NITROGEN FERTILIZER FOR SOYBEANS

There is the theory that nitrogen [N] fixation and soil residual N may not supply enough N for soybeans to maximize seed yield, especially during reproductive development when they are grown in high-yield environments.

Nebraska scientists, in a 2008 review of the results from a large number of studies conducted over a wide range of locations and a high-yi eld study conducted in Nebraska, reported the following.

- Soybeans produced an average of 12.7 lb of seed per lb of N uptake. Thus, a soybean crop that yields 75 bu/acre assimilates an average of about 355 lb of N in the aboveground portion of the plant. This translates to an average of about 4.75 lb of N assimilated per bushel of seed produced.
- The concentration of N in soybean seed averaged 6.34%, or 3.3 lb [dry weight basis] of N/bu of seed produced. Thus, a 60 bu/acre seed yield will remove about 200 lb of N/acre from a field site, while an 80 bu/acre seed yield will remove about 265 lb of N/acre. The N that is in the vegetative portion of the plant is assumed to stay on the field.
- N_2 fixation accounted for an average of 50–60% of the N in soybeans, with the remainder coming from nitrate and ammonium N in the soil.
- The proportion of fixed N decreased with the addition of fertilizer N. Thus, they are not additive in their effect on yield. In fact, the decline in N_2 fixation with N fertilizer addition is exponential—e.g. if 90 and 270 lb N/acre [3x increase] are applied as fertilizer in the upper 20 cm of soil or on the soil surface, maximum N_2 fixation would be expected to be 115 and 15 lb N/acre [7.5x decline], respectively.
- The maximum amount of N_2 that can be fixed was considered to be 300 lb/acre in the absence of N fertilizer. Using the above 4.75 lb of N assimilated per bu of soybean seed produced gives a maximum potential yield of about 63 bu/acre from fixed N alone.
- In a high-yield experiment in Nebraska, a 74.4 bu/acre average seed yield removed an average of 246 lb N/acre in the seed on a dry weight basis from the field site, or an average of 3.3 lb of N removed with each bushel of seed. This compares to the removal of 138 lb N/acre with an average yield of 40 bu/acre in the cited studies, or an average of 3.45 lb N removed with each bushel of seed. These values are similar.
- The average yield increase from the addition of N fertilizer in the cited studies was 7.7 bu/acre, and did not differ among N rate categories of < 45 lb/acre, 45–90 lb/acre, and > 90 lb/acre.

Research in several states has been and is being conducted to address the following scenarios.

N fertilizer applied to replace fixed N

A study in Mississippi evaluated applying a high rate of N fertilizer (>260 lb N/acre) that was deemed sufficient to replace or supplant N fixation. Yields were increased by 4.8 and 6.5 bu/acre above those obtained from soybeans receiving no N fertilizer in irrigated and nonirrigated studies, respectively. However, the increases were not profitable. These results indicate that N fixation is not sufficient to maximize seed yield, but replacing fixed N with N fertilizer is unprofitable. Results from a 2015-2017 study in eastern Kansas produced similar results, thus affirming that adding N fertilizer to replace N fixation in soybean is not profitable.

Results from a study conducted in 2014-2015 at Stoneville, MS determined the following.

- Soybean yield was significantly increased by adding N to both low- and high-CEC soils, but the increases were small [4.3-8.6 %] and likely were not economical.

- Addition of N to soil in greenhouse studies had no positive effect on soybean root growth parameters.
- Addition of N to soil in greenhouse studies resulted in large and significant reductions in number of nodules present on soybean roots.

Starter N fertilizer

Normal-time (April-May) plantings

Research in Mississippi [30 lb N/acre] and Missouri [25 lb N/acre] showed that starter N fertilizer either provided no yield increase or an increase that did not cover the cost of the fertilizer [this research was conducted before high soybean commodity price]. Thus, net returns were lowered in all cases.

Late plantings (June and July)

- In two Alabama studies, starter N fertilizer [~45 lb N/acre] was applied to soybeans planted at a time that mimics those planted as a doublecrop in the midsouthern U.S. All sites had low residual soil N [generally less than 50 to 70 lb N/acre]. Yield increases of ~2.2 bu/acre in one study did not increase profits, whereas yield increases of ~7.5 bu/acre in a second study increased profits over $30/acre [$6/bu commodity price and $0.40/lb N cost].
- The Kansas Soybean Production Handbook states that soybeans planted into large amounts of wheat straw may respond to small amounts [10 to 20 lb N/acre] of starter N fertilizer because soil N is temporarily immobilized by soil microorganisms decomposing the wheat straw.

