NITROGEN FERTILIZER AND SWINE MANURE APPLICATION TO SOYBEAN[1]

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Nitrogen (N) fertilization and manure application are not traditional nutrient management practices for soybean production. Soybean is a legume plant and assumed to obtain adequate N through symbiotic N_2-fixation. Also, since manure contains plant-available N in addition to other nutrients, it is preferentially used for corn production to gain economic advantage from the manure-N.

Over the years there has been interest in using N fertilization as a means to increase soybean yield due to the recognition of the large N requirement by soybean for high productivity. Despite the fact that soybean is a legume, research has shown soybean readily utilizes soil inorganic-N and at high yield levels results in net N removal from soil. Depending upon the amount of residual soil inorganic-N and soil mineralization characteristics, from 40 to 75% of the N in a mature soybean plant is derived from the soil (Shibles, 1998). Soybean appears to require this soil-derived N component of total plant N for high yield. Recognition of this soil N use, as well as other physiological aspects of soybean N metabolism, has sustained interest in enhancing N supply and use by soybean in hopes of increasing yield and grain protein.

As discussed in the review article by Shibles (1998), soybean has two N acquisition systems, inorganic-N from soil and symbiotic N_2-fixation. What is interesting is the negative impact soil nitrate supply has on *Bradyrhizobia* infection and symbiotic fixation (that is, delayed infection and reduced nodulation and N_2-fixation in response to increased soil nitrate). This interrelated N acquisition presents a significant difficulty to increasing total plant N through fertilization.

Preplant N Fertilizer Application

Nitrogen fertilizer application ahead of or at soybean planting is not a new concept and has been studied over many years throughout the Midwest USA. Interest partly stems from the recognition that initial nodulation takes time to develop and that significant N is not obtained from N_2-fixation until beginning flower, and partly from the overall large N demand. In general, preplant N application has not been successful in increasing soybean yield or providing enough yield enhancements to pay for the fertilizer. Work years ago in Iowa by Hanway and Weber (1971) found no impact of large N application (600 lb N/acre) to nodulating soybean. Other examples include data like that from Iowa and Illinois (Tables 1 and 2) where N application had either no positive impact to a slight decrease in yield (from increased plant height and lodging). Even with high N rates, positive effect on yield is inconsistent (Tables 1-3) and extremely high rates can also significantly suppress yield (Table 3).

Also of interest is the potential effect (either positive or negative) of residual soil nitrate from prior N application to corn. Similar to results found for preplant N application, soybean yield is not influenced the year following application to corn (Table 4).

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In a summary of studies on the effects of fertilizer-N application to soybean in Minnesota, Randall and Schmitt (1998) concluded that soybean yield could be increased by addition of soil-applied fertilizer, however responses were inconsistent and varied with season, variety, rate, fertilizer source, application timing, and other yield-limiting factors. Also, when response occurred, yield increase to fertilizer-N usually was insufficient to pay for the fertilizer.

In a review of soybean N fertilization research over many years in Wisconsin, Oplinger and Bundy (1998) summarized that in a few cases yields were increased by 2 to 3 bu/acre, but in the majority of cases there was no response to applied N. The most consistent increases were situations when early-season application reduced Brown Stem Rot (BSR) disease. A suggestion from the Oplinger and Bundy review was the potential for N fertilization on new soybean land, especially when inoculation and N_2-fixation is not effective or when production is expected to exceed 70 bu/acre. One caution was raised – with application of N, vegetative growth might be enhanced to the point of increasing lodging and development of white mold disease.

In some situations, preplant N application has increased soybean yield. Often these are sites with low inorganic-N supply, low soil organic matter, low residual soil nitrate (for example yield response was measured by Lamb et al. (1990) at 2 of 10 locations in Minnesota only when soil nitrate was less than 80 lb N/acre), low yield, short seasons, or soil conditions that limit effective nodulation and N_2-fixation (Tables 5-6). Soybean plants sometimes appear N deficient early in the growing season (light green color, reduced growth or small leaves), especially with reduced- and no-tillage. However, they normally recover by the 3^{rd} to 5^{th} trifioliate stages when either available soil N increases or N_2-fixation becomes more effective – resulting in no yield effect.

