 8 = 75 to 85 percent, 7 = 65 to 75 percent, and 6 = 55 to 65 percent.
Weed control of 5 or less is rarely significant.
For ratings for combinations (tank-mix and premix), see the component parts.

Premix	"Grass"	+	"Grass"
Commence:	Treflan	+	Command
Freedom:	Lasso	+	Treflan

Premix	"Grass"	+	"Broadleaf"
Passport:	Treflan	+	Pursuit
Pursuit Plus:	Prowl	+	Pursuit
Salute:	Treflan	+	Sencor
Squadron:	Prowl	+	Scepter
Tornado:	Fusilade	+	Reflex
Tri-Scept:	Treflan	+	Scepter
Turbo:	Dual	+	Sencor

Table 13.11. Soybean Postemergence Herbicides: Broadleaf Weed Control

Herbicide	AMG	BCC	CCB	JMW	LBQ	BNS	PGW	CRW	GRW	SMW	SFR	PSI	VLV	SBN
Contact postemergence														
Basagran	5	5	9+	9	7	3	4	7	8	9	8	8	8+	0
Blazer	8	7	7	9	5	8	9+	9	8	9	7	2	6	2
Galaxy	6	5	9	9	6	6	8	8	8	9	8	7	8+	1
Storm	7	6	8+	9	5	7	9	9	8	9	8	6	7+	1+
Cobra	8	8	8	9	4	8	9+	9	8	6	8	6	7	3
Reflex	7	6	7	9	5	7	9	8	7	7	7	2	6	1
Systemic postemergence														
Classic	7	8	9	8+	2	0	8	8	7	8	9	4	8+	1+
Pinnacle	4	2	6	4	8+	0	8+	5	4	8	6	4	8+	2
Classic and Pinnacle	6	6	9+	7	8+	0	8+	6	5	8	8	4	8+	2
Pursuit	7	8	8+	7	5	9+	9	7	7	8+	9	6	8+	1+
Scepter	3	6	9+	4	4	5	10	5	3	6	7	2	3	1

AMG = annual morningglory, BCC = burcucumber, CCB = cocklebur, JMW = jimsonweed, LBQ = lambsquarters, BNS = black nightshade, PGW = pigweed, CRW = common ragweed, GRW = giant ragweed, SMW = smartweed, SFR = wild sunflower, PSI = prickly sida, VLV = velvetleaf, and SBN = soybean response.

Rating Scale:
10 = 95 to 100 percent, 9 = 85 to 95 percent, 8 = 75 to 85 percent, 7 = 65 to 75 percent, 6 = 55 to 65 percent, and 5 = 45 to 55 percent.

per acre to control annual grasses, velvetleaf, and several other broadleaf weeds. Use the higher rate if Command is applied more than 30 days prior to planting. Command is also used at lower rates in some tank-mixes for velvetleaf control. Command can be used preplant prior to *drilled no-till soybeans* if the drill is equipped with fluted or wavy coulters and spring tines or harrow to enhance incorporation. Plant at 6 miles per hour or more for adequate incorporation. Planting can be delayed 8 hours if the soil is dry, but plant immediately if the soil is moist. **Commence 5.25L** is a premix of Command and Treflan used at 1.75 to 2.67 pints per acre.

Incorporate Command or Commence immediately if the soil is moist or within 8 hours after application if the soil is dry. *You must minimize drift (spray or vapor) to sensitive plants.* Do not apply within 100 feet of trees, ornamentals, vegetables, alfalfa, or small grains

Table 13.12. Soybean Herbicides: Preplant or Preemergence Rates per Acre

		Organic matter:[a]	1%	1-2%	3-4%	5-6%
Herbicide	Unit	Soil texture:[b]	sal	sil	sicl	sic
Bronco 4L	pt		6.0	8.0	8-10	10.0
Canopy 75DF	oz		5.0	6.0	6-7	7.0
Command 4E	pt		1.0	1.5	2.0	2.0
Commence 5.5L	pt		1.75	2.25	2.5	2.7
Dual 8E	pt		1.5	2.0	2.5	2.5
Dual 15G	lb		6-8	8-10	10.0	12.0
Freedom 3E	pt		5.5	6-7	7-8	8.0
Lasso 4E	pt		3-4	3-4	4-5	5-6
Lasso II 15G	lb		16.0	20.0	22.0	26.0
Lexone 75DF	lb		0.33[c]	0.33	0.50	0.67
Lorox 50DF	lb		0.75[c]	1.3	2.0[c]	[d]
Lorox + 60DF	oz		12.0	14.0	16.0	[d]
Micro Tech 4En	pt		3-4	3-4	4-5	5-6
Partner 65DF	lb		3-4	4.5	4.5	5.5
Passport 2.8E	pt		2.5	2.5	2.5	2.5
Preview 75DF	oz		6.0[c]	7.0	8-9	10.0[c]
Prowl 3.3	pt		1.5	2.0	2.4	3.0
Pursuit 2S	pt		0.25	0.25	0.25	0.25
Pursuit+ 2.9S	pt		2.5	2.5	2.5	2.5
Salute 4L	pt		1.5[c]	2.25	2.5	3.0
Scepter 1.5S	pt		0.67	0.67	0.67	0.67
Sencor 4L	pt		0.5[c]	0.67	0.75	1.0
Sencor 75DF	lb		—[d]	0.67	0.75	0.75-1
Sonalan 3E	pt		1.5	2.0	2.5	3.0
Squadron 2.3L	pt		3.0	3.0	3.0[d]	3.0[d]
Treflan 4E	pt		1.0	1.5	2.0	2.0
Tri-Scept 3S	pt		2.3	2.3	2.3[d]	2.3[d]
Turbo 8E	pt		1.5[c]	2.0	2.5	3.0

[a] Percent organic matter in the soil.

[b] sal = sandy loam, sil = silt loam, sicl = silty clay loam, sic = silty clay.

[c] Questionable due to crop injury or short persistence.

[d] Not recommended on this soil.

Table 13.13. Herbicide Tank-Mixes for Preplant-Incorporated or Preemergence Use in Soybeans

Herbicide	Sencor or Lexone	Canopy or Preview	Scepter[a]	Pursuit	Command	Lorox or Linex	Lorox Plus
Preplant-incorporated							
Command	1	1	1	—	—	—	—
Commence	1	1	1	—	—	—	—
Freedom	1	1	1	—	1	—	—
Salute	—	—	1	—	1	—	—
Sonalan	1	1	—	—	1	—	1
Trifluralin	1	1	1	1	1	—	1
Preplant-incorporated or preemergence							
Dual	1,2	1,2	1,2	1,2	1	2	1,2
Micro Tech	1,2	1,2	1,2	1,2	1	2	1,2
Prowl	1,2	1,2	1,2	1,2	1	2	1,2

1 = preplant incorporated, 2 = preemergence, and — = not registered.

[a] Only in Scepter label's "southern use area."

or within 1,000 feet of subdivisions or towns, nurseries, greenhouses, and commercial fruit or vegetable (except sweet corn) production areas.

Minimum recropping intervals are 9 months for field corn or sorghum and 12 months for wheat. See Table 13.2 or the label for more information. Carryover injury will appear as whitened or bleached plants after emergence. Corn has usually outgrown modest injury with little effect on yield. However, injury may be severe if application or incorporation is not uniform. Corn hybrids vary in tolerance to clomazone.

Dual (metolachlor) and Lasso or Micro Tech (alachlor) can be applied preplant or preemergence to control annual grasses and pigweed. Use the higher rates to improve black nightshade control and incorporate to improve yellow nutsedge control. They can be combined with other herbicides to improve broadleaf control. Dual can be applied up to 30 days prior to planting soybeans. The rate per acre is 1.5 to 3 pints of 8E or 6 to 12 pounds of 25G. Lasso or Micro Tech can be applied up to 30 days prior to planting soybeans. The rate per acre is 2 to 3 quarts of 4E or Micro Tech 4ME. Arena, Judge, Stall, Saddle, and Confidence are private brands of alachlor. Partner 65DF and Micro Tech are encapsulated formulations of alachlor. *Products containing alachlor are restricted-use pesticides.*

Freedom is a premix of alachlor (Lasso) and trifluralin (Treflan) which can be applied up to 14 days prior to planting soybeans. It controls the same weeds as Lasso but requires incorporation within 24 hours because of the trifluralin. Freedom 3E rate is 2.75 to 5.5 quarts per acre. *Freedom is a restricted-use pesticide.*

Soil-applied "broadleaf" herbicides (soybeans)

Canopy, Command, Lexone, Lorox, Lorox Plus, Preview, Pursuit, Scepter, and Sencor are soil-applied herbicides used for broadleaf weed control in soybeans (see Table 13.10 for weeds controlled). Lorox is not to be incorporated and Command should be incorporated (Command is discussed in the "grass" herbicide section). The others can be used preplant-incorporated or preemergence after planting soybeans.

Timely rainfall or incorporation is needed for uniform herbicide placement in the soil. Incorporation may improve control of deep-germinating (large-seeded) weeds, especially when soil moisture is limited. Accurate and uniform application and incorporation are essential to minimize potential soybean injury. Except for Command, these herbicides are photosynthetic inhibitors (PSI), meristematic inhibitors (MSI), or premixes of MSI (chlorimuron) and PSI (metribuzin or linuron).

Photosynthetic inhibitors

Metribuzin (Sencor or Lexone) and linuron (Lorox or Linex) are photosynthetic inhibitors (PSI). Preview, Salute, and Canopy are premixes that contain metribuzin, whereas Lorox Plus is a premix that contains linuron. These PSI herbicides can cause soybean injury from foliar or soil uptake, *so do not apply them after soybeans emerge.*

PSI herbicide injury symptoms are yellowing (chlorosis) and dying of lower soybean leaves, usually appearing about the first trifoliate stage. Atrazine and simazine carryover can intensify these symptoms. Soybeans usually recover from moderate PSI injury that occurs early. Metribuzin injury may be greater on soils with pH over 7.0. Soybean varieties differ in their sensitivity to metribuzin.

Sencor or Lexone (metribuzin) may be applied anytime within 14 days before planting soybeans. The Sencor or Lexone rate per acre used in tank-mixes is 1/2 to 1 pint of 4L or 1/3 to 2/3 pound of 75DF. Accurately adjust the rates according to soil texture and organic matter content. *Do not apply to sandy soil that is low in organic matter. Do not use on soils with pH greater than 7.5.* Reduced rates minimize soybean injury but lessen weed control. Split preplant and preemergence applications allow higher rates to improve weed control. Sencor or Lexone can control several annual broadleaves and can be tank-mixed with many herbicides to broaden the spectrum of control (see Table 13.13).

Turbo 8E, a premix of metribuzin (Sencor) plus metolachlor (Dual), can be applied preplant-incorporated or preemergence. The rate per acre is 1.5 to 3.5 pints.

Salute 4E, a premix of metribuzin (Sencor) plus trifluralin (Treflan), is applied preplant at 1.5 to 3 pints per acre and must be incorporated within 24 hours.

Preview 75DF and Canopy 75DF are premixes of metribuzin (Lexone) and chlorimuron (Classic), whereas **Lorox Plus 60DF** is a premix of linuron (Lorox, see next entry) and chlorimuron (Classic). These premixes may be applied preemergence or preplant-incorporated. They control cocklebur, velvetleaf, and wild sunflower better than metribuzin or linuron alone (see Table 13.10). Combinations with the grass herbicides can improve grass control (see Tables 13.9 and 13.13).

Broadcast rates per acre are 6 to 10 ounces of Preview 75DF, 4 to 7 ounces of Canopy 75DF, and 12 to 18 ounces of Lorox Plus 60DF. *Do not apply Preview, Canopy, or Lorox Plus to soils with pH greater than 6.8.* High soil pH may occur in localized areas in a field. Correct rate selection for the soil plus uniform, accurate application and incorporation are essential to minimize soybean injury and potential follow-crop injury. See PSI injury symptoms (above) and MSI injury symptoms (below).

Minimum recropping intervals for Preview, Canopy, and Lorox Plus are 4 months for wheat and 10 months for field corn. If Classic, Pursuit, or Scepter is applied the same year as Preview, Canopy, or Lorox Plus, the risk of carryover can increase, so labels should be checked carefully for rotational guidelines.

Lorox or Linex (linuron) is used after planting soybeans and before the crop emerges. Linuron is best suited to the silt loam soils of southern Illinois that contain 1 to 3 percent organic matter where the rate per acre is 1 to 1-2/3 pounds of 50DF or 1 to 1-2/3 pints of 4L per acre. *Do not apply to very sandy soils or soils containing less than 0.5 percent organic matter.*

Command (clomazone) is often used as a broadleaf herbicide in tank mixes, but it also controls annual grasses. Command is a pigment inhibitor and not a true photosynthesis inhibitor. See discussion under soil-applied "grass" herbicides section.

Meristematic inhibitors

Imazethapyr (Pursuit), imazaquin (Scepter), and chlorimuron (in Canopy, Preview, and Lorox Plus; see above) are meristematic inhibitors (MSI). See Table 13.10 for weeds controlled. *MSI herbicide injury symptoms* include temporary yellowing of upper leaves (golden tops) and shortened internodes of soybeans. Although plants may be stunted, yield is generally not affected. These MSI herbicides may carry over and injure certain sensitive follow crops. Symptoms on corn or grain sorghum are stunted growth, inhibited roots, and interveinal chlorosis or purpling of leaves.

Symptoms on small grains are stunted top growth and excess tillering.

Pursuit 2E (imazethapyr) is used at 4 fluid ounces per acre (1 gallon per 32 acres) to control broadleaf weeds (see Table 13.10). Velvetleaf and jimsonweed control are more consistent with incorporation. Grass control is improved by tank-mixing Pursuit with a grass herbicide (see Table 13.13). **Pursuit Plus and Passport** are both premixes of Pursuit and Prowl or trifluralin, respectively. Both are used at 2.5 pints per acre, which is equivalent to 0.25 pint of Pursuit plus 2.1 pints of Prowl 3.3L, or 1.5 pints of trifluralin, respectively.

