Nitrogen Management For Soybeans a Must

Economics and environment are two essentials.

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Summary: *Summary: Growers are unlikely to see yield increases when applying supplemental fertilizer or manure N to soybeans, except in the case of high-yielding irrigated soybeans. Growers should consider applications of supplemental N only when yield of irrigated soybeans consistently exceeds 60 bu/A.*

Soybeans are the second most widely produced crop in Delaware, ranking just behind corn for grain in 2012. Approximately 168,000 acres of soybeans were produced in Delaware with an average yield of 42.5 bu/A. Producers seeding to improve yields of soybeans and overall profitability may be considering application of supplemental N fertilizer or manures. However, growers should consider both economics and the environment when deciding to apply supplemental N to soybeans. The purpose of this article is to help guide decisions about application of supplemental N to soybeans.

Nitrogen sources

The N needs of soybeans are quite high due to the higher protein content (= 40%) in soybean grain. Soybean N removal in grain is estimated at 138 lbs/A for soybeans yielding 40 bu/A, respectively. This is roughly equivalent to the amount of N removed by 200 bu/A grain corn. An irrigated soybean crop yielding 70 bu/A would remove about 242 lbs N/A 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 soybeans.

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) N2 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 bacteria and the bacteria provide N to the soybean plant. Maximum N2 fixation potential by the soybean is estimated to be 300 lbs/A under ideal environmental conditions (e.g., adequate soil, soil moisture, fertility, and sunlight; no compaction in root zone, etc.).

Inorganic N

Soybeans can also obtain inorganic N from the soil in the plant-available forms of ammonium (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 a 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 lbs/A, with less mineralization expected in lower organic matter soils.

Supplemental N

Historically, application of commercial fertilizers and/or manures to soybeans was not recommended because N2 fixation and soil N was considered to be adequate to meet the N needs of soybean crops. However, due to improved genetics, expansion of irrigation, better weed control, and other production factors, soybean yields in many areas are increasing. There is some evidence that high-yielding soybeans (>60 to 80 bu/A) may benefit from supplemental N applications because N2 fixation and soil N may not be adequate to meet crop needs at high yields (Figure 1).

Potential consequences

There is no cut and dry 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 soybeans is NOT recommended because it can limit yield, waste money, or have a negative impact on the environment:

- Early-season application of manure and/or commercial N because of potential delayed and reduced nodulation and reduced activity of the nodule bacteria.
- When supplemental N is applied to soybeans, 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. For example, nodulation of soybeans planted at the Carvel Research and Education Center in Georgetown DE in 2014 was greatly reduced when fertilizer at planting with N (as urea fertilizer) at 100 lbs/A, compared to plants receiving no supplemental N (Figure 2).
- Nitrogen fixation by a soybean decreases exponentially as N

application rate increases, such that application of 45 lbs/A 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 modules 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. Research has indicated that supplemental N is most effective when applied near the R3 stage of plant development.

Other risks

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 of leachate. Application of supplemental N to soybeans may increase the rise 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/A: there is probably enough N available in the soil and via fixation.
- Soybeans have matured past R6 (full feed stage). The N requirement of soybeans is greatly reduced and supplemental N applications past this point are wasteful.
- Fields with a history of soybean cyst nematode: yields will be more limited by the impact of nematode feeding than N.
- Fields that have not produced soybeans for a long time (or ever). Skip the commercial or manure N and apply a good inoculant.

Maximum benefit

Application of supplemental N may provide a yield benefit for high-yield soybeans, but only in cases where expected yields are 60 to 70 bu/A or higher. If yields are consistently lower than 60 bu/A, skip the N and apply a good inoculant instead. Growers consistently exceeding 70 bu/A yield on irrigated soybeans should consider the following when considering applications of supplemental N:

- Research suggests yield increases were greatest (when yield increase were noted) when N applications were <30 lbs/A. If applying N preplant or early season, use methods of application that won't interfere with nodulation (e.g. deep placement of ammoniacal, 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

