FOLIAR FERTILIZATION OF SOYBEAN WITH NITROGEN, PHOSPHPORUS, AND POTASSIUM: WHERE, WHEN, AND WHY?

Antonio P. Mallarino [1/]

Renewed Interest in Foliar Fertilization of Soybean

Many producers are reducing or skipping preplant fertilization for soybean due to high fertilizer prices, and in 2008 many fields were planted late or replanted due to excess rainfall with colder than normal temperatures. Therefore, producers and crop consultants wonder if foliar-applied fluid fertilizer could improve soybean growth and grain yield. Prior to the 1990s, research in Iowa and the Midwest had focused mainly on foliar fertilization at late soybean reproductive stages (R4 to R7). Hundreds of trials from the 1970s to the middle 1980s included nitrogen (N), phosphorus (P), potassium (K), sulfur (S), and micronutrients treatments. 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 nutrients applied to the foliage at this time could increase yield by delaying leaf senescence and seed starvation. A few early experiments in Iowa suggested that spraying nutrients in the ratio 10-2.3-3.6-0.5 (N-P_2O_5-K_2O-S) between the R5 and R6 growth stages could increase yield by 7 to 8 bu/acre even after preplant fertilization. However, more than 200 subsequent trials in the region showed inconsistent results, with mostly no yield increases and frequent yield decreases. Work mainly during the late 1990s and early 2000s in rain-fed conditions of the Midwest has shown mostly yield decreases when N sources were sprayed at late growth stages. The more positive results were observed under very high yield conditions and irrigation in some starts of the Great Plains region. These results have discouraged further research and adoption of foliar fertilization of soybean at late reproductive stages. Because of concerns about Asian Soybean Rust spreading north and evidence of soybean grain yield response to midseason application of fungicides, however, some producers are considering mixing fluid fertilizers and fungicides for midseason foliar application to soybean.

Therefore, research in Iowa during the last few years has focused on the study of foliar fertilization of soybean at early vegetative stages and on the possibility of mixing fluid fertilizers and fungicides for application at early reproductive stages. This summary article reviews issues involved, provides a brief summary of many studies conducted in Iowa during the last few years, and provides some recommendations. Readers must understand that research results and recommendations for prevailing soil and climate conditions in Iowa should not be directly extrapolated to other regions.

Foliar Fertilization of Soybean at Vegetative 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 root growth and nutrient uptake even when soil nutrient levels are adequate. Small amounts of N, P, and (or) K applied to the foliage at early critical periods could be effective if foliar fertilization is viewed as a complement for soil P and K fertilization and symbiotic atmospheric N fixation. 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. All experiments were conducted at farmers' fields, and the treatments were replicated three to four times at each site using conventional small plots or strip trials.

[1/] Professor and Soil Fertility Extension Specialist, Dept. of Agronomy, Iowa State Univ., Ames, IA.

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), 8-0-8, and 10-10-10 both with or without S and sometimes with or without the micronutrients boron (B), iron (Fe), and zinc (Zn). The product application rates ranged from 2 to 6 gallons/acre applied once or twice spaced 8 to 10 days. The fields were managed with no-till, ridge-till, or chisel-plow tillage. The majority of fields tested Optimum or higher for P and K according to Iowa State University interpretation class but there were some low-testing soils.

Figure 1 summarizes results from 66 trials that compared three sets of six treatments. 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 trial set and year. Differences between treatments were inconsistent across fields but responses tended to be higher for a rate of 3 gallons/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. The average response to the best treatment (3 gallons/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. Twenty-three additional trials consisted of simpler comparisons of 3 gallons/acre of 3-18-18 fertilizer applied once at the V5-V6 growth stage and an untreated control because this was the fertilizer and rate most effective in the previous trials. These trials used a conventional small-plot methodology or were replicated strip trials, and the fertilizer often was mixed with glyphosate herbicide. The results of these trials showed a response in about 15 percent of the trials, and the average yield increase across all trials was about 0.5 bu/acre .

