Soybean

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Illinois is one of the largest soybean producers in the United States, with between 8.9 and 10.8 million acres a year over the past decade. Average yields in Illinois have increased by approximately 0.7 bushels per acre per year between 1990 and 2024, or about 61% (**Figure 3.1**). Soybean production in Illinois in 2024 was estimated at 688 million bushels, with an average yield of 64 bushels per acre. Soybean yields have been rising steadily over the past two decades, primarily due to improved genetics, with contributions also from improved plant protection and crop management. This chapter will address soybean management, growth and development, and considerations for variety selection and management to maintain or increase yields.

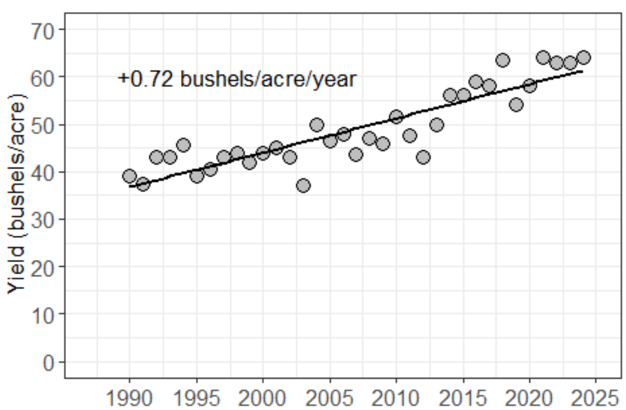

Figure 3.1. Average soybean yield in Illinois from 1990 through 2024. The trend line is shown in black, with the average per-year yield change.

Soybean Plant Development

Understanding how the soybean plant grows and identifying key growth stages that affect yield potential can help producers refine their management practices to achieve better yields. An overview of soybean growth, development, and management requirements for good yields can be found in *Soybean Growth and Development* (PM 1945, Iowa State University Extension) and *The Soybean Growth Cycle: Important Risks, Management, and Misconceptions* (Science for Success, a multi-state collaboration by Land-Grant University Extension Agronomists and sponsored by the United Soybean Board).

Soybean development is divided into vegetative and reproductive stages. Counting trifoliolate (three-leaflet) leaves on the main stem is the most common method for tracking soybean vegetative development. This method uses a V*n* system for vegetative growth stages, where *n* is the number of open trifoliate leaves. **Figure 3.2** shows a V7 (left) and a V6 (right) soybean plant with 7 and 6 opened trifoliate leaves on the main stem, respectively. A leaf is considered open when individual leaflets are unrolled, and their edges no longer touch. Under typical growing conditions, soybeans planted in early May reach the V7 or V8 stage by early July, and soon after that, the first flowers appear on the main stem of the plants. The plant continues to add stem nodes (where leaves are attached) and leaves through July, usually ending up with 18 to 20 nodes. This growth pattern is called *indeterminate*, meaning that the plants continue to produce vegetative growth as reproductive growth gets underway, with nodes having both leaves and flowers.

Figure 3.2. Soybean plants at the V7 (left) and V6 (right) growth stages. Note that in the first plant, the eighth and ninth trifoliolate leaves are present but not fully opened, and thus the plant is at the V7 stage with seven opened trifoliolate leaves in the main stem.

The transition to reproductive growth begins at the R1 stage, when the first flowers appear on the main stem **(Figure 3.3)**. Flowering usually begins between the third and the sixth node and progresses up and down the plant. Unlike corn plants, which initiate flowering based on accumulated heat units (measured in growing degree days), soybeans are photoperiod-sensitive, with flowering triggered by day length. Temperature is also critical for soybean development, including when flowering begins. Photoperiod works like this: soybean plants have a mechanism that converts a specific substance from the inactive to the active form in the dark. Light makes it revert to the inactive form. Night length increases as days shorten after the summer solstice; once nights are long enough to allow enough active form to accumulate, the plant starts the flowering process. Warm nights accelerate this process, while cool nights slow it down. Artificial light at night, such as streetlamps, can disrupt this signal, delaying flowering and maturity in affected areas **(Figure 3.4)**.

Figure 3.3. Soybean plants at the R1 growth stage, beginning flowering, with one open flower anywhere on the main stem.

Figure 3.4. A field of soybean plants showing uneven maturity near streetlights, with brown, senescing plants on the left and greener, less mature plants on the right, illustrating interrupted flowering caused by nighttime light exposure. The plants on the left were harvested soon after the photo. The plants on the right eventually ripened and lost their leaves.

For soybean varieties adapted to central Illinois, nights are long enough by about July 10 to allow flowering to start under average (night) temperatures. Other weather conditions can influence the duration of growth stages. For instance, drought stress typically extends vegetative growth stages, whereas warm nights under adequate soil water and nutrients shorten them. Early-maturing varieties do not need as long nights as late-maturing varieties, so they start to flower earlier. Moving a variety farther north shortens the night (days are longer in midsummer), so it delays the start of flowering.

Once flowering starts, track the chronological development of flowers, pods, and seeds as follows: beginning flowering (R1), full flowering (R2), beginning pod (R3), full pod (R4), beginning seed (R5), full seed (R6), beginning maturity (R7), and full maturity (R8). One advantage of soybeans is that the flowering and seed-filling stages take several weeks to complete, giving them more time to recover from stresses such as dry soil. This occurred in the 2022 and 2024 growing seasons, when dry weather restricted plant growth through late June and early July. The timely rainfall in late July and August resulted in plants with a good canopy with a dark green color during the seed-filling period and good yields. Soybeans are sometimes described as *drought-avoidant* to recognize this ability — linked to their indeterminate growth habit — to recover from periods of dryness.

