SOYBEAN SEEDING RATE AND PLANT POPULATION

It is an accepted fact that there is no perfect seeding rate for soybeans because of 1) the varying quality [germination and vigor] of seed that are planted, 2) the varying soil conditions [moisture, pathogen presence, soil texture, and seed-soil contact after planting] that affect germination and emergence, 3) the varying environmental conditions [amount of rainfall, air temperature] following planting that will affect germination and emergence, 4) the unknown or unsuspected pathogen presence in soil at the planting site, and 5) how the achieved plant population will be affected by both biotic and abiotic growing conditions that follow emergence.

According to soybean enterprise budgets published by MSU-Dept. of Agric. Economics, cost of soybean seed comprises from 12 to 22% of the estimated costs per acre for growing soybeans in the various soybean cropping systems–e.g. irrigated, nonirrigated, full-season, double-cropped–in Mississippi. Thus, planting too many seed or more than is estimated to achieve maximum yield is an expensive mistake.

So the question that will always be asked at the beginning of each growing season is "What seeding rate should I use", and from the above statements, it is obvious that the answer will be determined by both the known and unknown conditions of all of the above. Thus, it comes down to choosing a seeding rate within a range that has been shown to offset the effects of the myriad stresses stated above.

Every U.S. state that grows soybeans as a major row crop has publications that provide subjective answers to the seeding rate question. The remainder of this article is not meant to usurp those recommendations, but rather to provide growers with the myriad issues that should be considered when choosing a soybean seeding rate for their particular planting conditions.

Similar yields can be obtained across a range of plant populations. Therefore, the most profitable strategy is to plant at a rate that will achieve the minimal optimum plant population. It is generally agreed that about 100 thousand plants/acre is the minimum final soybean plant population [assuming stand uniformity] that is necessary to achieve maximum soybean yield regardless of row spacing [Robb, Delta Farm Press, Feb. 2020]. In fact, LSU researchers concluded that about 90 thousand plants/acre is the optimum minimum plants/acre required from soybean plantings in Louisiana [Board et al., LSU Bull. 892, 2013].

There are some basic points to consider when talking about a minimum acceptable soybean plant population.

FIRST, producers must determine the quality of the seed they are planting, and there are two accepted measures to determine this. The first is standard germination [SG] of the seed lot, and the second is vigor of the seed, usually determined by the accelerated aging [AA] test. However, there is no consistent relationship between these lab-measured traits and field emergence because of the soil and environmental variables at and subsequent to planting. Thus, seedling vigor involves both germination and post-germination growth through the soil until emergence occurs, and it is likely that the second process is more important than germination in affecting seedling vigor. When seedling vigor is poor, producers will have to increase seeding rate to compensate for decreased germination and increased seedling death before emergence.

The tag on the seed bag/container will have the estimated germination of the seed lot. However, the below issues described in the article by Egli and TeKrony [J. Prod. Agric., Vol. 9, 1996] where they reported results from 26 field experiments conducted across Kentucky [two to four planting dates per year] over a 10-year period should be considered.

- **Results of both the SG and AA tests accurately predicted field performance only in ideal field conditions**. The prediction accuracy of both tests decreased as seedbed stress increased.
- **As seedbed stress increased, the prediction accuracy of SG decreased faster than that of AA.** In moderate seedbed stress conditions [likely the most common], the AA test always was a better predictor of emergence than was SG. Thus, selecting seedlots based on AA rather than SG will provide higher prediction accuracy of seedling emergence.

  It is generally recognized that the standard warm germination [SG] test that is used to determine seed germination potential under ideal laboratory conditions is deficient as a measure of the potential field performance of seeds, and this is especially true for early plantings in the Midsouth. A seed vigor test more accurately measures seed properties that determine the potential for rapid and uniform emergence, and development of normal seedlings under a wide range of field conditions.