In-Season N Fertilizer Application

Information presented in several popular press articles and recently published research from Kansas (Wesley et al., 1998) sparked interest in the 1990's for soil application of fertilizer-N during the growing season, most notably around the R3 growth stage (early podding). This application timing has also been called late-season, however, in the life of the soybean plant and in relation to total N uptake, it is still early. Interest in this N application stems from the recognition that nitrate reduction within the soybean plant declines rapidly after this stage (partially due to soil nitrate depletion) and the greatest N requirement is when seeds are developing (Shibles, 1998). Interest therefore is in increasing the supply of N to the soybean plant without detrimentally affecting N_2-fixation. Also, past attempts to supply N and other nutrients through foliar application during this growth period were generally not successful.

Recent work by Wesley et al. (1998) showed an average 6.9 bu/acre yield increase from 20 or 40 lb N/acre applied at the R3 growth stage of irrigated soybean in Kansas (Figure 1). Yield increases occurred at 6 of 8 sites, with response to fertilizer sources not consistent across sites. Conditions specific to expected response in that study included high yield, low organic matter soil, low soil nitrate, and use of irrigation. Only sites yielding greater than 55 bu/acre responded positively to the in-season N application. Grain protein and oil were not significantly increased with N application. Recommendations from the researchers are for application of 20 lb N/acre at the R3 growth stage to high yielding, irrigated soybean. In that study, broadcast-sprayed UAN at 40 lb N/acre burnt leaf tissue and resulted in decreased yield.

Other research on the in-season N application timing (broadcast or injected soil application) has not been successful in increasing soybean yield. Mean response (Table 7) to two in-season application timings found no yield increase from 75 lb N/acre at 12 site-years in Minnesota (Schmitt et al., 2001). Seed protein and total seed N removal were increased slightly, but seed oil content was not affected. In that study soil nitrate was increased at the R6 growth stage (full seed) from N application, but this did not translate to increased yield. Studies in other states, including Illinois, Wisconsin, and South Dakota noted no yield enhancement with in-season N application (Tables 8-10). Also, broadcast application of liquid urea resulted in yield depression at two of the Minnesota sites in 1997 (Table 8).

A recent study conducted by Sawyer and Barker (2001) at 10 site-years across Iowa in 1999 and 2000 found no consistent impact on grain yield, grain quality components, grain N removal, or plant biomass N (R6 growth stage) with N applied at the late R2 to early R3 growth stage (generally applied the last week of July) (Tables 11-13). The N treatments applied were urea and poly-coated slow-release urea; 0, 40, and 80 lb N/acre; and broadcast and shallow banding between every-other-soybean row (60-inch fertilizer band spacing). The average grain yield difference between applied N and the control was 0.5 bu/acre. Differences in grain components like protein and oil were much greater between sites/varieties than due to N treatments. Reasons for lack of response to applied N likely include sites having high soil organic matter, not irrigated, or low yield. With high organic matter soils (adequate inorganic-N supplied from mineralization), along with topsoils often dry in summer, lack of irrigation to move applied N into the active root zone, and full canopy closure making application difficult, in-season N application is of limited value and not recommended for soybean production in Iowa.

Liquid Swine Manure Application

There are several reasons why producers would consider applying liquid swine manure to soybean. These include using phosphorus (P) and potassium (K) in manure for improving yield on deficient testing soils, ability to maintain sufficient soil residue cover after injection into cornstalks, increasing the available land for manure application, increasing the spring manure application window because soybean is often planted after corn, the high soil inorganic-N removal by soybean, and the potential for increased soybean yield even when soil tests are adequate (observing a yield increase when soil tests indicate no response from P and K application is expected).

