Nitrogen Fertilizer for Soybean?

Soybean has high protein content, which is rich in N, so its needs for N are high. Fortunately, N-fixation and uptake of residual and mineralized N from the soil are usually sufficient to supply most of the N needs of a soybean crop. However, some soil fertility recommendations are now suggesting that N fertilizer applications may be needed at very high soybean yield levels. This article discusses the N needs of today's higher yielding soybean crops, sources of N supply to the crop and whether N fertilizer applications may be needed for maximum soybean yields.

Nitrogen Demands of a Soybean Crop

Soybean is high in protein, so its needs for N are high.

When soybean is harvested, a large amount of N is removed from the field. This is because soybean grain has very high protein content (~40% or more on a dry weight basis), and protein contains about 16% N. For example, 60 bu of soybean contains ~210 lb N in the grain and ~80 lb N in the above-ground plant tissues, totaling ~290 lb N (Salvagiotti et al., 2008). This is more N than a high-yielding corn crop requires – 200 bu of corn contains about 270 lb N in the above-ground plant portion. The important question is: "How much of this can come from N fixation and how much can come from the soil?"

Sources of Nitrogen for a Soybean Crop

Unfertilized soybean receives its N from only two sources: N fixation and soil N (Figure 1). A recent review of scientific papers compared the N demand of high-yielding soybean to the capacity of soybean to fix N from the air and obtain it from the soil (Salvagiotti et al., 2008). Because N concentration in soybean seed is fairly constant, N plant uptake from fixation and soil sources increases proportionally to grain yield (Figure 1).

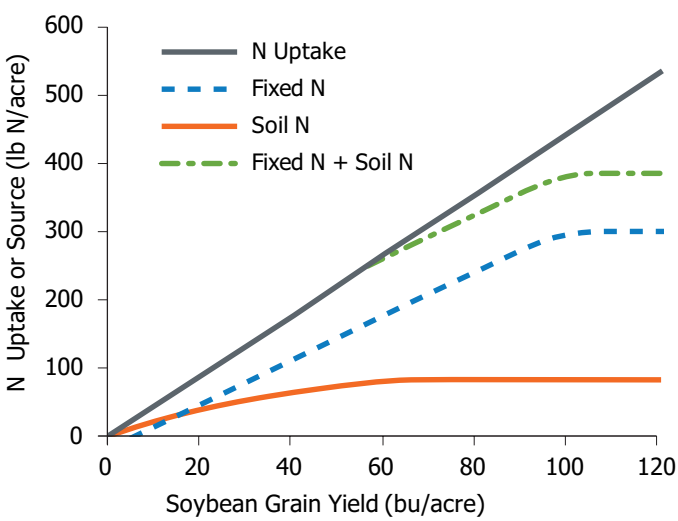

Figure 1. A generalized N budget for soybean. Adapted from Salvagiotti et al., 2008.

N-fixing nodules on soybean roots.

As Figure 1 indicates, average N fixed by soybean increases linearly with increasing yield, but only a portion of the total N requirement is met through N fixation (about 50 to 60% of the total N requirement at yields of 50 bu/acre or less). Based on the average of the 100+ studies represented in Figure 1, at a yield level of 60 bu/acre, fixed N provides about 180 lb of the 270 lb N uptake in soybean, or 65 to 70% of the total required N. For yields up to 60 bu/acre, the difference between total N uptake (i.e., plant requirement) and fixed N is usually provided by soil sources.

The N budget also illustrates that there may be a small N deficit for yields between 60 and 80 bu/acre, which means that yield could be restricted because of too little N. Realistically, conditions that are favorable for top soybean yields are usually conducive to high soil mineralization as well, so N would not always be limiting in this range. However, these studies clearly show that there are upper limits to the amount of N supplied by fixation (about 300 lb/acre) and soil sources (about 85 lb/acre). As yields increase above 80 bu/acre, it is clear that total N needs of the soybean crop will not be met by soil and fixation, and yield-limiting N shortfalls may occur without addition of N.

The Challenge of Applying N Fertilizer to Soybean

Recommendations vary regarding when, where and how N should be applied (if at all) in soybean production. Some indicate that soils with low organic matter, which mineralize less N, may potentially respond to N fertilizer. Others indicate that N fertilizer applied in the zone of N fixation (near the surface in the root zone) will inhibit N fixation, and the benefit of the additional N fertilizer is offset by less fixed N (see next page for more discussion of this). Regarding N timing, some say to apply N before flowering, while others indicate to apply during pod fill when the plant's demands for N are greatest.

In fact, there is neither clear proof from the scientific literature nor consistent anecdotal evidence to predict the conditions leading to a soybean response to fertilizer N. In addition, scientists have not yet been able to identify precisely when soybean will respond to N fertilizer and therefore, when to apply it. However, understanding more about a soybean plant's variable needs for N throughout its life cycle can provide some guidance for application timing. Nitrogen demand by soybean is illustrated in Figure 2.

Application at Early Reproductive Stages? At about 60 days after planting, or about the R4 growth stage, soybean begins to move N from the vegetative parts of the plant to the grain. This might suggest that the best time to apply additional N is prior to R4 (during the early reproductive growth stages) so that fertilizer N is readily available to the plant by R4. If this applied N could delay or minimize the shift of N from the vegetative parts to the seed, it may prolong the duration when the plant remains green and is moving carbohydrates to the seed and therefore, may increase overall grain yield.