Many reproductive stages are also influenced by day length: soybean plants can adjust their cycles to the growing season. For example, soybean plant development speeds up as days shorten in late summer. A study in Wisconsin showed that the period between the R1 and R6 stages dropped from 60 days when planting was on May 1 to only 45 days when planting was on June 1. Early-maturing varieties also develop faster, which means they may have a shorter window for recovery from drought stress. In 2023, rainfall during the second week of August relieved dry conditions at Urbana, and in the University of Illinois Variety Trial there, the early-maturing varieties averaged 7 bushels per acre less than the later-maturing varieties.

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 more leaf area than corn plants. The leaf area index (acres of leaves per acre of crop) is often as high as 6 or 7 in soybean compared to 4 to 5 in a good corn crop. With their ability to *flex* to fill in space between neighboring plants, soybean plants with low populations can expand their leaf area, making them less sensitive to lower plant populations than corn. Producing more leaf area also takes energy, and since not all leaf area is needed to achieve maximum yields, it can reduce plant efficiency.

At the same time, leaves are where soybean plants store nitrogen, and shaded leaves typically translocate that nitrogen to the active leaves, helping the plant fill seeds. In years with a lot of rainfall in June and July, though, large leaves and extended stems can result in internal shading that can reduce pod filling in the lower crop canopy, which can lead to lower yields. Seeds in a pod are typically 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 maturity groups (MG) based on their adaptation to day length and temperature. These groups range from MG 000 for short-season environments in northern latitudes to MG 9 for tropical regions. These are sometimes expressed as Roman numerals. The general rule is that a difference of one maturity group represents about a ten-day difference in maturity. It is common practice to add decimal numbers to denote gradations within a maturity group (e.g., MG 2.8 or 3.5), with each decimal representing about one day. Soybean breeders assign the MG numbers, and many names of commercial varieties incorporate the MG number (and often a decimal) — for example, Brand ABC34X would denote a MG 3.4.

Most acres in Illinois are planted with varieties from MG 2, 3, and 4 (from north to south). Early MG 2 varieties can be grown in northernmost Illinois, while early to mid-MG 4 varieties are best adapted in the southernmost region of the state. Growing soybeans that effectively use the entire growing season is beneficial to yield, as long as growing conditions are good throughout the season. However, very late-maturing varieties may not always yield as well as varieties that are a few decimal points earlier in maturity, even if they can complete seed fill before frost.

Long-term data from the University of Illinois Variety Testing Program illustrate these trends. Over 15 years (2009-2023), trials in northern, central, and southern Illinois showed that mid-maturity varieties consistently produced the highest yields (**Figure 3.5)**. On average, maximum yields occurred near MG 2.8 in northern Illinois, MG 3.6 in central Illinois, and MG 3.9 in southern Illinois. Most importantly, varieties within about 0.5 MG of the maximum typically yielded within one bushel per acre of the top variety. This means growers can select varieties slightly earlier or later than the optimum to allow fields to reach maturity over a week or two, helping spread harvest time without much impact on grain yield.

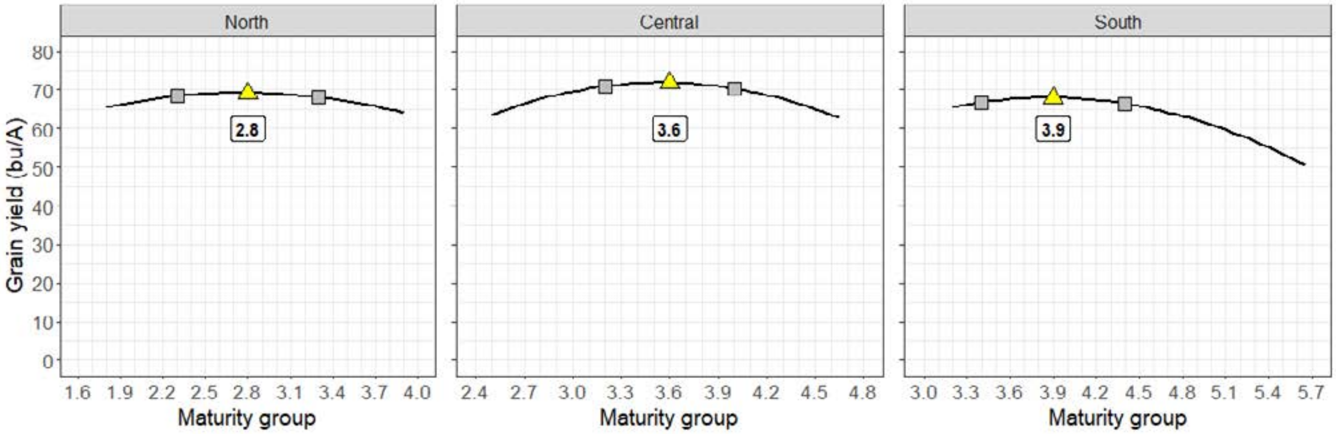

Figure 3.5. Soybean yield response to maturity group (MG) in the University of Illinois Variety Testing trials in northern, central, and southern Illinois over 15 years (2009-2023). The yellow triangle in each line indicates the maximum yield for each region (MG 2.8 for northern, MG 3.6 for central, and MG 3.9 for southern Illinois). Gray squares indicate the ends of the range over which yields are within 1 bushel per acre of the maximum.

When selecting varieties, yield and yield stability across multiple locations and years should be the primary considerations. Herbicide-tolerance traits are also critical, especially where herbicide-resistant weeds have hindered production. Many trait packages on the market for herbicide tolerance can be used alone or in combination for better weed control. Disease resistance is another key factor; while complete resistance is rare for some diseases, choosing varieties with strong ratings for prevalent pathogens on a farm can reduce risk. Seed companies can provide information on how their varieties respond to diseases.

