

# Soybean



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Illinois is first or second among states in soybean production in the United States, with between 8 and 10 million acres a year over the past decade. Average yields for Illinois during this period are shown in Figure 2.1, on page 13. While yields are high in Illinois compared to many parts of the world, they have not, at least in recent years, been trending upward steadily; instead they show relative stability, with variability related mostly to weather conditions. This chapter will address soybean management, including ways to bring yields up, if not in all of Illinois, then at least on your farm. This is a challenging task.

## Soybean Plant Development

A good understanding of how the soybean plant grows and functions can help producers refine their management practices to achieve better yields. An overview of soybean's growth, development, and management requirements for good yields is found in *Soybean Growth and Development* (PM 1945, Iowa State University Extension; parts of this publication can be seen at [extension.agron.iastate.edu/soybean/production\\_growthstages.html](http://extension.agron.iastate.edu/soybean/production_growthstages.html)).

The growth of soybean plants is tracked by a system that assigns a V number (for example, V1) to vegetative stages of growth depending on the number of the plant's expanded trifoliolate leaves (having three leaflets). **Figure 3.1** shows a V3 plant with three expanded trifoliolate leaves. A leaf is considered "expanded" when the younger leaf above it starts to unroll, so that the edges of the leaflets are no longer touching. Soybeans planted in early May usually reach the V7 or V8 stage by early July, and soon thereafter the first flowers appear on plants. This stage is designated as the first reproductive stage, or R1. Unlike in corn, vegetative stages continue to develop after reproductive stages begin; such development is called indeterminate, because the final size of the plant is not set by the time the plant flowers, and vegetative and reproductive stages overlap.

Unlike corn plants, which begin to flower once a certain accumulated temperature (measured by growing degree days) is reached, soybean plants are influenced to flower by the length of the day; this is called photoperiod sensitivity. Temperature is also important in the rate of soybean development, including when flowering begins. Photoperiod works like this: Soybean plants have a mechanism whereby a certain substance is converted from the inactive form to the active form in the dark. Light makes it revert back to the inactive form. Once nights are long enough to allow enough of the active form to accumulate, the plant starts the flowering process. Warm nights speed up this process, while lights at night, such as street lamps, will inhibit it (**Figure 3.2**) and can greatly delay flowering. For soybean varieties adapted to central Illinois, the nights are long enough by about July 10 or so to allow flowering to start, though warm nights will move this date up. Early-maturing varieties do not need nights to be as long as later varieties, so flowering starts earlier. Moving a variety farther north means that nights are shorter (days are longer in midsummer), so flowering will start later.



**Figure 3.1.** A V3 soybean plant. The cotyledons are attached, and above them are the cotyledonary leaves, which are single, not trifoliolate. Notice that the fourth trifoliolate leaf is not yet fully expanded. A branch is starting to form in the axil of the first trifoliolate leaf.



**Figure 3.2.** Interruption of flowering led to late maturity of soybean plants that receive the light from street lamps. These plants were frosted before the photo, but pods are still green.

Once flowering starts, we track the development of flowers and then pods and seeds, with stages R3, R5, and R7 marking the beginning of pod setting, pod filling, and maturity, and stages R2, R4, R6, and R8 marking stages of full flowering, pod setting, seed filling, and maturity. One advantage that soybean has over corn is that the flowering and seed-filling stages take several weeks to complete, and if there are stresses such as dry soils during this time, relief of such stresses during these critical stages can often allow the plant to recover. Early-maturing varieties develop more quickly, so they have a shorter time over which such recovery is possible. Pod filling normally starts in early August and can be nearly finished by early September.

Besides differing from corn in the timing and duration of yield-making events such as flowering and seed filling, soybean plants also tend to produce considerably more leaf area than corn plants, at least collectively in the field. The LAI (acres of leaves per acre of crop) is often as high as 6 or 7 in soybean compared to 3.5 or 4 in a good corn crop. This is part of the reason that soybeans are less sensitive to lower plant populations compared to corn. But producing so much leaf area also takes a great deal of energy, and to the extent that some of the leaf area is not normally needed to produce maximum yields, production of a lot of leaf area can lower plant efficiency. In years with a lot of rainfall in June and July, in fact, leaves are often larger and stems longer, which can result in shading and less seed filling of pods lower in the crop canopy. Seeds in a pod are usually filled using sugars from the leaf attached to the same node as that pod, so if leaves cannot reach into the light, the pods at the same node may not fill completely.

## Variety Selection

Soybean varieties are divided into groups according to their relative times of maturity. These maturity groups (MGs) are usually designated using Roman numerals, from 0 (or several zeroes, for very short-season varieties) to MG IX or higher for types developed for very warm climates with shorter days during the growing season. It is also common practice to add a decimal to the MG number, and to refer, for example, to a variety as MG 2.4 or 3.6, to denote gradations within a maturity group. MG numbers are assigned by breeders, and many naming systems for commercial varieties include the MG number (and often a decimal) as part of the name.