Pursuit and Pursuit Plus can be applied up to 45 days prior to planting soybeans. If sufficient rain does not occur before planting, then incorporate mechanically. *South of Interstate 80,* Pursuit Plus can be surface-applied up to 2 days after soybean planting. Minimum recropping intervals for Pursuit, Pursuit Plus, and Passport are 4 months for wheat, 9.5 months for field corn, and *18 months for grain sorghum.* Pursuit has less potential than Scepter to injure corn the next season and provides better control of velvetleaf. Thus, Pursuit is more adapted than Scepter to most soils of central and northern Illinois.

Scepter (imazaquin) is used at 2/3 pint 1.5E or 2.8 ounces of 70DG per acre and, if incorporated, is applied within 45 days (less with many tank mixes) before planting. Surface applications may be made up to 30 days before planting, during planting, or after planting but before the crop emerges. Scepter controls many broadleaf weeds such as pigweed and cocklebur (see Table 13.10) with adequate soil moisture, but it is somewhat weak on velvetleaf. Incorporation can improve weed control under low-rainfall conditions, and may improve control of velvetleaf and giant ragweed. Grass control is improved by mixing with "grass" herbicides (see Table 13.13).

Squadron and Tri-Scept are premixes of imazaquin (Scepter) plus pendimethalin (Prowl) or trifluralin, respectively. The rate per acre is 3 pints of Squadron or 2.33 pints of Tri-Scept, which is the equivalent of 2/3 pint of Scepter plus 1.5 pints of Prowl or trifluralin per acre. Incorporate Squadron within 7 days unless sufficient rain occurs. Tri-Scept must be incorporated within 24 hours.

A line across Peoria, extending west along Illinois Route 116 and east along U.S. Route 24, delineates Scepter, Squadron, or Tri-Scept rotational crop restrictions in Illinois (see Table 13.2). Region 3 is north of the line; Region 2 is south of the line.

There have been significant problems with carryover of Scepter and related premixes and tank mixes in Illinois. Soil and climatic conditions plus lack of uniformity in application and incorporation are associated with the carryover problem.

The potential for carryover is greater on soils with high organic matter and low pH. *Research and field results indicate that in Illinois, Scepter, Squadron, and Tri-Scept are best adapted to the soils and weeds south of Interstate 70.* Reduced rates, which can reduce potential carryover, are allowed for postemergence use of Scepter and in tank mixes with several other products. Imidazolinone-tolerant or -resistant hybrids can be used to minimize carryover problems.

Postemergence herbicides (soybeans)

Postemergence (foliar) herbicides are more effective when used in a planned program so that application is timely and not just an emergency or rescue treatment. Foliar treatments allow the user to identify the problem weed species and choose the most effective herbicide. Climatic conditions greatly affect foliar herbicides as penetration and action are usually greater with warm temperatures and high relative humidity. Rainfall soon after application can cause poor weed control. Weeds growing under droughty conditions are more difficult to control.

Rates and timing for foliar treatments are based on weed size. Early application when weeds are young and tender may allow the use of lower herbicide rates. Treatment of oversized weeds may only suppress growth temporarily, and regrowth may occur. A cultivation 7 to 14 days after application but before regrowth can often improve weed control. However, cultivation during or within 7 days of a foliar application may cause erratic weed control.

Crop-oil concentrates (COC) or nonionic surfactants (NIS) are usually added to the spray mix to improve postemergence herbicide effectiveness. A COC can be either petroleum oil (POC) or vegetable oil (VOC) based. VOC is sometimes methylated to form esters while NIS sometimes has fatty acids added to improve penetration. Dash is a special surfactant primarily for use with Poast. Fertilizer adjuvants such as 28-0-0 (UAN) or 10-34-0 may be specified on the label to increase control of certain weed species, such as velvetleaf. *Do not use brass or aluminum nozzles with fertilizer adjuvants. All fertilizer adjuvants should be rinsed from the tank before final cleanup with chlorine bleach.*

Postemergence herbicides for soybeans are either contact or translocated in action. Contact herbicides affect only the leaf tissue covered by the spray, so thorough spray coverage is critical. Contact herbicides should be applied to small weeds. Injury symptoms are usually noticeable within a day. Translocated herbicides do not require complete spray coverage as they move to the growing points (meristems) after foliar penetration. Their action is slow and symptoms may not appear for a week.

Contact herbicides for postemergence control of broadleaf weeds (soybeans)

Basagran, Blazer, Reflex, Cobra, Galaxy, and Storm are contact broadleaf herbicides. See Table 13.11 for weeds controlled. Table 13.14 gives herbicide rate by weed height or stage of growth. Spray volumes for ground application are 20 to 30 gallons per acre, and

Table 13.14. Postemergence Contact Herbicide Rates for Weed Heights or Growth Stages in Soybeans

	Basagran		Blazer		Galaxy		Storm		Cobra		Reflex	
Weed	Height	Rate	Height	Rate	Height	Rate	Height	Rate	Stage	Rate	Stage	Rate
	in.	*pt/A*	*in.*	*pt/A*	*in.*	*pt/A*	*in.*	*pt/A*	*leaves*	*fl oz/A*	*leaves*	*pt/A*
AMG	. . .	. . .	2	1.0	2	2	2	1.5	2	12.5	2 to 4	1.25[a]
			4	1.5								
CCB	4	1	2	1.5	6	2	6	1.5	6	12.5	2	1.25[a]
	6	1.5										
	10	2										
JMW	4	1	4	1.0	6	2	6	1.5	4	12.5	4	1.00
	6	1.5	6	1.5							6	1.25[a]
	10	2										
LBQ[b]	1	1	2	1.5	2	2	2	1.5	. . .	. . .	2	1.00
	2	2										
BNS	. . .	. . .	<2	1.0	<2	2	2	1.5	6	12.5	4	1.00
			2	1.5							6	1.25[a]
PGW	. . .	. . .	<4	1.0	2	2	2 to 3	1.5	6	12.5	4	1.00
			4	1.5							6	1.25[a]
CRW	3	2	2	1.0	3	2	3	1.5	6	12.5	4	1.00
			3	1.5							6	1.25[a]
GRW	6	2	<2	1.0	6	2	6	1.5	4	12.5	. . .	. . .
			3	1.5								
SMW	4	1.0	4	1.0	6	2	6	1.5	. . .	. . .	4	1.00
	6	1.5	6	1.5							6	1.25[a]
	10	2										
SFR	3	1	. . .	. . .	5	2	. . .	. . .	2	12.5	. . .	. . .
	5	1.5										
	8	2										
PSI	3	1.5	. . .	. . .	3	2	2	1.5	4	12.5	. . .	. . .
	4	2										
VLV	2	1.5	. . .	. . .	5	2	2	1.5	4	12.5	. . .	. . .
	5	2										
YNS[c]	6	1.5	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .
	8	2										

AMG = annual morningglory, CCB = common cocklebur, JMW = jimsonweed, LBQ = lambsquarters, BNS = black nightshade, PGW = pigweed, CRW = common ragweed, GRW = giant ragweed, SMW = smartweed, SFR = common sunflower, PSI = prickly sida, VLV = velvetleaf, YNS = yellow nutsedge.

[a] Reflex at 1.25 pints per acre to be applied south of I-70 only.

[b] Control of lambsquarters is often inconsistent with contact herbicides.

[c] May need to repeat application for complete control.

spray pressure should be 40 to 60 psi. Hollow cone or flat-fan nozzles provide much better coverage than flood nozzles.

Low temperatures and humidity will reduce contact activity. Soybean leaves may show contact burn under conditions of high temperature and humidity. This leaf burn is intensified by crop-oil concentrate or Dash. Soybeans usually recover within 2 to 3 weeks after application. A rain-free period of several hours is required for effective control with most contact herbicides.

Smaller weeds that are actively growing may allow the use of reduced herbicide rates. Most contact herbicides have little soil residual activity, so do not apply too early. Apply 2 to 3 weeks after soybean emergence or when soybeans are in the one- to two-trifoliate stage. Larger weeds not only require increased rates, but the weeds may recover and regrow. Contact herbicides should not be applied after soybeans begin to bloom. Preharvest intervals are generally 50 to 90 days.

Basagran (bentazon) is used at 1 to 2 pints per acre. See Table 13.14 for specifics on weed sizes and rates. Most weeds should be small (1 to 3 inches) and actively growing. Velvetleaf control is improved if 28-0-0 (UAN) is added to the spray mixture. Crop-oil concentrate is preferred if the major weed species are common ragweed or lambsquarters. Split applications can improve control of lambsquarters, giant ragweed, wild sunflower, and yellow nutsedge. Adding 2,4-DB can improve annual morningglory control. Do not spray if rain is expected soon after application.

Blazer (acifluorfen) is used at 0.5 to 1.5 pints per acre when broadleaf weeds are 2 to 4 inches tall and actively growing. Split applications are allowed 15 days apart, but do not apply more than 2 pints per acre per season. See the label for specifics on adjuvants, and see Table 13.14 for rates and weed sizes. Velvetleaf control is improved with the use of fertilizer adjuvants or the addition of Basagran. Adding 2,4-DB can improve cocklebur and morningglory control. Blazer may cause soybean leaf burn. However, the crop usually recovers within 2 to 3 weeks. Do not spray if rain is expected within 4 to 6 hours.

Basagran plus Blazer improves control of pigweed and morningglory over Basagran alone. **Storm 4S and Galaxy 3.67S** are premixes of Basagran and Blazer. Storm at 1.5 pints per acre is equivalent to 1 pint of Basagran plus 1 pint of Blazer. Galaxy at 2 pints per acre is equivalent to 1.5 pints of Basagran plus 0.67 pint of Blazer. See the labels for adjuvant specifics.

Cobra 2E (lactofen) is applied at 12.5 fluid ounces per acre with crop-oil concentrate (COC) at 0.5 to 1 pint per acre. One gallon per acre of 28-0-0 (UAN) may be substituted for COC under favorable growing conditions. Reduced rates are used in some combination. See Table 13.14 for weed size. Cobra usually causes soybean leaf burn, but soybeans usually recover within 2 to 3 weeks. Apply Cobra only once during the season and no later than 90 days before harvest. Do not apply if rain is expected within 30 minutes.

Reflex 2LC (fomesafen) is used at 0.75 to 1 pint per acre north of Interstate 70 and at 1.25 pints south of Interstate 70. **Tornado 1.75E,** a premix of fomesafen and fluazifop-P, is used at 1 quart per acre (equivalent to 1 pint of Reflex and 1.5 pints of Fusilade) to control broadleaf and grass weeds. Add crop-oil concentrate or nonionic surfactant with Reflex or Tornado.

Reflex or Tornado should be applied before soybeans bloom. Do not spray if rain is expected within 4 hours of application. Be sure applications are accurate and even as there is a potential for carryover with fomesafen. Do not apply Reflex or Tornado to any field more than once every 2 years. Recrop intervals are 4 months for small grains, 10 months for corn, and 18 months for other crops.

Translocated herbicides for postemergence control of broadleaf weeds (soybeans)

Classic, Pinnacle, Pursuit, and Scepter are translocated herbicides that primarily control broadleaf weeds in soybeans. See Table 13.11 for weeds controlled. Table 13.15 gives herbicide rate by weed height or stage of growth. All four have the same mode of action and some soil residual activity. Weeds should be actively growing (not moisture- or temperature-stressed). Do not make applications when weeds are in the cotyledon (very early seedling) stage. Annual weeds are best controlled when less than 3 to 5 inches tall (within 2 to 4 weeks after soybean emergence). A 1-hour rain-free period after application is usually adequate for these herbicides.

These herbicides inhibit growth of new meristems, so symptoms of weed injury may not be exhibited for 3 to 7 days. Injury symptoms are yellowing of leaves followed by death of the growing point. Death of leaf tissue in susceptible weeds is usually observed in 7 to 21 days. Less susceptible plants may be suppressed, remaining green or yellow but stunted for 2 to 3 weeks.

Soybeans may show temporary leaf yellowing (golden tops), growth retardation (stunting), or both, especially if the soybeans are under stress. Under favorable conditions, affected soybeans may recover with only a slight reduction in height and no loss of yield.

Total spray coverage is not critical for translocated herbicides. A minimum spray volume of 10 gallons per acre may be used for ground application using flat-fan nozzles at 20 to 40 psi or hollow cone nozzles at 40 to 60 psi. Nonionic surfactant (NIS) is usually specified at 1 to 2 pints per 100 gallons of spray. Crop-oil concentrate (COC) may improve weed control but may increase crop injury. Fertilizer additives (28-0-0 or 10-34-0) improve control of some weeds and are specified for velvetleaf control on the Classic, Pinnacle, and Pursuit labels. *Tank-mixing these herbicides with postemergence herbicides for grass may reduce grass control, so sequential applications are often specified* (Table 13.16).

Classic 25DF (chlorimuron) is used at 0.5 to 0.75 ounce per acre plus 1 quart of surfactant or 1 gallon of crop-oil concentrate per 100 gallons. Fertilizer adjuvants improve velvetleaf control. Pigweed control varies with rate and species. Check the label or Table 13.15 for weed sizes and rates. Split applications can improve control of burcucumber, giant ragweed, and annual morningglory. Do not apply Classic within 60 days of harvest. Recrop intervals are 3 months for small grains and 9 months for field corn, sorghum, alfalfa, or clover. If Classic is applied after Preview, Canopy, Lorox Plus, Pursuit, or Scepter, check the label for recrop intervals as carryover injury to corn can occur, especially if soil pH is above 6.8. Corn will appear stunted with interveinal chlorosis or purpling of leaves and inhibition of roots.

