NITROGEN FERTILIZATION OF SOYBEAN

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Nitrogen (N) requirement of soybean is high because of the high protein seed produced. One bushel of soybean requires over 3.5 pounds of N in the grain alone. Symbiotic N_2 fixation supplies N for soybean, but Harper (1974) reported that only 25 to 60% of the N in a mature soybean plant comes from N fixation while the other 40 to 75% comes from the soil. However, application of N fertilizer to soybean remains a very controversial issue because of mixed results of previous research.

Nitrogen and Nodulation

Several researchers (Weber, 1966: Beard and Hoover, 1971; Allos and Bartholomew, 1955) have shown both soil NO_3 and fertilizer N to effectively reduce or delay nodule formation in soybean. Fewer nodules reduce the amount of N supplied to the plant from N_2 fixation, which in turn was replaced by fertilizer N (Johnson et al., 1975). Herridge et al. (1984) found delayed nodule initiation and development when soil NO_3-N levels were high (30 ppm in top 12 in.). The relationship between soil NO_3 and fertilizer N on nodulation is a complicating factor when trying to study N fertilization of soybean and is likely part of the reason for inconsistent results.

Preplant and Early Season N Fertilization

Effects of preplant or planting time N fertilization on soybean grain yield have been measured in many studies. Past research indicated positive responses in soybean yield to N fertilization, but other work indicated no response.

Sorenson and Penas (1978) reported soybean yield increases with N fertilization on 9 of 13 sites in southeastern Nebraska. They concluded that soil parameters including pH, organic matter and NO_3-N content affected the magnitude of response. Several other researchers have reported positive responses to preplant or planting time N fertilization (Al-Ithawi et al., 1980: Eaglesham et al., 1983; Touchton and Rickerl, 1986; Stone et al., 1985; Brevedan et al., 1978). Bhangoo and Albritton (1976) studied soybean grain yield response to N fertilization on soils with a range of organic matter levels. They noted yield increases with N fertilization on soils with 1% organic matter, but no response on soils with higher organic matter contents. Lamb et al. (1990) evaluated the effects of inoculation and fertilizer N on soybean in 12 field experiments in northwest Minnesota. Eleven of the sites had never been in soybean previously and the 12 locations represented a range in soil NO_3-N contents from 22 to 164 lb/acre in the 0-2 ft. depth. Inoculum had no effect on yield at 10 of 12 locations. Soybean grain yield response to N fertilizer was noted only when soil NO_3-N content was less then 80 lb/acre (0-2 ft). They concluded that inoculum even at 2x the recommended rate was not adequate for providing N to

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soybean in the first year of production. Their results indicated that soil NO_3-N contents are not the total cause of poor nodule formation on soybean roots. They further concluded that when soil NO_3-N levels (0-2 ft) were less than 80 lb/acre, soybean grain yields were still increasing with fertilizer rates of 120 lb N/acre. (Table 1)

Table 1. Effects of inoculation and N fertilizer on soybean

	Soybean Grain Yield, West Polk Co., MN	
N Rate	Inoculated	Not Inoculated
lb/a	-----bu/acre-----	
0	18	15
30	19	17
60	20	18
90	23	22
120	24	23

-Lamb et al. (1990) Soil NO_3-N (0-2 ft): 50 lb/acre

However, lack of response of soybean to N fertilization-or even negative effects - have also been observed. For example, in 116 Illinois trials that included a variety of N application methods, Welch et al. (1973) found only 3 trials resulted in a positive yield response and these responses occurred at noneconomic rates of N fertilizer. Many other researchers have reported no response by soybean to preplant or planting time N fertilization (Buttery, 1986; Beard and Hoover, 1971; Diebert et al., 1979; Ham et al., 1975; Johnson et al., 1975; Weber, 1966). Buttery (1986) concluded that the route that N takes during mobilization in the soybean plant was affected by N fertilization, but grain yield was not.

Obviously, a large amount of evidence exists showing preplant or planting time N fertilization can increase soybean yields. However, an equally large amount of evidence shows no response by soybean to N fertilization. What are the reasons for the inconsistencies. Many factors are likely involved. The fact that successful N_2 fixation in soybean is dependent on bacteria whose function can be affected by soil pH, moisture, temperature, organic matter levels, and soil NO_3-N levels complicates the situation. Whenever symbiotic N_2 fixation is slowed or stops, fertilizer N may become more important. Even though soybean roots are well nodulated, that doesn't guarantee efficient N_2 fixation. Nearly all of the work discussed was done on nodulating lines of soybean. Any one or all of the soil parameters mentioned can play a big role in whether or not soybean will respond to an N fertilizer application.