Hundreds of soybean varieties – nearly all privately developed – are sold by seed companies, and choosing the best ones can be challenging. To ensure producers have access to unbiased soybean yield information, the University of Illinois Variety Testing Program conducts annual crop performance tests, including yields and average yields from the previous 2 to 3 years, as well as protein and oil concentrations. Trial results are published soon after harvest and are available at vt.cropsci.illinois.edu. The number of entries in these trials has decreased over time, and producers today need to get additional performance information from company sources. Still, seed companies are highly competitive, so less productive varieties are often not produced or sold.

Planting Date

Planting date is one of the most influential management decisions for soybean yield. Early planting allows plants to produce more nodes on the main stem and to close the canopy sooner, increasing light interception and helping suppress weeds. In recent years, however, many have been discussing whether soybeans should be planted before corn, sometimes as early as March if possible. The reasoning behind this is the assumption that soybeans must set their first flowers by the summer solstice (the longest day of the year, about June 20) to maximize yield potential by lengthening the reproductive period. Because of the flowering mechanism described above, later planting often does not delay flowering as much in soybeans as it might in corn; the general rule is that soybeans need about 6 weeks of warm weather to reach a size that supports best yields by the time flowering occurs. Certain weather patterns, such as dry weather followed by timely rains, can break this *rule*, but it is a reasonable goal.

Figure 3.6 summarizes the results of 37 planting date trials conducted in recent years in central and northern Illinois. Target planting dates ranged from early April to mid-June; each trial included four planting dates. Planting between April 10 and April 30 nearly maximized yields – 99% of the maximum yield. Yields declined slowly with planting delays during the first half of May, reaching about 95% of the maximum yield by May 15. Yield loss accelerated after that, dropping to 88% of the maximum by May 31, 79% by June 15, and 76% by June 20. Of the 37 trials, three had the first planting before April 10, but yields were no higher when planting occurred between April 10 and the end of April, indicating that the early planting advantage was generally maximized if planting was done by the end of April. The data show greater variability with planting in late May and June because conditions later in the season can either exacerbate or mitigate potential problems from late planting.

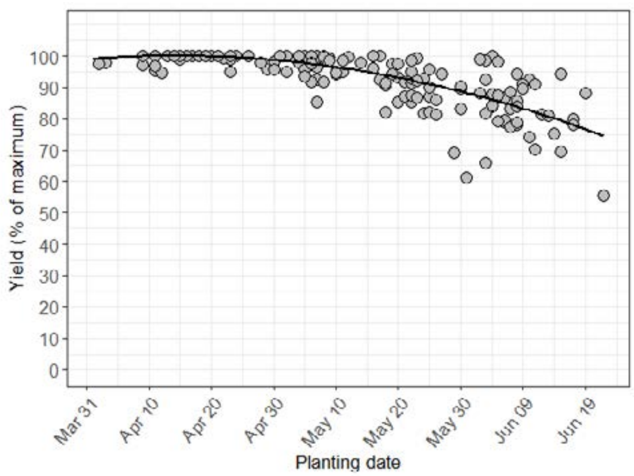

Figure 3.6. Response of soybean yield to planting date across 37 trials in Illinois between 2010 and 2024. Yields are a percentage of the maximum yield at each site. The average maximum yield was 70 bushels per acre, so each percent change in yield is 0.7 bushels per acre.

Planting into June often results in shorter soybean plants with considerably fewer nodes and with lower yield potential. It is possible to offset some such changes in plant morphology by planting late-seeded soybeans in narrow rows at a seeding rate higher than that used for early planting. Double-crop soybeans, which are planted after wheat harvest and therefore always planted late, often benefit from narrow rows and moderately higher seeding rates. If, for any reason, soybean planting extends into July, a producer may want to choose a variety earlier by 0.5 to 1.0 MG to lower the risk of frost damage in the fall. This may lower yield potential, which may or may not offset the benefit of earlier maturity.

Seeding Rate

Soybeans have a remarkable ability to compensate for differences in plant population by producing additional branches, nodes, and pods when space and resources allow. This flexibility means that soybean yield often changes very little across a wide range of plant stands. Research in Illinois and other Midwestern states has shown that maximum yield is typically achieved when the harvested stand is around 100,000 plants per acre under normal planting conditions. In some cases, yields have been similar with stands as low as 50,000 plants per acre, although such low populations increase the risk of incomplete canopy closure and weed competition.

The main reason low stands reduce yield is that they fail to form a full canopy by the time pods begin to develop, usually in late July. A complete canopy intercepts nearly all available sunlight, maximizing photosynthesis and supporting pod retention and seed filling. Thin stands allow more light to reach the soil surface, encouraging weed growth and causing plants to branch excessively, which can lead to pods forming close to the ground and increasing harvest losses.

There has been a great deal of debate about soybean seeding rates in recent years, with some reports of high yields from relatively low seeding rates and even recommendations to plant fewer than 100,000 seeds per acre. Higher soybean seed quality and improved seed treatments have improved emergence in recent years, but stands can still be reduced by poor conditions after planting, especially wet soils. Soybeans germinate more quickly in warm soils, which can worsen emergence problems under wet conditions because oxygen depletion occurs faster, and seeds die more quickly. As a starting point, 85% of planted seed might be expected to establish; this percentage should be adjusted downward (and the seeding rate increased) if planting into poor conditions or if germination tests indicate less than 90%.

Recent studies in Illinois illustrate the economic implications of seeding rate decisions. In 25 trials conducted between 2015 and 2018, seeding rates ranged from 50,000 to 200,000 seeds per acre (in 50,000 increments), and actual stands averaged 86-92% of planted seeds (**Figure 3.7A**). Yield responses were highly variable: the two highest yields in the study came at 70,000 plants per acre (93 bushels per acre) at one site in 2015 and 200,000 plants per acre (92 bushels per acre) at another site in 2018. The data also showed that the optimum plant stand was not correlated with yield level (field productivity), which ranged from 54 to 90 bushels per acre; indicating that sites with the highest yields did not necessarily required the highest stands (**Figure 3.7B**).

