

Soybean Production in Kentucky

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Seed Quality

Soybean seed quality is very important for crop establishment. In general, seed quality is an indicator of a seed's ability to produce a seedling in field conditions and includes both seed germination and seed vigor. Most producers are familiar with seed germination since they have seen it on a seed tag. Fewer are familiar with seed vigor.

Seed germination is the percent of seeds that are capable of producing a normal seedling within 7 to 10 days in ideal conditions (68° to 86°F, which is 20° to 30°C). In Kentucky, all soybean seed sold in one pound containers or larger must be labeled with a tag that lists germination percentage along with other information about the seed. Most soybean seed sold in Kentucky has a germination of at least 90 percent. However, germination is affected by its production environment and seed with less than 90 percent germination may be sold in years following stressful growing seasons or when seed supply is limited.

Seed germination varies by seed lots within a single variety. Knowing the seed germination for each seed lot can help the producer adjust the seeding rate to get the desired initial plant population. For example, if a producer wants a plant population of 120,000 plants per acre and the seed to be planted has 95 percent germination, then 126,316 seeds per acre should be planted: $120,000/0.95=126,316$. If the seed lot has 80 percent germination, then the producer needs to plant 150,000 seeds per acre ($120,000/0.80=150,000$) to obtain a plant population of 120,000 plants per acre.

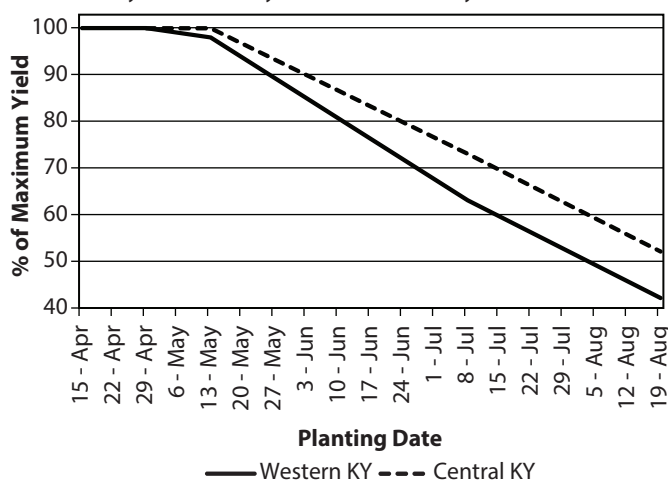
Using the same seeding rate on seed lots with different seed germination ratings will result in different final plant populations. For example, only 114,000 plants per acre are possible when the seeding rate is 120,000 seeds per acre with 95 percent seed germination while only 96,000 plants per acre are possible for the same seeding rate with 80 percent seed germination. While the seed germination listed on the seed tag provides an accurate estimate of seed emergence under ideal conditions, it may not be as accurate for seeds germinating in stressful environments. It is not uncommon for two soybean seed lots with the same germination percentage to produce two very different plant populations when planted in the field. This is often due to differences in seed vigor. Seed vigor is the ability of soybean seed to produce normal seedlings when environmental conditions are not ideal. Seed vigor is not required on seed tags and is typically not stated. However, it is an important indicator of initial plant populations in the field.



There are two tests that are commonly used to determine soybean seed vigor: accelerated aging and cold germination. Both of these tests apply a controlled set of stressful conditions prior to germination. The accelerated aging test places soybean seed in high temperature (130° to 139°F; 54° to 59°C) and relative humidity (100 percent) for three days. After that time the seed are germinated in ideal conditions (68° to 86°F; 20° to 30°C) and total seed germination is determined after seven to 10 days. The cold germination test begins when the seed are planted into wet soils (greater than 70 percent water holding capacity) and placed at 40°F to 50°F (4°C to 10°C) for seven days prior to germination in ideal conditions for seven to 10 days. Both of these tests provide insight into how the seeds will perform under stressful conditions.