Varieties of MG I can be grown in northernmost Illinois, but they are too early for good growth and yield farther south. Varieties of MG IV are best adapted in southern Illinois, and a few MG V varieties are grown in the southernmost areas. Growing soybeans that effectively use the full growing season is generally beneficial to yield, though we have seen limited benefits from using very late-maturing varieties, even if they are able to complete seed fill before frost. As is the case with corn, there has been more breeding attention paid to improving varieties in MG I through MG III than in later-maturing groups. One reason for this is that the mid-South (Arkansas, Tennessee) now produce earlier-maturing soybeans—often MG III and IV—in order to escape hot, dry conditions in late summer. This has diminished the demand for varieties in MG V and later.

Nearly all soybeans grown in the Midwest have an indeterminate growth habit, meaning that vegetative growth continues beyond the time when flowering begins, up to about the time that seed filling begins (R5). Several decades ago, some short-statured determinate or semideterminate (cross of determinate and indeterminate) varieties with maturities appropriate to Illinois were released. The short stature helps these varieties resist lodging in high-yield environments. But they also need above-average growing conditions before flowering to consistently offer a yield advantage, and stress early in the season can result in very short plants and low yields. As a result, few determinate varieties are grown today.

Hundreds of soybean varieties—nearly all privately developed—are named and sold by seed companies. Most soybean acres in Illinois are planted from MG II, III, or IV, with a few MG I and V varieties grown in the northern and southern ends of the state, respectively. For specific performance data on both public and private varieties, consult the latest issue of *Performance of Commercial Soybeans in Illinois*, or visit the website at [vt.cropssci.illinois.edu/soybean.html](http://vt.cropssci.illinois.edu/soybean.html).

Since their first release in the mid-1990s, Roundup Ready soybean varieties have come to occupy more than 90% of the soybean acreage in Illinois. Most people agree that some of the early-released varieties of Roundup Ready soybeans were agronomically inferior, mostly because only limited germplasm was available for release. These varieties have been replaced by newer releases, and today most available data indicate that if there is a yield difference between these two groups of varieties, it is probably in favor of the Roundup Ready varieties. Because these varieties make up such a high percentage of the seed market, private breeding companies have directed most of their efforts to improvement of these and other GM varieties.

While the several different glyphosate-resistant genes are the only GM trait now widely available in commercial varieties, the next few years will see commercial release of GM varieties with traits to give resistance to other herbicides (glufosinate, or Liberty; and dicamba, or Banvel and other trade names) and possibly some with disease resistance and even “yield” genes, though it’s not clear that the latter will require gene transfer (or be called GM), since they will likely come from soybean. Other GM traits of interest in soybean might include Bt for insect resistance and some quality traits. There continues to be some consumer resistance to GM soybeans regardless of what trait is involved. This may continue to slow the release of some novel GM traits in soybean, especially those varieties developed for use in foods.

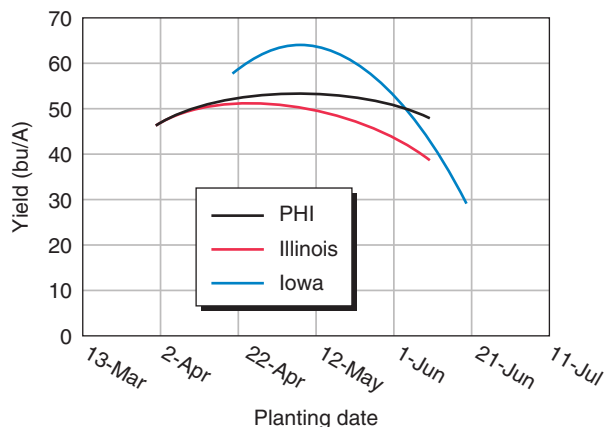
When choosing a variety, first consider a suitable maturity coupled with a good yield record. Further refine your selection by considering the variety’s genetic resistance to prevalent pest problems. Another trait to keep in mind is standability, though this is not as big an issue as with corn or as it was with older soybean varieties. Commercial varieties have also been selected against the tendency to have seed shatter from pods before harvest, though unusual weather can still cause some of this. If you are producing for niche-market contracts, your choices will be relatively limited and may not include the best-yielding or most pest-resistant varieties.

So far, there have been few releases of varieties bred especially to have more protein, oil, or other constituents than do normal varieties. Such quality traits are important, however, and breeders avoid releasing varieties that are lower than normal in protein and oil. The use of soybean oil as biodiesel has increased demand for the oil, and the increased availability of corn protein extracted during ethanol production has meant increased competition with soybean protein for use in animal feed. Improvements in the nutritional and feed quality of protein and oil are certainly possible. But it remains difficult to breed for large changes in content, if not quality, of these key components.

## Planting Date

Because of the flowering mechanism described, later planting often does not delay flowering as much in soybean as it might in corn; the rule of thumb is that soybean need about 6 weeks of warm weather to develop enough size for best yields by the time flowering occurs. If it’s warm and soybean plants begin to flower during the first or second week of July, planting later than late May will not usually allow enough growth for best yields, unless conditions are ideal later in the season. For this reason, soybeans generally yield best when planted in May, with full-season varieties tending to yield best when planted in early May. Earlier varieties tend to be less sensitive to planting date, as long as they are planted by late May. When planting of full-season varieties is delayed until late May, the loss in yield is comparatively less than the penalty for planting corn late. Planting soybeans after corn has been planted is thus the best strategy.