  The accelerated aging (AA) test is the preferred method for evaluating the vigor of soybean seeds. This test evaluates the germination capacity of seeds that have been subjected to high temperature and humidity stresses for a defined period before the standard germination test. Farmers who anticipate

planting early should request information on seed vigor from the supplier of a seed lot, or obtain this information from an independent laboratory.
- AA of seedlots that are stored/carried over for 18 to 30 months will be significantly lower than that of seeds harvested the fall before planting. The prediction accuracy for germination of carryover seedlots dropped significantly when those seed were planted in high seedbed stress environments. Click here for additional information about storage conditions for soybean planting seed that are to be held over.
- In these Kentucky tests, it was necessary to select seedlots with a minimum AA of 80% [an estimate of the minimum vigor that will provide adequate stands in most planting environments] and use a minimum emergence standard of 60%. In fact, lowering the minimum acceptable emergence to 60% resulted in near 100% prediction accuracy when a seedlot had an AA of 80% or greater.
- So if a seedlot with an AA of 90% is planted in commonly-occurring seedbed conditions in the Midsouth and 60% emergence is assumed, a seeding rate of 150,000/acre should result in at least 81,000 plants/acre. If a producer assumes 80% emergence from the same seedlot, then a seeding rate of 120,000/acre should result in at least 86,000 plants/acre.

SECOND, accurate sampling is required to determine the final plant population following complete emergence. Click here for a link to a reference [p. 345-347] that describes how to use the line-intercept method to do that. Below is a basic summary of steps to use in this method. Remember, accurate sampling to objectively determine final stand is much cheaper than subjective assumptions that may lead to expensive replanting.
- Divide the field into management units that are comprised of plants with similar phenology.
- Within each of these management units, randomly place one to four straight transect sampling lines across (perpendicular to) the planted rows. It is best that each of these lines cross at least two planter passes. Count the plants in 3 ft. of each row on both sides of the transect line. Remember, the more lines and the more planter passes the translect line crosses, the greater the accuracy of the stand estimate.
- Record the number of plants in each counted section of rows crossed by the transect line.
- Calculate the average number of plants/sq. ft, then multiply this number by 43,560 sq. ft. in an acre to determine plants/acre.

THIRD, accepting a minimum number of plants per acre as sufficient assumes that those plants are uniformly distributed/spaced regardless of the row spacing. Again, proper sampling protocol should be followed to ensure this is the case.

FOURTH, the acceptable minimum plant population assumes that there will be no abiotic or biotic stresses to significantly reduce stand later in the season. Regrettably, there is no objective way to determine this since growing conditions and pest presence for the subsequent growing season cannot be accurately predicted.

A report from Louisiana State University researchers [Board et al., Res. Bull. 892, 2013] provids the following details.
- Comprehensive field studies were conducted over three years [2009-2011] at four locations [Baton Rouge, Crowley, St. Joseph, and Winnsboro] on soils that ranged from silt loam to clay and row spacings that were wide [38-40 in.] and narrow [16-20 in.].
- The AA test was used to calculate seeding rate.
- Significant plant death occurred at three of the locations when initial plant populations reached 140 to 180 thousand/acre.
- The trend at all locations was for economic losses to increase [money wasted on planting too many seed] as plant populations increased above about 125 thousand/acre.
- The results indicated that the minimal optimal plant population should be about 90 thousand plants/acre.

An MSU-ES publication authored by Dr. Trey Koger provides the recommended final soybean plant populations for varying Mississippi soybean planting environments and required seeding rates using an expected 80% emergence of planted seed necessary to achieve those plant populations. These seeding rates should be adjusted according to the above narrative to achieve lower optimal plant populations for Midsouth environments. Also remember that using the appropriate fungicide seed treatment will likely allow a 10% lower seeding rate.

Results reported in a 2018 thesis titled "Impact of planting strategies on soybean (*Glycine max* L.) growth, development, and yield" that was authored by Mr. Shane Carver with the MSU-ES SMART program under the direction of Dr. Trent Irby provided the following [click here for detailed summary].
- Planting soybeans at 120 and 140 thousand seeds/acre resulted in the greatest net returns to seeding rate. This is similar to the finding by Smith et al. [CFTM Nov. 2019] from research conducted on clay soils in the Delta.
- Using a seeding rate greater than 140 thousand/acre will

not result in increased yield and will likely lower net return.
- Using a seeding rate lower than 100 thousand/acre will likely result in both lower yield and net return.