Reasons for yield increases from foliar fertilization in low-testing soils are obvious. However, yield increases in fields testing Optimum or higher in P and K were difficult to explain. 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 with Optimum or high soil-test levels had slower early plant growth and P or K uptake than non-responsive fields due to cool early temperatures or 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 many others have not been able to identify a reliable critical or optimal nutrient concentration in young soybean tissue.

Foliar Fertilization and Fungicide Application to Soybean

Five field trials were conducted in 2005 and 2006 to study foliar fertilization and fungicide application alone or in a spray mixture for soybean. Adapted glyphosate-resistant varieties were used at all trials. Soybean was planted using narrow rows (7.5 inches) at the three sites and spaced 30 inches at two sites. Eight treatments were replicated three times at each site using conventional small plots. Foliar fertilization treatments consisted of a control, a single application of 3 gallons/acre of 3-18-18 fluid fertilizer at the V5-V6 and R2-R3 growth stages, 3-18-18 applied at both V5-V6 and R2-R3 stages, and 3.3 gallons/acre of 28% urea-ammonium nitrate (UAN) solution (10 lb N/acre) applied at the R2-R3 stage. The fungicide *Pyraclostrobin* [Headline® (BASF)] was sprayed at 12 oz/acre at the R2-R3 growth stage alone and in combination with 3-18-18 and UAN fertilizers. All solutions sprayed at the R2-R3 stage were mixed with a 90% non-ionic surfactant at a rate of 0.1 quart/10 gallons. Solutions turned a slight milky-white color when fertilizers and fungicide were mixed but no precipitation or material settling was observed. Treatments were sprayed with a CO_2 powered sprayer calibrated to apply 30 gallons of liquid/acre at 25 psi based on product recommendations. Spraying was done in early morning or evening to lessen the risk of leaf burning, and there was no rainfall 24 hours before and after treatment application.

The UAN fertilizer caused moderate leaf burning at most sites while application of 3-18-18 fertilizer caused minor or no burning (not shown). Fungicide application consistently and significantly delayed leaf senescence and increased green leaf area late in the season (not shown). Foliar fertilization affected soybean maturity only at one site, where 3-18-18 and UAN sprayed at the R2-R3 growth stage advanced maturity. Brown Spot and Bacterial Blight were the most prevalent diseases. The fungicide reduced incidence and/or severity of Brown Spot at three sites and, unexpectedly, the fungicide also reduced incidence or severity of Bacterial Blight at four sites, which is a result we cannot fully explain. Foliar fertilization seldom affected disease incidence and never affected the fungicide effect on disease control. All treatments reduced incidence of Cercospora at one site, and at another site both incidence and severity of Brown Spot were lowest when either 3-18-18 or UAN were sprayed in mixture with the fungicide.

The fungicide applied alone increased soybean grain yield significantly at four sites of the five sites, although the yield response was clearly explained by disease control only at two sites. Therefore, the fungicide effect at delaying leaf senescence may partly explain the yield responses. Foliar fertilization with 3-18-18 or UAN had inconsistent effects on yield. The 3-18-18 fertilizer increased yield slightly at two sites when it was sprayed at the V5-V6 growth stage but not when sprayed at the R2-R3 stage. Fertilization with UAN did not affect yield at two sites, increased it slightly at one site, and decreased it significantly at two other sites. Mixing fluid fertilizers with the fungicide did not influence the effect of each product applied separately. Figure 2 shows average treatment effects on grain yield across the five sites. The 3-18-18 fertilizer applied alone did not affect yield, UAN fertilizer applied alone decreased yield by 2.1 bu/acre, and the fungicide applied alone or in mixture with 3-18-18 increased yield by 3.5 bu/acre.

