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7-3-2008

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Recommended Citation
Mallarino, Antonio P., "What About Foliar Fertilization for Soybean This Year?" (2008). *Integrated Crop Management News*. 807.
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Abstract
This year soybean was planted late or replanted in many fields due to excess rainfall and late spring temperatures were colder than normal. Therefore, some producers wonder if foliar fertilization could help improve soybean growth and grain yield. The short answer is that it may, but probably not in fields that have been well fertilized or where growth is limited by factors other than nutrient supply. This short article reviews major issues involved, provides a brief summary of many studies conducted in Iowa during the last few years, and provides some recommendations.

Keywords
Agronomy

Disciplines
Agricultural Science | Agriculture | Agronomy and Crop Sciences

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What About Foliar Fertilization for Soybean This Year?

By Antonio P. Mallarino, Department of Agronomy

This year soybean was planted late or replanted in many fields due to excess rainfall and late spring temperatures were colder than normal. Therefore, some producers wonder if foliar fertilization could help improve soybean growth and grain yield. The short answer is that it may, but probably not in fields that have been well fertilized or where growth is limited by factors other than nutrient supply. This short article reviews major issues involved, provides a brief summary of many studies conducted in Iowa during the last few years, and provides some recommendations.

Foliar Fertilization at Late Reproductive Growth Stages

Prior to the 1990s research had focused on foliar fertilization at late soybean reproductive stages (R4 to R7). There were hundreds of field experiments during the middle 1970s and early 1980s in Iowa and other regions that included nitrogen (N), phosphorus (P), potassium (K), sulfur (S), and other nutrients. The soybean plant has a sharp decline in root activity during late seed development stages with large nutrient translocation from leaves and pods into the developing seed. Researchers theorized that if nutrients were applied to the foliage at this time, leaf senescence and "seed starving" could be alleviated and grain yields would increase. A few early experiments in Iowa suggested that spraying the soybean canopy with a mixture in a ratio 10-2.3-3.6-0.5 N-P_2O_5-K_2O-S between the R5 and R6 growth stages could increase yields by 7 to 8 bu/acre. However, more than 200 subsequent trials in Iowa, the Midwest, and Southern states from the late 1970s to the middle 1980s showed inconsistent results, responses varied from a maximum increase less than 5 bu/acre to a yield decrease up to 6 bu/acre. More recent work in the Midwest under rain-fed conditions showed similar results, and often yield decreases when N sources were sprayed alone or in a mixture. The more positive results were observed under very high yield conditions and irrigation in Kansas. Therefore, these results have discouraged further research and adoption of foliar fertilization of soybean at late reproductive stages.

Foliar Fertilization at Vegetative to Early Reproductive Stages

Small amounts of nutrients sprayed onto soybean foliage at early stages could supplement inadequate pre-plant fertilization and increase nutrient supply at a time when roots and N fixing root nodules are not well developed. Furthermore, foliar fertilization could enhance growth if soil conditions limit nutrient uptake when soil levels are adequate. About 100 replicated field trials were conducted from 1994 until 2006 to evaluate these possibilities by spraying foliar fertilizers with or without mixing it with glyphosate herbicide or a fungicide at the V5 to R3 growth stages. The products tested (not all products were included in all trials) included the low-salt fluid fertilizer 3-18-18 (N-P_2O_5-K_2O) and 10-10-10 (N-P_2O_5-K_2O) both with or without S and with or without the micronutrients boron (B), iron (Fe), and zinc (Zn); and also 8-0-8 (N-P_2O_5-K_2O). Product rates ranged from 2 to 6 gal/acre applied once or

twice (spaced 8 to 10 days). The fields were managed with no-till, ridge-till, or chisel-plow tillage.

Figure 1 summarizes results from 66 trials that compared three sets of six treatments. The majority of fields tested Optimum or higher for P and K according to Iowa State University interpretation class but there were also low-testing soils in some trials. Each graph shows averages across all fields and averages for fields where at least one treatment was statistically different from the control. Foliar fertilization increased yield in 15 to 30 percent of the fields depending on the set and year. The average response to the best treatment (3 gal/acre of 3-18-18), which was common to the three sets of trials, across all trials was 0.7 bu/acre but the average response across the responsive trials was 4.1 bu/acre.