Although, the tests conducted to evaluate seed vigor produce percentage germination data, seed vigor is typically categorized as either "high" or "low." High seed vigor would suggest that a high percentage of soybean seedlings will successfully establish in stressful field conditions. As soybean seed vigor declines soybean seedling emergence in the field also declines, which can result in reduced plant populations. Soybean seed vigor is not required for the seed label, therefore is unknown to the purchaser in most cases. Reputable seed companies typically offer seed with high vigor; however many factors affect seed vigor and not all seed sold is equal. Soybean seed vigor can vary dramatically among seed lots, because it is impacted by production environment and storage conditions. A majority of the time, soybean seed production fields are not subjected to severely stressful conditions, thus soybean seed vigor is typically

Figure 1. Effect of soybean planting date on grain yields for group IV soybean cultivars in Kentucky. Approximately 0.50% yield loss occurs each day after optimal planting date of early May in Western Kentucky and mid-May in Central Kentucky.



high. However, there are years in which severe environmental stresses occur, such as drought, which can greatly reduce seed vigor.

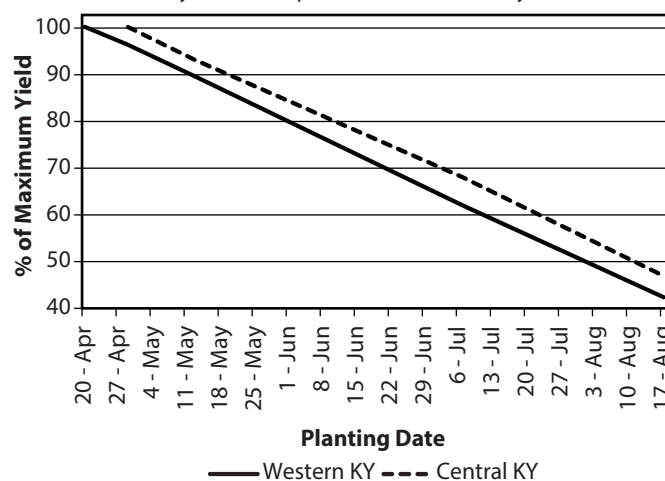
Farmers intending to plant soybean seed into more stressful conditions should get those seed lots tested for seed vigor, either at Regulatory Services at the University of Kentucky (www.rs.uky.edu/seed/) or at a private laboratory. Soybean vigor tests may not be the same for different laboratories; therefore, it may be best to use the same laboratory to obtain comparable results.

The more common threat to soybean seed vigor is seed storage conditions. The combination of seed moisture, air temperature and relative humidity directly influences seed vigor. Typically, seed vigor decreases in storage as grain moisture content increases above 10 percent and as air temperature and relative humidity of the storage environment increases. Additionally, fluctuations in air temperature and relative humidity also greatly reduce seed vigor, without necessarily reducing seed germination. For example, a study in Iowa found that air temperature and relative humidity of a seed storage warehouse can range from 18° to 82°F (-8° to 28° C) and 37 percent to 74 percent relative humidity over a 20-month period. In this study, seed vigor and germination were high, both greater than 90 percent, when placed into the warehouse for storage. Just 4 months later, the seed vigor had declined to 40 percent, while germination was still greater than 90 percent. After 12 months of storage in a warehouse the seed vigor declined to 10 percent while germination was still around 90 percent. This study implies that these storage conditions would result in a seed lot that would germinate well under ideal field conditions, but have very low germination rates under stressful field conditions.

Planting Dates

Soybean planting dates are determined by field conditions, such as soil temperature and moisture, and the projected weather forecast in combination with the calendar. Ideally, soybean seed should be planted as soon as soil temperatures are between 50° and 60°F (10° to 15.5°C), with adequate soil

Figure 2. Effect of soybean planting date on grain yields for late-group II soybean cultivars in Kentucky. Approximately 0.42% yield loss occurs each day after optimal planting date of mid-April in Western Kentucky and late April in Central Kentucky.



moisture to promote soybean seed germination and to support equipment without causing compaction, and a projected weather forecast that will maintain soil temperatures above 50°F.