For Midsouth soybean plantings, the following tenets should be considered.
- Preferably, lower quality seeds should not be planted in the conditions that usually occur with early planting. However, when seed lots with a lower-than-desired germination/vigor must be used, the vigor test is especially important. Also, these seed should be planted at an increased rate.
- In less-than-ideal seedbed conditions at planting, AA germination will more accurately predict emergence percentage.
- High-quality seeds that have received an appropriate fungicide seed treatment to control both seed- and soil-borne pathogens will germinate and emerge. Emergence time may be extended by cold soils, but emergence will occur as long as adequate soil moisture is available. It is generally agreed that applying the appropriate [broad spectrum, contact + systemic] fungicide seed treatment will allow a 10% reduction in planting rate. **Thus, if a seeding rate of 140,000/acre was planned, the appropriate seed treatment should allow a seeding rate of about 125,000/acre to get the same stand.**
- Producers must decide on a field-by-field basis what planting rate they believe will achieve a minimum optimal plant population of about 90 to 100 thousand plants/acre.
- A seeding rate that results in more than 125,000 soybean plants/acre will likely result in an economic loss because of money wasted on seed.
- As discerned from the above narrative, there is no one seeding rate that will fit all soybean planting conditions. However, all of the above information can be used by individual producers to estimate the best seeding rate(s) for their planting conditions that only they can estimate with some accuracy and confirm by proper sampling after emergence.
- The minimum optimal soybean plant population after complete emergence assumes that the stand will be protected against the myriad biotic and abiotic stresses that will occur during the growing season.

A web-based seeding rate calculator devised by the University of Illinois Dept. of Crop Science Extension and Outreach is a handy tool for calculating the number of seed to plant to obtain a desired plant population, and the cost associated with that seeding rate. The results in the below tables are based on the price of a 50-lb. bag of seed for a soybean variety with 2800 seeds/lb. and planted in 20-in.-wide rows to achieve a final stand of 100,000 plants/acre. If cost of a chosen seeding rate is of no interest, just leave the "cost of seed per unit" cell blank to obtain only seeding rate and amount data.

This calculator, with a modification, can also be used to calculate the cost of seed per acre when they are sold on a per 1000 seed basis. To make this modification, divide 1000 by the number of seeds per pound of the variety and place the resulting number in the "pounds of seed per unit" cell. Results from this modification applied to the calculator using the same variety and 90% AA are shown in the below tables.

Table 1. Calculation of seeding rate needed to achieve a soybean population of 100,000 plants/acre from seed with 90% germination and expected emergence of 60%.

Input		Output	
Field Size *(acres)*	50	Seeding rate *(seeds per acre)*	185,000
Seed Variety	Dyna-Gro 31RY45	Planter calibration number *(seeds dropped per foot of row)*	7
Cost of seed per unit–$ per 50-lb. bag	75.5	Seed spacing *(inches)*	2
Germination % from seed container tag	90	Pounds per acre	66
Row spacing *(inches)*	20	Units per acre	1.32
Desired final plant pop. *(thousands/acre)*	100	Units of seed to plant this field	66
% of seeds expected to result in plants *(0-100)*	60	Seed cost–$/acre	99.86
Seed size *(seeds per pound)*	2800		
Pounds of seed per unit	50	Total cost–$ for entire field	4993

Table 2. Calculation of seeding rate needed to achieve a soybean population of 100,000 plants/acre from seed with 90% germination and expected emergence of 80%.