Of most interest has been recently documented soybean yield increases resulting from swine manure application. Yield improvement does not always occur, but several studies have found yield increases with preplant and in-season application (Tables 14-17). The exact reasons for the yield increases are not known, but they do occur – even when soil test P and K indicate no expectation for response. Possible explanations include response to applied N, continuous ammonium release and supply to soybean from manure, lower negative impact than fertilizer-N on N_2-fixation (Table 14), or other unknown factors (Anderson, 1998; Schmidt et al, 2000). Soybean yield increase to swine manure application is not consistent (Tables 16-17), indicating specific situations may be required for yield enhancement, or factors other than just N are responsible. Variable response from manure-N application is similar to that observed with fertilizer-N application. Work by Schmidt et al. (2001) in Minnesota noted greater yield increase at sites with lower available soil-N levels in mid-June, and that positive response varied by soybean variety (most consistent variety response occurred at the most responsive site). Except at one site where yield was reduced because of increased lodging and incidence of white mold, swine manure application generally resulted in yield increase. It would be favorable, however, to better predict which fields and varieties would produce yield improvement with manure application.

The work in Minnesota by Schmidt et al. (2000) also documented the ability of soybean to access and readily utilize N from swine manure. As long as the crop available manure-N application rate is less than accumulated N in a soybean crop, the potential environmental impact appears minimal (low residual soil nitrate (Figure 2) and apparent manure-N uptake with no adverse agronomic or yield impact). This is important because of concerns related to potential residual soil nitrate remaining after harvest. Despite soybean being a legume, as mentioned before it will utilize inorganic-N if it is available in the soil. From the data collected in Minnesota and Iowa, soybean appears equally efficient in using N from swine manure or fertilizer. This should allow swine manure use for soybean production with limited potential for nitrate accumulation at reasonable manure-N application rates. Research continues to evaluate these impacts for Iowa conditions.

There are a few precautions related to liquid swine manure use for soybean production. One, soybean seed germination and emergence are quite sensitive to salt. If manure is preplant applied close to planting time there is a potential for injury, especially if the seed is planted into or near the manure. Manure should be incorporated or dispersed away from the seeding zone to minimize this potential injury. Two, compaction is a concern with manure application, especially when spring applied. Three, soybean diseases may be enhanced. This is especially a concern with white mold as manure application may enhance vegetative growth, resulting in more favorable conditions for white mold development and lodging. Also, manure application, especially spring application, can affect the potential for diseases such as *Pythium* and *Phytophthora* damping off (Yang and Martinson, 1996). Manure application to soybean should be avoided on fields with a history of these diseases, manure applied well ahead of planting, or use of resistant varieties or seed treatments if appropriate. Four, the application rate should not exceed the capacity of the soybean crop to readily utilize N available in the manure. Five, the rate of P and K application should be monitored so that excessive amounts are not applied (see example in Table 18), especially for P because of surface water quality concerns. In most corn-soybean rotations, consider applying swine manure only once in the rotation to avoid over application of P.

Summary

Nitrogen fertilizer application to soybean seldom produces a yield increase, especially one large enough or consistent enough to recoup the material and application costs. Preplant or in-season N application is not a recommended practice for soybean production in Iowa. Liquid swine manure application to soybean does sometimes improve yield, although this response is not consistent or predictable at this time. If soil test P or K were deficient, those nutrients in applied manure would be expected to produce yield improvement. However, when those soil tests are adequate, soybean yield increase sometimes occurs from direct swine manure application. It also appears that soybean can readily utilize N from liquid swine manure. This is a lost economic opportunity when no yield increase is obtained, but should limit environmental concerns as residual soil nitrate after harvest appears low as long as application rates remain below soybean grain N removal. Research on this question continues in Iowa.

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Tables and Figures

Table 1. Effect of preplant N application on nodulating and non-nodulating soybean, adapted from Johnson et al., 1975.

Applied N	Nodulating	Non-Nodulating
lb/acre	- - - - - - bu/acre - - - - - -	
0	41.8	26.4
100	42.4	36.3
200	40.5	40.3
400	43.8	44.2
$LSD_{(0.05)}$	3.6	
University of Illinois		

Table 2. Soybean response to preplant N fertilization, adapted from Bharati et al., 1986.

Applied N	1982	1983
lb/acre	- - - - - - bu/acre - - - - - -	
0	44.9	55.5
120	43.9	55.7
240	44.2	56.3
$LSD_{(0.05)}$	0.9	NS
Iowa State University		

Table 3. Effect of high preplant N application rates on soybean yield, Hoeft and Peck, 2001.