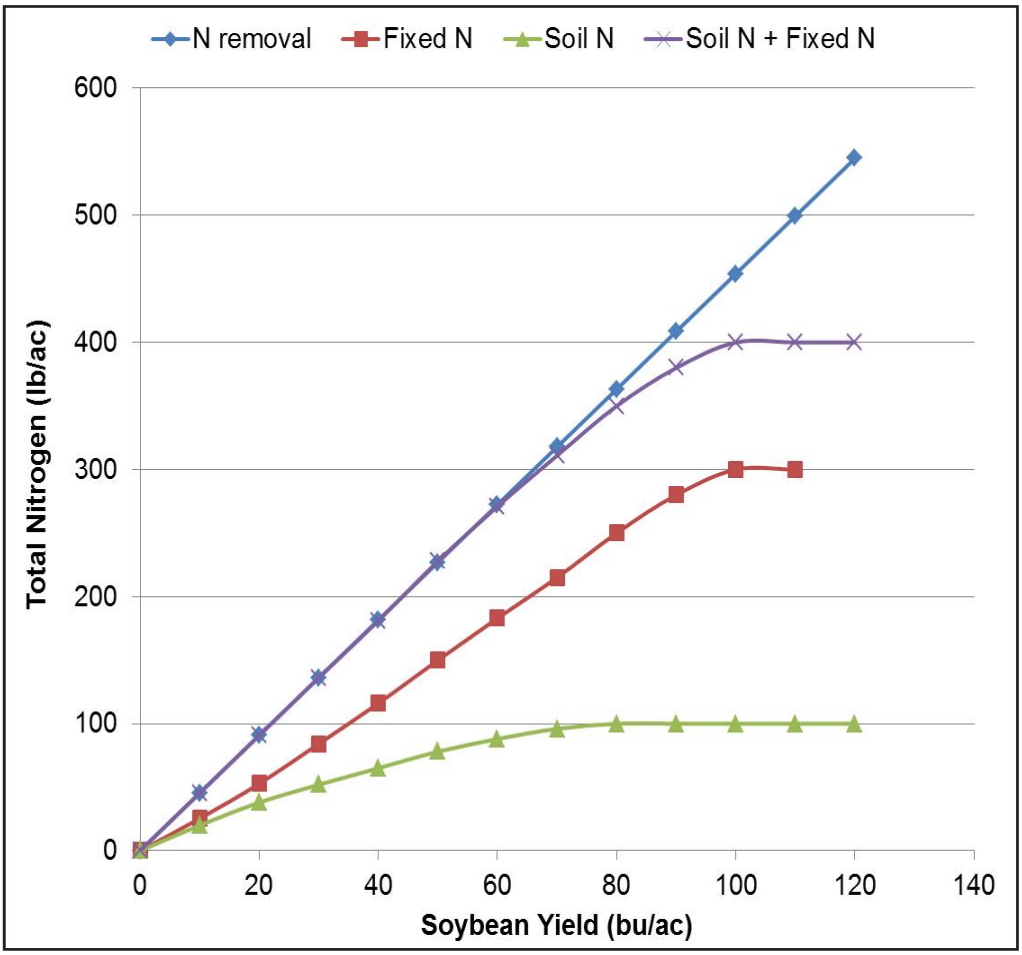

Figure 1. Conceptualized N budget for soybean is based on grain N uptake (grain removal + stover removal), maximum soil N mineralization of 100 lb/ac and maximum N fixation of 300 lb/ac. Note that soil N + fixed N should meet crop N needs for grain yeld.

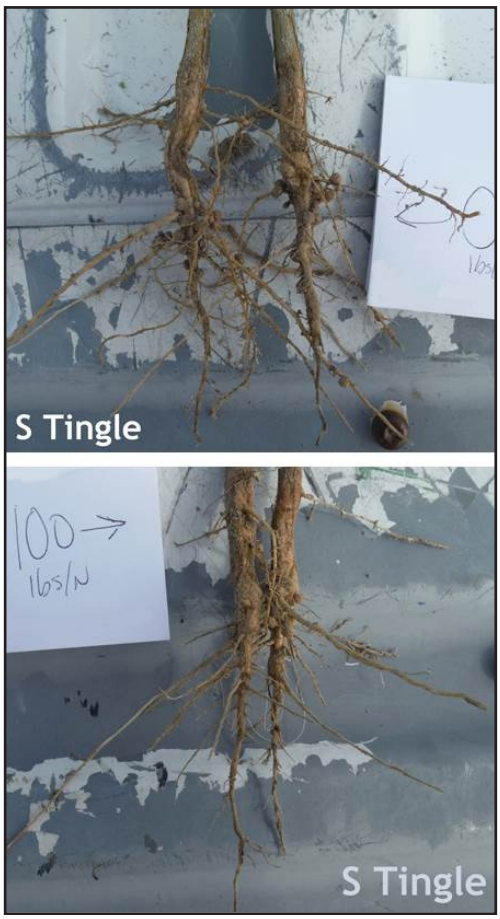

Figure 2. Comparison of soybean nodule development on unfertilized plants (upper) and plants fertilized with urea at N rate of 100 lb/ac. Photo credit: Shawn Tingle, University of Delaware.

any injury impacts module efficiency. Application of N through the irrigation system can prevent equipment damage to the standing crop.

- Consider application of B at a rate of 0.05 lb/A 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, pre-plant application of 2 tons/A of poultry litter will supply about 114 lbs/A of total N (approximately 68 lbs plant-available N), which exceeds the rate at which N fixation can be impacted. Delaware trials showed that beans receiving manure sometimes ran out of mineralizable N at the beginning of flowering, which can delay before nodulation and N fixation and lead to significant yield reductions.

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.

Inoculation

In moderate yield scenarios, 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 a Delaware Soybean Board project many years ago.

Summing up

Soybeans are leguminous plants that are able to fix atmospheric N. Seed inoculation with one of the new improved strains of Bradyrhizobia inoculant is recommended. In general, fixed N and soil N should be adequate to meet the N requirements of soybeans. Growers are unlikely to see yield increases from late-season (R3) supplemental fertilizer N in situations where yields are likely to exceed 60 bu/A. In production scenarios where yields are likely to be less than 60 bu/A, application of supplemental N is more likely to result in unnecessary expense and increased environmental impact.

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