Pinnacle 25DF (thifensulfuron) is used at 0.25 ounce per acre to control lambsquarters, pigweed, smartweed, and velvetleaf. See Table 13.15 for weed sizes. The addition of 1 gallon of UAN (28-0-0) per acre improves velvetleaf control. Tank-mixing with 0.25 ounce of Classic 25DF per acre with Pinnacle can improve control of cocklebur, jimsonweed, and wild sunflower. Add nonionic surfactant at 1 to 2 pints per 100 gallons. *Do not use crop-oil concentrate unless conditions are droughty.* Pinnacle has less persistence than Classic. Any crop may be planted 45 days after application of Pinnacle alone. For the Classic plus Pinnacle tank mix, the Classic recropping intervals apply.

Pursuit 2E (imazethapyr) is used at 0.25 pint per acre plus surfactant at 1 quart per 100 gallons of spray. Add 1 quart per acre of 28-0-0 or 10-34-0. (See Table 13.15 for weed sizes.) Lambsquarters, common ragweed, and annual morningglory control may be poor. It can also provide control of foxtails and shattercane

Table 13.15. Postemergence Translocated Herbicide Rates for Broadleaf Weed Heights in Soybeans

	Classic		Pinnacle		Classic + Pinnacle		Pursuit		Scepter	
Weed	Height	Rate	Height	Rate	Height	Rate of each	Height	Rate	Height	Rate
	in.	*oz/A*	*in.*	*oz/A*	*in.*	*oz/A*	*in.*	*fl oz/A*	*in.*	*pt/A*[a]
AMG	2 3 4	0.50 0.66 0.75	. . .	. . .	1 to 2[b]	0.25	1 to 2	4	. . .	. . .
CCB	6 8 12	0.50 0.66 0.75	2 to 6[b]	0.25	2 to 4	0.25	1 to 8	4	1 to 8 9 to 12	0.33 0.66
JMW	4 6	0.50 0.75	2 to 4[b]	0.25	2 to 5	0.25	1 to 3	4	. . .	. . .
LBQ	. . .	. . .	2 to 4	0.25	2 to 4	0.25	1 to 2	4	. . .	. . .
BNS	. . .	. . .	. . .	. . .	. . .	. . .	1 to 3	4	. . .	. . .
PGW	2 3 4	0.50[c] 0.66[c] 0.75[c]	2 to 12	0.25	2 to 12	0.25	1 to 8	4	1 to 4 5 to 12	0.33 0.66
CRW	3 4	0.66 0.75	. . .	. . .	1 to 3[b]	0.25	1 to 3	4	. . .	. . .
GRW	6	0.75	. . .	. . .	. . .	. . .	1 to 3	4	. . .	. . .
SMW	2 3 4	0.50 0.66 0.75	2 to 6	0.25	2 to 8	0.25	1 to 3	4	. . .	. . .
SFR	5 6 8	0.50 0.66 0.75	2 to 6[b]	0.25	2 to 8	0.25	1 to 3	4	1 to 4 5 to 8	0.33 0.66
VLV	4 6	0.66 0.75	2 to 6	0.25	2 to 8	0.25	1 to 3	4	. . .	. . .
YNS	3 4	0.50 0.75	. . .	. . .	. . .	. . .	1 to 3	4	. . .	. . .

AMG = annual morningglory, CCB = common cocklebur, JMW = jimsonweed, LBQ = lambsquarters, BNS = black nightshade, PGW = pigweed, CRW = common ragweed, GRW = giant ragweed, SMW = smartweed, SFR = common sunflower, VLV = velvetleaf, YNS = yellow nutsedge, . . . = not on label.

[a] Or equivalent rates of 70DG formulation.

[b] Suppression only.

[c] Redroot pigweed only, smooth pigweed and tall waterhemp only suppressed.

Table 13.16. Postemergence Herbicide Tank-Mixes for Soybeans

	Basagran	Blazer	Galaxy	Reflex	Cobra	Classic	Pursuit
Registered for broadleaf weed control in soybeans							
Basagran	—	X	—	X	X	X	X
Classic	X	X	X	X	X	—	—
Scepter	X	X	—	X	X	—	—
Pinnacle	X	—	X	—	—	X	—
2,4-DB	X	X	X	X	X	X	—
Registered for grass + broadleaf weed control in soybeans[a]							
Assure II	X	—	—	—	X	X	X[b]
Fusilade	X	X	—	X	X	X	X[b]
Fusion	X	X	X	X	X	X	—
Option II	X	X	—	X	—	X	X[b]
Poast Plus	X	X	X	X	—	X	X
Pursuit	X	X	X	X	X	—	—
Select	X	X	—	X	—	X	X

X = registered and — = not registered.

[a] Check labels for special instructions. Sequential application may be preferable.

[b] To improve volunteer corn and shattercane control only.

but not volunteer corn. Do not apply Pursuit within 85 days of soybean harvest. Recropping intervals are 4 months after application for wheat, 9.5 months for field corn, and 18 months for other field crops *including grain sorghum.* See Table 13.2. Do not apply products containing chlorimuron or imazaquin the same year as Pursuit because such combinations increase the potential for injury to subsequent crops.

Scepter (imazaquin) can be used postemergence to control pigweed, cocklebur, wild sunflower, and volunteer corn in soybeans. The low rate is 1/3 pint of 1.5E or 1.4 ounces of 70DG. A higher rate is labeled, but rotational guidelines change. Scepter is better on cocklebur and volunteer corn, but Pursuit is better on velvetleaf and shattercane. Use a nonionic surfactant at 1 quart per 100 gallons. Do not tank-mix Scepter with postemergence herbicides for grass control. Do not apply Scepter within 90 days of soybean harvest. Follow rotational guidelines on the Scepter label or see Table 13.2. Also see the recrop discussion on Scepter in the section on "Soil-applied 'broadleaf' herbicides (soybeans)."

Scepter O.T. is a premix combination with 0.5 pound a.i. of imazaquin and 2 pounds a.i. acifluorfen per gallon to broaden the spectrum of control to include annual morningglories, copperleaf, and smartweed. Rate is 1 pint per acre with addition of 1 quart nonionic surfactant per 100 gallons. The addition of 1 to 2 fluid ounces of 2,4-DB added to Scepter O.T. may further improve control of annual morningglories.

Translocated herbicides for control of grass weeds

Poast Plus, Assure II, Fusilade, Option II, Fusion, and Select can control many annual and perennial grasses in soybeans (see Table 13.9). Table 13.17 gives herbicide rate by size of grass weed. Pursuit also has some postemergence grass control. Grasses should be actively growing (not stressed or injured) and not tillering or forming seedheads. Cultivation within 5 to 7 days before or after application may decrease grass control. Addition of crop-oil concentrate is usually specified, especially if the weeds are somewhat droughty or label limitations on weed size are approached.

Rates vary by weed size and species, so consult the label or Table 13.17 before applying. Rate reductions may be optional on small weeds or under ideal conditions, whereas rate increases may be needed for larger weeds. Control of johnsongrass and quackgrass often requires follow-up applications for control of regrowth. *Volunteer cereals* such as wheat and rye can be controlled by Assure II, Fusion, or Fusilade; Poast Plus or Select can provide good control if the plants have not tillered or overwintered.

Specified spray volume per acre is 10 to 20 gallons for ground application or 3 to 5 gallons for aerial application. A 1-hour rain-free period after application is needed. Avoid drift to sensitive crops such as corn, sorghum, or wheat. Apply before bloom stage of soybeans and at least 80 to 90 days before harvest.

These herbicides do not control broad-leaved weeds. Most labels allow tank-mixing with certain broadleaf herbicides, but limitations are made as to rate, timing, and spray coverage. *Check the label before applying grass and broadleaf herbicide tank mixes or sequences. Control of grass weeds may be reduced or increased rates may be specified.*

Poast Plus 1.0E (sethoxydim) is used at 1.5 pints per acre to control most annual grasses including foxtails, fall panicum, volunteer corn, or shattercane. See the label or Table 13.17 for weed sizes and special rates for smaller or larger weeds. Fertilizer adjuvants are specified for control of volunteer corn and shattercane. Always add 2 pints per acre of Dash or crop-oil concentrate. See the "Problem perennial weeds" section below for control of perennial grasses.

Assure II 0.88E (quizalofop) is used at 7 fluid ounces per acre to control foxtails and fall panicum. Use 5 fluid ounces per acre to control volunteer corn or shattercane. Add either 1 gallon of crop-oil concentrate or 1 quart of nonionic surfactant per 100 gallons of spray. Refer to the label or Table 13.17 for rates and weed sizes. See the "Problem perennial weeds" section for perennial grass control.

Fusilade 2000 1E (fluazifop-P) is applied at 0.75 pint per acre for volunteer corn, shattercane, or seedling johnsongrass. Refer to the label or Table 13.17 for weed sizes and rates. Add either 1 gallon of crop-oil concentrate or 1 quart of nonionic surfactant per 100 gallons of spray. See "Problem perennial weeds" for control of perennial grasses.

Fusion 2.66E (fluazifop + fenoxaprop) is a premix of Fusilade and Option to improve the annual grass control of Fusilade. The rate is 6 to 8 fluid ounces per acre when used alone or 8 to 10 fluid ounces when tank-mixed. Reduced rates are allowed on susceptible weeds when applied under optimum growing conditions. See Table 13.17 for maximum height limitations and rates. Always add crop-oil concentrate or nonionic surfactant with Fusion.

Option II 0.79E (fenoxaprop) is used at 0.4 to 0.8 pint per acre to control most annual grass weeds (see Table 13.17). Add crop-oil concentrate to control most grasses; do not use COC on rhizome johnsongrass. See Table 13.17 or 13.18 for control of perennial grasses.

Select 2E (clethodim) is used at 6 to 8 fluid ounces plus a quart of crop-oil concentrate per acre for control of annual grass weeds. Use the lower rate under minimum grass pressure and/or when grasses are less than maximum height. Table 13.17 lists rates and grass height limits. Rhizome johnsongrass and quackgrass will require higher rates and may require two applications (see "Problem perennial weeds" below).

Roundup (glyphosate) may be applied through wiper applicators to control volunteer corn, shattercane, and johnsongrass. Hemp dogbane and common milkweed may also be suppressed. Weeds should be at least 6 inches taller than the soybeans to avoid contact with the crop. Adjust the height of the applicator so that the wiper contact is at least 2 inches above the soybean plants. Mix 1 gallon of Roundup with 2 gallons of water for wiper applicators. Spot treatment can be made on a spray-to-wet basis using a 2 percent solution of Roundup in water. Motorized spot treatment may provide less complete spray coverage of weeds, so use a 5 percent solution of Roundup. Minimize spray contact with the soybeans.

Table 13.17. Application Rates and Grass Size for Treatment with Postemergence Herbicides for Soybeans

	Assure II		Fusilade 2000		Poast Plus		Option II		Fusion		Select	
Grass Weed	Height	Rate	Height	Rate	Height	Rate	Height	Rate	Height	Rate	Height	Rate
	in.	*fl oz/A*	*in.*	*fl oz/A*	*in.*	*fl oz/A*	*in.*	*pt/A*	*in.*	*fl oz/A*	*in.*	*fl oz/A*
Annuals												
Barnyardgrass	2 to 6	8	2 to 3	24	1 to 4 Up to 8	18 24	1 to 3 3 to 6	0.6 0.8	2 to 3	8	2 to 6	8
Crabgrass[a]	2 to 6	8	1 to 2	24	Up to 6	24	1 to 2 2 to 6	0.8 1.1	1 to 2	8	2 to 6	8
Fall panicum	2 to 6	7	2 to 6	24	1 to 4 Up to 8	18 24	1 to 3 3 to 6	0.6 0.8	2 to 6	8	2 to 6	8
Giant foxtail	2 to 8	7	2 to 6	24	1 to 4 Up to 8	18 24	1 to 3 3 to 6	0.4 0.6	2 to 6	8	2 to 6	8
Yellow foxtail	2 to 4	7	2 to 4	24	Up to 8	24	1 to 2 2 to 6	0.6 0.8	2 to 4	8	2 to 6	8
Woolly cupgrass	2 to 4	7	2 to 4	24	Up to 8	24	1 to 3 3 to 6	0.8 1.1	2 to 4	8	2 to 6	8
Sandbur	2 to 6	7	2 to 6	24	Up to 3	30	. . .	. . .	2 to 6	8	2 to 6	8
Shattercane	6 to 12	5	6 to 12	12[b]	6 to 18	24	2 to 6 6 to 12	0.4 0.6	6 to 12	6	4 to 10	8
Volunteer corn	6 to 18	5	12 to 24	12[b]	1 to 12 12 to 20	18 24	2 to 10 10 to 24	0.4 0.6	12 to 24	6	4 to 18	8
Volunteer cereal	2 to 6	7	2 to 6	16	Up to 4	36	. . .	. . .	2 to 6	8	2 to 6	8
Downy brome	. . .	. . .	2 to 6	16	. . .	. . .	. . .	. . .	2 to 6	6		
Perennials												
Johnsongrass (seedling)	2 to 8	5	2 to 8	12[b]	Up to 8	24	2 to 6 6 to 12	0.4 0.6	2 to 8	6	4 to 10	8
Johnsongrass (1st appl.)	10 to 24	10	8 to 18	24	15 to 25	24	10 to 20	1.0	. . .	. . .	12 to 24	10
Regrowth (2nd appl.)	6 to 10	7	6 to 12	16	6 to 12	24	10 to 20	0.5	. . .	. . .	6 to 10	8
Quackgrass (1st appl.)	6 to 10	10	6 to 10	24	6 to 8	36	. . .	. . .	6 to 10	12	4 to 8	16
Regrowth (2nd appl.)	4 to 8	7	10	16	6 to 8	24	. . .	. . .	10	8	4 to 8	16
Wirestem muhly (1st appl.)	4 to 8	8	4 to 12	24	Up to 6	30	1 to 2	0.8	4 to 12	8	. . .	. . .
Regrowth (2nd appl.)	4 to 8	7	4 to 12	24	Up to 6	30	2 to 6	1.1	4 to 12	8	. . .	. . .