1st Year	2nd Year	3rd Year	1st Year	2nd Year	3rd Year
N Rate, lb/acre			Soybean Yield, bu/acre		
0	0	0	54	53	40
40	200	200	54	57	41
80	400	400	56	57	45
120	800	800	53	55	42
160	1,600	1,600	55	34	36
University of Illinois, Urbana, IL					

Table 4. Effect of N applied to the preceding corn crop on soybean yield, Iowa State University.

N Applied To Corn	Northern Research Farm (1985-1998)	Northeast Research Farm (1979-1998)
lb/acre	Average Soybean Yield, bu/acre	
0	41.9	43.2
80	42.6	44.7
160	42.9	44.1
240	42.0	43.6
Nitrogen spring applied as incorporated urea to corn in a corn-soybean rotation. Iowa State University research farm reports ISRF98-13 and ISRF98-22, A.P Mallarino, D. Rueber, and K. Pecinovsky, 1998.		

Table 5. Effect of preplant N fertilizer application on soybean yield in a short growing season, with low soil nitrate, and limited nodulation, Lamb et al., 1990.

Applied N Rate	Soybean Grain Yield
lb/acre	bu/acre
0	15
30	17
60	18
90	22
120	23
Soil nitrate-N (0-2 ft) 50 lb/acre. West Polk County, MN. University of Minnesota	

Table 6. Effect of at planting N fertilizer and inoculation on soybean at a site (Aurora, SD) not having soybean grown for five years and low soil nitrate. Adapted from Woodard et al., "The effect of N application on agronomic parameters and soybean nodulation." South Dakota State Univ., 1997 Plant Science Research Report.

N Rate	Grain Protein	Grain Yield	Total Nodules at Early Bloom
lb/acre	%	bu/acre	no. per plant
Inoculated	33.8	35.4	61
0	33.9	33.6	78
75	33.4	36.1	30
150	33.6	37.6	22
225	36.2	39.9	8
$LSD_{(0.05)}$	0.23	1.4	14
No soybean for previous five years. Soil nitrate (0-2 ft) 44 lb/acre.			

Table 7. Effect of in-season N fertilizer application to soybean from 12 site-years in Minnesota, 1998-1999, adapted from Schmitt et al., 2001.

N Application	Seed Yield	Seed Protein	Seed Oil	Seed N Removal
	bu/acre	%	%	lb/acre
Control	49.4	37.2	19.6	154
Broadcast urea (July)	50.3	37.0	19.6	155
Knifed urea (July)	50.3	37.4	19.6	157
Broadcast poly-coated urea (July)	51.0	37.4	19.5	159
Knifed poly-coated urea (July)	50.3	37.5	19.5	157
Broadcast urea (August)	50.3	37.6	19.5	158
$Significance_{(0.05)}$	NS	Sign.	NS	Sign.
July application in third week of July, R2 growth stage. August application in second week of August, R4-R5 growth stage. Knifed = six inch placement depth. Broadcast = over-the-canopy with no incorporation. All N applications at 75 lb N/acre. University of Minnesota				

Table 8. Soybean yield as influenced by 75 lb N/acre applied during the growing season. Personal communication, M.A. Schmitt, 1997, Univ. of Minnesota.

Fertilizer Source	Application Time	Application Method	Grain Yield
			bu/acre
None	-----	-----	40
Urea	mid-July	Inject	40
Coated Urea	mid-July	Broadcast	42
Liquid Urea	mid-July	Inject	39
Liquid Urea	August	Broadcast	31
University of Minnesota			

Table 9. In-season and preplant N application to soybean, adapted from Oplinger and Bundy, 1998.

N Timing and Application Rate		Soybean Grain Yield	
Preplant	Mid-July	Location 1	Location 2
- - - - - - lb N/acre - - - - - -		- - - - - - - bu/acre - - - - - - -	
0	0	44	38
40	0	44	39
0	40	44	39
40	40	44	39
Chippewa County, University of Wisconsin. F. Thomposn,1994.			

Table 10. In-season N application to soybean at several sites. Adapted from J. Gerwing, South Dakota State Univ., 1998 Dakota Dirt Newsletter, Vol. 6, #4.