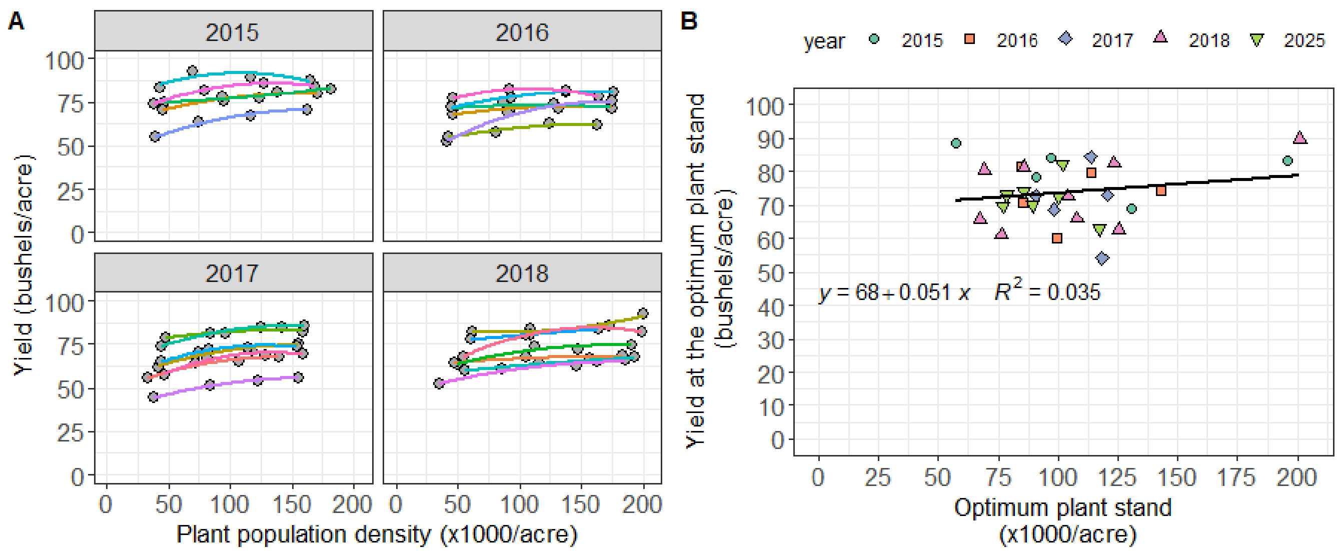

Figure 3.7. Panel A shows soybean yield response to plant stands in 25 trials in Illinois between 2015 and 2018. Seeding rates were 50, 100, 150, and 200 thousand seeds per acre. Panel B shows the relationship between the optimum plant stand and yield at that stand from field trials across Illinois.

To translate these results into practical recommendations, researchers turned yield response curves into economic response curves by calculating the return to seed, which accounts for seed cost and soybean price. **Table 3.1** provides estimated economic optimum plant population densities for a range of soybean prices and seed costs, based on the average of the response curves across Illinois field trials. For example, at a seed bag cost of $90 per 140,00 units and a soybean price of $11 per bushel, the economic optimum plant density is about 110,100 plants per acre. To calculate seeding rates from these values, divide by the expected percent establishment. For instance, 110,100 plants per acre divided by 85% emergence equals about 129,500 seeds per acre. Many companies sell 140,000 soybean seeds as a unit, and in this case, planting a unit or slightly less than a unit per acre should produce enough plants to maximize return to seed.

Table 3.1. Economic optimum plant population density (x1000/acre) for combinations of market soybean price per bushel and seed bag cost per 140,000 seed unit.

Seed cost per 140k unit	$9.00 per bushel	$10.00 per bushel	$11.00 per bushel	$12.00 per bushel	$13.00 per bushel	$14.00 per bushel
$50	122,100	124,600	126,600	128,400	129,800	131,100
$60	117,000	120,000	122,500	124,600	126,300	127,800
$70	111,900	115,500	118,100	120,800	122,800	124,600
$80	106,900	110,900	114,200	117,000	119,300	121,300
$90	101,800	106,400	110,100	113,200	115,800	118,100
$100	96,800	101,800	106,000	109,400	112,300	114,800

Note: To calculate seeding rates from the values in this table, divide by the expected percent establishment. For example, 110,000 plants per acre divided by 85% emergence equals 129,412 seeds per acre.

Modern planters allow variable-rate seeding within fields, and many producers wonder if adjusting rates by soil type or topography could improve return on investment. However, **Figure 3.7B** shows that yield responses are relatively flat across a wide range of stands. In other words, it makes little difference in most fields whether there are 100,000 or 150,000 plants per acre, and without a clear basis for deciding where to put more seed and where to put less, there is likely to be little benefit from varying seeding rates within a field. The most important goal is to ensure adequate stands across the entire field. If a producer chooses to vary seeding rates, it should be done sensibly. For example, dropping more seeds in low-lying areas where water sometimes stands may seem reasonable, but water that stands long enough to kill soybean plants leaves few or no survivors. In such cases, extra seed simply means more dead plants, and when there is no standing water, the additional plants will not boost yield.

Plant spacing uniformity is a topic of some debate in soybean production. With their capacity to produce more stem and leaf tissue to fill the available space, and with soybean seeds averaging less than 2 inches apart in 30-inch rows and less than 4 inches apart in 15-inch rows, it seems unlikely that increasing seed-to-seed spacing uniformity would have much effect. There may be a small advantage to *singulating* seeds so they are not in groups of two or three down the row, but researchers are not aware of any research documenting a yield advantage.