**Figure 3.3** shows planting date responses from several studies, one conducted by University of Illinois agronomists in northern Illinois in the early 1990s, the second by Pioneer Hi-Bred International agronomists over a range of Corn Belt locations in 2001, and the third by Dr. Palle Pedersen of Iowa State University at several sites in 2004, a year of very high yields. These results show the variability over years and environments in the response of soybean to planting date. But planting in the first half of May normally produces the best yields. Planting in April, especially early April, can reduce yields, even when stands are good. Planting delays to the end of May often carry relatively mild penalties, though this varies a great deal among years. The reason we see such variability is that



**Figure 3.3.** Soybean planting date response in three different trials. The PHI results were generated by agronomists with Pioneer Hi-Bred International using several different varieties, the Illinois results are from trials run in northern Illinois, and the Iowa results are from Dr. Palle Pedersen of Iowa State University, from work done in 2004.

conditions later in the season can add to or greatly diminish potential problems from late planting. For example, the 2008 season was relatively cool and wet, and widespread delays in planting were followed by very slow development and late maturity. Even so, yields ranged from good to very good, even in fields planted in mid-June or later.

If temperatures are close to normal, planting date affects the length of time required for soybeans to mature, with delays resulting in fewer days needed for the plant to complete its life cycle. The period from planting to the beginning of flowering is typically 45 to 60 days for full-season varieties planted at the normal time. This interval is shortened as planting is delayed; it may be only about 25 days when such varieties are planted in late June or early July, but this also means that plants may be small and canopy may be less than adequate when flowering starts. A rule of thumb is that for each 2- to 3-day delay in planting, plants reach maturity one day later. The lengths of the flowering and pod-filling periods also are shortened, but the effect of late planting on these phases of development is minor.

Planting dates that extend into June often decrease yield substantially. Such late planting tends to result in a shorter soybean plant with considerably fewer leaves, reducing the yield potential per plant. It is possible to offset somewhat the changes in plant morphology by planting late-seeded soybeans in narrow rows and at a seeding rate higher than is used for early planting. Double-crop soybeans, which are planted after wheat harvest and so are always planted late, often benefit from having narrow rows and high seeding rates. Dry soils can significantly delay soybean emergence and can thus turn it into a “late-planted” crop even if it was planted on time. It is clear why late-planted soybeans are risky and why planting on time is important.

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## Planting Rate and Seed Issues

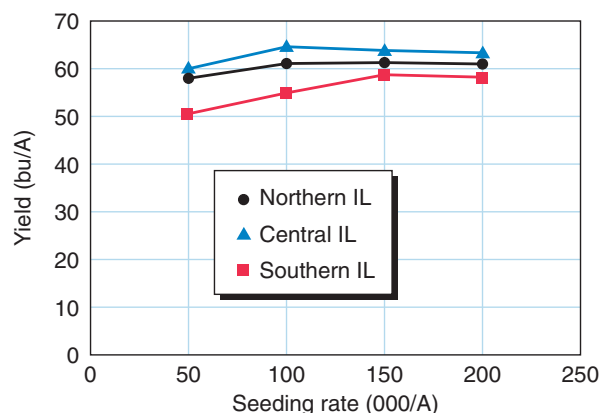
Research in Illinois and elsewhere has shown that soybean yields tend to reach a maximum at populations of about 100,000 plants per acre when the crop is planted at the normal time. In some cases, only 50,000 plants have produced yields as high as plant populations 2 to 4 times that high. This illustrates the capacity of an individual soybean plant to increase its size in response to having more room in which to grow. Most data also show a very wide “plateau” over which yields respond little if at all to increasing or decreasing population. In rare cases, plant population can be high enough to reduce yield, but this seldom occurs unless conditions are dry and having more plants causes faster loss of water.

Low soybean plant populations yield less mostly because of their inability to form a complete crop canopy and to

intercept all of the sunlight they need to produce higher yields. An insufficient plant population will thus limit yield to about the extent that plants fail to form a complete canopy of leaves. It is important to soybean yield that the canopy be more or less complete—that is, that nearly all of the sunlight is being intercepted—by the time pods begin to form, typically by sometime in the second half of July. A full canopy of healthy leaves on a well-watered crop enables photosynthetic rates to be near their maximum, which helps flowers to stay on the plant and to develop into productive pods. Thin stands also allow more weed competition to develop in the crop, and they encourage plants to branch and forms pod closer to the soil line, possibly adding to harvest losses.

**Figure 3.4** shows seeding-rate responses from a series of recent Illinois trials. These trials were done using small plots, and plant establishment, as a percentage of seed planted, was high. Variety maturities used were MG II, III, and IV for northern, central, and southern Illinois, respectively. These results show little response from planting more than 100,000 seeds in northern and central Illinois, but some response from 100,000 to 150,000 in southern Illinois. These trials were conducted in 30-inch rows; other research has shown no consistent effect of row spacing on plant population responses in soybean when planting is relatively early. The leveling off at seeding rates above 100,000 in most of these trials is consistent with data from other recent research in Illinois and in other states. Of the 16 trials included in the northern and central regions, only one showed a yield response above 100,000 seeds per acre, and two showed some yield loss as seeding rate increased. Of the seven southern sites, three produced higher yields at 150,000 than at 100,000 seeds.