	Location			
N Rate	Estelline	Aurora	Aurora Exp.	Brookings Exp.
lb/acre	- - - - - - - - - - - - - - - - - bu/acre - - - - - - - - - - - - - - - - - -			
0	48	37	43	30
25	48	37	42	--
50	48	36	41	--
50 - [a]	50	38	43	31
50 + [a]	49	38	43	30
100	50	36	43	--
Significance$_{(0.05)}$	NS	NS	NS	NS

[a] - = urea without Agrotain, + = urea with Agrotain.
Other N applications from ammonium nitrate.
South Dakota State University

Table 11. Site characteristics and rainfall after N application for the in-season soybean N fertilization study conducted in Iowa during 1999-2000, Sawyer and Barker, 2001.

Site	Days from Application to > 0.25 Inch Rain (Amount)	Application to Aug. 30 Rainfall	Soil Name	Soil Organic Matter	Soybean Variety	Tillage
	days (inch)	inch		%		
1999						
Armstrong	10 (1.75)	5.13	Marshall sicl	3.9	Pioneer P93B01	No-Till
Southeast	9 (1.10)	6.03	Kalona sicl	5.4	Stine 3398-8	Fall Chisel-Disk-F.C.
Northern	13 (0.26)	1.22	Canisteo cl	6.1	Midwest G1912	Fall Chisel-Disk-F.C.
Northeast	2 (1.34)	4.83	Kenyon l	3.5	Asgrow 1980-4	Fall Chisel-Disk-F.C.
Northwest	27 (0.48)	0.75	Galva sicl	4.1	Kruger K2343+	Fall Chisel-Disk-F.C.
2000						
Armstrong	2 (0.30)	1.58	Marshall sicl	4.0	Pioneer 93B01	No-Till
Southeast	3 (0.58)	2.39	Mahaska sicl	5.3	Stine 3398-8	Fall Chisel-Disk-F.C.
Northern	10 (0.67)	3.99	Canisteo cl	6.0	Midwest G1912	Fall Chisel-Disk-F.C.
Northeast	8 (0.39)	3.46	Kenyon l	3.8	Asgrow 2301	Fall Chisel-Disk-F.C.
Northwest	5 (0.58)	4.71	Galva sicl	4.1	Kruger K2343+	Fall Chisel-Disk-F.C.

Nitrogen treatments applied approximately the last week of July at late R2 to beginning R3 growth stage.
Iowa State University, 2001

Table 12. Average impact of in-season N fertilizer application on soybean grain yield and protein in 1999-2000 at 10 site-years, Sawyer and Barker, 2001.

Nitrogen Material	Placement	N Rate, lb N/acre 40	N Rate, lb N/acre 80	Placement Mean	Material Mean	N Rate, lb N/acre 40	N Rate, lb N/acre 80	Placement Mean	Material Mean
		- - - - - - - grain yield, bu/acre - - - - - -				- - - - - - - grain protein, % - - - - - - -			
Urea	Broadcast	51.8	52.1	52.0		35.3	35.3	35.3	
	Band	51.5	52.2	51.8		35.2	35.3	35.3	
	Urea Mean	51.7	52.1		51.9	35.3	35.3		35.3
PCU	Broadcast	51.6	51.6	51.6		35.4	35.5	35.4	
	Band	51.1	51.2	51.2		35.4	35.4	35.4	
	PCU Mean	51.3	51.4		51.4	35.4	35.5		35.4
	Broadcast Mean	51.7	51.9	51.8		35.3	35.4	35.3	
	Band Mean	51.3	51.7	51.5		35.3	35.4	35.4	
	N Rate Mean	51.5	51.8			35.3	35.4		
	N Application Mean	51.6				35.4			
	Control (No N)	51.1				35.3			

No statistically significant treatment effects or interactions, P=0.05.
Iowa State University, 2001

Table 13. Average effect of in-season N application on soybean grain yield, quality components, and R6 aboveground plant biomass in 1999-2000 at 10 site-years, Sawyer and Barker, 2001.

