



Nitrogen Management for Soybean

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Introduction

Soybean is the second most widely produced crop in DE, ranking just behind corn for grain. In 2022, approximately 160,000 acres of soybeans were produced in Delaware with an average yield of 43 bu/ac. Producers seeking to improve yields of soybean and overall profitability may be considering application of supplemental N fertilizers or manures. However, growers should consider both economics and the environment when deciding to apply supplemental N to soybean. The purpose of this publication is to help guide decisions about the application of supplemental N to soybean.

Nitrogen Sources Available to Soybean

The N needs of soybean are quite high due to the higher protein content ($\approx 40\%$) in soybean grain. Soybean N removal in grain is estimated at 138 lb./ac for soybean yielding 40 bu/ac, respectively; this is roughly equivalent to the amount of N removed by 200 bu/ac grain corn. An irrigated soybean crop yielding 70 bu/ac would remove about 242 lb N/ac in the grain. The main sources of N that are available to meet the N needs of soybeans are the atmosphere and the soil. In some cases, commercial fertilizers and/or manure may also be used to meet N needs of soybean.

Soybeans are a legume and are able to obtain N from the atmosphere because they form a symbiotic relationship with N fixing bacteria called *Bradyrhizobium japonicum*. These N fixing bacteria colonize the roots of the soybean plant forming nodules. Within these nodules, the bacteria are able to convert (or fix) N_2 gas from the atmosphere to ammonium (NH_4^+), which is a plant-available form. The relationship is considered to be symbiotic because the soybean plant provides a food source (carbon) for the bacteria and the bacteria provide N to the soybean plant. Maximum N_2 fixation potential

by soybean is estimated to be 300 lb/ac under ideal environmental conditions (e.g., adequate soil, soil moisture, fertility, and sunlight; no compaction in root zone; etc.).

Soybean can also obtain inorganic N from the soil in the plant available forms of NH_4^+ or nitrate (NO_3^-). Some plant available N may be residual in the soil, meaning it was left over from fertilization of previous crops or breakdown of crop residues and residual manure applications. Soil organic matter is also a source of plant available N. When organic matter is broken down by soil microbes, the organic N is converted to NH_4^+ via a process called mineralization. Maximum soil N mineralization is estimated at 100 lb/ac, with less mineralization expected in the lower organic matter soils that are typical of Delaware.

Historically, application of commercial fertilizers and/or manures to soybean was not recommended because N_2 fixation and soil N should be adequate to meet the N needs of soybean crops. However, due to genetics, expansion of irrigation, and other factors, soybean yields in Delaware are increasing. There is some evidence that high-yielding soybeans (>60 to 80 bu/ac) may benefit from supplemental N applications because N_2 fixation and soil N may not be adequate to meet crop needs at high yields (Figure 1).

Potential Consequences of Supplemental N Application to Soybean

There is definitive recommendation about whether or not to apply N fertilizers or manure to a soybean crop. However, there are situations when application of supplemental N to soybean is NOT recommended because it can limit yield, waste money, or have a negative impact on the environment.

Early season applications of manure or commercial N fertilizer to soybean should be avoided because

application of supplemental N can delay or reduce overall nodulation, or limit the activity of the nodules. When supplemental N is applied to soybean, the plants essentially “get lazy” because it is easier to take up the supplemental N than it is to establish a symbiotic relationship with soil microbes.

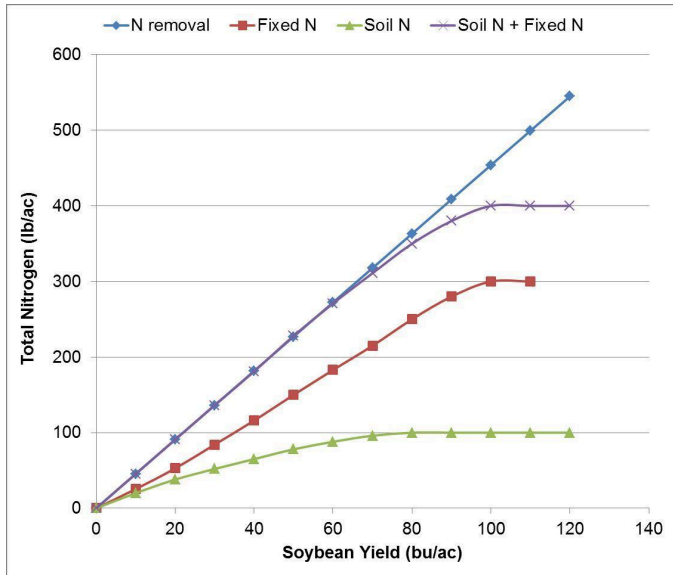


Figure 1. Conceptualized N budget for soybean is based on grain N uptake (grain removal + stover removal), maximum soil N mineralization of 100 lb/ac and maximum N fixation of 300 lb/ac. Note that soil N + fixed N should meet crop N needs for grain yields >70 bu/ac (Adapted from Salvagiotti et al., 2008).