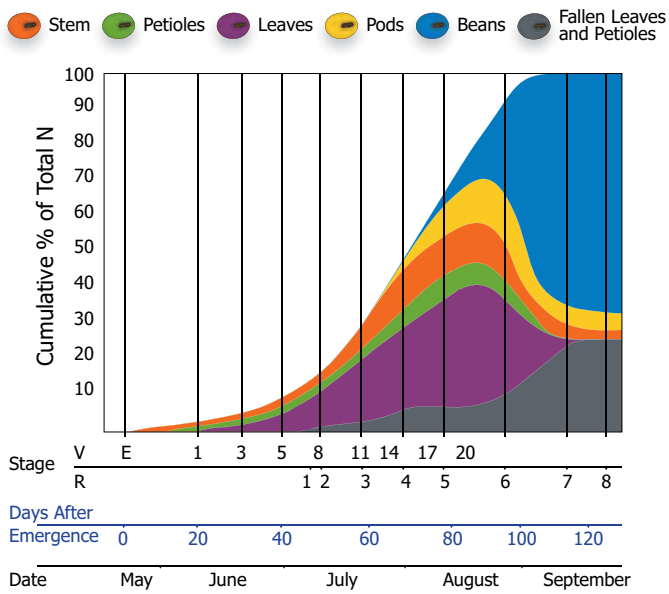

Figure 2. Nitrogen uptake of soybean by growth stage and date for various above-ground plant tissues. Adapted from Ritchie et al., 1982.

Although an N fertilizer application during early reproductive growth stages is during a period of great demand by soybean, it is not known if the N applied would be additive to the N fixed by the plant. Conversely, it could decrease N fixation by some amount, even up to the total quantity of N applied, thus resulting in a zero net gain in available N to soybean.

N Fixation Reduced by Soil Nitrate - Research on N fixation in the presence of soil nitrate is consistent: N fixation by soybean is inhibited in the presence of elevated levels of soil nitrate (NO_3^-). This means that when N fertilizer is applied, soybean simply fixes less N. From a physiological perspective, this makes sense because the process of initiating the symbiotic relationship with rhizobia is energy-demanding. If soybean can avoid the additional "expense" of fixing N by obtaining inorganic N already present in the soil, it will forego, or at least postpone, N fixation. Because all N fertilizers ultimately change to the nitrate form in the soil, this limitation applies to all N-containing fertilizers.

How might N fertilizer be applied to soybean without adversely affecting N fixation? An approach taken in a Nebraska study was to apply slow release N fertilizer (polymer coated) eight inches below the soil surface midway between the rows (Salvagiotti et al., 2009). The placement was intended to avoid or minimize the reduction of N fixation by putting the N fertilizer below the zone where most N fixation occurs. Results showed that this treatment was successful in not reducing the amount of N fixed by the soybean.

Conclusions

Research studies have not consistently identified the conditions for yield increases from supplemental N applications. However, the N budget shown in Figure 1, which was derived from a summary of over 100 research studies, may represent the best estimate of N supply from soil and N-fixation sources and resulting sufficiency or need in soybean production. The budget indicates that a yield-limiting N deficit may exist as yields increase above 60 to 80 bu/acre.

Nitrogen needs that are unmet by the combination of N mineralization by the soil and N fixation by the plant can be supplied by other sources, such as N fertilizer or manure. These supplemental N amounts to meet crop demands are shown below for various soybean yield levels.[1,2] These are based on the potential N deficit (difference between N supply and crop needs) shown in Figure 1 for soybean yields above 60 bu/acre.

Nitrogen Needs[1,2] of Soybean Based on N Budget Shown in Figure 1

50 to 60 bu/acre soybean yields - Additional N is likely not needed, except perhaps in soils with very low inherent N mineralization.[1,2]

60 to 80 bu/acre soybean yields - 0 to 30 lbs/acre additional N may be needed to reach this yield level.[1,2] In soils with high mineralization capability, N may be sufficient.

80 to 100 bu/acre soybean yields - 30 to 60 lbs/acre additional N may be needed to reach this yield level.[1,2]

100 bu/acre and higher soybean yields - More than 60 lbs/acre additional N may be needed to reach this yield level.[1,2]

[1] These N needs are only approximations based on the N budget shown in Figure 1. Soybean fields are subject to a wide variety of environmental effects, including climatic, disease and insect pressures. Mineralization of N by soils and soybean N fixation is affected by soil moisture, temperature and other factors that vary within season and from season to season. Consequently, soybean needs for fertilizer sources of N are variable and difficult to predict. Individual results may vary.

[2] In soils with low mineralization capacity (soils with low organic matter), an additional 20 lbs N/acre may be needed.

Even if soybean needs for supplemental N are identified, the question of cost-effectiveness of applications remains. That question will only be answered over time with broad-based research studies and side-by-side comparisons in growers' fields. With that in mind, the best approach to determine if supplemental N is required for your high-yielding soybean field may be to simply try a low rate of N in alternate strips on a few acres and adjust future trial rates based on year-to-year results.

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