Soybean seed prices have increased a great deal in recent years, in part due to the fact that most varieties have patented GM traits for which licensing fees are charged. Thus some consideration might be given to applying economics to seeding rates, with increases or decreases in rates depending on the ratio of seed price to the price of soybeans. Soybean seeds are still sold mostly by weight (in 50-lb units), but some are beginning to be sold by number, in the same way that corn seed is sold. If a 50-lb unit of seed has 140,000 seeds (2,800 seeds per pound, which is typical for soybean seed) and costs \$32, and the predicted price for soybeans at harvest is \$13 per bushel, then calculations using the data in **Figure 3.4** show that the seed just pays for itself (that is, is at its economically optimal rate) at a seeding rate of about 90,000 in northern and central Illinois and about 160,000 in southern Illinois. If the same seed costs \$50 per unit and the soybean price falls to \$8 per bushel, the optimum seeding rates drop to about 80,000 in northern and central Illinois and about 130,000



**Figure 3.4.** Seeding rate responses in Illinois trials, 2005 to 2007. Each region includes data from 7 to 9 trials. Rows were 30 inches apart. Trials were conducted by Ralph Esgar, University of Illinois.

in southern Illinois. While it helps to be aware of the fact that inputs such as seed should be used at rates that take into account costs and returns, it is also clear that having soybean plant populations too high for the conditions does not usually mean lower yield, just some seed cost that did not provide a return. On the other hand, having seeding rates too low, either purposefully or due to reduced emergence, costs both yield and profit. Thus it is unlikely that a seeding rate of only 80,000 should be used, despite the possibility that this will be enough in some cases.

### Seed Quality and Testing

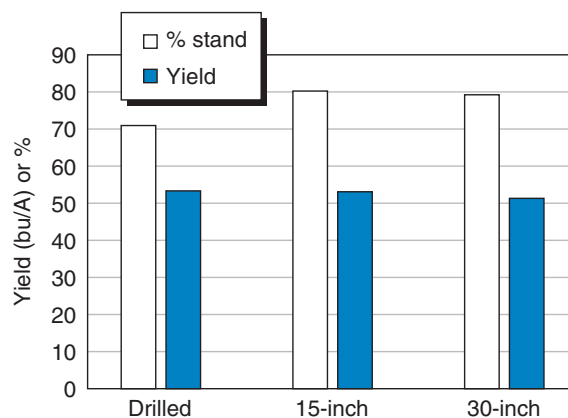
One important issue in choosing seeding rates is estimating how many of the seeds will germinate and emerge and how many of the emerged plants will survive to be productive. This number is affected by soil type, seed quality, type of planter used, and especially weather conditions after planting; it is not uncommon for good-quality soybean seed planted into good soil conditions to fail to produce adequate stands if heavy rain falls after planting and before emergence. Failure to produce a soybean stand is more common when planting is early, due to cooler soils and increased time to emergence. Planting too deep or just before heavy rain increases the chance of emergence problems due to soil crusting, and it can result in the death of seeds or seedlings due to lack of soil oxygen and increases in seedling diseases. It may also be useful to try to estimate how emergence might be affected by seed quality and planting conditions. The seed drop calculator at [iah.ipm.illinois.edu/seed\\_drop\\_calculator](http://iah.ipm.illinois.edu/seed_drop_calculator) can help with estimating and with calibrating planters.

In the research reported in **Figure 3.5**, drilling soybean seed in 7- or 8-inch rows produced stand counts of about 70% of the numbers of seeds planted, while planting with row units in either 15-inch or 30-inch rows produced about

80% stand establishment. The main reason for this is that drills tend not to place the seed at uniform depth in the soil and to firm soil around the seed as well as do row units. In soils that tend to form a crust, having seeds closer together in the row—as happens in wider rows—makes it possible for seeds to exert more force, per foot of row, to emerge through a crust. Seeds in narrow rows, which are typically planted 5 or 6 inches apart in the row, are too far from one another to “help” neighboring plants emerge.

Among agronomic crops, the seed of soybean is among the most difficult to produce and maintain with high quality. Germination percentages can be reduced by poor weather—especially wetting and drying several times—before harvest. And if the seed dries to below 10% moisture before harvest, even the most careful harvesting and handling can cause mechanical damage that reduces germination. Because of the potential for problems with quality, soybean seed is cleaned thoroughly to remove any seeds with unusual shapes, including splits (cotyledons that separate when the seedcoat breaks).