	Iowa State University Research and Demonstration Farm									
	Armstrong		Southeast		Northern		Northeast		Northwest	
	Plus N [1]	No N [2]	Plus N	No N	Plus N	No N	Plus N	No N	Plus N	No N
1999										
Grain Yield, bu/acre	59.4	58.5	54.9	56.9	53.2	52.9	53.6	53.4	55.0	53.5
Grain Protein, %	34.2	34.1	37.6	37.8	30.7	31.3	37.1*	37.4	34.0	33.9
Grain Oil, %	18.4	18.5	17.6	17.6	18.7	18.5	17.1	17.0	18.1	18.2
Grain Fiber, %	5.3	5.3	5.2	5.1	5.4	5.4	5.1	5.1	5.2	5.2
Grain N, lb/acre	187	186	186	194	144*	156	175	174	161	157
Grain N, lb/bu	3.2	3.2	3.4	3.4	2.7*	3.0	3.3	3.3	2.9	2.9
Aboveground Biomass, lb/acre	6350	6581	6510	6607	5988*	6847	6247	6676	5865	6016
Aboveground Biomass N, lb/acre	213	201	200	200	148*	175	214	225	179	180
2000										
Grain Yield, bu/acre	34.0*	31.8	50.5	50.2	51.6	51.7	60.9	61.8	43.2	39.8
Grain Protein, %	35.6	35.4	37.0	37.2	33.9	33.4	36.3	36.3	37.0*	37.4
Grain Oil, %	19.1*	19.4	18.2	18.0	19.0	19.1	19.2	19.3	18.1	18.0
Grain Fiber, %	5.2	5.2	5.1	5.1	4.9	5.0	4.8	4.7	4.9	4.9
Grain N, lb/acre	103*	94	161	169	152	151	191	194	137	127
Grain N, lb/bu	3.0	3.0	3.2	3.4	2.9	2.9	3.1	3.1	3.2	3.2
Aboveground Biomass, lb/acre	5484	5968	6752	6768	6314	6523	7003	6957	6142	5612
Aboveground Biomass N, lb/acre	163	167	210	224	178	166	267	248	193	175

[1] Plus N is the mean across all N rate, material, and application method treatments at each site.
[2] No N is the control with no N applied.
* Statistically different between plus N and no N, 0.05 probability level
At the Armstrong site in 2000, severe hail damage occurred to the plots immediately before N application which induced plot variability and resulted in reduced plant growth, aboveground biomass, and grain yield.
Iowa State University, 2001

Table 14. Effect of in-season liquid swine manure application on soybean yield and nodulation at Ames, IA. Adapted from Anderson, 1998.

	Treatment					
Cultivar	E	E-M	M-L	E-M-L	N Fertilizer	Control
	- - - - - - - - - - Grain Yield, bu/acre - - - - - - - - - -					
Asgrow 2242	57a	58a	55a	56a	52b	53b
Jack	51a	51a	50a	51a	48b	46b
Non-nod.	40a	39a	39a	40a	39a	16b
	- - - - - - - - - - Nodulation, % - - - - - - - - - -					
Asgrow 2242	26	37	48	71	18	100
Jack	37	42	55	79	23	100

Swine manure surface applied four times at weekly to 16 day intervals to soybean beginning approximately at initial flowering (E) or pod set (M).
Manure applied at 145 lb total N/acre and fertilizer at 215 lb N/acre.
Values in a row with the same letter are not different at 95% probability.
Iowa State University

Table 15. Effect of liquid swine manure application on soybean yield in a corn-soybean rotation, adapted from R. Killorn, 1999.

Manure Application Frequency in Rotation	Average Yield
	bu/acre
Every Year	50
Every Other Year to Corn	48
Every 4th Year to Corn	43
No Manure	43
Significance of Manure Frequency	Pr < 0.01

Average yield across four N rates applied to corn (0, 50, 100, and 150 lb N/acre). Iowa State Univ. Northern Research and Demonstration Farm, Kanawha, IA

Table 16. Effect of preplant liquid swine manure application on soybean yield and lodging at seven locations in Minnesota, adapted from Schmidt et al., 2001. University of Minnesota.