For example, nodulation of soybean planted at the Carvel Research and Education Center in Georgetown, DE in 2014 was greatly reduced when fertilized at planting with N (as urea fertilizer) at 100 lb/ac compared to plants receiving no supplemental N (Figure 2). Nitrogen fixation by soybean decreases exponentially as N application rate increases, such that application of 45 lb/ac N can lead to a 40% or greater reduction in N fixation over the maximum achievable N fixation when no supplemental N is applied. Applications of N at higher rates can further reduce N fixation. If nodules do develop in the presence of supplemental N, it is possible that those nodules will be inactive and will not fix N (Figure 3). If supplemental N and soil N pools are not sufficient to supply the entire amount of N needed for optimum yield, nodulation or reactivation of existing nodules may be delayed and the plant will be unable to fix enough N to support maximum growth when the demand for N peaks during pod development. If plants are N deficient at the time of pod set/seed fill, a significant loss of yield may occur.



Figure 2. Comparison of soybean nodule development on unfertilized plants (upper) and plants fertilized with urea at an N rate of 100 lb/ac. Photo credit: Shawn Tingle, University of Delaware.

While application of supplemental N might not reduce yield in all situations, it will often result in wasted money. In addition, some forms of N are easily lost to the environment in runoff or leachate. Application of supplemental N to soybean may increase the risk for N losses, which may have negative impacts on water quality. Application of supplemental N should be avoided under the following situations because the economic and environmental risks are increased:

- Non-irrigated soybeans – Water will likely be more limiting than N (or any other nutrient). Expected yield is <60-70 bu/ac – There is

probably enough N available in the soil and via fixation.

- Soybeans have matured past R6 (full seed stage) – The N requirement of soybean is greatly reduced and supplemental N applications past this point are wasteful.
- Fields with a history of soybean cyst nematode – Yield will be more limited by the impact of nematode feeding than N.
- Fields that have not had soybean for a long time (or ever) – Skip the commercial or manure N and apply a good inoculant.



Figure 3. Soybean nodules with a pink color are actively fixing atmospheric N. Soybean nodules with a green or milky-white color are inactive. Photo credit: Richard Taylor, University of Delaware.

Suggestions for Getting Maximum Benefit from Supplemental N Application to Soybean

Application of supplemental N might provide a yield benefit for irrigated high-yield soybean, but only in cases where expected yields are 60-70 bu/ac or higher. If yields are consistently lower than 60 bu/ac, skip the N and apply a good inoculant instead. Growers consistently exceeding 70 bu/ac yield on

irrigated soybean should consider the following when considering applications of supplemental N:

- Keep rates low. Research suggests yield bumps were greatest (when yield increases were noted) when N applications were <30 lb/ac. If applying N pre-plant or early season, consider methods of application that won't interfere with nodulation (e.g., deep placement of slow- or controlled-release fertilizers).
- Apply N in season between growth stages R2 and R4 to provide N just before pod set, when N uptake is most rapid. However, applications of N at R2 to R4 must be done to minimize damage to the soybean plant since any injury impacts nodule efficiency. Application of N through the irrigation system can prevent equipment damage to the standing crop.
- Consider application of B at a rate of 0.5 lb/ac in addition to N since some researchers showed a yield benefit of B application.
- If possible, save manure for corn. The soybean crop should still benefit from residual manure N/soil organic matter benefits of the manure. If you must apply manure, keep the rates very low. On average in Delaware, pre-plant application of 2 tons/ac of poultry litter will supply 114 lb/ac of total N (approximately 68 lb plant available N), which exceeds the rate at which N fixation can be impacted. Trials at UD showed beans receiving manure sometimes ran out of mineralizable N at the beginning of flowering; the delay before nodulation and N fixation can occur can lead to significant yield reductions.

Inoculation of Soybean To Improve Yields

In many cases, growers will see more yield benefit from applying one of the new improved strains of Bradyrhizobia inoculant than they would from applying supplemental N. Growers should consider applying one of the new high efficiency strains of Bradyrhizobia to the seed every second or third time soybeans are planted. Many soybean yield trial winners report that they apply fresh inoculum to every soybean crop planted. With the new liquid inoculants, the time and expense of applying soybean

inoculant is much less than that experienced in the past. Many of the soybean fields in Delaware were found to contain strains of Bradyrhizobia that were either very inefficient at fixing N or actually produced toxins that could reduce soybean yield according to results of a past Delaware Soybean Board project. When using an inoculant, it is important to take care when also applying seed treatments because some seed treatments (particularly fungicides) may result in reduced inoculant efficiency.

Summary

Soybeans are leguminous plants that are able to fix atmospheric N. In general, fixed N and soil N should be adequate to meet the N requirements of soybean. Growers are unlikely to see yield increases when applying supplemental fertilizer or manure N to soybean, except in the case of high-yielding, irrigated soybeans. In fact, application of supplemental N to soybeans is more likely to result in wasted money and increased risk to the environment. Under some circumstances, application of supplemental N could also reduce yields leading to an economic loss to the farmer. In most cases, application of a good inoculant will be more beneficial than applications of commercial N fertilizer or manure. Growers should consider applications of supplemental N only when yield of irrigated soybean consistently exceeds 60 bu/ac.

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