Soybean seed is tested to determine its emergence potential, and it often undergoes one or more “stress tests” that attempt to predict emergence under less-than-ideal conditions. The standard warm test, run on absorbent paper in the laboratory, is required on commercial seed containers; it estimates emergence under ideal conditions of moisture and temperature and of little disease. The “cold test” is the most common stress test; it is designed to see how well seed will germinate and emerge under cold, wet soil conditions. It includes the use of soil in an attempt to duplicate field conditions. Cold test scores vary some by laboratory, because soils and soil organisms differ among labs. Because of this, cold test scores need to be used with care; they are most helpful in comparing one lot of seed with



**Figure 3.5.** Effects of row spacing and planter on soybean yield and on percentage of seeds that produced plants, averaged over 7 Illinois sites. Data provided by Eric Adee, University of Illinois.

another tested in the same laboratory. Unlike warm tests, the results of cold tests need not be provided to the seed purchaser. Cold scores tend to be “worst-case” predictors; they are often considerably lower than warm scores and are usually lower than actual field emergence.

Another type of seed stress test is the accelerated aging test, in which seed is exposed to high temperatures and humidity before germination is tested. Such conditions are rarely encountered by seed before it is planted, but this test provides an estimate of seed vigor, which is the extent to which the seed has maintained intact its ability to germinate and produce a healthy seedling. Vigor is not exactly the same as germinability; over time, vigor typically starts to decline before germination percentage declines. A measure of vigor can thus be helpful in predicting whether good seed will remain good until it is planted.

### Seed Size

The fragility of soybean seed compared to the seed of many crops is due to its relatively large size; its growth inside pods with thin walls that do not protect it particularly well from weather, insects, and diseases; and the ease with which it can be mechanically damaged. It is also subject to quality problems if conditions are very warm and humid during maturation. Fortunately, soybean seed develops its ability to germinate relatively early in the seed-filling process—by the time it reaches half to two-thirds its final weight—meaning that the inherent quality of soybean seed does not appear to depend on the final size of the seed. Thus seeds that end up smaller than normal due to dry conditions or some other stress during seed filling are very often as capable of germinating and establishing plants as are larger seeds of the same variety.

This means that, especially when seed quality tests show no problem with the smaller seed, the use of small seed represents little if any risk. Small seed may even have some advantages: some small-seeded varieties used in parts of the world have excellent seed quality and storability; small seeds need to take up less water in order to germinate and so may germinate faster; and smaller soybean cotyledons may be able to move up through the soil during emergence more easily than larger ones would. In fact, with most soybean seed sold by weight (as 50-lb units) and with seeding rates recommended by number and not weight, smaller seed may mean lower seed costs than larger seed.

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## Inoculation

Soybean is a member of the legume family of plants, most of which have relatively high protein content in their

seeds and so need to take up a lot of nitrogen. Many of these plants have the ability to host bacteria in special structures, called nodules, on their roots. The plant forms nodules as a reaction to the infection of the root by these bacteria. Bacteria live in the nodules and are fed by sugars moving down from the leaves. In turn, the bacteria convert the nitrogen from air into forms usable by the plant. Active nodules have a pink color inside. Plants growing in soils with a lot of nitrogen from fertilizer usually do not have very many, or very active, nodules. So carryover N from a previous crop or N produced from soil organic matter can delay or reduce the fixation of N in nodules. On average, soybean plants take up about half of their N from the soil and the other half from N fixation. Somewhat surprisingly, even though N fixation requires energy from the plant and so would seem to detract from yield potential, using fertilizer to supply the N the crop needs very seldom increases soybean yield.

Scientists many years ago recognized that a legume such as soybean grown in a field where it did not grow before will form effective nodules only if some of the necessary bacteria are provided. Bacteria are formulated into an inoculant material, which is added to soybean seed or into the soil near the seed at planting. The type of bacteria needed to produce nodules persists for some years in the soil once a nodule crop is grown. For this reason, it is rare to get a response to inoculation if soybeans grew in the same field previously. Research with some of the newer inoculants, including some that use newer, better strains of bacteria, has shown no consistent yield increase in fields where soybeans have been grown recently in rotation.

If soybean grew in a field more than five years earlier, or if soybean never grew in that field before, then inoculation with a high-quality inoculum is recommended in Illinois. Failure of soybeans to form nodules will usually reduce yields substantially, unless soils contain unusually large amounts of N. In cases where soybeans are planted on land with no recent history of soybean—for example, on land coming out of CRP—but inoculation is not done, it might pay to add N fertilizer, up to 200 or 250 pounds of N, with more on soils with less organic matter. In some such cases, however, no N has been added and soybean plants still seem to get enough N, either from N released from organic matter and stored in the soil or from active nodules, presumably from bacteria that persisted for a long time in the soil. One strategy in such a case is to watch the crop for signs of N deficiency and of nodule formation and to apply fertilizer N only if deficiency symptoms (lightening of green leaf color) develop and nodules fail to form. If needed, N should be applied before flowering begins. Applying half then and the rest at the beginning of pod filling might help assure the supply of N at critical stages.

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## Planting Depth

Emergence will be more rapid and stands will be more uniform if soybeans are planted at uniform depths of 1-1/4 to 1-3/4 inches. Deeper planting often results in slower emergence and poor stands, because soils are often cooler with increasing depth and because deep planting provides more time for unfavorable weather events and soil crusting to take place before emergence. Though there have been few if any measurements of the effects of uneven emergence on soybean yield, it is clear that uniform emergence, which is often related to uniform planting depth and soil conditions at the seed, is a good goal.