The optimum soil temperature for soybean planting is 60°F (15.5°C) or greater, because rapid seed germination and seedling emergence will occur. However, when soil temperature is at least 50°F soybean seed will consistently germinate and establish acceptable plant populations. Soybean should not be planted when soil temperature is less than 50°F because seed germination is inconsistent at these temperatures and will likely result in inadequate plant populations.

In Western Kentucky, the optimum planting date for full-season soybean historically is mid-April to early May for group IV soybean cultivars and mid- to late April for late-group II soybean cultivars.

In Central Kentucky, the optimum planting date for full-season soybean historically is mid-May for group IV soybean. Data indicate that if a late-group II soybean cultivar is produced in central Kentucky then a late April planting would optimize yields; however, group II soybean cultivars are rarely grown in Central Kentucky.

Double-crop soybean are planted much later than the optimum planting dates; however it is very important to plant them as soon as possible because the yield potential for soybean planted after the optimal planting dates is reduced by 0.50 percent per day for group IV soybean cultivars and 0.42 percent for the late-group II soybean (figures 1 and 2). Therefore, as little as a 10 day delay can reduce potential yield by 5 percent.

When considering early planting dates for soybean the risk of a late-spring freeze and colder soil conditions are the primary concerns. For most of Western Kentucky, the last frost generally occurs in late April, while the last frost typically occurs in early May for Central Kentucky (Table 1). Soybean can be planted prior to the last spring freeze as long as the plants do not emerge from the soil before the last freeze occurs. In most cases, it will be about 14 days before early-planted soybeans emerge because of cool soil temperatures. Therefore, planting 10 to 14

Table 1. Probabilities for the date of the last spring freeze (32°F or less) in Kentucky based upon data from 1981 to 2010 (Arguez et al., 2010 provided by S. Foster, State Climatologist for Kentucky).

Kentucky Location	Date of Last Spring Freeze (32°F or less in Kentucky by Probability Level ¹		
	90%	50%	10%
Ashland	19-Apr	3-May	19-May
Bardstown	11-Apr	25-Apr	11-May
Bowling Green	5-Apr	21-Apr	7-May
Covington	13-Apr	27-Apr	13-May
Danville	7-Apr	22-Apr	7-May
Glasgow	10-Apr	24-Apr	10-May
Henderson	4-Apr	18-Apr	3-May
Hopkinsville	5-Apr	20-Apr	4-May
Leitchfield	24-Apr	8-May	26-May
Lexington	10-Apr	25-Apr	10-May
Mayfield	4-Apr	19-Apr	4-May
Monticello	16-Apr	30-Apr	16-May
Murray	29-Mar	13-Apr	26-Apr
Nolin River Lake	15-Apr	1-May	18-May
Princeton	8-Apr	24-Apr	9-May
Russellville	6-Apr	23-Apr	12-May
Shelbyville	23-Apr	7-May	25-May
Somerset	15-Apr	1-May	17-May

¹ Probabilities that the last spring freeze will occur on or after the date listed. For example, for 90% probability the last spring freeze will occur on or later than the date listed 90% of the time (nine out of ten years), while at the 10% probability level the last spring freeze will occur on or later than the dates listed 10% of the time (one out of ten years).

days before the last expected frost (Table 1) at the probability level that makes the producer most comfortable is one way to reduce the risk of a late spring freeze damaging the crop.

High vigor soybean seed is essential for early soybean planting dates and farmers should get seed lots tested for vigor. Most seed testing laboratories can test soybean seed vigor, such as the University of Kentucky's Division of Regulatory Services Seed Department. Some farmers may be tempted to not test for seed vigor because so many seed companies offer large discounts on replanting soybeans. However, the time and effort to plant can be wasted if low vigor seed is planted early and those costs are not offset by discounts for replanting.

Soybean seed treated with a fungicide is recommended for early plantings, because delayed seedling emergence typical of early soybean planting will increase the risk of seedling fungal pathogens. Early planted soybeans are at greater risk for Sudden Death Syndrome, so tolerant varieties are recommended.