Input		Output	
Field Size *(acres)*	50	Seeding rate *(seeds per acre)*	139,000
Seed Variety	Dyna-Gro 31RY45	Planter calibration number *(seeds dropped per foot of row)*	5
Cost of seed per unit–$ per 50-lb. bag	75.5	Seed spacing *(inches)*	2
Germination % from seed container tag	90	Pounds per acre	50
Row spacing *(inches)*	20	Units per acre	1
Desired final plant pop. *(thousands/acre)*	100	Units of seed to plant this field	50
% of seeds expected to result in plants *(0-100)*	80	Seed cost–$/acre	74.90
Seed size *(seeds per pound)*	2800		
Pounds of seed per unit	50	Total cost–$ for entire field	3745

Table 3. Calculation of seeding rate needed to achieve a soybean population of 100,000 plants/acre from seed with AA of 90% and expected emergence of 60%.

Input		Output	
Field Size *(acres)*	50	Seeding rate *(seeds per acre)*	185,000
Seed Variety	Dyna-Gro 31RY45	Planter calibration number *(seeds dropped per foot of row)*	7
Cost of seed per unit–$ per 1000 seed	.55	Seed spacing *(inches)*	2
AA %	90	Pounds per acre	66
Row spacing *(inches)*	20	Units per acre (1000-seed units)	185
Desired final plant pop. *(thousands/acre)*	100	Units of seed to plant this field (units of 1000 seed)	9260
% of seeds expected to result in plants *(0-100)*	60	Seed cost–$/acre	102
Seed size *(seeds per pound)*	2800		
Pounds of seed per unit	.3571	Total cost–$ for entire field	5093

Table 4. Calculation of seeding rate needed to achieve a soybean population of 100,000 plants/acre from seed with AA of 90% and expected emergence of 80%.

Input		Output	
Field Size *(acres)*	50	Seeding rate *(seeds per acre)*	139,000
Seed Variety	Dyna-Gro 31RY45	Planter calibration number *(seeds dropped per foot of row)*	5
Cost of seed per unit–$ per 1000 seed	.55	Seed spacing *(inches)*	2
AA %	90	Pounds per acre	50
Row spacing *(inches)*	20	Units per acre (1000-seed units)	139
Desired final plant pop. *(thousands/acre)*	100	Units of seed to plant this field (units of 1000 seed)	6950
% of seeds expected to result in plants *(0-100)*	80	Seed cost–$/acre	76.50
Seed size *(seeds per pound)*	2800		
Pounds of seed per unit	.3571	Total cost–$ for entire for field	3820

Replanting a Failed Stand

On some occasions, producers must determine if a soybean stand that is less than desired should be replanted. Results reported in a 2018 thesis titled "Impact of planting strategies on soybean (*Glycine max* L.) growth, development, and yield" that was authored by Mr. Shane Carver with the MSU-ES SMART program under the direction of Dr. Trent Irby provided the following [click here for detailed summary].

- When an initial stand [seeding rate of 130 thousand/acre] was reduced by 25% with no replanting, yield was not significantly reduced below that from the initial seeding rate with no stand reduction; thus, there was no yield advantage to replanting the lost 25% and the cost of replanting was not recouped.
- When 50% of the initial stand was removed with no replanting, yield was significantly reduced below that from the initial seeding rate with no stand reduction, but replanting an amount of seed that equaled the percentage stand loss did not result in increased yield. Thus, the cost of replanting was not recouped.
- When 75% of the initial stand was lost with no replanting, yield was significantly reduced below all yields from treatments with less stand loss. Replanting an amount of seed that equaled the percentage stand removal of 75% resulted in a significant yield increase above that from not replanting. These results indicate that replanting should occur when the initial soybean plant population is reduced by more than 50%.
- When complete reduction of an existing stand occurred, replanting at the seeding rate to equal 100% of the lost stand resulted in a yield below that from the initial stand that was not reduced. However, replanting this 100% failed stand at a seeding rate that equaled only 50% of the initial seeding rate resulted in a yield that was equivalent to that obtained from replanting at the 100% seeding rate. Thus, it may not be economically feasible to replant a completely failed stand at the initial seeding rate.

FINAL THOUGHTS

- Planting more than about 130 to 140 thousand soybean seeds/acre will likely lower net return. This is supported by the preponderance of cited research results.
- A seeding rate of 125 thousand high quality seed/acre that have been treated with a broad spectrum seed treatment should be ideal in good planting conditions.
- A final soybean stand of 90 to 100 thousand plants/acre will be sufficient to maximize yield in most situations.
- A replanting decision should be based on uniformity and health of the remaining plants since replanting will be later and may not increase yield above that from the reduced stand.