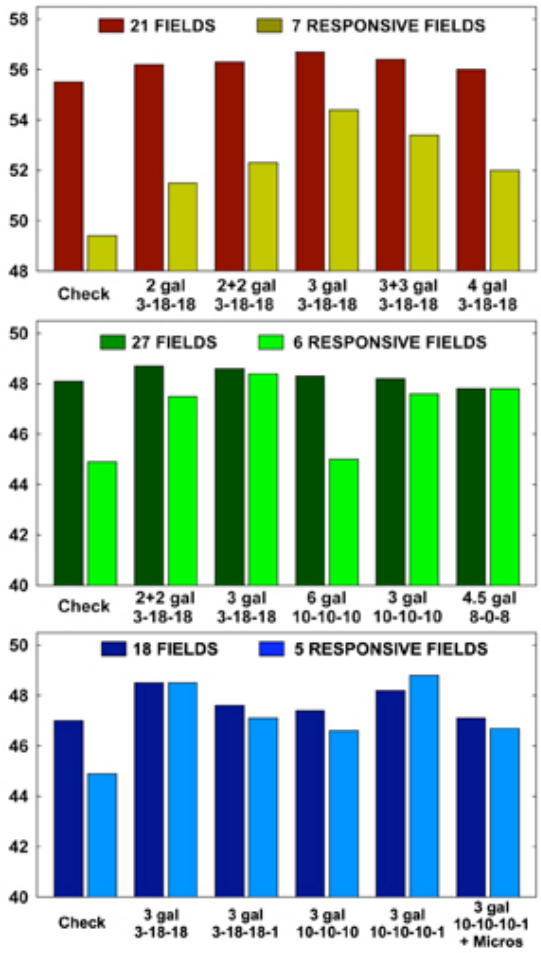

Figure 1. Average soybean grain yield response across three sets of trials to several foliar fertilizers. The different bars represent yield responses across all trials and only the responsive trials for each set of experiments.

Differences between treatments were not consistent across fields but responses tended to be higher for a rate of 3 gal/acre of 3-18-18. Adding S or micronutrients did not produce higher yield. The highest rate of 10-10-10 (with or without S) and 8-0-8 fertilizers reduced yield in a few fields (some leaf burn was observed). Double applications were statistically similar to single applications. Responses were observed in low-testing fields and also in fields testing Optimum or higher.

Reasons for positive responses in fields testing Optimum or higher in P and K were difficult to identify. Complex multivariate statistical analyses were used to understand the relationship between yield response and soil-test values, soil type, tillage system, nutrient uptake at early or late growth stages, rainfall, temperature, planting date, etc. These analyses did not support strong

conclusions but suggested conditions in which a response to foliar fertilization was more likely. In some years, responses were higher and more frequent in ridge-till and no-till fields compared with chisel-plow tillage. In general, the responsive fields had slower early plant growth and P or K uptake than non-responsive fields because of low-testing soil, cool early temperatures, and excessive rainfall. Therefore, conditions that inhibit root growth and/or nutrient uptake early during the growing season (except drought) increase the likelihood of a yield response. Unfortunately there is no simple "absolute yardstick" that can be used to identify these conditions that increase chance of response to foliar fertilization in producers' fields. For example, this project and others could not identify a useful critical or optimal nutrient concentration in young plant tissue.

Twenty-three additional trials were conducted in conventional small-plot trials or replicated strip trials. These were simple comparisons of 3 gal/acre of 3-18-18 to a control because this was the fertilizer and rate most effective in the first 66 trials. The results of these trials showed a response in about 15 percent of the trials. Grain quality analysis of soybean grain showed no effect of foliar fertilization on oil or protein concentrations.

Five field trials were conducted in 2005 and 2006 to study foliar fertilization and fungicide application alone or in a spray mixture. Eight treatments were a non-treated control, four foliar fertilization treatments without fungicide (a single application of 3 gal/acre of 3-18-18 at the V5 and R2 to R3 growth stages, a double 3-18-18 application at V5 and R2 to R3 stages, and 3.3 gal/acre of 28% UAN at the R2 to R3 stages), and three fungicide (Headline®) treatments at the R2 to R3 growth stages (alone and in combination with 3-18-18 or UAN fertilizer). On average the fungicide increased yield by 2.9 bu/acre, although the responses were statistically significant at only three fields. The fungicide delayed leaf senescence at most fields, although disease control by the fungicide was observed only for Brown Spot in three fields. Spraying soybean with 3-18-18 fertilizer did not affect yield at four fields and increased it slightly at one field. Spraying with UAN did not affect yield at two fields, increased it slightly at one field, and decreased it at two fields. The UAN application caused moderate leaf burning and the 3-18-18 application caused very minor or no burning. An important result was that there was no interaction between foliar fertilization and fungicide application at any field. Mixing the two fertilizers used in this project with the fungicide did not cause problems or an additional yield response compared to the products alone.

Recommendations

Foliar fertilization of soybean will not be cost-effective in Iowa when applied across all fields because the expected average response is less than 1 bu/acre. The probability of a larger yield increase is 15 to 20 percent. Except for too high rates of products with high salt content, N, or S that produced leaf burn and sometimes decreased yield, research has shown inconsistent differences between nutrient ratios or frequencies of application. However, a single application of 3 gal/acre of 3-18-18 usually produced the highest and more consistent yield responses. Mixing this fertilizer with glyphosate for early applications or with Headline® fungicide for mid-season applications caused no problems but did not increase the efficacy of either product. The probability of a yield response that offset costs will be increased by targeting fields for spraying. These include fields with low soil nutrient levels due to insufficient pre-plant fertilization and conditions where soil or climate factors limit nutrient uptake in late spring and early summer. Unfortunately these conditions often cannot be easily identified in the field.

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This article was published originally on 7/3/2008 The information contained within the article may or may not be up to date depending on when you are accessing the information.

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Last Updated 7/4/2008