[a] Crabgrass: length of lateral growth, not height.
[b] Use 16 ounces if droughty or when tank-mixing with broadleaf herbicides.

Soybean preharvest treatments

Roundup can be applied *preharvest* in soybeans after soybean pods have set and lost all green color. Allow a minimum of 7 days between application and soybean harvest. By air, Roundup may be applied at a rate of 1 quart per acre. Ground application at a higher rate is also allowed but is usually only feasible for spot treatment. Do not graze or harvest treated crop for livestock feed within 25 days of the last preharvest application. Do not treat soybeans grown for seed beans as there may be a reduction in germination or vigor.

Gramoxone Extra (paraquat) may be used for drying weeds in soybeans just before harvest. For indeterminate varieties (most of the varieties planted in Illinois), apply when 65 percent of the seed pods have reached a mature brown color or when seed moisture is 30 percent or less. For determinate varieties, apply when at least half of the leaves have dropped and the rest of the leaves are turning yellow.

The rate is 12.8 ounces of Gramoxone Extra 2.5S. The total spray volume per acre is 2 to 5 gallons for aerial application and 20 to 40 gallons for ground application. Add 1 quart of nonionic surfactant per 100 gallons of spray. Do not pasture livestock within 15 days of treatment, and remove livestock from treated fields at least 30 days before slaughter. *Gramoxone Extra is a restricted-use pesticide.*

Problem perennial weeds

Perennial weeds are increasing in Illinois because of reduced tillage, less crop rotation, and reduced competition from annual weeds.

Perennial weeds are often found in dense localized infestations or lightly scattered in fields. Even small

Table 13.18. Problem Perennial Weeds

Weed	Crop	Herbicide	Remarks
Bindweed	Corn	2,4-D ester 0.5 pt/A or amine 1 pt/A of 3.8 a.e.[a]	Apply in spring when leaves are fully expanded or apply preharvest after brown silk stage in corn. The ester formulation is preferred. Use drop nozzles when corn is over 8 inches tall.
		Banvel 0.5 to 1 pt/A	Use the 0.5 pt rate of Banvel on sandy soils and on corn taller than 8 inches and up to 2 weeks before tasseling.
	Soybeans	Blazer, Cobra, Basagran (rates on label)	Vines may be suppressed by applications. Control can be improved by adding 2 fluid ounces/A of Butyrac 200.
Bigroot morningglory	Corn	2,4-D amine 1 pt/A or ester 0.5 pt/A of 3.8 a.e.	Use on actively growing plants that have sufficient vine growth (10 to 24 inches) to which the herbicide can be applied.
Canada thistle	Corn	Banvel 0.5 to 1 pt/A or 2,4-D amine 1 pt/A or ester 0.5 pt/A of 3.8 a.e.	Use the 0.5 pt rate of Banvel on sandy soils and on corn taller than 8 inches. Do not apply Banvel within 2 weeks of tasseling. Use drop nozzles when corn is over 8 inches tall.
		Laddok 3.5 pt/A	Suppression only. Apply when Canada thistle is 8 to 10 inches tall. Use with 2 pt/A COC.
		Buctril 1.5 pt/A or Buctril + Atrazine 2 to 3 pt/A	Suppression only. Apply to weeds from 8 inches tall to the bud stage or up to tassel emergence on corn. Do not add spray additives. Apply before corn is 12 inches. May be combined with Stinger.
		Stinger ⅓ to ⅔ pt/A	Apply as broadcast spray from 4-inch rosette to before bud stage. Do not apply after the corn is 24 inches tall; do not apply more than ⅔ pt/A per year.
	Corn/soybeans	Roundup 2 to 3 qt/A	Apply after harvest and prior to tillage in the fall. Do not till for 3 days after application. Weeds should be actively growing.
		Basagran 1 qt/A	Will suppress thistle growth. Retreatment 7 to 14 days later with Basagran, or cultivation may be necessary to maintain suppression.
Common milkweed and hemp dogbane	Corn	2,4-D amine 1 to 2 pt/A or ester 1 to 2 pt/A of 3.8 a.e.	Apply mid- to late-season after corn silks have turned brown and plants are actively growing and have adequate foliage.
	Soybeans	Blazer, Cobra (rates on label)	Suppresses common milkweed but not hemp dogbane.
		Roundup 33% solution; 1 gal Roundup with 2 gal water	Apply with wiper applicator (ropewick or sponge) used above crop.
Honeyvine milkweed	Corn	2,4-D ester 0.5 pt/A or 2,4-D amine 1 pt/A of 3.8 a.e. or Banvel 0.5 to 1 pt/A or 2,4-D + Banvel at half rates	The ester formulation of 2,4-D is preferred; however, a combination of 2,4-D and Banvel may be better than 2,4-D used alone. Check Banvel label for restrictions.
Jerusalem artichoke	Corn	Banvel 0.5 to 1 pt/A or Banvel + 2,4-D at half rates	Treat weeds when they are 8 to 16 inches tall. Use the 0.5 pt rate of Banvel on sandy soils and on corn taller than 8 inches and up to 2 weeks before tasseling. Use drop nozzles when corn is over 8 inches tall.
		Stinger ¼ to ½ pt/A	Apply up to the 5-leaf stage. Do not apply more than ⅔ pt/A per year if retreatment is necessary. Do not apply to corn taller than 24 inches.
		Beacon ¾ oz/A	Apply to 1- to 4-inch artichoke.
	Soybeans	Pursuit 4 fluid oz/A or Classic 0.75 oz/A	Pursuit should be applied to plants that are 6 to 8 inches tall and Classic to plants less than 8 inches tall. Small weeds just emerging may have sufficient root or tuber reserves to begin regrowth after treatment and a cultivation may be required. Use a surfactant at 0.25 percent, or 1 qt in 100 gallons of spray.

Table 13.18. Problem Perennial Weeds (cont.)

Weed	Crop	Herbicide	Remarks
Swamp smartweed	Corn	Banvel 0.5 to 1 pt/A	Use the higher rate on corn shorter than 8 inches. Use the lower rate on taller corn up to 36 inches or up to 2 weeks before tasseling, whichever comes first, or on sandy soils. Use drop nozzles if the corn is more than 8 inches tall.
		Stinger ¼ to ½ pt/A	Suppression only. Apply to weed at 2- to 3-leaf stage. Do not apply after corn is 24 inches. Do not apply more than ⅔ pt/A per year.
	Corn/soybeans	Roundup 3 to 5 qt/A; see label for low-rate technology.	Apply before spring tillage or after harvest. Allow at least 7 days before tillage.
Yellow nutsedge	Corn	Sutan+, Eradicane (labeled rate for soil)	Apply preplant-incorporated.
		Laddok 3.5 pt/A	Suppression only. Add 2 pt/A COC.
	Corn/soybeans	Lasso, Dual	Use higher rate for soil type and incorporate thoroughly.
		Basagran 2 pt/A	Apply 1.5 to 2 pt/A when plants are 6 to 8 inches tall. Reapply 7 to 10 days later if needed. Add 2 pt/A COC with each application.
	Soybeans	Scepter 0.6 pt/A or Pursuit 0.25 pt/A	Thoroughly incorporate for best control.
		Classic 0.5 oz to ¾ oz/A	Apply Classic at the 4- to 6-leaf stage. Use a nonionic surfactant at 1 qt per 100 gallons of spray.
Rhizome or seedling johnsongrass	Corn	Accent ⅔ oz/A	Apply to 4- to 10-inch tall seedling johnsongrass, or apply up to 1⅓ oz (in split application) on rhizome johnsongrass 8 to 12 inches tall. Use a nonionic surfactant at 1 qt per 100 gallons of spray or COC at 4 qts per 100 gallons of spray. See label for restrictions.
		Beacon ¾ oz/A as a single or split application	Apply to seedling johnsongrass when 4 to 12 inches tall and rhizome johnsongrass when 8 to 16 inches tall. Add nonionic surfactant at 1 qt per 100 gallons of spray or COC at 1 to 4 pts/A. See label for restrictions.
	Soybeans	Assure II 10 fl oz/A	Apply to johnsongrass when 10 to 24 inches tall. Apply additional 7 fl oz to regrowth 6 to 10 inches tall if needed.
		Poast Plus 1.5 pt/A	Apply to johnsongrass 15 to 25 inches tall. Use Dash or COC. Treat 6- to 12-inch regrowth with same rate.
		Select 8 fl oz/A	Apply to johnsongrass 12 to 24 inches tall. Apply 6 fl oz/A to regrowth if needed.
		Fusilade 1.5 pt/A	Apply to 8- to 18-inch johnsongrass. Retreat 6- to 12-inch regrowth at 1 pt/A. Use COC or nonionic surfactant.
		Option II 1.0 pt/A	Apply to 10- to 20-inch johnsongrass. *Do not add COC.* Apply 0.5 pt/A to regrowth.
		Roundup 33% solution; 1 gal Roundup with 2 gal water	Apply with wiper application (ropewick or sponge) used above crop.
Quackgrass	Corn	Accent ⅔ oz/A	Apply to 2- to 4-inch tall quackgrass or apply up to 1⅓ oz (in split application) on quackgrass up to 6 inches tall. Use a nonionic surfactant at 1 qt or COC at 4 qts per 100 gallons of spray. See label for restrictions.
		Beacon ¾ oz/A	Apply to quackgrass when 4 to 8 inches tall. Control of this species is not immediate and symptoms may take several days to develop. Add nonionic surfactant at 1 qt per 100 gallons of spray or COC at 1 to 4 pts/A. See label for restrictions.
		Eradicane Extra 4 qt/A or Eradicane 6.7E 7.3 pt/A	A lower rate may be used on lighter infestations. Use a tank-mix with atrazine to improve control.

populations can cause reductions in crop yield, grain quality, and harvesting efficiency and can become serious infestations if left untreated.

Control of most perennials is often difficult due to the fact that perennials reproduce both by vegetative propagation and by seed. Light tillage, such as the use of a chisel plow or field cultivator, may drag root sections about the field where new shoots emerge and the problem spreads. If tillage is to be beneficial, root sections displaced by tillage must be exposed to the freeze-thaw cycle of winter weather or left on the soil surface to desiccate. Repeated mowings, where possible, or row cultivation can deplete food reserves these plants store in the roots.

Table 13.18. Problem Perennial Weeds (cont.)

Weed	Crop	Herbicide	Remarks
Quackgrass (cont.)	Corn/soybeans	Roundup 1 to 2 qt/A	Apply prior to spring tillage or after harvest in the fall. Do not till for 3 days before or after application. Weeds should be actively growing and greater than 8 inches tall.
	Soybeans	Assure II 10 fl oz/A	Apply when quackgrass is 6 to 10 inches tall. For regrowth apply 7 fl oz/A when quackgrass is 4 to 8 inches tall. Add COC at 2 pt/A.
		Fusilade 1.5 pt/A	Apply to 6- to 10-inch quackgrass. For regrowth, apply 1 pt/A to quackgrass up to 10 inches tall. Use COC or nonionic surfactant.
		Fusion 12 fl oz/A	Apply to quackgrass that is 6 to 10 inches tall. Treat regrowth (up to 10 inches) with 8 fl oz/A.
		Poast Plus 2.25 pt/A	Apply to quackgrass 6 to 8 inches tall and retreat at 1.5 pt/A for regrowth. Use Dash or COC at 2 pt/A.
		Select 1 pt/A	Apply to quackgrass 4 to 8 inches tall and retreat regrowth at the same rate and size if needed. Add COC at 2 pt/A.
Wirestem muhly	Soybeans	Assure II 8 fl oz/A	Apply when wirestem muhly is 4 to 8 inches tall. For regrowth, apply 7 fl oz/A. Add COC at 2 pt/A.
		Fusilade 1.5 pt/A	Apply to 4- to 12-inch wirestem muhly. Apply to regrowth at the same size and rate. Use COC or nonionic surfactant.
		Fusion 12 fl oz/A	Apply to wirestem muhly that is 4 to 12 inches tall. Treat regrowth up to 10 inches tall with 8 fl oz/A. Add COC or nonionic surfactant.
		Poast Plus 2.25 pt/A	Apply to wirestem muhly up to 6 inches tall. Retreat at same rate and size for regrowth. Use Dash or COC.
		Option II 1.1 pt/A	Apply to 3- to 6-inch wirestem muhly. Use COC or nonionic surfactant.

[a] a.e. = acid equivalent. If not 3.8 lb/gal, use equivalent amount.

Effective control of perennial weeds will often rely on a combination of mechanical control methods and the use of translocated (systemic) herbicides. Tillage and herbicide applications used together will weaken the vegetative regeneration of plant parts and suppress seedling development. Since no program is completely effective, elimination of perennial weeds from a single location may take several years. When using systemic herbicides, control of perennials is often more effective when low-dosage, multiple treatments are applied. This results in better movement of the herbicide into the roots and a more complete kill of perennial plant parts. Contact herbicides may suppress certain perennials but will not be effective in preventing regrowth from plant roots.

Table 13.18 lists common herbicides that are recommended for control or suppression of many perennial weeds. Although not indicated in this table, it should be emphasized that isolation of an infested area is often necessary to effectively treat perennial weeds. This can be done by rotating the affected field to small grains or forage legumes, government set-aside, or to a crop for which herbicides or mechanical controls can be used.