Seed Quality and Testing

Soybean's large seed size (for a legume), high protein and oil content, and the fact that soybean emergence requires the seedling to pull the cotyledons out of the soil and into the sunlight makes emergence more challenging in soybean than in corn. These characteristics make soybeans more sensitive to adverse conditions during germination and emergence. Even high-quality seed planted in good seedbeds can fail if heavy rain falls after planting and before emergence, causing soil crusting or oxygen depletion. Planting too deep or just before heavy rains increases the risk of seed or seedling death due to lack of oxygen and, in some cases, seedling disease.

Seed quality is commonly assessed using germination and seed vigor tests. The standard warm germination test, required by law and reported on seed tags, measures the percentage of normal seedlings that develop within 7 to 10 days under ideal moisture and temperature conditions (usually in a growth chamber). This test provides a baseline for potential performance under favorable conditions. The cold germination test, or cold test, evaluates seed performance under cold, wet conditions by using soil to simulate field environments. Cold test scores can vary among laboratories due to differences in procedures and soil types, so they are most useful for comparing seed lots tested in the same lab. Soybean seeds with high warm germination but lower cold germination can still perform well, but they will emerge better after soils warm up than in cold soils.

Another measure of seed vigor test is the accelerated aging test, which exposes seeds to high temperature and humidity for three days before germination under ideal conditions. This test estimates physiological soundness and is often used to predict how well seeds will withstand stress during storage or during planting. As with the cold test, accelerated aging may underestimate emergence under favorable field conditions.

Inoculation

Soybeans have high seed protein content, which requires a substantial amount of nitrogen (N), – about 4.5 pounds per bushel, of which about 3.5 pounds is harvested with the grain. Like other legumes, soybeans meet much of this demand through a symbiotic relationship with N-fixing bacteria. These bacteria, primarily *Bradyrhizobium japonicum*, infect soybean roots and form nodules where they convert atmospheric nitrogen into forms the plant can use. The plant supplies sugars to the bacteria, and in return, the bacteria provide nitrogen. This process is called biological nitrogen fixation, or BNF. Active nodules have a pink interior, indicating the presence of leghemoglobin, which facilitates oxygen transport for nitrogen fixation.

On average, 40 to 50 percent of the nitrogen needed by a soybean crop comes from the soil, and the remaining 50 to 60 percent is supplied by biological nitrogen fixation. While taking up soil nitrogen requires less energy than fixing nitrogen, applying large amounts of nitrogen fertilizer to soybeans rarely increases yield on productive soils. Research in Illinois and other states consistently shows that nitrogen fertilizer seldom pays for itself in soybean production, even when applied at high rates. This is because soybeans adjust nodulation and nitrogen fixation in response to soil nitrogen availability — high soil N reduces nodule formation and activity.

Inoculants containing *Bradyrhizobium japonicum* are most used in Illinois. There are several inoculants available on the market, which nowadays are nearly all formulated for application to seeds during seed treatment. In most Illinois fields, using seed inoculants often results in little or no yield increase. This is because the bacteria persist in the soil for several years after a well-nodulated crop is grown. However, inoculation with a high-quality inoculum is recommended for new soybean fields, fields out of soybean production for five years or more, or fields with a history of poor nodulation. Failure of soybeans to form nodules, while very rare in Illinois, will usually substantially reduce yields unless soils contain unusually high levels of nitrogen.

Seed Treatment

Most seed companies offer fungicide and insecticide seed treatment packages designed to protect emerging seedlings. These seed treatments are most beneficial under conditions that slow germination and increase disease or insect pressure, such as planting early into cold, wet soils, no-till fields, or fields with a history of stand establishment problems. By reducing seedling stress and protecting against pathogens and early-season insects, treated seed can help maintain uniform stands and reduce the risk of replanting.

Biological seed treatment is a growing market in the U.S., with numerous products available to growers. Although the terms *biologicals* or *biostimulants* are used to refer to a wide range of products, most are single or mixed living microbes, such as bacteria and fungi, marketed to increase grain yield and provide a positive return on investment. These products are often classified into N-fixing bacteria, phosphorus-solubilizing microbes, and arbuscular mycorrhizal fungi. Free-living N-fixing bacteria (those in the soil near the roots, not in nodules) can provide N to crops, although soybeans may not need such a boost. As the name suggests, these are heterotrophic bacteria living on or near the roots that convert atmospheric N (N_2) into ammonia (NH_3) via the enzyme nitrogenase. *Azospirillum brasiliense, Azotobacter binelandii,* and *Klebsiella variicola* are commonly found in products. Phosphorus-solubilizing microorganisms such as *Aspergillus, Penicillium, Bacillus,* and *Pseudomonas* can increase plant-available phosphorus. Arbuscular mycorrhizal fungi have a symbiotic association with crops, where the fungi's hyphae extension provides greater soil contact for the root, thereby increasing access to water and nutrients. Other categories of biostimulants include humic substances, amino acids and other N compounds, chitosans, and plant and algae extracts.

Table 3.2 shows soybean yield data from a field study researchers conducted at two Illinois locations over two years (2022-2023), as part of a multi-state project that evaluated yield response to commercially available biological seed treatment products. Five of the nine products tested in 2022 were not available in 2023; substitutes are listed in the table. The products were applied to the seeds using a small-batch seed treater per the product label. Soybeans were planted with 30-inch row spacing at 160,000 seeds per acre. Yield and data quality were good, but the study found no yield response to the biological seed treatment products in either year or location.