Varieties differ some in their ability to emerge when planted deeper than normal, though such differences may be less than they were among older varieties. If the description of a variety mentions an “emergence score,” this score reflects the ability of the seedling hypocotyl to elongate to allow emergence when planting is deeper than recommended. This is a genetic trait, typically measured in sand, which may or may not be related to the vigor of the seed or its ability to emerge through soil crusts or under other poor conditions. So the main use of such scores may be to provide a warning not to plant too deep with some varieties (those with a high score, indicating low ability to emerge from depth). That’s a good goal with all soybean seed, so such scores may not be very useful.

One ongoing issue with soybean planting depth is whether seeds should be planted deeper than normal to reach moister soil in order to germinate under dry conditions. The alternatives are to plant at normal depth, letting the seed wait until it rains to germinate, or to wait to plant until after it rains. There is not a clear answer to this dilemma, and every choice has drawbacks. In light soils such as sandy loams, planting to a depth of 2-1/2 or 3 inches to reach moisture might be a good strategy, since rainfall after planting on such soils poses little problem for emergence. In heavier soils, rainfall after planting will often mean failure of emergence, unless the rainfall amount and intensity are modest. Waiting to plant until after it rains can result in considerable delays in planting and emergence. One approach to this problem is to prevent it, by using less soil-drying tillage before planting and by planting faster so that soils don’t dry out before planting.

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## Row Width

Recent survey data show that about 60% of soybean acres in Illinois are planted in 15-inch rows, with the rest split more or less equally between drilled (less than 10-inch) and 30-inch rows, and a few percent in rows wider than 30

inches. The increase in 15-inch rows has been rapid, rising from less than 20% of the acres in the late 1990s. Most of this increase has been at the expense of drilled soybeans, which occupied more than 50% of the acres in the mid-1990s. This rapid change followed the introduction of split-row planters, with 30-inch rows used for corn and row-splitting units to make 15-inch soybean rows. Wider planters (40 to 60 feet wide) help speed up soybean planting, and the use of row units often provides better seed metering and placement than can be achieved with drills.

Much research has been done on row width in soybean, with most studies showing that soybean yields increase when row width is decreased to less than 30 inches. Many such trials have shown that this yield increase tends to level off as rows reach 20 inches or less, though some, especially in environments where water limits yields, showed maximum yields at row spacings of 10 inches or less. **Figure 3.5** gives the results from a set of trials conducted in Illinois. In this study, drilled and 15-inch rows yielded the same, while 30-inch rows yielded about 2 bushels per acre, or about 4%, less. That study included different seeding rates, but there was no effect of seeding rate on yield, nor did seeding rate interact with row spacing to suggest that changing the row spacing calls for changing the seeding rate.

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 predict whether narrower rows will increase yield, follow this rule of thumb: If a full canopy of leaves is not developed by the time pod development begins in wide rows, then narrower row spacings may well produce higher yields. This helps explain why later-maturing varieties, which nearly always grow taller with more leaf area, usually respond less to narrow rows. It also helps to explain why narrow rows usually increase yield relatively more under dry conditions or late planting, both of which reduce plant growth.

Some seed companies describe the “growth habit” of their soybean varieties with regard to how wide the canopy spreads out when the plants grow in the row. While there are indications that some soybean varieties have longer petioles connecting leaves to stems and hence wider canopies, there is no solid evidence that this trait changes the way that a variety should be managed. Thus we see little or no reason why some “thin-line” varieties should always be in narrow rows while some “bush-type” varieties are better suited to wider rows. The main reason early-planted soybean plants fail to form complete canopies is most often related to dry weather that causes reduced growth of stems, leaves, and petioles, not to differences in growth habit.

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## Double-Cropping Considerations

Double-cropped soybeans, planted following harvest of winter wheat in mid- to late June, can be successfully produced most years in southern parts of Illinois, and sometimes in central Illinois as well, though the percentage of time we can expect good yields drops when moving north from Interstate 70. This practice is more successful in southern Illinois both because wheat harvest and soybean planting are earlier there and because warmer weather in the fall, with later frost dates, means that the crop matures more often there.

Development of soybean plants that are planted so late is typically shortened, due to the early onset and completion of the flowering process in relation to vegetative stages; to dry weather after emergence that often limits growth; and because high temperatures, especially at night, speed development. This effect is often greater when the soybean seeds are planted into dry soil and need to wait for rain to bring them up. The ripening wheat crop extracts water from the upper soil and may leave it very dry at the time of wheat harvest and soybean planting. An exceptionally early frost in the fall can damage the crop, which typically needs all of an average growing season to reach maturity. Yield potential of double-cropped soybeans is typically 40% to 60% of that obtained with full-season soybean planted in May, but double-cropped soybean yields vary widely.