With many perennial weed infestations, if the affected area is small enough or if plants are lightly scattered through a field, spot treatment with a 2 percent solution of Roundup (3 ounces in 1 gallon) in a hand-held sprayer is highly effective. Although Roundup is nonselective and must be kept from contacting desirable vegetation, it can be applied to perennial weeds almost any time they are actively growing and have sufficient foliage to absorb and translocate the herbicide.

Roundup can also be used in wiper applicators and applied to weeds exceeding crop height by at least 6 inches. For wiper applicators, dilute 1 gallon of Roundup in 2 gallons of water. Do not till for 5 days before or after applying Roundup.

Table 13.18 includes recommendations for control of the most common perennial weeds in Illinois. Observe all precautions (listed on the herbicide labels) regarding drift and crop injury when applying these herbicides.

Chapter 14.

1993 Weed Control for Small Grains, Pastures, and Forages

Good weed control is necessary for maximum production of high-quality small grains, pastures, and forages in Illinois. When properly established, these crops can usually compete effectively with weeds so the need for herbicide applications is minimized. However, weeds can sometimes become significant problems and warrant control. For example, wild garlic is considered the worst weed problem in wheat in southern Illinois. Because its life cycle is similar to that of winter wheat, wild garlic can establish itself with the wheat, grow to maturity, and produce large quantities of bulblets by wheat-harvest time. Economic considerations often make it necessary to control wild garlic in winter wheat to minimize dockage.

In pastures, woody and herbaceous perennials can become troublesome. Annual grasses and broadleaf weeds such as chickweed and henbit may cause problems in hay crops. Through proper management, many of these weed problems can be controlled effectively.

Several herbicide labels carry the following groundwater warnings under either the enviromental hazard or the groundwater advisory section: "X is a chemical that can travel (seep or leach) through soil and enter groundwater which may be used as drinking water. X has been found in groundwater as a result of its use as a herbicide. Users of this product are advised not to apply X where the soils are very permeable (that is, well-drained soils such as loamy sands) and the water table is close to the surface." See Table 14.1 for a list of herbicides that carry this warning. A few labels also warn against contamination of surface water.

Small grains

Good weed control is critical for maximum production of high-quality small grains. Often, problems with weeds can be dealt with before the crop is established. For example, some broadleaf weeds can be controlled effectively in the late fall with **2,4-D, Banvel** (dicamba), or **Roundup** (glyphosate) after corn or soybean has been harvested, if seeding is not too late.

Tillage helps control weeds. Although generally limited to preplant or postharvest operations, tillage can destroy many annual weeds and help suppress certain perennials. Good cultural practices such as proper seeding rate, optimum soil fertility, and timely planting help to ensure the establishment of an excellent stand and a crop that is better able to compete with weeds.

Winter annual grasses such as downy brome and cheat are very competitive in winter wheat. Illinois wheat producers are often limited to preplant tillage operations for control of these species, as few herbicides have label clearances for annual grass control in winter wheat. If a severe infestation of downy brome or cheat exists, planting an alternative crop or spring crop may be best for that field.

A decision to use postemergence herbicides for broadleaf weed control in small grains should be based on several considerations:

1. *Nature of the weed problem.* Identify the species present and consider the severity of the infestation. Also note the size of the weeds. Weeds are usually best controlled while small.

2. *Stage of the crop.* Most herbicides are applied after full tiller until the boot stage. Do not apply herbicides from the boot stage to the hard-dough stage of most small grains. (See Figure 14.1 for a description of growth stages of small grains.)

3. *Herbicide activity.* Determine crop tolerance and weed susceptibility to herbicides by referring to Tables 14.2 and 14.3. The lower rates in Table 14.3 are for more easily controlled weeds and the higher rates for the more difficult-to-control species. Tank-mixes may broaden the weed spectrum and thereby improve control; check the herbicide label for registered combinations.

4. *Presence of a legume underseeding.* Usually 2,4-D

Table 14.1. List of Herbicides, Formulations, and Special Statements

Trade name	Common name	Formulation	Restricted use	Groundwater advisory	Key word
Ally 60 DF	metsulfuron methyl	60%	—	—	Caution
Balan 1.5E	benefin	1.5 lb/gal	—	—	Danger
Banvel	dicamba	4 lb a.e.*/gal	—	—	Warning
Buctril	bromoxynil	2 lb/gal	—	—	Danger[a]
Butyrac 200	2,4-DB	2 lb a.e./gal	—	—	Caution
Butoxone 200	2,4-DB	2 lb a.e./gal	—	—	Caution
Crossbow	2,4-D + triclopyr	2 + 1 lb a.e./gal	—	—	Caution
Eptam 7E, 10G	EPTC	7 lb/gal, 10%	—	—	Caution
Fusilade 2000	fluazifop	1 lb a.e./gal	—	—	Caution
Gramoxone Extra	paraquat	2.5 lb/gal	Yes	—	Danger[a]
Harmony Extra 75DF	thifensulfuron + tribenuron	75%	—	—	Warning
Kerb 50W	pronamide	50%	Yes	—	Caution
Lexone 75DF	metribuzin	75%	—	Yes	Caution
MCPA	MCPA	several	—	—	Warning
Option II	fenoxaprop	0.79 lb a.e./gal	Yes	—	Danger[a]
Poast Plus	sethoxydim	1 lb/gal	—	—	Warning
Prowl	pendimethalin	3.3 lb/gal	—	—	Warning
Roundup	glyphosate	3 lb a.e./gal	—	—	Warning
Sencor 4L	metribuzin	4 lb/gal	—	Yes	Caution
Sencor 75DF	metribuzin	75%	—	Yes	Caution
Sinbar 80W	terbacil	80%	—	—	Caution
Spike 20P	tebuthiuron	20%	—	—	Warning
Stinger	clopyralid	3 lb a.e./gal	—	Yes	Caution
Treflan	trifluralin	4 lb/gal	—	—	Warning
Velpar L	hexazinone	2 lb/gal	—	—	Danger[a]
2,4-D amine	2,4-D	3.8 lb a.e./gal	—	—	Danger[a]
2,4-D ester	2,4-D	3.8 lb a.e./gal	—	—	Caution

* a.e. = Acid equivalent for these herbicides. All others are active ingredient (a.i.) formulations.

[a] Danger: Check label for safety equipment and precautions.

ester formulations and certain other herbicides listed in Table 14.3 should not be applied because they may damage the legume underseeding.

5. *Economic justification.* Consider the treatment cost in terms of potential benefits such as the value of increased yield, improved quality of grain, and ease of harvesting the crop.

Table 14.3 outlines current suggestions for weed control options in wheat and oats, the two small grains most commonly grown in Illinois. Please refer to Table 14.4 for grazing restriction information concerning herbicides used in small grains. Always consult the herbicide label for specific information about the use of a given product.

For annual broadleaf weeds, postemergence herbicides such as **2,4-D, MCPA, Banvel,** and **Buctril** (bromoxynil) can provide good control of susceptible species (Table 14.2). Herbicides must be applied during certain growth stages of the crop to avoid crop injury and for optimum weed control. Refer to Figure 14.1 for a description of the growth stages of small grains.

Some perennial broadleaf weeds may not be controlled satisfactorily with the low herbicide rates used in small grains, and higher rates are not advisable because they can cause serious injury to crops. To control perennial weeds, translocated herbicides such as **2,4-D, Banvel,** or **Roundup,** in combination with tillage after small grain harvest or after soybean harvest but before establishing small grains, may be the best approach.

Stinger (clopyralid) may be used to control broadleaf weeds in wheat, oats, and barley. Stinger controls Canada thistle as well as a number of annual broadleaf weeds (Table 14.2).

Wild garlic continues to be a serious weed problem in winter wheat. **Harmony Extra** (thifensulfuron + tribenuron), when applied in the spring at 0.3 to 0.6 ounce of 75DF per acre, effectively controls wild garlic aerial bulblets and some underground bulbs as well. Harmony Extra also helps control chickweed, henbit, common lambsquarters, smartweed, and several species of mustard. See Tables 14.2 and 14.3 for additional information on controlling weeds in small grains.

Grass pastures

Unless properly managed, broadleaf weeds can become a serious problem in grass pastures. They can compete directly with forage grasses and reduce the nutritional value and longevity of the pasture. Certain species, such as white snakeroot and poison hemlock, are also poisonous to livestock and may require special consideration.

Perennial weeds are of great concern in pasture management. They can exist for many years, reproducing from both seed and underground parent rootstocks. Occasional mowing or grazing helps control certain annual weeds, but perennials can grow back from underground root reserves unless long-term control strategies are implemented.

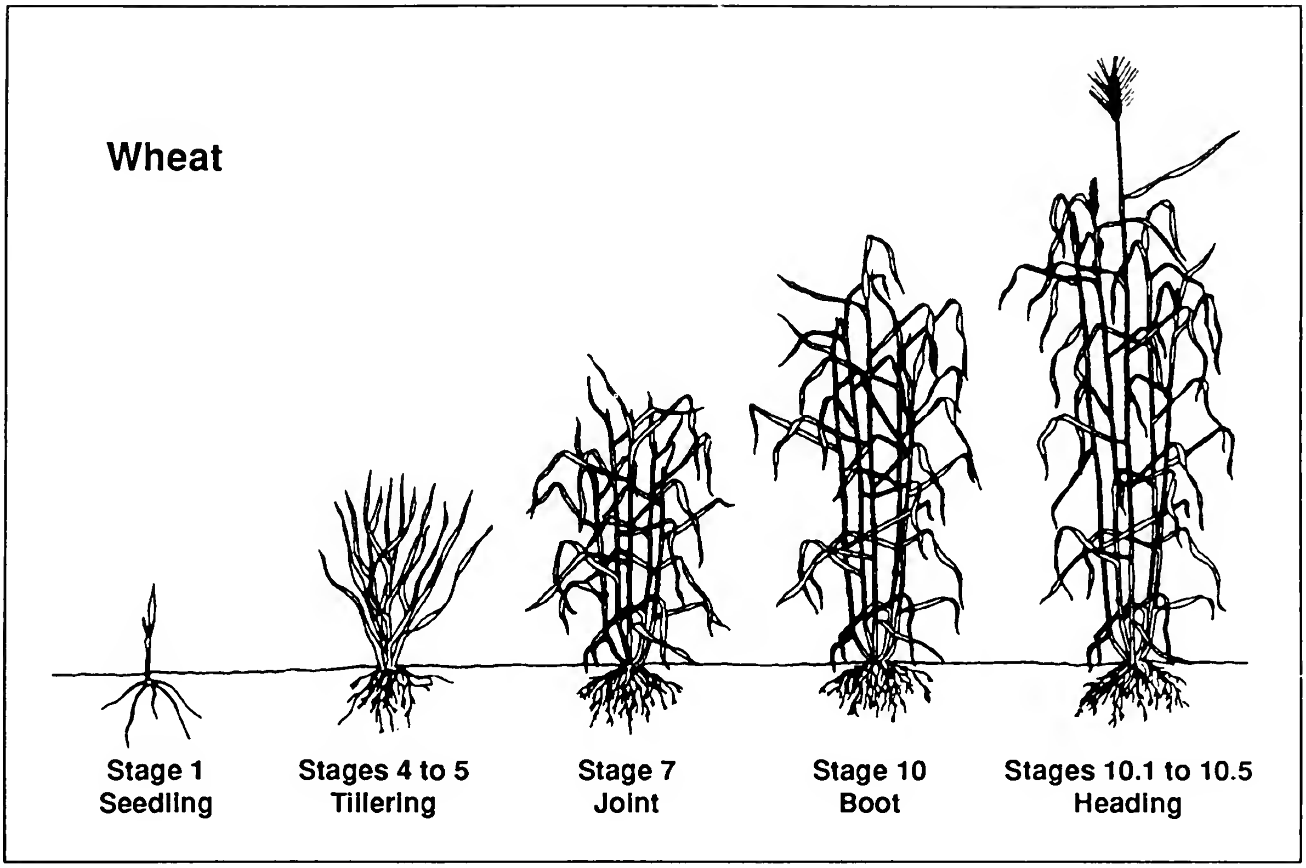


Figure 14.1. Growth stages of small grains.

Seedling

Stage 1. The coleoptile, a protective sheath that surrounds the shoot, emerges. The first leaf emerges through the coleoptile, and other leaves follow in succession from within the sheath of the previously emerging leaf.

Tillering

Stages 2 to 3. Tillers (shoots) emerge on opposite sides of the plant from buds in the axils of the first and second leaves. The next tillers may arise from the first shoot at a point above the first and second tillers or from the tillers themselves. This process is repeated until a plant has several shoots.

Stages 4 to 5. Leaf sheaths lengthen, giving the appearance of a stem. The true stems in both the main shoot and in the tillers are short and concealed within the leaf sheaths.

Jointing

Stage 6. The stems and leaf sheaths begin to elongate rapidly, and the first node (joint) of the stem is visible at the base of the shoot.

Stage 7. Second node (joint) of stem is visible. The next-to-last leaf is emerging from within the sheath of the previous leaf but is barely visible.

Stage 8. Last leaf, the "flag leaf," is visible but still rolled.

Stage 9: Preboot stage. Ligule of flag leaf is visible. The head begins to enlarge within the sheath.

Stage 10: Boot stage. Sheath of flag leaf is completely emerged and distended because of enlarging but not yet visible head.

Heading

Stages 10.1 to 10.5. Heads of the main stem usually emerge first, followed in turn by heads of tillers in order of their development. Heading continues until all heads are out of their sheaths. The uppermost internode continues to lengthen until the head is raised several inches above the uppermost leaf sheath.

Flowering

Stages 10.5.1 to 10.5.3. Flowering progresses in order of head emergence. Unpollinated flowers result in barren kernels.