Table 3.2. Average soybean grain yield for each treatment (product) evaluated in this study. (Average of six replications; Std. Dev. = standard deviation of the mean; CV = coefficient of variation)

2022			2023		
Treatment (Product)	**Monmouth**	**Urbana**	**Treatment (Product)**	**Monmouth**	**Urbana**
Untreated Control	79.6	79.6	Untreated Control	74.6	74.5
1	80.3	78.2	1	78.5	72.6
2	76.7	78.8	10	77.7	74.2
3	78.3	74.3	3	77.4	75.9
4	74.0	79.4	11	73.8	75.0
5	78.7	77.2	12	76.3	77.9
6	72.6	80.1	13	78.8	76.9
7	79.4	77.3	7	78.5	71.5
8	77.2	76.3	8	76.1	75.6
9	78.5	78.5	14	74.6	73.9
p-value†	0.235	0.386	N/A	0.473	0.682
Overall mean	77.5	77.8	N/A	76.6	74.8
Std. Dev.	7.1	4.7	N/A	5.5	5.5
CV (%)	9.1	6.1	N/A	7.1	7.4

†p-value = is the calculated probability that the difference in yields occurred by chance or other uncontrolled factors, not the treatments.
Active ingredients:
Product 1 = *Azospirillum brasilense, Bacillus licheniformis, Bacillus amyloliquefaciens, Bacillus subtillis, Pseudomonas fluorescens, Rhizobium.*
Product 2 = *Trichoderma virens.*
Product 3 = *Bradyrhizobium spp.*
Product 4 = *Bacillus subtillis, Bacillus amyloliquefaciens, Bradyrhizobium japonicum.*
Product 5 = *Pantoea agglomerans.*
Product 6 = *Pseudomonas brassicacearum.*
Product 7 = *Bradyrhizobium elkanii, Delftia acidovorans + Bacillus velezensis.*
Product 8 = *Bacillus velezensis.*
Product 9 = *Glomus intraradices, Glomus mosseae, Glomus aggregatum, Glomus etunicatum.*
Product 10 = *Kosakonia cowanni* Strain SYM00028.
Product 11 = *Bacillus subtillis + Bradyrhizobium japonicum.*
Product 12 = *Bacillus amyloliquefaciens* Strain PTA-4838.
Product 13 = *Methylobacterium hispanicum.*
Product 14 = *Glomus intraradices, Glomus mosseae, Glomus agregatum, Glomus etunicatum4.*

While biological seed treatments may offer benefits under certain conditions, they should be carefully evaluated for economic returns. As with other inputs, the key question is whether the additional cost results in enough increase in yield to justify the investment. With so many products on the market, it is impossible for universities to provide neutral data on every one. Farmers interested in these products might consider setting up replicated strips (with and without the product) to see how the product performs in their fields, and University of Illinois Extension and commodity groups can assist with this. While such comparisons are generally straightforward, strips laid out with the planter need to be harvested straight with the rows, not at an angle like most fields are harvested today.

Planting Depth

Planting depth is a critical factor for achieving uniform emergence and establishing a healthy stand. Soybeans generally emerge more quickly and uniformly when planted at a consistent depth of about 1¼ to 1¾ inches. Planting deeper than this can delay emergence and increase the risk of stand loss if heavy rainfall or soil crusting occurs before seedlings emerge. While the effects of uneven emergence on yield are difficult to measure, uniform emergence is a good goal because it helps maintain canopy development and reduces variability in plant growth.

Under warm and dry conditions, planting slightly deeper than normal may help seeds reach the moisture needed for germination. However, this should generally not exceed 2½ to 3 inches, and in fine-textured soils, even this depth can be risky. Planting too deeply in fine-textured soils followed by heavy rain can restrict oxygen and cause seeds to die before emergence. Alternatives include planting at normal depth and allowing seeds to wait for rain or delaying planting until after rainfall. Each approach has trade-offs: waiting for rain can delay planting and reduce yield potential, while planting deep can increase the risk of emergence failure if conditions turn unfavorable. In light soils such as sandy loams, planting up to 3 inches deep to reach moisture may be a reasonable strategy because these soils drain quickly and pose less risk of crusting after rainfall.

Row Spacing

Row spacing influences canopy development, light interception, and ultimately yield. Averaged over the past five years (2018-2022), Illinois producers reported planting 64% of their soybeans in 15-inch rows, 30% in 30-inch rows, and 6% in rows narrower than 15 inches. Much research has been conducted on row width in soybeans, with most studies showing that yields increase when row width is reduced from 30 inches to less than 30 inches. Research trials across 40 Illinois sites from 2010 to 2018 found that 15-inch rows outyielded 30-inch rows at about half the sites, with an overall average difference of just over 2 bushels per acre. Other row spacing trials have shown that the narrow-row advantage over 30-inch rows tends to diminish as rows reach 20 inches or less. The yield advantage of narrow rows is usually greatest when canopy development is limited, such as with late planting, dry weather, or early-maturing varieties. Narrow rows help the crop intercept more sunlight earlier in the season, which can improve pod retention and seed filling. Conversely, when full canopy closure occurs before flowering in wide rows, the benefit of narrowing rows is minimal. Very narrow rows (less than 10 inches) or drilled soybeans can provide additional yield benefits under severe stress conditions, but these systems are less common due to equipment limitations and management challenges.

A practical rule is to consider row spacing in relation to canopy development: if a full canopy is unlikely by early pod set in wide rows, narrower rows may increase yield. This helps explain why later-maturing varieties, which grow taller and produce more leaf area, often respond less to narrow rows than early-maturing varieties. Narrow rows also tend to provide better weed suppression, which can be an added advantage in fields with high weed pressure.