Most states are not generally recommending preplant or planting time N fertilizer for soybean production. Some states are recommending some fertilizer N where soybean have never been grown before or on ground coming out of CRP. This is in addition to a recommendation for thorough inoculation in these instances.

Late-season Supplemental N Fertilization

Several researchers have shown the period of peak N demand in soybean is during pod fill or growth stages R1 to R6 (Diebert et al., 1979; Herman, 1982; Harper, 1971). The N demand at this time is great and fixed N alone may not be enough to meet this demand. Harper (1974) reported both soil-N and fixed N were necessary for maximum soybean yield and that soybean plants at full bloom are capable of responding to fertilizer N. Other research has shown that most of the N used by soybean during pod fill is supplied by the soil (Brevedan et al., 1977; Diebert et al., 1979). More recently, several studies have evaluated late-season (R1 to R5) supplemental N fertilization on soybean.

Gascho (1991) reported that late-season N fertilization increased soybean yields (Table 2). This Georgia work concluded that applying 25 lb N/acre at R3 to R5 growth stage to irrigated soybean through irrigation systems provided an excellent economic return. An increase of 1.2 to 2.2% in crude protein of the soybean seed was also noted.

Table 2. Soybean yield as affected by N fertilization

N Rate	Time of Application	Yield
lb/acre		bu/acre
0	—	45 b*
25	R3	50 a
50	R3	52 a
25	R5	51 a
50	R5	50 a

-Gascho, 1991 Lakeland sand, N applied as UAN (fertigation)
*Yields followed by same letter are equal at 90% probability level

Other researchers (Flannery, 1986; Oplinger, 1991; Wood et al., 1993) have reported fertilizer N applied at the R1 to R5 growth stages increased soybean yields. Little of this work, however, was conducted in the Midwest.

We initiated work in Kansas in 1994 to evaluate the effects of late-season N fertilization on the yield and protein and oil contents of irrigated soybean with high yield potential. Can soybeans fix enough N to meet the demand of a high yielding irrigated crop? Producers of irrigated soybeans are now routinely achieving yields in excess of 60 bu/acre. A 70 bu/acre soybean crop requires nearly 250 lb N/acre to be translocated into the developing seeds during pod-fill. Late-season supplemental N may increase yields in these instances. In addition, future soybean marketing strategies may include protein and oil concentrations. Late-season supplemental N has potential to affect these seed quality considerations.

This research was conducted in 1994 and 1995 at four irrigated sites each year.

Locations: Johnson County (JO94, JO95), Shawnee County (SN94, SN95), Reno County (RN94, RN95), Stafford County (SF94, SF95)

N Rates: 0, 20, 40 lb N/acre applied at R-3 growth stage (first pods 1/4-1/2" long)

N Sources: urea ammonium nitrate solution (UAN), urea, urea + NBPT, ammonium nitrate

All sites were managed for optimum production. Table 3 and 4 summarize cultural practices and soil test information, respectively, for the study locations.

Table 3. Location and cultural practice for research sites.