Stage 10.5.4: Premilk stage. Flowering is complete. The inner fluid is abundant and clear in the developing kernels of the flowers pollinated first.

Ripening

Stage 11.1: Milk stage. Kernel fluid is milky white because of accumulating starch.

Stage 11.2: Dough stage. Kernel contents are soft and dry (doughy) as starch accumulation continues. The plant leaves and stems are yellow.

Stage 11.3. The kernel is hard, difficult to divide with the thumbnail.

Stage 11.4. Ripe for cutting. Kernel will fragment when crushed. The plant is dry and brittle.

Table 14.2. Effectiveness of Herbicides on Weeds in Small Grains

This table compares the relative effectiveness of herbicides on individual weeds. Ratings are based on labeled application rate and weed size or growth stage. Performance may vary due to weather and soil conditions, or other variables.

Weed	Susceptibility to herbicide					
	2,4-D	MCPA	Banvel	Buctril	Harmony Extra	Stinger
Winter annual						
Buckwheat, wild	5	8	10	9	8	8
Chickweed, common	5	5	6	6	9	0
Henbit	5	5	6	8	9	0
Horseweed (marestail)	8	8	10	6	7	9
Lettuce, prickly	10	9	8	6	8	9
Mustard spp., annual	10	10	6	9	9	0
Pennycress, field	10	10	6	8	9	0
Shepherdspurse	10	10	8	8	9	0
Summer annual						
Lambsquarters, common	10	10	10	10	8	0
Pigweed spp.	10	10	10	7+	9	0
Ragweed, common	10	9	10	9	0	9
Ragweed, giant	10	9	10	8	0	10
Smartweed, Pennsylvania	6	7	9	9	9	6
Perennial						
Dandelion	9	8	8	0	6	9
Garlic, wild						
aerial bulblets	6[a]	5	5	0	9	0
underground bulbs	0	0	0	0	5	0
Thistle, Canada	7	7	8	6	7	9

[a] 2,4-D ester at maximum use rate.

Rating Scale:
10 = 95 to 100%, 9 = 85 to 95%, 8 = 75 to 85%, 7 = 65 to 75%, 6 = 55 to 65%, 5 = 45 to.55%, and 0 = less than 45% control or not labeled.

Table 14.3. Weed Control in Small Grains

Herbicide	Broadcast rate/acre	Remarks: See Table 14.4 for grazing restrictions.
Oats and wheat with legume underseeding		
2,4-D amine (3.8 lb a.e.)	½ to 1½ pt	Winter wheat more tolerant than oats. Apply in spring after full tiller but before boot stage. Do not treat in fall. Use lower rate if underseeded with legume. Some legume damage may occur. May be used as preharvest treatment at 1 to 2 pints per acre during hard-dough stage.
MCPA amine	¼ to 3 pt	Less likely than 2,4-D to damage oats and legume underseeding. Apply from 3-leaf stage to boot stage. Rate varies with crop and weed size and presence of legume underseeding.
Buctril 2E	1 to 2 pt	Apply Buctril alone to fall-seeded small grains in the fall or spring, but before the boot stage. Weeds are best controlled before the 3- to 4-leaf stage. Buctril may be applied at 1 to 1½ pints per acre to small grains underseeded with alfalfa.
Oats and wheat without legume underseeding		
Banvel, 4 lb a.e.	4 fl oz	*Do not use with legume underseeding.* In fall-seeded wheat, apply before jointing stage. In spring-seeded oats, apply before oats exceed 5-leaf stage.
Stinger 3 lb a.e.	¼ to ⅓ pt	*Do not use with legume underseeding.* Apply to small grains from the 3-leaf stage up to the early boot stage. For control of Canada thistle, ⅓ pint per acre should be used. For control of additional weeds, Buctril, Banvel, Harmony, MCPA, or 2,4-D may be tank-mixed with Stinger.
Wheat only		
2,4-D ester (3.8 lb a.e.)	½ to ¾ pt	*Do not use with legume underseeding.* Apply in spring after full tiller but before boot stage. For preharvest treatment, apply 1 to 2 pints per acre during hard-dough stage. For control of wild garlic or wild onion, apply 1 to 2 pints in the spring when wheat is 4 to 8 inches high, after tillering but before jointing; these rates may injure the crop.
Harmony Extra 75DF	0.3 to 0.6 oz	*Do not use with legume underseeding.* Apply to the crop after the 2-leaf stage, but before the flag leaf is visible. Wild garlic should be less than 12 inches tall, with 2 to 4 inches of new growth. Annual broadleaf weeds should be past the cotyledon stage, actively growing, and less than 4 inches tall or across. Nonionic surfactant at 0.25% v/v should be included in the spray mixture. When liquid fertilizer is used as the carrier, use $^{1}/_{16}$-¼% v/v surfactant. Temporary stunting and yellowing may occur when Harmony Extra is applied using liquid fertilizer solution as the carrier. These symptoms will be intensified with the addition of surfactant. Without surfactant addition, wild garlic control may be erratic. Do not plant any crop other than wheat or barley within 60 days after application.

Table 14.4. Small-Grain Herbicides and Livestock Use

Herbicide name				Days after treatment before			
				Graze green			
Trade	Common	Crops[a]	Applied	Beef	Dairy	Feed straw	Withdraw for meat
Banvel	dicamba	WOB	Prejoint	No	No	Yes	0
Buctril	bromoxynil	WORBT	Preboot	30	30	30	30
Harmony Extra	2:1 mixture of thifensulfuron + tribenuron	WB	Before flagleaf	No	No	Yes	0
Many	2,4-D	WORB	Preboot	0	14	0	14
Many	2,4-D–late	WORB	Before harvest	No	No	No	. . .[b]
Many	MCPA	WORB	Prejoint	0	7	0	7
Stinger	clopyralid	WOB	Preboot	0	7	No	7

[a] Crops: W = wheat, O = oats, R = rye, B = barley, T = triticale.

[b] No grazing information available.

Table 14.5. Effectiveness of Herbicides on Weeds in Grass Pastures

This table compares the relative effectiveness of herbicides on individual weeds. Ratings are based on labeled application rate and weed size or growth stage. Performance may vary due to weather and soil conditions or other variables.

Weed	Susceptibility to herbicide					
	Ally	2,4-D	Banvel	Crossbow	Stinger	Roundup[a]
Winter annual						
Horseweed (marestail)	9	9	10	10	9	10
Pennycress, field	0	10	8	9	0	10
Summer annual						
Ragweed, common	0	10	10	10	9	10
Ragweed, giant	0	10	10	10	10	10
Biennial						
Burdock, common	0	10	10	10	8	9
Hemlock, poison	0	9	10	10	0	9
Thistle, bull	0	10	10	10	9	10
Thistle, musk	9	10	9	9	9	10
Perennial[b]						
Daisy, oxeye	0	8	10	10	9	9
Dandelion	0	10	8	10	9	8
Dock, curly	0	7	10	10	8	9
Goldenrod spp.	0	8	9	8	0	10
Hemlock, spotted water	0	9	10	10	0	9
Ironweed	0	8	10	9	0	10
Milkweed, common	0	6	8	8	0	8
Nettle, stinging	0	9	9	9	0	9
Plantain spp.	0	10	8	10	0	9
Rose, multiflora[c]	9	8	9	9	0	9
Snakeroot, white	0	8	9	9	0	8
Sorrel, red	0	5	10	10	6	8
Sowthistle, perennial	0	8	9	10	7	9
Thistle, Canada	9	8	9	9	10	8

[a] Spot treatment only.

[b] Perennial weeds may require more than one application.

[c] Spike is also an effective herbicide for multiflora rose control (weed susceptibility = 10).

Rating Scale:
10 = 95 to 100%, 9 = 85 to 95%, 8 = 75 to 85%, 7 = 65 to 75%, 6 = 55 to 65%, 5 = 45 to 55%, and 0 = less than 45% control or not labeled.

Certain biennials can also flourish in grass pastures. The first year they exist as a prostrate rosette, so that even close mowing does little to control growth. The second year, biennials produce a seedstalk and a deep taproot. If these weeds are grazed or mowed at this stage, root reserves can enable the plant to grow again, increasing its chance of surviving to maturity.

In general, the use of good cultural practices such as maintaining optimum soil fertility, rotational grazing, and periodic mowing can help keep grass pastures in good condition and more competitive with weeds. Where broadleaf weeds become troublesome, however, **2,4-D, Banvel,** or **Stinger** may be used. **Roundup** may also be used as a spot treatment, and **Crossbow** (2,4-D plus triclopyr) or **Ally** (metsulfuron methyl) are labeled for control of broadleaf and woody plant species in grass pastures. **Spike 20P** (tebuthiuron) may also be used in grass pastures for brush and woody

Table 14.6. Broadleaf Weed Control in Grass Pastures

Herbicide	Rate/acre	Remarks: See Table 14.7 for grazing restrictions.
2,4-D, 3.8 lb a.e. (amine or low-volatile ester)	2 to 4 pt	Broadleaf weeds should be actively growing. Higher rates may be needed for less susceptible weeds and some perennials. Spray bull or musk thistles in the rosette stage (spring or fall) while they are actively growing. Spray perennials such as Canada thistle in the bud stage or the fall regrowth stage. Spray susceptible woody species in spring when leaves are fully expanded. Do not apply to newly seeded areas or to grass when it is in boot to milk stage. Be cautious of spray drift.
Ally 60 DF	⅒ to 3/10 oz	Apply in the spring or early summer before annual broadleaf weeds are 4 inches tall. As a spot application for control of multiflora rose, blackberry, or Canada thistle, apply Ally at 1 ounce per 100 gallons of water and spray foliage to runoff. Include a surfactant of at least 80% active ingredient at 1 pint to 1 quart per 100 gallons spray solution (⅛ to ¼% v/v). Bluegrass, bromegrass, orchardgrass, timothy, and native grasses such as bluestem and grama have demonstrated good tolerance. Bluegrass, bromegrass, orchardgrass, and timothy should be established for at least 6 months and fescue for 24 months at the time of application or injury may result. Application to fescue may result in stunting and seedhead suppression. Do not apply to ryegrass or pastures containing desirable alfalfa or clovers. Ally is persistent in soil, and crop rotation guidelines on the label must be followed.
Banvel, 4 lb a.e.	Annuals: 1 to 1½ pt Biennials: ½ to 3 pt Perennials: 1 to 12 pt	Use lower rates for susceptible annuals when they are small and actively growing and for susceptible biennials in the early rosette stage. Use higher rates for larger weeds, for less susceptible weeds, for established perennials in dense stands, and for certain woody brush species. Be cautious of spray drift.
Crossbow	Annuals: 1 to 2 qt Biennials and herbaceous perennials: 2 to 4 qt Woody perennials: 6 qt	Apply to foliage during warm weather when brush and broadleaf weeds are actively growing. When applying as a spot spray, thoroughly wet all foliage. See herbicide label for more specific rate recommendations. Be cautious of spray drift. Best control of multiflora rose occurs when application is during early- to mid-flowering stage.
Roundup	1 to 2% solution (spot treatment)	Controls a variety of herbaceous and woody brush species such as multiflora rose, brambles, poison ivy, and quackgrass. Spray foliage of target vegetation completely and uniformly, but not to point of runoff. Avoid contact with desirable nontarget vegetation. Consult label for recommended timing of application for maximum effectiveness on target species. No more than ⅒ of any acre should be treated at one time. Further applications may be made in the same area at 30-day intervals. Use only where livestock movement can be controlled to prevent grazing for 14 days. Treated areas can be reseeded after 14 days.
Spike 20P	10 to 20 lb	For control of brush and woody plants in rangeland and grass pastures. Requires sufficient rainfall to move herbicide into root zone. May kill or injure desirable legumes and grasses where contact is made. Injury is minimized by applying when grasses are dormant. Do not apply on or near field crops or other desirable vegetation. Do not apply where soil movement is likely. Refer to product label for additional restrictions.
Stinger, 3 lb a.e.	⅔ to 1⅓ pt	Apply when weeds are young and actively growing. Grasses are tolerant, but new grass seedlings may be injured. For Canada thistle, apply to thistle at least 4 inches tall but before thistle reaches bud stage. Do not spray pastures containing desirable forbs, such as alfalfa or clover, unless injury can be tolerated. Do not use hay or straw from treated areas for composting or mulching on susceptible broadleaf crops. Refer to product label for additional precautions.

Table 14.7. Restrictions on Herbicides Used in Permanent Grass Pastures

Herbicide Name		Days after treatment (DAT) before use				
		Grazing		Grass hay		Slaughter withdrawal
Trade	Common	Beef	Dairy	Beef	Dairy	
Ally	metsulfuron	0	0	0	0	0
Banvel	dicamba	0	7 to 60[a]	0	37 to 90[a]	30
Crossbow	triclopyr + 2,4-D	0	14	7	365	3
Many	2,4-D	0	7 to 14[b]	30	30	3 to 7[b]
Stinger[c]	clopyralid	0	0	0	0	0
Roundup	glyphosate					
Spot-treat		14	14	14	14	. . .[d]
Renovation		56	56	56	56	. . .[d]
Spike 20P	tebuthiuron	(spot treatment)				
< 20 lb/A		0	0	365	365	. . .[d]
> 20 lb/A		Do not use for livestock for 1 year				
Weedmaster	dicamba + 2,4-D	0	7	37	37	30

[a] Varies with rate used per acre — see label.
[b] Labels vary (withdrawal unnecessary if > 14 DAT).
[c] Do not transfer livestock onto a broadleaf crop area within 7 days of grazing treated area.
[d] No information available.

Table 14.8. Effectiveness of Herbicides on Weeds in Legume and Legume-Grass Forages

This table compares the relative effectiveness of herbicides on individual weeds. Ratings are based on labeled application rate and weed size or growth stage. Performance may vary due to weather and soil conditions or other variables.