Double-Crop Soybeans

Double-crop soybeans, planted after winter wheat harvest in mid-to-late June or early July, can be successfully grown in southern Illinois most years and occasionally in central Illinois. The likelihood of success decreases as when moving north from Interstate 70 because wheat harvest occurs later and fall frost arrives earlier. Southern Illinois offers better conditions for double cropping because wheat harvest is earlier, and warmer fall temperatures allow soybeans to mature before frost.

Interest in double-crop soybeans has increased in recent years in response to higher wheat and soybean prices, spreading to parts of central Illinois, where wheat acreage has been limited in recent decades. The yield potential of double-cropped soybeans is typically 40 to 60% of that obtained with full-season soybeans planted in early May, but yields can vary widely from year to year. As discussed above, late planting shortens the vegetative period and reduces the time available for pod development and seed filling. Dry soil at wheat harvest can further delay emergence, and high night temperatures during July and August can accelerate

Table 3.3. Average crop yields (bushels per acre) of corn, soybean, and winter wheat in a rotation study in Piatt County, Illinois. Corn planting was prevented by wet soils in 2019.

Crop	2016	2017	2018	2019	2020	2021	2022	2023	Avg., 2016-2023
Corn	206	259	265	N/A	231	241	237	225	243
Soybean	75	80	97	75	71	84	85	89	83
Wheat	101	98	88	102	92	106	96	105	99
Double-crop soybean	54	55	52	25	20	53	32	35	41

development, reducing seed size and yield. Early fall frost remains a risk, though warming trends have reduced its frequency.

Table 3.3 summarizes results from an on-farm crop rotation study in Piatt County, Ill., conducted between 2016 and 2023. The trial was set up in three fields, each with a different phase of the corn-soybean-winter wheat/double-crop soybean sequence each year. Wheat was planted in 15-inch rows with the same planter used for soybeans. All three crops have yielded very well, with full-season soybeans averaging 83 bushels per acre compared to 41 bushels per acre for double-crop soybeans. Wheat yields averaged 99 bushels per acre, and corn yields averaged 243 bushels per acre over the same period. These are reasonable yield expectations for productive soils in central Illinois, including the variability in double-crop soybean yields over the years.

Advances in genetics, planting equipment, and harvest technology have improved the feasibility of double cropping. Rotary combines allow an earlier wheat harvest at higher moisture levels, enabling earlier soybean planting. Breeding for earlier-maturing wheat varieties, including efforts at the University of Illinois, has also helped. Whether this system expands further into central Illinois will depend on crop prices and the consistency of yields across different soils and years.

Replanting Soybeans

Deciding whether to replant soybeans after a poor initial stand can be challenging because it involves weighing the cost of replanting against the potential yield loss from delayed planting. In many cases, the decision is straightforward when stands are extremely low or zero in parts of the field, but in intermediate situations it requires careful evaluation. Yield losses from late planting generally accelerate after late May, so replanting before that date often pays when stands are inadequate.

The need for replanting is obvious when heavy rainfall or standing water eliminates plants in low-lying areas or across entire fields. In such cases, replanting only the damaged areas may be possible, but wide planters often require covering large portions of the field. When stands vary across the field, *repair planting* can be done in the worst areas, but this approach can still involve planting most of the field if variability is widespread.

Uniformly poor stands across a field require accurate stand counts before deciding to replant. Causes of low stands include poor seed quality, incorrect planter settings, planting too deep or too shallow, and unfavorable soil conditions after planting. If the average stand is less than half of the target population and replanting can be done by late May, it is usually justified because the yield loss from low stands will exceed the loss from delayed planting.

Even when it is clear that a soybean stand should be replanted, there may be questions about how to replant. In particular, should the original stand be destroyed using herbicides or tillage before replanting, or should the drill or planter be used to repair plant without destroying the initial stands? Should replanting be done in narrow rows if the original planting was in wider rows? A study conducted over three years at two locations (Pike and DeKalb County) compared these strategies. Initial planting was made in early May using drilled or 30-inch rows, and low stands were produced by reducing seeding

Table 3.4. Effect of replanting method on soybean stands and yields.

Original Planting	Original Stand	Replanted? (Tillage/ Row Spacing)	Final Stand (X000/A)	Yield (Bu/A)
Drilled	High	Not replanted	171	58
Drilled	Low	Not replanted	54	50
30-inch rows	High	Not replanted	157	55
30-inch rows	Low	Not replanted	37	45
Drilled	Low	No-till/drilled	163	54
Drilled	Low	No-till/30-inch	161	53
30-inch rows	Low	No-till/drilled	161	53
30-inch rows	Low	No-till/30-inch	153	53
Drilled	Low	Tilled/drilled	183	54

rates. Replanting occurred 3 to 4 weeks later using either a drill or 30-inch rows, with or without tillage to remove the original stand.

Results show that replanting low initial stands of 50,000 or fewer plants per acre was justified, especially when the low stands were in 30-inch rows. Drilled soybeans planted early produced about 3 bushels per acre more than 30-inch rows, but among the replanting methods, there was no significant difference in final yield. Replanting low stands — whether by drilling or using a row planter, and whether the original stand was tilled — produced yields similar to those of full initial stands in 30-inch rows **(Table 3.4)**.

Specialty Types of Soybeans

There are several categories of specialty soybeans. While genetically modified (GMO) varieties, mostly with herbicide resistance traits, are widely grown in Illinois, non-GMO varieties grown for specific markets, including export, can command a modest premium. One concern is that, because the seed industry has concentrated its breeding efforts on GMO soybeans, the performance of non-GMO soybeans may not be keeping pace. Another challenge to growing non-GMO soybeans is that herbicide-resistant weeds have made weed control more difficult. Results from the University of Illinois Variety Testing trials 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 tend to yield less than GMO varieties.

Several other types of specialty soybeans are produced to meet the needs of different markets.