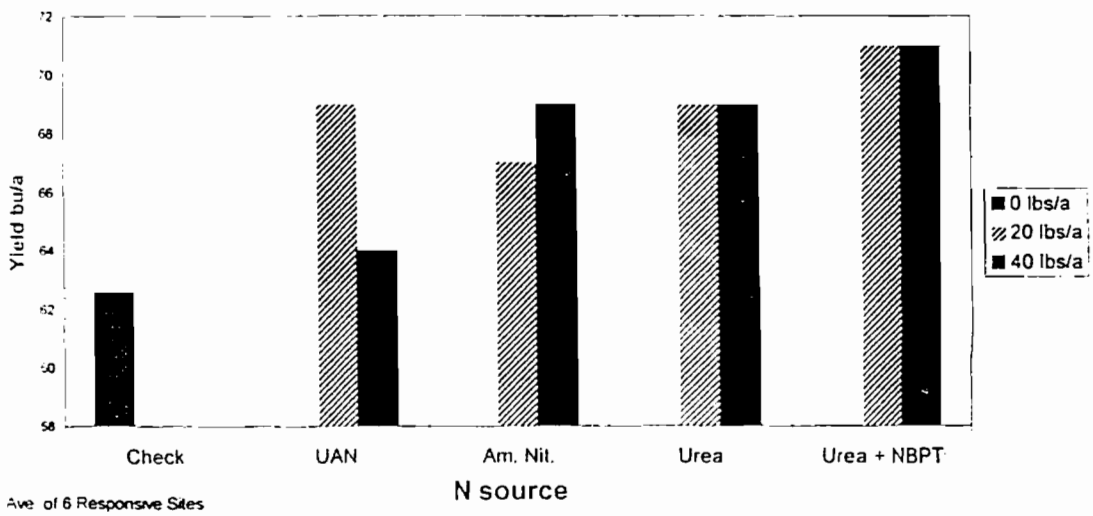
Location	Site	Row Spacing	Variety	Seeding Rate
		in.		Seeds/acre
Johnson Co.	JO94	30	Asgrow A4138	160,000
Brunker Farm	JO95	30	Asgrow A4138	160,000
Shawnee Co.	SN94	36	Asgrow A3935	180,000
Parr Farm	SN95	36	Asgrow A3935	180,000
Reno Co.	RN94	7.5	Asgrow A3935	200,000
Seck Farm	RN95	7.5	Asgrow A3834	200,000
Stafford Co.	SF94	30	Resnick	125,000
Sandyland Field	SF95	30	KS3494	125,000

Table 4. Selected soil characteristics of research sites.

Site	pH	Bray-1 P	K	Organic Matter	Profile N	
				0-6 in.	0-6 in.	6-24 in.
		-----ppm-----		%	-----ppm-----	
JO94	6.9	41	125	0.7	4.1	—
JO95	6.8	44	165	0.8	3.0	5.5
SN94	7.3	65	305	2.8	6.7	—
SN95	7.7	67	240	3.1	7.9	6.3
RN94	6.8	50	210	1.2	2.7	—
RN95	6.8	48	190	1.7	3.0	2.2
SF94	6.9	31	140	0.9	3.1	—
SF95	6.7	52	130	1.3	7.8	4.5

Late-season supplemental N application increased soybean grain yield at six of eight locations in Kansas (Fig. 1). Nitrogen sources performed similarly, except the 40 lb N/acre rate of UAN which resulted in lower yield than other N rate/sources. The high rate of UAN caused severe leaf burn at most locations. The UAN was applied through flat fan nozzles with a backpack sprayer in 40 GPA total volume. Leaf burn would not be a problem with UAN applied through an irrigation system. Visual inspection of soybean root systems indicated prolific, healthy-looking nodules at all study locations.

Fig. 1. Effects of Late Season N Application on Soybean Yield



Soybean protein concentrations were increased at four of eight locations and oil concentrations were increased at three of seven sites.

In summary, this Kansas research shows soybean yields were increased by late-season N fertilization at six of eight sites. Differences between N rates were minimal and N sources performed similarly. In nearly all cases, 20 lb N/acre was sufficient to achieve the positive responses noted. The two nonresponsive sites had yields below 50 bu/acre. Results suggest that soybean with high yield potential (greater than 55 bu/acre) may not be able to supply enough N during peak demand via N_2 fixation. The 11.8% practice economically viable for producers of high-yielding irrigated soybean. Assuming prices of $7.00/bu for soybean and $0.30/lb N, these results would show a return of $48.30 per acre for a $6.00 per acre investment (at 20 lb N/acre). This work was recently published (Wesley et al., 1998).

Summary

The issue of N fertilization of soybean will likely remain controversial. Whenever adequate nodulation and N_2 fixation occur, response to preplant or planting-time N fertilization of rain-fed soybean is not likely. However, since this is a biological process affected by many things, situations are possible where preplant or planting-time N fertilization may be beneficial.

Limited research on late-season N fertilization shows a more consistent positive impact, particularly in high yield environments.

References

Al-Ithawi, B., E.J. Deibert, and R.A. Olson. 1980. Applied N and moisture level effects on yield, depth of root activity, and nutrient uptake by soybean. Agron. J. 72:827-832.

