SDSU Extension

iGrow Soybean

BEST MANAGEMENT PRACTICES

Chapter 24: N Fixation Problems and In-season N Applications

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In-season N applications has been proposed as a management tool to increase soybean yields in high-yield environments as well as to increase yields when the soybean plant does not have effective nodules (Fig. 24.1). This chapter investigates the feasibility of using this practice to increase South Dakota soybean yields.

N fixation problems

Soybeans can obtain over 50% of their N from the soil, with the remainder being provided through N fixation. N fixation is a biological process where N2 is converted to plant N. This process requires a great deal of energy. The bacteria responsible for this conversion, Bradyrhizobium japonicum, requires oxygen (Fig. 24.1). Effective N fixation will not occur if the soil does not contain this bacteria, the soil contains high amounts of inorganic N, and soil conditions do not provide an adequate amount of oxygen. The bacteria convert N2 gas into ammonia and then into amino acids. The energy for this conversion is derived from photosynthesis.

Biological nitrogen fixation can occur in many organisms including legumes, bluegreen algae, and lichens. Nitrogen fixation can be reduced by stresses that reduce plant activity. Nodules can be seen on soybean roots shortly after emergence with fixation starting between V2 to V3 (Fig. 24.2). To assess nodulation, dig up at least 10 plants 5 to 6 weeks after seeding. At this time, the nodules should be large and active. The soil can be removed from the roots by immersing them in water. There should be 8 to 20 large active nodules per plant. http://msue.anr.msu.edu/news/evaluating_soybean_nodulation

Figure 24.1. Colonizing bacteria that supply nitrogen to legumes. The bright red color of the opened nodule is an indication of healthy rhizobia inside. (Photo courtesy of Jennifer Dean, Penn State University; live.psu.edu/story/39092)

Figure 24.2. Nodules on soybean plant around V3. (Photo courtesy of Han Krandel, North Dakota State University; available at http://www.ag.ndsu.edu/cpr/plant-science/soybean-nodulation-6-21-12)

Nodule activity can be checked by cutting the nodule open. Active nodules have pink centers while inactive nodules are grey. The pink color is caused by leghemoglobin. Oxygen causes this iron-containing compound to turn red. Leghemaglobin helps reduce the inactivation of the enzyme nitrogenase by oxygen. If they are small and white, they are not actively fixing N. Green, brown or mushy nodules are not fixing N.

Poor nodulations can result from:

- Low bacteria populations in the soil resulting from soybeans not being grown for several years.
- High or low levels of residual inorganic N.
- Coarse-textured soil.
- Flooded or high soil bulk density.
- Low (<5.5) or high (>7.3) soil pH.

Under certain conditions, N provided by the soil and by N_2 fixation may not meet the plant needs. Soybeans without effective nodules will respond to N like any other crop. Nitrogen deficiencies resulting from ineffective nodulation can be minimized by the application of 50 to 100 lbs N/acre (Scharf and Wiebold, 2003; Ferguson et al., 2006). These N deficiencies are fundamentally different than late-season N applications that are designed to increase yields from 60 bu/acre to 70 bu/acre.

High yielding fields: Late-season N additions

In South Dakota, soybean yields can be limited by too little or too much water. The spatial variability across our fields can be very high. For example, low-yielding areas may be < 25 bu/acre while high-yielding positions may be > 50 bu/acre (Fig. 24.3). The question is, can the yields in low- and high-yield areas be increased by adding late season N?

Research conducted in other states suggests that benefit from late-season N (R2 to R6) can be obtained under very high yield conditions (Westley et al., 1998). These yield increases are attributed to the N fixing bacteria not having the capacity to meet the plants' N requirement under very high-yielding conditions. In dryland fields, late season N has produced mixed results because rainfall is required to move this N into the soil (Kharel et al., 2011; Kim et al., 2008).

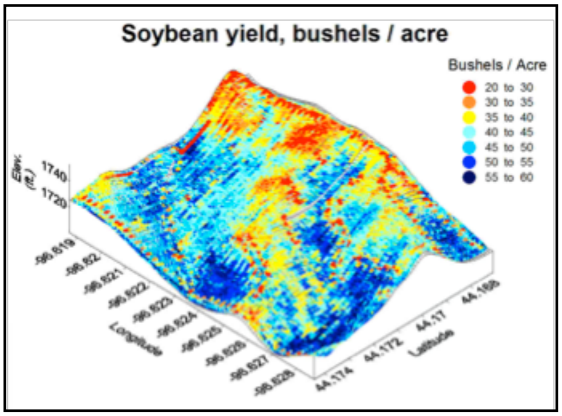

Figure 24.3. Soybean yield map from 2000 superimposed on a topographic map.
(Source: D.E. Clay, SDSU)

Soybean response to water stress

In the low-yielding zones, often located in high elevation areas, soybeans respond to water stress by closing the stomata. Closing the stomata reduces the CO_2 concentration in the leaves, which in turn reduces CO_2 fixation, transpiration, leaf size, leaf area index, biomass production, seed size and numbers, and accelerates leaf senescence (Souza et al., 1997). In addition, water stress in soybeans can reduce nodule activity (Serraj and Sinclair, 1996; Serraj et al., 1998). Serraj et al. (1998) hypothesized that water-stressed plants maybe N-limited because Bradyrhizobium may be more sensitive to water stress than the plant. Purcell and King (1996) tested this concept and reported that due to the extreme sensitivity of nodules to drought, it may be possible to increase yields in water-stressed areas by adding N fertilizer (Sall and Sinclair, 1991).

Summary

In summary, N fertilizer may increase soybean yields if nodulation is poor and if the N fixation does not meet the plant requirement. Benefits from in-season N may not increase yields in all fields and years. Research conducted in other states suggests that benefits are unlikely in moderate-yielding environments. As we attempt to push our yields from 50 to 60 or even 70 bu/acre, late-season N applications may become common. However, this needs to be confirmed by research.

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