Based on the fact that late planting makes the available growing season so short, many believe that using shorter-maturity varieties makes sense. That is not the case: If a variety that is early for a location is planted very late, vegetative development prior to flowering is extremely limited, and plants will often end up very short, with incomplete canopies and low node and pod numbers even in narrow rows. Instead, the best varieties for double-cropping yields are those that are classified as midseason to full-season for the area. If wheat harvest is early and planting can be done by June 15 to 20, then use varieties at least as late as those planted at the normal time. If planting is delayed into July or is into dry soil so the crop won't come up quickly, it might be slightly less risky, from the standpoint of avoiding frost at the end of the season, to plant a variety that is about half a maturity group shorter (say MG 4.0 instead of 4.5).

Despite sound management of double-cropped soybeans, it is quite common for the weather to turn dry after the crop has started to grow and for yields to be low. In some cases yields are too low to even pay to harvest the crop. The use of glyphosate-resistant varieties, while adding expense for seed, has greatly improved the flexibility of

the double-cropping system, by delaying expenditures for weed control until it's clear whether there is good potential for yield. When wheat yields are good and the soybean receives enough water to do well, double-cropping can be very profitable.

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## Replanting Soybean

Though we recognize the potential loss in yield when soybean stands are incomplete due to poor emergence or to injury after emergence, replanting guidelines are somewhat difficult to develop and to put into practice. In many cases, due to the fragility of soybean seed, emerged stands are so poor that the decision to replant is an easy one. The fact that the yield losses with planting delays are more gradual in soybean than in corn also makes it easier to decide to replant soybeans that have poor stands. For example, many people would replant without much questioning a field with half a stand if this could be done by the end of May or even early June, knowing both that the reduced stand probably would not have produced full yields and that the date of replanting is not so late that it will result in large yield losses. One advantage to having soybean planting typically later than corn planting, and into warmer soil, is that stand problems appear more quickly and can be dealt with quickly. Still, replanting costs time and money, and it should be done only if the need for it is clear.

The answer to when an original stand should be replanted is often obvious—for example, when heavy rainfall or standing water reduces stands to zero in parts of fields or to very low levels in entire fields. Where there are no plants left in low-lying areas but the rest of the field has adequate stands, only the damaged areas need be replanted. Where stands vary across the field from low to high, then “repair planting” can be done in the more damaged areas. Wide planters now in common use make it necessary to plant wide strips in order to fix small problem areas, so some “repair” plantings turn into replanting most or all of a field.

Soybean stand reduction is often related to non-uniform field conditions, including topography and soil type differences. But some fields have stands uniformly reduced over the entire field. Seed of marginal quality, planting using the wrong planter settings, and planting too deep or too shallow might cause this in some cases. Such stands require counting in various spots to get a good average and then to decide whether replanting will pay. The response curves shown in **Figure 3.6** can give some guidance on whether to replant a uniformly reduced stand. Stand reductions in this study were made by removing randomly

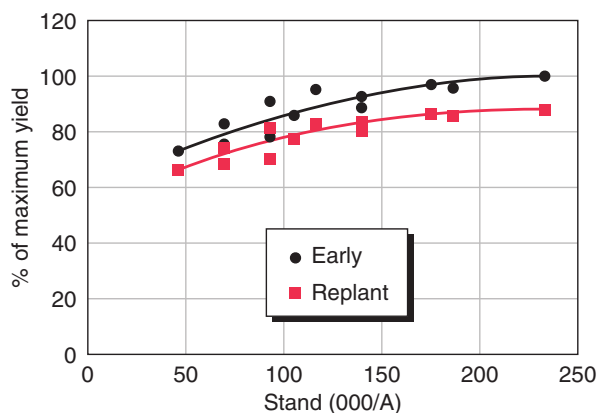


chosen 1-foot segments of row, resulting in some gaps in the row. The highest yield produced by replanted soybeans (the bottom curve) was about 88% of that produced by full stands planted early. This yield was equivalent to the yield produced by about half of the original stand. If the original stand was very uneven, with a lot of longer gaps, then it took more of the original stand to justify keeping it and not replanting. As a general rule of thumb, gaps of 16 inches or less in 30-inch rows have minimal effect on yield, as long as the overall stand is adequate.

Even when it's clear that a soybean stand should be replanted, there can be questions about how the replanting should be done. In particular, should the original stand be destroyed using herbicide or tillage before replanting, or should the drill or planter be used to "repair plant" without destroying the initial stand? Should replanting be done in narrow rows if the original planting was in wider rows?

**Table 3.1** gives the results of a study done at two Illinois locations over three years (2003–2005). Planting dates were early May for the initial planting and 3 to 4 weeks later for the replanting treatments. Original stands were established as either drilled or 30-inch rows, with both full stands and deficient stands produced by different seeding rates. Low initial stands were left or were replanted using either a drill or 30-inch rows without tilling to destroy the original stand, or with a drill after tilling the original stand.

Results show that replanting low initial stands of 50,000 or less per acre was justified, especially when the low stand was in 30-inch rows. As expected, full, early-planted stands produced the highest yield, and about 3 bushels per acre more than 30-inch rows. But how the replanting was done—using the drill or row planter, and with or without tilling the initial stand—made no difference in the final yield. Note that replanting 30-inch row soybeans produced about the same yield as the full, initial stand produced



**Figure 3.6.** Response of early-planted and replanted soybeans to plant stand. Data from Gary Pepper, University of Illinois.