General Recommendations

Foliar fertilization of soybean will not be cost-effective 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 application rates of products with high salt content, N, or S which often burned leaves sometimes decreased yield, the research showed inconsistent differences between nutrient ratios or frequencies of application. However, a single application of the low-salt 3-18-18 fertilizer at 3 gallons/acre resulted in the more consistent yield increases. Mixing this fertilizer with glyphosate for early application or with Headline® fungicide for mid-season application caused no problems but did not increase the efficacy of either product. The probability of a yield response that offsets 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.

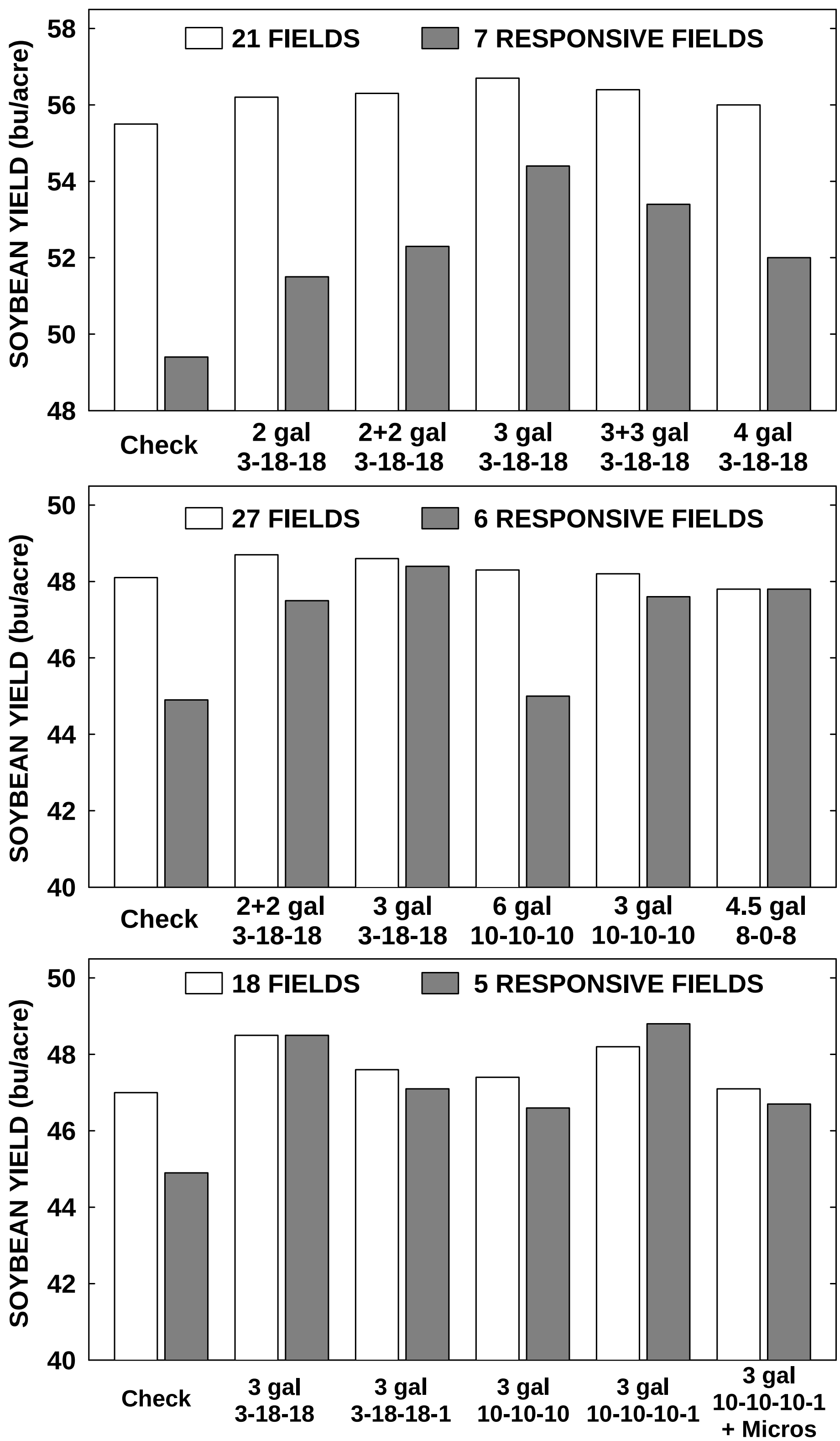

Figure 1. Soybean grain yield response to foliar fertilization across sites of three sets of trials conducted in Iowa with different treatments. The bars represent average yield responses across all sites and only the responsive sites for each trial set.