- **High-oleic soybeans** (such as such as Plenish®, SOYLEIC®, Vistive Gold) contain more than 80% oleic acid and less than 3% linolenic acid, improving oil stability and reducing trans fats in processed foods. These varieties were developed using a non-GMO gene discovered at the University of Missouri.
- **Tofu-type soybeans** (clear hilum) are preferred for tofu and soy milk production because the colorless hilum prevents visible seedcoat fragments in the final product.
- **Natto-type soybeans** have very small seeds and are used in fermented foods popular in some Asian countries. They may also be used for bean sprouts.
- **Edamame soybeans** are harvested while still green and consumed as a vegetable. These varieties typically have large seeds and pods.
- **High-sucrose soybeans** improve flavor and digestibility in soy-based foods such as soy milk, cheese, and meat analogs.
- **Organic soybeans** are grown for markets that require production without synthetic chemicals. These systems often involve additional management challenges and certification requirements.

- **High-protein soybeans** have protein concentrations about 1 to 2 percentage points higher than commodity varieties and are used in food processing.

Specialty soybean production requires careful attention to variety selection, identity preservation, and market specifications. While premiums can offset some yield differences, growers should confirm contract details and evaluate whether the added management and segregation requirements fit their operation.

How High Will Soybean Yields Go?

Soybean yields in Illinois have increased steadily over the past three decades, driven primarily by genetic improvement and supported by better crop management. Breeding programs have focused on traits such as lodging resistance, extended reproductive periods, and improved nutrient and water use efficiency. Modern varieties grow faster, develop more robust root systems, and tolerate stress better than older varieties, allowing them to maintain yield potential under challenging conditions.

To estimate genetic progress, researchers compared the average yield of the top ten varieties in the University of Illinois Variety Testing Program for central Illinois over the past 30 years with the state average yield during the same period (**Figure 3.8**). Both trends show similar rates of increase — about 0.84 bushels per acre per year for the top varieties and 0.85 bushels per acre per year for the state average. This parallel progress suggests that genetic improvement accounts for most of the yield gain, with management practices contributing the remainder. A 2014 study comparing soybean varieties released over 80 years concluded that roughly two-thirds of the yield improvement was genetic and one-third was due to better crop management and protection.

Although there is no official national soybean yield contest, several producers over the past few decades have received significant attention for reporting very high yields. The highest reported yield comes from a farmer in southern Georgia, who reported producing an average of 206.7 bushels per acre on a small part of a field in 2023. Several previous records have also been produced in that part of Georgia, on well-weathered soils, with irrigation,

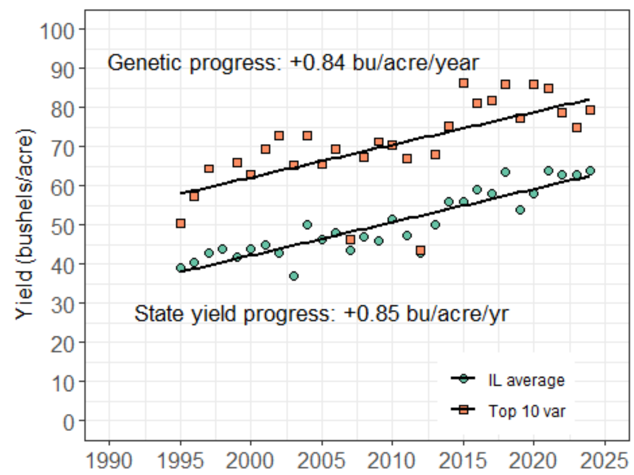

Figure 3.8. Average soybean yields for Illinois (circle) and the top 10 varieties in the University of Illinois Variety Testing trials in central Illinois (square) between 1995 and 2024.

and under very warm temperatures. Besides irrigation, inputs commonly reported in such *contest fields* include in-season N applications, other nutrients (including micronutrients), fungicides, and sometimes other, less-conventional inputs. While records from such fields may provide some insight into the yield potential of current varieties under unusual levels of inputs on weathered soils and at high temperatures, they do little to improve soybean yields and profitability on productive soils without irrigation in the Corn Belt.

The Push for High Yields

Although most people understand that soybeans cannot be forced to yield 100 bushels per acre or more, that does not keep some people from trying. Headlines in the farm press point to 100-bushel soybeans as a goal, and many companies sell seed and other inputs with strong hints that they can help push yields to such heights. In recent years, producers in several Illinois regions have reported yields above 90 bushels per acre, and sometimes above 100 bushels per acre. Most who report such yields are fully aware that they resulted from good management, but with a large assist from favorable weather. Intensive soybean breeding for yield has transformed our expectations: the trendline soybean yield in Illinois reached 60 bushels per acre in 2023, about 23 bushels (61%) more than it was in 1990, and almost double what it was in 1980. The highest county yield reported to date was 80.4 bushels in Sangamon County in 2018. Concerns from the 1980s and 1990s that soybean yields were stagnating have largely given way to amazement at yields and yield stability over the past decade, during which Illinois soybean yields have averaged 59.4 bushels and only ranged from 54 (in 2019, with a record-wet spring) to 64 (in 2024).

The basics of setting soybean up for high yields are clear: choose a top-yielding variety, plant on time at a modest seeding rate, maintain adequate soil nutrients, pH, and drainage, and protect the crop from weeds and diseases. Inputs such as biologicals and biostimulants, frequent application of various nutrients, repeated applications of insecticides and fungicides, and other products may satisfy the urge to provide everything that the crop could possibly need, but are unlikely to add much yield in most cases, at least enough yield to pay the cost of the products and their application. Instead, to lower the per-bushel cost of production, keep in mind the cost of the last bushel of added yield: was this cost equal to or less than the price to recieve for that bushel — that is, was it profitable?