A final consideration for early soybean planting dates is increased seeding rates. In Kentucky, field emergence of soybean seedlings has been found to be reduced by about 15 percent for early planting dates (mid-April in Western Kentucky and early May in Central Kentucky), while reductions of about 5 percent are found a few weeks later (late April/early May in Western Kentucky).

As such, a seeding rate of approximately 130,000 seeds per acre will be needed if a seed lot with 90 percent germination is used for an April 17 planting in Western Kentucky with a desired final plant population of 100,000 plants per acre.

To adjust seeding rate for seed germination rate:

$$\frac{100,000}{0.90} \frac{\text{plants per acre}}{\text{seed germination}} = 111,111 \text{ seed per acre}$$

To adjust seeding rate for early planting date:

$$\frac{111,111}{0.85} \frac{\text{seed per acre}}{\text{to increase seeding rate by 15 percent}} = 130,719 \text{ seed per acre}$$

Table 2 provides seeding rates for various seed germination rates and assumed stand losses to obtain final plant populations of 100,000 and 140,000 plants per acre.

Plant Populations and Seeding Rates

In Kentucky, full-season soybean typically attain maximum yield when the harvested plant population is near 100,000 plants per acre. The only exception is when severe droughts occur. In these conditions, the lowest plant populations generally produce the greatest yield. For double-crop soybean maximum yield is usually attained when final plant populations are 140,000 to 180,000 plants per acre. The higher plant populations for

Table 2. Soybean seeding rates for full-season and double-crop soybean at different seed germination and assumed stand loss rates.

Assumed Stand Loss ¹	Full-Season Soybean (100,000 plants/A Harvest Population)				Double-Crop Soybean (140,000 plants/A Harvest Population)			
	Standard Germination (from seed tag)							
	80%	85%	90%	95%	80%	85%	90%	95%
	Seeding Rate (seeds per acre)							
5%	132,000 ²	124,000	117,000	111,000	184,000	173,000	164,000	155,000
10%	139,000	131,000	123,000	117,000	194,000	183,000	173,000	164,000
15%	147,000	138,000	131,000	124,000	206,000	194,000	183,000	174,000
20%	156,000	147,000	139,000	132,000	219,000	206,000	194,000	184,000
25%	167,000	157,000	148,000	140,000	233,000	220,000	207,000	196,000
30%	179,000	168,000	159,000	150,000	250,000	235,000	222,000	211,000

¹ Assumed stand loss is the anticipated loss in stand due to planting date, field conditions, field history, or any other known cause that can reduce final plant populations.

² Seeding rates are rounded to the nearest thousand.

double-crop soybeans is related to the fact that seed is often planted into drier soil conditions and the plants have less time between emergence and flowering than full-season soybeans. Given that yield of double-crop soybean is often less than full-season soybean, the lower population of 140,000 plants per acre is generally more profitable than higher plant populations.

Harvest plant populations are directly influenced by initial seeding rate, seed germination, seed quality, seedbed conditions, and environmental conditions of the field. Therefore all should be considered when determining seeding rates. Most soybean seed will have a seed germination rate of 90 percent or greater. However, in years when severe stress occurred during seed production, seed germination can be as low as 80 percent. Soybean seed quality, typically measured with seed vigor tests, is important when choosing soybean seeding rates. In the case where soybean will be planted in April, it is essential that only high quality seed, as determined by seed vigor tests, be used.

Seedbed and environmental conditions also greatly affect final plant populations. In general soybean seedling losses are greater in heavy clay soils than silt loam soils, because clay soils are more prone to surface crusting after a rain event. Soil temperature and moisture also has a great effect on final plant populations; planting into cool (50-59°F; 10-15°C) and wet soils can reduce soybean seed germination and seedling emergence therefore when planting in these conditions seeding rates should be increased.

Table 2 provides a list of seeding rates for full-season and double-crop soybean at several seed germination and assumed stand loss rates.