N fertilizer applied during reproductive [R3 to R4] development

- Results from irrigated Delaware studies that included both full-season and doublecropped soybeans showed that the application of N fertilizer at rates of 25 and 50 lb N/acre from R2 to R4 did not increase yield.
- Results from Kansas [irrigated] and Missouri [some irrigated] studies show mixed results from this practice. Results from Missouri [25 lb N/acre] showed no yield increase and thus decreased profits. The Kansas (20 lb N/acre) results showed an average yield increase of 7 bu/acre (~12% yield increase) where yields ranged from 56 to 83 bu/acre. Most of the Kansas study sites had low residual soil N.
- Results from Minnesota [75 lb N/acre] studies showed that in-season N fertilizer applied from R2 to R4 did not improve seed yield compared to unfertilized plots. Most of the Minnesota study sites had >3% organic matter.
- Results from an Iowa study [organic matter >3.5%] showed no yield increase from 40 and 80 lb N/acre applied at R3. Yields were >50 bu/acre.
- In an irrigated Illinois study [Ebelhar and Anderson, DSAC], N applied to soybeans at 20 and 40 lb/acre at R3 generally increased yields by no more than 2 bu/acre, and there was no indication to predict if and when yield increases would occur. The authors concluded that the likelihood of a favorable yield response to this practice is low. Also, it is unlikely that this yield increase was or would be profitable.

Summary

- **Soybeans planted in a normal timeframe (April-May) do not respond profitably to application of preplant or "starter" N fertilizer.**
- In late plantings, and especially those following a small grain, applying preplant N fertilizer at <50 lb N/acre **may** increase soybean yields and profits at sites with low residual soil N. **This should be verified each season using current commodity and N prices, plus measured soil N**.
- Producers desiring to maximize yields from irrigated plantings on soils with low residual soil N [< 50 lb/acre] should consider applying 20 to 25 lb N/acre at beginning podset to ensure that N deficiency does not limit yields on these high-yield [> 55 bu/acre] sites. A key

point with this option is to irrigate following surface N fertilizer application to ensure immediate uptake.

Additional points

- Adding starter [early-season] N fertilizer to soybeans may delay or impede nodulation, and thus can delay the onset of N fixation that normally would have occurred in the absence of the starter N.
- Results from a Nebraska study provide evidence that adding N fertilizer to soybeans before planting may be beneficial in high yield environments if the N is placed in the soil below the nodulation zone, or deeper than about 8 inches. This will significantly mitigate the N fertilizer-induced reduction in bacterial N fixation compared to that resulting from N applied on the soil surface or in the nodulation zone.
- Soybean plants growing under moisture deficit conditions may appear N-deficient, but in fact the lack of water has suppressed N fixation and this will not be remedied by application of N fertilizer.
- It is not possible to predict soybean response to N fertilizer based on soil properties. However, situations with positive responses generally have either very low residual soil N, low N mineralization capability, no or a low population of N-fixing bacteria, or soil pH so low that it inhibits nodulation and N fixation. As stated above, a measure of residual soil N is necessary for making a truly informed decision about adding N to soybeans.
- One of the environmental strong points of growing any legume crop is not having to add supplemental N fertilizer. Therefore, this should be considered if and when this practice is found to be a key point in reaching a higher soybean yield plateau since loss of N from cropland is a significant concern in USDA-NRCS's conservation practice standard for nutrient management.

FINAL THOUGHTS

All of the above cited results indicate that the likelihood of a favorable yield response to the application of N fertilizer to soybeans in any environment or at any time during the growing season is low at best, and is neither predictable nor profitable.

The only potential cases for applying N to soybeans appears to be 1) in high-yield environments where N uptake during seed fill may be limited due to the late-season decline in biological N fixation and a concurrent lowered soil N, and 2) in fields where native inoculum is absent and/or there are not sufficient N-fixing bacteria to supply the plant's needs beyond that obtained from residual soil N. In this second case, applying *Rhizobium* inoculum at or soon after planting is a much cheaper option to remedy this suspected or expected problem.

All of the above results should be evaluated each year using current commodity and N prices. However, there will only be the rarest of cases where supplemental N applied at any time will produce an economical soybean seed yield increase.

CONCLUSION

IN THE VAST MAJORITY OF CASES, ADDING SUPPLEMENTAL NITROGEN TO SOYBEANS AT ANY TIME WILL LOWER NET RETURNS.

MAY 2023 UPDATE

Click here for an article that provides information about nodules and nodulation, and their relationship to the N health of the soybean plant.

SEP 2024 UPDATE

An article titled "Soybean response to nitrogen fertilizer in different soils" by Vonk, Nafziger, and Fontes appears in the Crop Forage & Turfgrass Mgmt.

online journal. A summary of the conduct of and results from the research reported in this article follow.

- The research involved conducting nine field experiments in Illinois during 2014-2017. Soybeans were planted in May at all locations in all years.
- Urea N fertilizer was broadcast on the soil surface at planting, R1, R3, or R5, and at all four times.
- Over the range of soil types and environments in this study, there was rarely an increase in soybean yield as a result of N application.
- In the few cases where soybean yield was increased by the addition of N fertilizer, the yield increases were not sufficient to cover N fertilizer costs.
- The authors concluded that the addition of N fertilizer at planting might be advantageous on fields that support limited early-season growth.
- **The results from this research support the findings from other research cited above–i.e. adding N fertilizer to soybeans is not economical even if yield increases result from the practice.**

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