Weed	Balan	Buctril	Butyrac	Eptam	Gramoxone	Kerb	Poast Plus	Roundup[a,b]	Sencor/ Lexone[a]	Sinbar	Velpar
Winter annual											
Brome, downy	9	0	0	9	9	9	9	9	9	9	8
Chickweed, common	8	6	6	7	9	8	0	10	9	9	9
Henbit	5	8	6	9	9	8	0	8	9	9	8
Mustard, wild	0	8	10	6	9	5	0	9	9	9	9
Pennycress, field	0	9	8	6	9	5	0	10	9	9	9
Shepherdspurse	0	9	9	7	9	5	0	9	9	9	9
Yellow rocket	0	7	8	0	8	0	0	9	9	8	9
Summer annual											
Barnyardgrass	9	0	0	9	8	8	10	10	6	6	7
Crabgrass spp.	9	0	0	9	6	8	10	9	5	7	7
Foxtail spp.	9	0	0	9	9	8	10	10	6	7	7
Lambsquarters, common	9	10	8	9	9	6	0	9	9	9	9
Nightshade spp.[c]	0	9	8	8	9	6	0	9	5	6	6
Panicum, fall	9	0	0	9	9	6	10	10	6	6	6
Pigweed spp.	9	8	8	9	9	6	0	10	9	8	9
Ragweed, common	0	9	9	5	9	5	0	9	8	8	8
Smartweed, Pennsylvania	0	9	6	5	9	5	0	9	9	8	8
Perennial											
Canada thistle	0	0	0	0	0	0	0	9	0	0	0
Dandelion	0	0	7	0	0	0	0	8	8	6	7
Dock, curly	0	0	5	0	0	0	0	9	6	6	6
Nutsedge, yellow	0	0	0	8	0	0	0	7	0	0	0
Orchardgrass	5	0	0	6	5	7	6	8	5	5	6
Quackgrass	5	0	0	8	5	8	7	9	5	5	5

[a] Lexone, Sencor, and Roundup are labeled for use in mixed legume-grass forages. No other herbicides are cleared for this use.
[b] Spot treatment only.
[c] Control of different species may vary.

Rating Scale:
10 = 95 to 100%, 9 = 85 to 95%, 8 = 75 to 85%, 7 = 65 to 75%, 6 = 55 to 65%, 5 = 45 to 55%, and 0 = less than 45% control or not labeled.

plant control. (See Tables 14.5 and 14.6 for additional information.)

Proper identification of target weed species is important. As shown in Table 14.5, weeds vary in their susceptibility to herbicides. Timing of herbicide application may also affect the degree of weed control. Annuals and biennials are most easily controlled while young and relatively small. A fall or early spring treatment works best if biennials or winter annuals are the main weed problem. Summer annuals are most easily controlled in the spring or early summer. Apply translocated herbicides to control established perennials when the weeds are in the bud to bloom stage. Perennials are most susceptible at this reproductive phase because translocated herbicides can move downward with food reserves to the roots, thus killing the entire plant.

For control of woody brush, apply **2,4-D, Banvel,** or **Crossbow** when the plants are fully leafed and actively growing. Where regrowth occurs, a second treatment may be needed in the fall. During the dormant season, oil-soluble formulations of **2,4-D, Banvel** or **Crossbow** may be applied in fuel oil to the trunk. **Spike** controls many woody perennials and should be applied to the soil in the spring. Spike requires rainfall to move it into the root zone of target species. **Ally** as a spot treatment controls multiflora rose, Canada thistle, and blackberry (*Rubus spp.*) or suppresses these weeds and controls several annual broadleaf weeds when applied as a broadcast treatment at the lower rate range.

The weed control options in grass pastures are shown in Table 14.6. Refer to Table 14.7 for information concerning grazing restriction for herbicides used in grass pastures. Be cautious with any pesticide and always consult the herbicide label for specific information about the use of a given product.

Forage legumes

Weed control is important in managing forage legumes. Weeds can reduce the vigor of legume stands, reducing yield and forage quality. Good management begins with weed control that prevents weeds from becoming serious problems.

Establishment

To minimize problems, prepare the seedbed properly so that it is firm and weed-free. Select an appropriate legume variety. If you use high-quality seed and follow the recommendations for liming and fertility, the legume crop may compete well with many weeds and reduce the need for herbicides.

Table 14.9. Weed Control in Legume Forages

Herbicide	Legume	Time of application	Broadcast rate/acre	Remarks: See Table 14.10 for haying restrictions.
Seedling year				
Balan 1.5EC	Alfalfa, birdsfoot trefoil, red clover, ladino clover, alsike clover	Preplant incorporated	3 to 4 qt	Apply shortly before seeding. Do not use with any companion crop of small grains.
Eptam 7E,10G	Alfalfa, birdsfoot trefoil, lespedeza, clovers	Preplant incorporated	3½ to 4½ pt (7E) 30 lb (10G)	Apply shortly before seeding. Do not use with any companion crop of small grains.
Gramoxone Extra	Alfalfa only	Between cuttings	12.8 fluid oz	Apply within 5 days after cutting and before alfalfa regrowth is 2 inches. Add surfactant according to label instructions. Do not apply more than twice during seedling year. *Gramoxone Extra is a restricted-use pesticide.*
Buctril 2E	Alfalfa only	Postemergence	16 to 24 fl oz	Apply in the fall or spring to seedling alfalfa with at least 4 trifoliate leaves. Apply to weeds at or before the 4-leaf stage or 2 inches in height (whichever is first). May be tank-mixed with 2,4-DB for improved control of pigweed; however, crop burn may occur from this mixture, especially under warm, humid conditions. Eptam, previously used, may enhance Buctril burn to alfalfa. Do not apply when temperatures are likely to exceed 70°F during or for 3 days following application or when the crop is stressed. Do not add a surfactant or crop oil.
Butyrac 200 or Butoxone 200	Alfalfa, birdsfoot trefoil, ladino clover, red clover, alsike clover, white clover	Postemergence	1 to 3 qt (amine)	Use when weeds are less than 3 inches tall or less than 3 inches across if rosettes. Use higher rates for seedling smartweed or curly dock. May be tank-mixed with Poast Plus. *Do not use on sweet clover.*
Kerb 50W	Alfalfa, birdsfoot trefoil, crown vetch, clovers	Postemergence	1 to 3 lb	In fall-seeded legumes, apply after legumes have reached trifoliate stage. In spring-seeded legumes, apply next fall.
Poast Plus	Alfalfa only	Postemergence	1⅛ to 2¼ pt	Best grass control is achieved when applications are made prior to mowing. If tank-mixed with 2,4-DB, follow 2,4-DB harvest and grazing restrictions. Do not apply more than a total of 9.75 pints of Poast Plus per acre in one season.

In fields where companion crops such as oats are used to reduce weed competition, seed the small grain at half the rate for grain production to ensure that the legumes will become established with minimum stress. If the legume is seeded without a companion crop (direct-seeded), the use of an appropriate herbicide is suggested.

Preplant-incorporated herbicides. Balan (benefin) and **Eptam** (EPTC) are registered for preplant incorporation for legumes that are not seeded with grass or small-grain companion crops. These herbicides will control most annual grasses and some broadleaf weeds. In fall plantings, the weeds controlled include winter annuals such as downy brome and cheat. In spring legume plantings, the summer annual weeds controlled include foxtails, pigweeds, lambsquarters, crabgrass, and fall panicum. **Eptam** can help suppress johnsongrass, quackgrass, yellow nutsedge, and shattercane, in addition to controlling many annual grasses and some broadleaf weeds. Neither herbicide will effectively control mustards, smartweed, or established perennials.

Balan and **Eptam** *must* be thoroughly incorporated soon after application to avoid herbicide loss. They should be applied shortly before the legume is seeded so they remain effective as long as possible into the growing season.

Weeds that emerge during crop establishment should be evaluated for their potential to become problems. If they do not reduce the nutritional value of the forage or if they can be controlled by mowing, they should not be the primary target of a postemergence herbicide. For example, winter annual weeds do not compete vigorously with the crop after the first spring cutting. Unless they are unusually dense or production of weed seed becomes a concern, these weeds may not be a significant problem. Some weeds such as dandelions are palatable and may not need to be controlled if the overall legume stand is dense and healthy, but undesirable weeds must be controlled early to prevent their establishment.

Postemergence herbicides. Poast Plus (sethoxydim) may be applied to seedling alfalfa for control of annual and some perennial grass weeds after weed emergence. Grasses are more easily controlled when small. **Butyrac** (2,4-DB) controls many broadleaf weeds and may be applied postemergence in many seedling forage legumes. **Buctril** (bromoxynil) may be used to control broadleaf weeds in seedling alfalfa. Be sure to apply Buctril while weeds are small, and use precau-

Table 14.9. Weed Control in Legume Forages (cont.)

Herbicide	Legume	Time of application	Broadcast rate/acre	Remarks: See Table 14.10 for haying restrictions.
Established stands				
Butyrac 200 or Butoxone 200	Alfalfa only	Growing	1 to 3 qt (amine)	Spray when weeds are less than 3 inches tall or less than 3 inches wide if rosettes. Fall treatment of fall-emerged weeds may be better than spring treatment. May be tank-mixed with Poast Plus.
Kerb 50W	Alfalfa, birdsfoot trefoil, crown vetch, clovers	Growing or dormant	1 to 3 lb	Apply in the fall after last cutting, when weather and soil temperatures are cool. *Kerb 50W is a restricted-use pesticide.*
Sencor or Lexone	Alfalfa and alfalfa-grass mixtures	Dormant	¾ to 2 pt (4L) ½ to 1⅓ lb (75 DF)	Apply once in the fall or spring before new growth starts. Rate is based upon soil type and organic-matter content. Higher rates may injure grass component. Do not use on sandy soils or soils with pH greater than 7.5.
Sinbar 80W	Alfalfa only	Dormant	½ to 1½ lb	Apply once in the fall or spring before new growth starts. Use lower rates for coarser soils. Do not use on sandy soils with less than 1 percent organic matter. Do not plant any crop for 2 years.
Velpar L	Alfalfa only	Dormant	1 to 3 qt	Apply in the fall or spring before new growth exceeds 2 inches in height. Can also be applied to stubble after hay crop removal but before regrowth exceeds 2 inches. Do not plant any crop except corn within 2 years of treatment. Corn may be planted 12 months after treatment provided deep tillage is used.
Poast Plus 1E	Alfalfa only	Postemergence	1⅛ to 2¼ pt	Best grass control is achieved when applications are made prior to mowing. If tank-mixed with 2,4-DB, follow 2,4-DB grazing and harvest restrictions. Do not apply more than a total of 9.75 pints of Poast Plus per acre in one season.
Gramoxone Extra	Alfalfa only	Dormant	1½ to 2 pt	For dormant season, apply after last fall cutting or before spring growth is 1 inch tall. Weeds should be succulent and growing at the time of application. Do not apply if fall regrowth is more than 6 inches. *Gramoxone Extra is a restricted-use pesticide.*
		Between cuttings	12.8 fl oz	Between cutting treatments should be applied immediately after hay removal within 5 days after cutting and with less than 2 inches of growth. Weeds germinating after treatment will not be controlled. *Gramoxone Extra is a restricted-use pesticide.*
Roundup	Alfalfa, clover, and alfalfa or clover-grass mixtures	Growing	1 to 2% solution (spot treatment)	No more than ⅒ of any acre should be treated at one time. Further applications may be made in the same area at 30-day intervals. Avoid contact with desirable, nontarget vegetation because damage may occur. Refer to label for recommended timing of application for maximum effectiveness on target species.

tions to avoid an adverse effect on the crop. (See Table 14.8 for specific weed control ratings and Table 14.9 for rates and remarks.)

Established legumes

The best weed control practice in established forage legumes is maintenance of a dense, healthy stand with proper management techniques. Chemical weed control in established forage legumes is often limited to late fall or early spring applications of herbicide. **Sencor** or **Lexone** (metribuzin), **Sinbar** (terbacil), and **Velpar** (hexazinone) are applied after the last cutting in the fall or in the early spring. These herbicides control many broadleaf weeds and some grasses, too. **Kerb** (pronamide) is used for grass control and is applied in the fall after the last cutting. The herbicide **2,4-DB** controls many broadleaf weeds in established alfalfa; it should be applied when the weeds are small and actively growing. Refer to Tables 14.8 and 14.9 for additional remarks and weed control suggestions.

Once grass weeds have emerged, they are particularly difficult to control in established alfalfa. **Poast Plus** herbicide may be used in established alfalfa for postemergence control of annual and some perennial grasses. Optimum grass control is achieved if Poast Plus is applied when grasses are small and before the weeds are mowed.

Table 14.8 outlines current suggestions for weed control options in legume forages. The degree of control will often vary with weed size, application rate, and environmental conditions. Be sure to select the correct herbicide for the specific weeds to be

Table 14.10. Herbicides Used in Forage Legumes and Restrictions

Herbicide name		Applied on/at		Days before	
Trade	Common	Forage[a]	When[a]	Graze	Hay
Seedling legumes					
Balan	benefin	AL, CL, BT	PPI	. . .[b]	. . .[b]
Eptam	EPTC	AL, CL, BT	PPI	. . .[b]	. . .[b]
Butyrac, Butoxone	2,4-DB	AL, CL, BT	Post	60	60
Buctril	bromoxynil	AL	Post-fall	60	60
		AL	Post-spring	30	30
Gramoxone Extra	paraquat	AL	After cut[c]	30	30
Poast Plus	sethoxydim	AL	Post	7	20
Established legumes					
Many	2,4-DB	AL	Post	30	30
Gramoxone Extra	paraquat	AL	After cut[c]	30	30
Poast Plus	sethoxydim	AL	Post	7	20
Roundup	glyphosate	AL, CL, BT	Spot-treat	14	14
Roundup	glyphosate	AL, CL, BT	Renovate	56	56
Gramoxone Extra	paraquat	AL	Dormant	60	60
Kerb	pronamide	AL, CL, BT	Dormant	120	120
Lexone	metribuzin	AL	Dormant	28	28
Sencor	metribuxin	AL	Dormant	28	28
Sinbar	terbacil	AL	Dowmant	. . .[b]	0
Velpar	hexazinone	AL	Dormant	30	30

[a] AL = alfalfa, CL = clover (red, alsike, or ladino), BT = birdsfoot trefoil, PPI = preplant-incorporated.