Seed Inoculant

Soybean is a legume that can produce its own nitrogen by fixing atmospheric nitrogen with the help of the bacterium *Bradyrhizobium japonicum*. The *Bradyrhizobium japonicum* form nodules on the soybean roots, which is where the plant-available nitrogen is produced by the bacterium (Figure 3a). The interior of root nodules that are actively fixing nitrogen are also called “functional” and will be pink to bright pink in color (Figure 3b). When root nodules are not fixing nitrogen, “non-functional,” the interior of the nodules will not be pink and typically will be white or brown (Figure 3c).

In most cases, residual nitrogen in the soil and healthy root nodules of soybean plants will provide all the nitrogen the soybean plant requires to produce high yields. In conditions where soil residual nitrogen is excessive, root nodulation and nitrogen fixation can be either greatly reduced or impeded in severe cases. When root nodulation and nitrogen fixation are reduced or impeded nitrogen applications may be needed to produce high yielding soybean crops because there are about 3 pounds of nitrogen in one bushel of soybean seed. Thus, 50 bushels of soybean contain 150 pounds of nitrogen, while 70 bushels contain 210 pounds of nitrogen.

There are many *B. japonicum* seed inoculants commercially available. Most cost just a few dollars per acre, which is much less expensive than nitrogen fertilizer. For most of Kentucky,

annual use of a seed inoculant is not necessary. However, there are cases where *B. japonicum* seed inoculants are known to increase soybean yield, such as:

- A new soybean field
- A field that has not produced soybean for three to five years
- A field in which the previous soybean crop had poor nodulation
- A field that has remained excessively saturated for extended periods

Some producers prefer to inoculate soybean each year, regardless of soil type. Considerable research has found that in most cases, except the list above, seed inoculants do not increase soybean yield.

Seed inoculant is packaged and sold in both liquid and dry, peat-based formulations. While both formulations are effective, the liquid formulations generally provide better coverage of individual seed. When using dry forms, some type of sticking agent should be used to help the dry material adhere to the surface of each seed.

Nitrogen-fixing root nodules are formed only if bacteria of the seed inoculant are alive and viable. Therefore, it is essential that extreme temperatures and dry conditions are avoided. Most companies include expiration dates on their packages to ensure that only living and viable inoculant is sold. Many companies also include date limits once an inoculant package is opened and date limits once the inoculated is applied to the seed. Some of those labels are as short as 24 hours. In most cases, the best practice is to plant the seed immediately after it is inoculated to ensure that *Bradyrhizobium japonicum* remain viable and capable of producing root nodules.

Fungicides and fertilizer molybdenum can impair *B. japonicum*, and producers should avoid premixes containing all three. Instead, seed treated with either fungicides or molybdenum can be inoculated and immediately planted. If the time between inoculation of the treated seed and planting is more than a few hours, the viability of the inoculant may be impaired.

Seed Treatments

Fungicide and insecticide seed treatments are becoming very common in soybean seed. Most studies indicate that such fungicide seed treatments are beneficial when planting early into very cool, wet soils because prolonged seed germination and seedling emergence which result in seedlings that are prone to damping off (caused by several fungal species) and *Phytophthora* spp. Insecticide seed treatments may also be beneficial for early plantings because cool conditions cause slower plant growth and in some cases could make insect feeding more severe. An insecticide seed treatment might protect seedlings from some of these insects, especially seedling damage from adult overwintering bean leaf beetles.

In most years, seed treatments do not increase soybean yield when planted early May or later in Western Kentucky and mid-May or later in Central Kentucky. If soybean seed is treated and a seed inoculant is used it is important to plant immediately following seed inoculant application.



Figure 3a. Soybean root with numerous round nitrogen-fixing root nodules.



Figure 3b. The interior of functional soybean root nodules (blue arrows) are bright pink.



Figure 3c. The interior of non-functional soybean root nodules (at blue arrow) are not pink and are typically white or brown.