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APR 2023 UPDATE

VARIABLE-RATE SEEDING [VRS] FOR SOYBEANS

In U.S. soybean production, VRS is being used on an increasing number of acres because of the increasing cost of planting seed. Ideally, VRS is applied to distinct zones in a field that have been identified based on their distinct soil properties [e.g. CEC, organic matter, soil pH and potassium level, soil texture, terrain attributes such as elevation] and yield history. The intent is to plant different areas of a field with different seeding rates that are based on the perceived economic benefit that will be derived from planting fewer seed in certain areas of a field. The assumption is that fewer seed can be planted on the "better" field areas [higher CEC, medium-textured soils with greater organic matter and higher CEC that should support more vigorous plant growth] vs. using a perceived best seeding rate on the entire field. It is likely that two rates–i.e. "normal" and "lower"–in an individual field will be the most manageable and economical.

Variable-rate seeding of soybean should be conducted only after first identifying distinct management zones within a field that should be based on the factors listed above. Otherwise, the effect of lowering the seeding rate in some field portions may not accomplish the desired effect–i.e., there should be a valid reason based on soil factors and yield history for planting fewer seed in identified field zones.

An article titled "Comparison of variable-rate prescriptions and optimum seeding rate in soybean" appears in Crop, Forage, & Turfgrass Mgmt. The conduct of the research reported in this article and subsequent results follow.

- On-farm studies were conducted at four Ohio locations in 2017, and three Ohio locations and three Michigan locations in 2018.
- The objectives of the research reported in this article were to 1) determine the agronomic optimum seeding rate [AOSR] for soybean in predetermined management zones of a field, and 2) compare the AOSR to each producer's VRS practice. Each cooperating producer selected the factors [e.g. yield history of a field, soil map unit, soil organic matter, soil pH] that were used to define the management zones within an individual field.
- Four seeding rate treatments were applied at each location each year. They were uniform rates of 100, 140, and 180 thousand seeds/acre and a VRS of 80 to 180 thousand seeds/acre in the Ohio studies. In the Michigan studies, uniform rates of 70-95, 110-145, and 150-195 thousand seeds/acre [dependent on location] and a VRS of 85 to 140 thousand seeds/acre were used. The VRS at all locations was based on properties of pre-determined management zones within a field at each site.
- Plant population [stand counts conducted at V2-V3 and R8 stages] and seed yield data were recorded for each seeding rate treatment in all management zones of a field.
- Management zone seldom affected plant population and never influenced soybean seed yield at any of the sites.
- In 13 of the 28 management zones across the 10 site-years of the study, there was no significant response of yield to seeding rate treatment. This was likely because soybean plants can compensate for low populations by increasing the number of branches per plant.
- The authors calculated an AOSR for each management zone that had a significant yield response to seeding rate, and found that in most cases [53%] the farmer-selected seeding rate resulted in underseeding in management zones with a calculated AOSR. This underseeding was attributed to low stand establishment that resulted from adverse conditions that occurred after planting.
- The authors recommend that producers take a stand count after VRS planting that is based on predetermined field management zones to ensure that the seeding rate they chose for each zone was in fact correct for those zones, and if it was not, adjust the seeding rate up or down accordingly.
- The takeaway from this research is 1) producers should identify under-performing areas of each soybean field, and determine if a higher seeding rate will improve performance in those areas, and 2) determine if a higher seeding rate in under-performing field zones can be offset by a lower seeding rate that may be used in normal and/or high performing zones so that seed costs can be held constant or even lowered.

An article titled "Crop physiological considerations for combining variable-density planting to optimize seed costs and weed suppression" was published in 2022 in the journal Weed Science. The conduct of and results from the portion of this study that dealt with soybean follow.