[b] No grazing information on label.

[c] Between cuttings (less than 5 days after cut with less than 2 inches regrowth).

controlled (Table 14.8). Refer to Table 14.10 for grazing and harvesting restrictions for forage legumes. Always consult the herbicide label for specific information about the use of a given product.

Acreage Conservation Reserve program

Investing in good weed control on Acreage Conservation Reserve (ACR) land will help alleviate some problem weeds when rotating back to row crops. For example, perennial broadleaf weeds such as hemp dogbane and common milkweed may be controlled or suppressed in small-grain production or when a perennial grass or legume species is grown. In addition, mowing or alternative herbicide options may be available. Whether using tillage, mowing, herbicides, or combinations, the best approach is to remain flexible and use cost-effective methods that fit your weed problems and management system.

Clover, alfalfa, or other forage legumes may be one of the best options for ACR acres. The cover helps conserve soil, improves soil structure, and adds nitrogen. Clover and alfalfa can be quite economical, particularly if grown for at least two consecutive years. The use of a herbicide for legume establishment can allow a vigorous legume stand and alleviate the need for weed control measures later. If annual broadleaf weeds become a problem, consider applying **2,4-DB** or mowing. Herbicides for use on forage legumes on ACR acres include some of those registered for commercial production fields (Table 14.8). In addition, **Treflan** (trifluralin) or **Prowl** (pendimethalin) may be used preplant incorporated to control annual grasses and some small-seeded broadleaf weeds. Some stand reduction may occur with Treflan or Prowl, but good weed control can compensate to allow for good establishment of the legume. **Fusilade** (fluazifop), **Poast Plus** (sethoxydim) or **Option II** (fenoxaprop) may be used for grass control postemergence on some forage legumes on ACR land. With many of these products, haying and grazing are not allowed; therefore, be sure to follow all restrictions imposed by the pesticide label.

Oats are commonly grown as a cover crop on set-aside acres. Oat seed is inexpensive and easy to obtain. If the Agricultural Stabilization and Conservation Service (ASCS) does not require clipping before seed maturity, oats can reseed for fall cover. Wheat, rye, or barley are other small-grain cover crop possibilities.

Sowing clean small-grain seed is the first step toward minimizing weed problems. Small grains generally provide relatively good cover until they mature or the area is mowed; then weeds can soon proliferate. However, winter wheat or rye may be sown in the spring, and without the overwintering period (vernalization), little or no seed production occurs and a dense cover remains. Annual broadleaf weeds can be controlled by mowing and by the use of the herbicides listed in Table 14.3. Tilling before small-grain planting will help control established weeds.

Sorghum-sudan grass can make a rapid, vigorous cover that also effectively suppresses many weeds. Although herbicides are rarely needed in sorghum-sudan grass stands, mowing and tillage may be difficult, and viable seed sometimes causes weed problems the next year.

Planting a small-grain/legume combination is another option for set-aside. Using the small grain as a companion crop may help reduce weed pressure and alleviate the need for herbicides. If weeds become a problem, refer to Table 14.8 for more information in selecting the appropriate herbicide.

In addition to those herbicides listed in Table 14.8, **Buctril** may be used to control broadleaf weeds in seedling alfalfa-grass mixes on Conservation Reserve Program (CRP) acres. Refer to current label rates and restrictions.

Acreage Conservation Reserve land may offer an opportunity for controlling certain problem weeds, such as perennials, and may keep other, more common weeds in check. By managing ACR land this year, controlling weeds in future row crops will be less difficult and more economical.

Selected Publications

Readers interested in reading more about a particular topic are referred to these publications, which were mentioned in the handbook. The publications are available from your local Extension office. Many of them are also available for purchase from the Office of Agricultural Communications and Education (OACE), 69 Mumford Hall, 1301 West Gregory Drive, Urbana, Illinois 61801. Addresses for publications from other sources are also indicated.

Chapter 1.

Soils of Illinois, B778 (available from OACE).

Performance of Commercial Corn Hybrids in Illinois — annual report on hybrid performance, available each year after harvest, AG-2056 (available from Department of Agronomy, N-307 Turner Hall, University of Illinois, 1102 South Goodwin Avenue, Urbana, Illinois 61801 or your local Extension office).

Chapter 2.

Narrow-Row Soybeans: What to Consider, C1161 (available from OACE).

Managing Deficient Soybean Stands, C1317 (available from OACE).

Double-Cropping in Illinois, C1106 (available from OACE).

Performance of Commercial Soybeans in Illinois (available from Department of Agronomy or your local Extension office).

Chapter 3.

Wheat Performance in Illinois Trials — 1990, AG-2054 (available from Department of Agronomy or your local Extension office).

Chapter 7.

1993 Illinois Agricultural Pest Control Handbook, IPC1991 (available from OACE).

Chapter 8.

Illinois Seed Law publications — updated as there are changes to the law (available from Illinois Department of Agriculture, Division of Plant Industries and Consumer Services, P.O. Box 19281, Springfield, Illinois 62794-9281).

Chapter 10.

Illinois Voluntary Limestone Program Producer Information — annual publication (available from the Illinois Department of Agriculture, Division of Plant Industries and Consumer Services).

Average Organic Matter Content in Illinois Soil Types, Agronomy Fact Sheet SP-36 (available from the Department of Agronomy).

Color Chart for Estimating Organic Matter in Mineral Soils, AG-1941 (available from OACE).

Soil Plan (available from IlliNet Software, 330 Mumford Hall, 1301 West Gregory Drive, Urbana, Illinois 61801).

Compendium of Research Reports on the Use of Nontraditional Materials for Crop Production (available from Publications Distribution, Printing and Publications Building, Iowa State University, Ames, Iowa 50011 or your local Extension office).

Chapter 11.

The Residue Dimension — Managing Residue to Control Erosion (CES fact sheets, *Land & Water Series No. 9, June 1989.* This ongoing series covers a wide range of water quality and soil conservation issues. For more information, write to Land & Water Publications, 305 Mumford Hall, 1301 West Gregory Drive, Urbana, Illinois 61801).

A Farm Machinery Selection and Management Program — J. Siemens, K. Hamburg, and T. Tyrrell (*J. Prod. Agric.*, 3:212-219, April-June 1990).

Estimating Your Soil Erosion Losses with the Universal Soil Loss Equation (USLE), C1220 (available from OACE).

Chapter 12.

Illinois Drainage Guide, C1226 (available from OACE).

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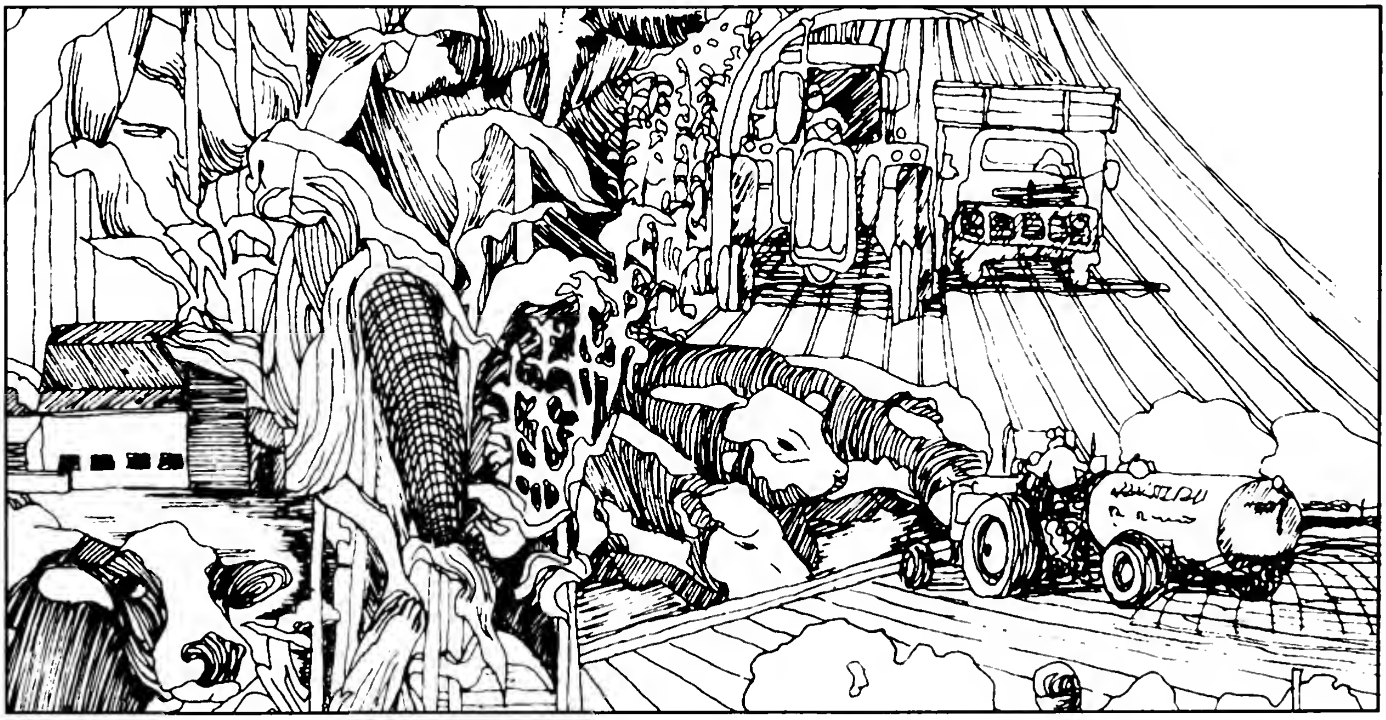


Useful Facts and Figures

To convert column 1 into column 2, multiply by	Column 1	Column 2	To convert column 2 into column 1, multiply by
	Length		
0.621	kilometer, km	mile, mi	1.609
1.094	meter, m	yard, yd	0.914
0.394	centimeter, cm	inch, in.	2.54
16.5	rod, rd	feet, ft	0.061
	Area		
0.386	kilometer^2, km^2	mile^2, mi^2	2.59
247.1	kilometer^2, km^2	acre, acre	0.004
2.471	hectare, ha	acre, acre	0.405
	Volume		
0.028	liter	bushel, bu	35.24
1.057	liter	quart (liquid), qt	0.946
0.333	teaspoon, tsp	tablespoon, tbsp	3
0.5	fluid ounce	tablespoon, tbsp	2
0.125	fluid ounce	cup	8
29.57	fluid ounce	milliliter, ml	0.034
2	pint	cup	0.5
16	pint	fluid ounce	0.063
	Mass		
1.102	ton (metric)	ton (English)	0.907
2.205	kilogram, kg	pound, lb	0.454
0.035	gram, g	ounce (avdp.), oz	28.35
	Yield		
0.446	ton (metric)/hectare	ton (English)/acre	2.24
0.891	kg/ha	lb/acre	1.12
0.891	quintal/hectare	hundredweight/acre	1.12
0.016	kg/ha-corn, sorghum, rye	bu/acre	62.723
0.015	kg/ha-soybean, wheat	bu/acre	67.249
	Temperature		
(9/5·C)+32	Celsius	Fahrenheit	5/9(F−32)

Plant Nutrition Conversion

P(phosphorus) × 2.29 = P_2O_5

K(potassium) × 1.2 = K_2O

$P_2O_5 \times .44 = P$

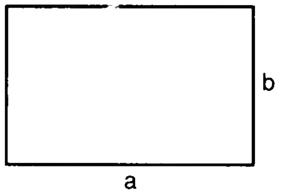
$K_2O \times .83 = K$

ppm × 2 = lb/A (assumes that an acre plow depth of 6⅔ inches weighs 2 million pounds)

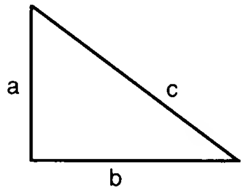
Useful Equations

$$\text{Speed (mph)} = \frac{\text{distance (ft)} \times 60}{\text{time (seconds)} \times 88}$$

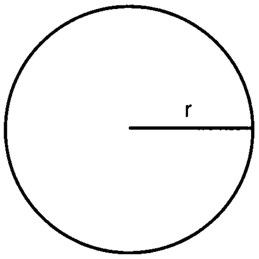
1 mph = 88′/min



Area = a × b



Area = ½ (a × b)



Area = πr^2

$\pi = 3.1416$

$$\text{lb}/100\ \text{ft}^2 = \frac{\text{lb/acre}}{435.6}$$

$$\text{Example: 10 tons/acre} = \frac{20{,}000\ \text{lb}}{435.6} = 46\ \text{lb}/100\ \text{ft}^2$$

$$\text{oz}/100\ \text{ft}^2 = \frac{\text{lb/acre}}{435.6} \times 16$$

$$\text{Example: 100 lb/acre} = \frac{100}{435.6} \times 16 = 4\ \text{oz}/100\ \text{ft}^2$$

$$\text{tsp}/100\ \text{ft}^2 = \frac{\text{gal/acre}}{435.6} \times 192$$

$$\text{Example: 1 gal/acre} = \frac{1}{435.6} \times 192 = .44\ \text{tsp}/100\ \text{ft}^2$$

Water weight = 8.345 lb/gal

Acre-inch water = 27,150 gal