Planting Depth

Soybean seed should be planted about 1 to 1.5 inches (2.5 to 3.8 cm) deep into moist soil with good seed-to-soil contact to ensure maximum seed germination and final plant populations. Shallow seed placement increases the risk that fluctuating soil moistures will reduce germination or negatively impact seedling growth and development. Deep seed placement delays emergence and increases the risk that the soybean seedling will not reach the soil surface. Variations in soil texture, temperature, and moisture will dictate slightly different planting depths. Soybean seed should be planted to a depth of:

1 inch (2.54 cm)

- Soils that are cool and moist, which will delay germination and seedling growth

1 to 1.5 inches (2.5 to 3.8 cm)

- Most conditions and soil types including heavy clay soils prone to surface crusting

2 inches (5 cm)

- Sandy soils, which often lose soil moisture quickly and become droughty
- Dry soil conditions, if possible delay planting until after a rainfall event and plant 1 to 1.5 inches deep

In Kentucky, *never* plant soybean seed less than 1 inch or greater than 2 inches. Shallow planting depths can result in poor harvest populations due to poor seedling establishment and/or lodging. Excessively deep planting depths (>2 inches) can result in poor seedling establishment due to plants dying before they reach the soil surface.

Some herbicides dictate a slightly deeper planting depth, for which the herbicide label should be followed. Seeding depth should be checked at the start of each field and modified if soil conditions change during planting. Planters, equipped with soybean cups or air delivery, generally provide more accurate seed depth and placement **and** better soil-to-seed contact than drills. Planters also provide more accurate seeding rates and are easier to calibrate than drills. For these reasons, soybean in 15-inch rows with a planter is favored over soybean in 7.5-inch rows with a drill.

Row Width

Considerable research has shown that soybean grown in 15-inch rows yield more, or at least equal to, 30-inch rows. Conversely, soybean in 30-inch rows almost never yield more than soybean in 15-inch rows. In most cases 15-inch rows produce greater yield because of a more rapid canopy closure, which intercept more sunlight. Greater light interception of the soybean plants result in increased plant growth, dry matter accumulation and thus seed yield. More rapid canopy closure can also provide more shading of the soil surface, which can reduce weed emergence and soil moisture loss.

Soybean can be drilled in 7.5-inch rows in Kentucky. In general, the yield of drilled soybean is similar to those planted in 15-inch rows. However, as mentioned above planters generally provide more accurate seed depth, placement and soil contact than drills.

The 15-inch row width is ideal when full-season soybean are planted after the optimum planting date and for double-crop soybeans. In these situations, soybean yield is greater for 15-inch rows (or narrower), because with these row widths they are more likely to reach canopy closure and intercept more sunlight by flowering than wider row widths.

Re-Planting

Except for extreme cases soybean re-planting is generally not profitable because soybean plants can compensate for low populations and gaps in stands by branching out and producing similar yields with reduced plant populations.

For full-season soybean, replanting generally will not be profitable until the initial stand drops below 50,000 plants per acre. The relatively low yield loss from a final stand greater than 50,000 plants per acre combined with the expected yield loss of a later planting date and additional cost of re-planting normally does not justify replanting.

When considering a re-plant, the first thing to determine is the yield potential of the re-planted soybean crop. This can be accomplished by estimating the yield loss based upon planting date. For example, assume the field in question is in Western Kentucky and a group IV soybean cultivar will be planted on July 24. The expected yield loss for a group IV soybean in western Kentucky is 0.50 percent per day beginning May 9. If the typical yield of this field is 80 bushels per acre then the maximum yield expected would be 49.6 bushels per acre:

22 days in May + 30 days in June + 24 days in July
= 76 days past the optimum planting date

0.50 percent yield loss per day x 76 days past the
optimum planting date
= 38 percent yield loss

80 bu/A field average x (100-38 percent yield loss)
= 49.6 bu/A

The actual cost to re-plant should also be considered, which includes fuel, machinery, and labor.

There are certain situations in which a re-plant would be desirable, despite profitability. These may include the proximity of the field to your home, your neighbors, and/or landlords.

Resources

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