**Table 3.1.** Effect of replanting method on soybean stands and yields.

Original planting	Original stand	Replanted? (tillage/row spacing)	Final stand (000/A)	Yield (bu/A)
Drilled	High	Not replanted	171	58
Drilled	Low	Not replanted	54	50
30-in. rows	High	Not replanted	157	55
30-in. rows	Low	Not replanted	37	45
Drilled	Low	NT/drilled	163	54
Drilled	Low	NT/30-in. rows	161	53
30-in. rows	Low	NT/drilled	161	53
30-in. rows	Low	NT/30-in. rows	153	53
Drilled	Low	Tilled/drilled	183	54

Data are averaged over 3 years and two locations (Perry and DeKalb) and were generated by Mike Vose and Lyle Paul.

in 30-inch rows, meaning that the benefit of narrow rows nearly cancelled out the advantage of earlier planting.

## Specialty Types of Soybeans

There are several categories of specialty soybeans. Concerns over claims of health and environmental effects of genetically modified (GMO) varieties have translated into market demands in a number of countries and locales for non-GMO soybeans, mostly for processing into food. Other than requiring careful separation from soybeans carrying the gene for glyphosate resistance (e.g., Roundup Ready varieties) and some possible challenges in managing weeds without using glyphosate, many producers have the opportunity to help meet this demand. There are tests available that are often conducted at non-GMO soybean buying points to detect the presence of the glyphosate resistance gene, and loads with amounts above the limit (often 1%) of GMO presence are often prevented from entering the non-GMO market.

One concern is that the seed industry has concentrated its breeding efforts so much on GMO soybean that performance of non-GMO soybeans may not be keeping pace. Results available at the University of Illinois variety trial website ([vt.cropsci.uiuc.edu/soybean.html](http://vt.cropsci.uiuc.edu/soybean.html)) show that the number of conventional (non-GMO) varieties entered into the trials is much lower than the number of GMO entries and that, on average, non-GMO varieties have tended to yield less than the GMO varieties, especially in recent years. As with corn, seed companies have incentives to market GM varieties, and this may be showing up as lower performance of commercial non-GMO varieties.

There are a number of other different types of specialty soybeans produced to meet the needs of different markets. Tofu-type (clear hilum) soybeans are used for tofu production, with the colorless hilum desirable because small pieces of the seedcoat that might remain in the light-colored tofu product are not visible. Natto-type soybeans have very small seeds and are used in a fermented soybean food popular in some Asian countries, and in some cases for bean sprouts. High-oleic, low-linolenic, and low-saturated-fat soybeans are grown to produce edible oil considered to be better for health. More recently, trans fats, which are not found naturally but are produced when vegetable oil is hydrogenated to change its physical properties (for example, to produce margarine), have been identified as a serious threat to health, and their use is being banned in some places. Because saturated fats cannot be hydrogenated and so cannot form trans fats, there has also been some interest in high-saturated-fat soybean varieties. High-sucrose soybeans offer improved flavor and digestibility in foods such as soy milk, cheese, and meat analogs. Organic soybeans are in demand by consumers concerned about chemical inputs commonly used in soybean production.

### High-Yield Soybeans

In 2007, Kip Cullers, a farmer in southwestern Missouri, produced soybeans that yielded more than 150 bushels per acre. This followed his yields of more than 130 bushels per acre in 2006, the first year he produced soybeans. These yields are much higher than any yields previously reported, and they are higher than many scientists believed to be likely from a physiological standpoint. Cullers's production practices include the use of poultry litter applied to the soil the previous fall, narrow or twin-row planting at populations above 250,000 seeds per acre, irrigation,

nitrogen, micronutrient mixtures, plant growth hormones, and fungicide. The soil is well weathered but has good internal drainage and fair water-holding capacity.

A number of farmers and scientists have started work designed to duplicate conditions that produced such high yields. A study that we initiated at Urbana in 2008 produced the results given in **Table 3.2**. This was a relatively wet growing season, but August was dry, with only about an inch of rain. Irrigation increased yield by about 10%. Nitrogen fertilizer (90 lb N split into two applications) and foliar fungicide (applied twice) produced modest yield increases in irrigated soybeans, but micronutrients had no effect, and combining treatments did not give further yield increases. A similar study at Dixon Springs showed no response to irrigation or to any of a set of treatments similar to those used at Urbana. These are results from only one year, and this work will continue. But it clearly will not be easy to move yields up quickly through changes in management.

**Table 3.2.** Results from a “high-yield” trial with irrigation, nitrogen, fungicide, and micronutrients at Urbana, 2008.

Treatment	Irrigated (bu/ac)	Not irrigated (bu/ac)
Untreated	63	59
Nitrogen	71	59
Fungicide	68	59
Micronutrients	62	58
Nitrogen + fungicide	68	60
Nitrogen + fungicide + micronutrients	67	61
Average	66	59