- The study was conducted under the premise that high plant densities of a crop [in this study, corn, cotton, and soybean] will contribute to weed suppression.
- The high cost of seed will likely cause reluctance among producers to adopt and use this practice across a whole field that has sporadic areas of high weed density.
- A field study was conducted in 2019 and 2020 at Rocky Mount, N.C., and in 2020 at Goldsboro, N.C.. Soil texture at both sites was a loamy sand.
- In each year, six treatments were used. They were: 1) normal density [control]; 2) 75% of normal density; 3) 50% of normal density; 4) 25% of normal density; 5) a sequential arrangement of alternating 25% and 75% densities; and 6) a sequential arrangement of alternating 75% and 25% densities.
- C25947LL, a MG 5 soybean variety, was planted in early May each year.
- To offset the high cost of seed when using greater crop plant densities to suppress weeds, the authors developed a model to optimize seeding rate so that higher seeding rates are used only in field areas where targeted weeds are present, and lower seeding rates are used in field areas where there will be little or no weed interference.
- The results from this study were used to develop a model that can be used to optimize seeding rate in field areas

devoted to high and low seeding rates without increasing the cost of seed.

- The authors concluded that using their developed model for seeding rate optimization would allow the use of VRS on a large scale–i.e. in field-scale plantings–to benefit weed suppression while minimizing seed costs.
- The optimization model allows growers to adopt variable rate planting to increase seeding rate in areas with a dense population of weeds, and decrease seeding rate in areas that are nearly or completely weed-free.
- Soybean's ability to compensate for variable population density made the VRS a non-factor in the crop's sensitivity to yield differences among the seeding rate schemes used in this study.
- Further research is needed to determine which, if any, problematic weed species in soybean are significantly susceptible to suppression by this approach that uses VRS to aid in weed control.

An article titled "The art and science of variable rate seeding" by Hawkins and Singh provides the following points that should be considered before applying VRS technology to a field.

- When using yield history of field areas to optimize VRS, it is important to use multiple years of data. Also, 1) accurate yield data are critical when using it to optimize VRS in a field, and 2) relatively stable yield responses over time are ideal.
- For soybeans, seeding rates are usually decreased in high productivity field areas, and increased in field areas with a history of low productivity.
- When using VRS, it is imperative that seeding rate prescriptions are validated over time to ensure that they are in fact accurate for the areas where they are used.
- Use check strips in fields where VRS is used to compare the prescribed seeding rates to the seeding rate that is used as a standard practice. This should lead to seeding rate adjustments that may be needed to maximize returns to the VRS practice.

An article titled "Variable Seeding Rate for Soybean" by Laura Lindsey provides the following points that should be considered before using VRS technology.

- Most new planters are capable of VRS.
- For VRS to be successful, relatively uniform management zones within a field must be identified so that a valid "prescription" seeding rate for each zone can be determined.
- Creating field management zones based on a soil map is likely inaccurate for VRS purposes. Rather, creating management zones based on soil properties that are listed above is likely more accurate.
- The variables that are used to identify uniform management zones within a field will be specific for each individual field.

An article titled "Interactive soybean variable-rate seeding simulator for farmers" by Correndo et al. [Agron. J. 2022;114:3554-3565] provides details about an online tool that can help soybean producers optimize seeding rates. Pertinent points from that article follow.

- The Soybean Variable-Rate Seeding Simulator was developed because adjusting seeding rates based on potential yield from management zone(s) within a field can significantly lower seed costs.
- The simulator is a publicly available interactive web-based tool that is designed to enhance VRS decisions. It uses a farmer's own field data.
- The simulator uses inputs such as historical soybean yield data [3 years minimum], soybean seed cost and grain price, total soybean production costs, and plant survival rate to identify management zones where VRS can be applied by producers.
- The simulator allows users to conduct economic analyses that includes the estimation of associated costs and returns as well as a breakeven analysis of the investment to adopt VRS technology.
- Click on the above link to the paper for the step-by-step process to use this tool.

An article titled "Eight Tips to Follow for Variable-Rate Seeding in Soybeans" by Laurie Bedford appears in Successful Farming magazine, and offers useful tips for using VRS.

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