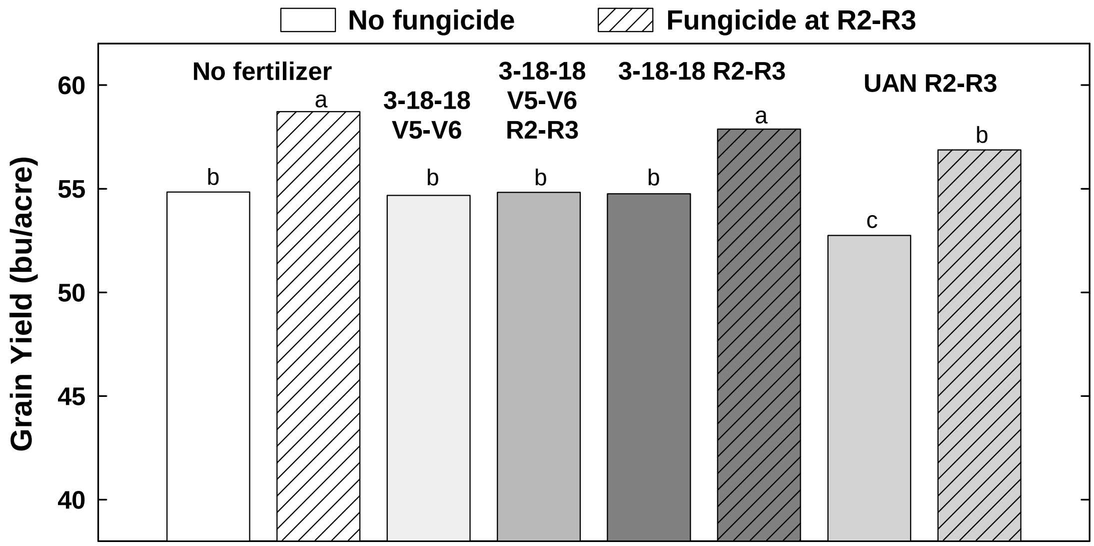

Figure 2. Effects of foliar fertilization and fungicide application on grain yield of soybean (averages across five trials conducted in Iowa).

Useful References

Haq, M.U., and A.P. Mallarino. 1998. Foliar fertilization of soybean at early vegetative stages. Agron. J. 90:763-769.

Haq, M.U., and A.P. Mallarino. 2000. Soybean yield and nutrient composition as affected by early season foliar fertilization. Agron. J. 92:16-24.

Haq, M.U., and A.P. Mallarino. 2005. Soybean grain oil and protein concentrations response to foliar and soil fertilization. Agron. J. 97:910-918.

Kaiser, D.E., and A.P. Mallarino. 2008. Foliar fertilization and fungicide application for soybean. *In* North-Central Extension-Industry Soil Fertility Conf. Proceedings. Vol. 24. Des Moines, IA.

Mallarino, A.P., and M.U. Haq. 2000. What about foliar fertilization of soybeans? Fluid J. 8:8-11.

Mallarino, A.P., M. U. Haq, D.J. Wittry, and M. Bermudez. 2001. Variation in soybean response to early-season foliar fertilization among and within fields. Agron. J. 93:1220-1226.

Mallarino, A.P., M.U. Haq, and T.S. Murrell. 2005. Early season foliar fertilization of soybeans. Better Crops Plant Food 89(3):11-13.