	Location						
Manure Amount	Austin	Northrop	Goodhue	Kasson	Lamberton	Waseca	Lake Crystal
	bu/acre						
Control	39.7†	40.3†	41.5†	44.1†	41.2†	43.9†	43.3†
Low	45.2	41.5	42.6	45.8	45.8	45.4	40.2
High	48.7	40.3	44.4	45.8	46.9	47.2	40.3
	Lodging score; 1 = upright, 5 = flat						
Control	1.8†	2.2†	3.3	2.5†	1.6†	1.6†	2.2†
Low	2.0	2.6	3.2	3.9	2.5	2.2	2.7
High	2.2	2.6	3.4	3.5	2.6	2.3	3.2

Average of 12 varieties. P and K soil tests adequate at all sites. Manure rate varied between sites, with the low rate being approximately half the high rate. Averaged across all sites, the low rate = 175 lb available N/acre and the high rate 330 lb available N/acre.
† Significant difference between two non-zero manure treatments and the control.

Table 17. Impact of liquid swine manure application on soybean yield at three Iowa locations in 2000 where soil test P and K were optimum to very high, preliminary information from Sawyer and Mallarino, 2000. Iowa State University.

	County		
Swine Manure Rate	Clay	Webster	Harden
	bu/acre		
Control	47.2	41.6	53.6
Half	48.1	44.1	54.7
Full	49.1	45.4	53.5
Significance $_{(0.10)}$	NS	NS	NS

Control - no manure applied; Half - approximately 100 lb total N/acre; Full – approximately 200 lb total N/acre. Manure applied preplant either in fall or spring before soybean planting.

Table 18. Example N, P, and K application from liquid swine manure at three application rates and calculated nutrient removal in corn and soybean grain.

	Crop Nutrients from Liquid Pit Swine Manure with Rate Based on Total N Application			Nutrient Removal in Grain Based on 55 bu/acre Soybean and 150 bu/acre Corn Yields		
	Manure Application, gal/acre					S-C
Nutrient	3000	4000	5000	Soybean	Corn	Rotation
	- - - - - - - - lb/acre - - - - - - - - -			- - - - - - - - lb/acre - - - - - - - -		
N	150	200	250	170	110	280
P_2O_5	105	140	175	44	56	100
K_2O	75	100	125	83	45	128
Example manure nutrient values for swine grow-finish pit system: 50 lb total N/1000 gal; 35 lb P_2O_5/1000 gal; 25 lb K_2O/1000 gal.						

Figure 1. Effect of N fertilizer applied at the R3 growth stage on grain yield of irrigated soybean averaged across six sites in Kansas, adapted from Wesley et al., 1998.

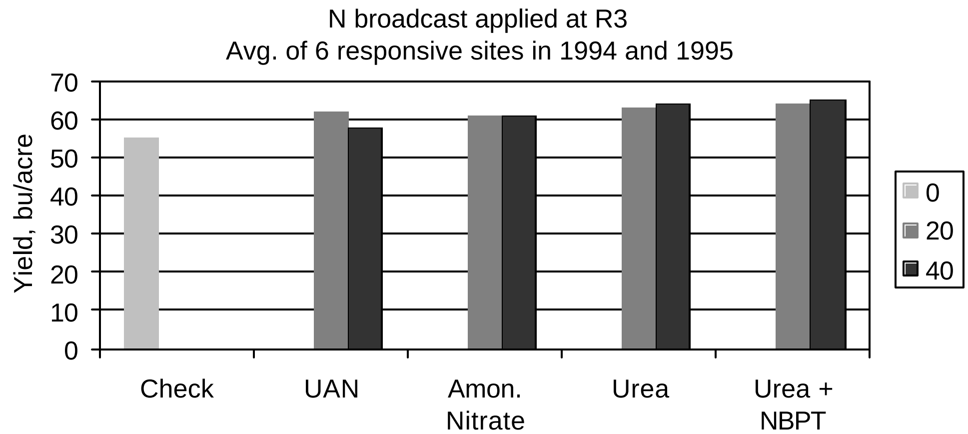

Figure 2. Post soybean harvest soil profile nitrate (0-4 ft) as influenced by swine manure (applied N calculated at 65% of total N) and N fertilizer, adapted from Schmidt et al, 2000.