Allos, H.F. and W.V. Bartholomew. 1955. Effect of available nitrogen on symbiotic fixation. Soil Sci. Soc. Am. Proc. 19:182-184.

Beard, B.H., and R.M. Hoover. 1971. Effect of nitrogen on nodulation and yield of irrigated soybeans. Agron. J. 63:815-816.

Bhangoo, M.S. and D.J. Albritton. 1976. Nodulating and non-nodulating Lee soybean isolines response to applied nitrogen. Agron. J. 68:642-645.

Brevedan, R.E., D.B. Egli, and J.E. Leggett. 1978. Influence of N nutrition on flower and pod abortion and yield of soybean. Agron. J. 70:81-84.

Buttery, B.R. 1986. Effects of soil nitrate level on nitrogen distribution and remobilization in field grown soybeans. Can. J. Plant Sci. 66: 67-77.

Deibert, E.J., M. Bijeriego, and R.A. Olson. 1979. Utilization of ^{15}N fertilizer by nodulating and non-nodulating soybean isolines. Agron. J. 71:717-723.

Eaglesham, A.R.J., S. Hassouna, and R. Seegers. 1983. Fertilizer-N effects on N_2 fixation by cowpea and soybean. Agron. J. 75:61-66.

Flannery, R.L. 1986. Plant food uptake in a maximum yield soybean study. Better Crops with Plant Food. Fall 1986, pp. 6-7.

Gascho, G.J. 1991. Late-season nitrogen application for soybeans. Fluid Fert. Found. 1991 Research Sym., Proc. Pp. 96-114.

Ham, G.E.., I.E. Liener, S.D. Evans, R.D. Frazier, and W.W. Nelson. 1975. Yield and composition of soybean seed as affected by N and Se fertilization. Agron. J. 67:293-297.

Harper, J.E., and R.L. Cooper. 1971. Nodulation response of soybeans (glycine max (L.) Merr.) To application rate and placement of combined nitrogen. Crop Sic. 11:438-440.

Harper, J.E. 1974. Soil and symbiotic nitrogen requirements for optimum soybean production. Crop Sci. 14:255-260.

Herman, J.C. 1982. How a soybean plant develops. Iowa State Univ. Coop Ext. Serv. Spec. Rep. No. 53.

Herridge, D.F., R.J. Roughley, and J. Brockwell. 1984. Effect of rhizobia and soil nitrate on the establishment and functioning of the soybean symbiosis in the field. Aust. J. Agric. Res. 35:149-161.

Johnson, J.W., L.F. Welch and L.T. Kurtz. 1975. Environmental implications of N fixation by soybean. J. Environ. Qual. 4:303-306.

Lamb, J.A., G.W. Rehm, R.K. Severson and T.E. Cymbaluk. 1990. Impact of inoculation and use of fertilizer nitrogen on soybean production where growing seasons are short. J. Prod. Agric. 3:241-245.

Oplinger, E.S. 1991. Soybean fertilization with nitrogen, calcium, and boron solutions. Fluid Fert. Found. 1991 Research Sym., proc. pp. 185-193.

Sorenson, R.C. and E.J. Penas. 1978. Nitrogen fertilization of soybean. Agron. J. 70:213-216.

Stone, L.R., D.A. Whitney and C.K. Anderson. 1985. Soybean yield response to residual $N0_3$-N and applied N. Plant Soil 84:259-265.

Touchton, J.T. and D.H. Rickerl. 1986. Soybean growth and yield response to starter fertilizers. Soil Sci. Soc. Am. J. 50:234-237.

Weber, C.R. 1966. Nodulating and non-nodulating soybean isolines: II. Response to applied nitrogen and modified soil conditions. Agron. J. 58:46-49.

Welch, L.F., L.V. Boone, C.G. Chambliss, A.T. Christiansen, D.L. Mulvaney, M.G. Oldham and J.W. Pendleton. 1973. Soybean yields with direct and residual nitrogen fertilization. Agron. J. 65:547-550.

Wesley, T.L., R.E. Lamond, V.L. Martin and S.R. Duncan. 1998. Effects of late-season nitrogen fertilizer on irrigated soybean yield and composition. J. Prod. Agric. 11:331-336.

Wood, C.W., H.A. Torbert and D.B. Weaver. 1993. Nitrogen fertilizer effects on soybean growth, yield, and seed composition. J. Prod. Agric. 6:354-360.

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