IMPROVING NITROGEN FERTILIZATION EFFICIENCY FOR NO-TILLAGE CORN PRODUCTION

D.D. Howard [1], Essington [2], and W. M. Percell [3]

AUTHORS: [1] Plant and Soil Sci. Dept, West Tennessee Experiment Station, 605 Airways Blvd., Jackson, TN 38305; [2] Plant and Soil Sci. Dept., University of Tennessee, P. O. Box 1071, Knoxville, TN 37901-1074; and [3] West Tennessee Experiment Station, 605 Airways Blvd., Jackson, TN 38305. Corresponding author: D.D. Howard (dhoward@utk.edu).

ABSTRACT

Application of nitrogen (N) fertilizers for no-till corn (*Zea mays* L.) production is an environmental concern. Research is needed to evaluate methods for improving N efficiency through either reduced N rates or delayed injected applications. Research was initiated in 1996 and continued through 1998 on two soils located in West Tennessee. Nitrogen treatments included broadcasting urea and urea-ammonium nitrate (UAN) at 150 lb N/A at planting, injecting UAN at 150 lb N/A at planting, and injecting UAN at the 6- to 8-leaf growth stage at 150, 130, 110, and 90 lb N/A. Some treatments received a 10 lb N in-furrow starter. Delayed N applications were 51, 52, and 44 days after planting (DAP) on the Memphis soil and 43, 42, and 48 DAP on the Collins soil. Ear leaves were collected at mid-silking for N analysis. Injecting N at planting produced higher yields than broadcasting N. Delaying N application increased yields approximately 6 to 10% during years that weather did not restrict treatment effects. The combination of high temperatures and/or lack of rainfall between time of delayed applications and harvest affected yields and restricted treatment effects. In some years, the combination of starter fertilizer and delayed N application improved N efficiency. Either higher yields were produced or lower N rates (90, 110, 130 lb N/A) were needed to produce yields comparable with those produced from application of higher N rates at planting.

INTRODUCTION

Concern over nitrogen (N) use efficiency has increased over the past decade with increased emphasis on environmental issues. Nitrogen efficiency may be improved by using a management method as simple as applying the nutrient closer to the time of increased plant utilization rather than applying it before the plant develops an adequate root system for nutrient uptake. For corn production, applying N at such a growth stage would require that the N application be delayed until after plant emergence, which may require a change in the current management program. Producers routinely broadcast N several days to 1 month before planting. Applying N at, or in advance of, planting contributes to N losses through volatilization, immobilization, leaching, and erosion. Additional production factors that affect N efficiency for no-till (NT) corn include N source, rate of application, and method of application (Howard and Essington, 1998; Howard and Tyler, 1989a).

Surface broadcasting ammonium nitrate (AN), urea, and urea-ammonium nitrate solution (UAN) produced significantly lower yields than injecting UAN (Howard and Essington, 1998). They reported the efficiency of N sources to decrease in the following order ammonium nitrate (AN)>UAN (liquid 32% N)>urea when 150 lb N/A was surface broadcast on NT corn. Efficiency of urea-containing N sources for NT corn was increased by injecting UAN compared with surface applications (Howard and Tyler, 1989a; Howard and Tyler, 1989b; Howard and Essington, 1998). Even though injection improves N efficiency, it costs more than broadcasting because it requires more time and equipment (Roberts et al., 1995). Even with the increased application cost, injecting N was more profitable for NT corn produced on a soil having a winter wheat cover. Splitting a surface band UAN application improved NT corn yields compared with surface banding the rate at planting (Howard and Tyler, 1989a). Injecting UAN at planting produced higher yields than were obtained from either surface banding at planting or splitting the band. Howard and Duck (1987) reported that delaying the application of AN to conventional-tilled corn until the 5- to 7-leaf growth stage did not reduce yields compared with applying AN at planting.

Additional strategies for increasing N efficiency for NT corn are needed. The objective of this research was to evaluate delayed N applications on NT corn compared with applications at planting.

MATERIALS AND METHODS

Research was established in 1996 and continued through 1998 on a loess-derived Memphis silt loam (fine-silty, mixed, thermic, Typic Hapludalfs) at the Milan Experiment Station, Milan, TN, and on a Collins silt loam (coarse-silty, mixed acid, thermic, Aquic Udifluvent) at the West Tennessee Experiment Station, Jackson, TN. Standard soil test results indicated that the Memphis soil tested low-P and medium-K while the Collins soil tested high-P and high-K (Mehlich-I extractant).

Nitrogen treatments included broadcasting urea and UAN at 150 lb N/A at planting, injecting UAN at 150 Ib N/A at planting, and injecting UAN at the 6- to 8-leaf growth stage at 150, 130, 110, and 90 lb N/A. A 10-lbN/A in-furrow (I-F) starter was applied to certain treatments. Individual treatments are listed in Table 1. The starter, 2.8 gal/A of 32% UAN, was applied through a straight stream metering orifice, No. 24 Delavan Co. The metering orifice was attached to a special bracket for insecticide tubes that was attached to the rear of each planter unit. The starter was applied using a CO_2 pressurized system. Broadcast treatments were hand-applied, while the injected treatments were applied using a four-row injector having a knife configured behind a coulter. The injected treatments were applied approximately 2 to 5 inches off the row and approximately 3 inches deep.

The cultivar Pioneer 3245 was planted on the Memphis soil and Pioneer 3163 was planted on the Collins soil. Planting dates for the Memphis soil were Apr. 1, 1996, Mar. 31, 1997, and Apr. 6, 1998, while the Collins soil was planted Apr. 10, 1996, Apr. 10, 1997, and Apr. 2, 1998. A seeding rate of 25,500 kernels/A were planted at each location. The experimental design was a randomized complete block with six replications. Individual plots were 30 feet long and 10 feet wide (30-inch centers). Delayed N was applied May 24,1996, May 21,1997, and May 20,1998 on the Memphis soil and May 22,1996, May 23, 1997, and May 20,1998 on the Collins soil. The applications were delayed 51, 52, and 44 days after planting (DAP) on the Memphis soil and 43,42, and 48 DAP on the Collins soil for the 3 years, respectively. Phosphorus and potassium were broadcast before planting at 60 to 75 lb P_2O_5/A using triple super-phosphate and 60 to 75 lb K_2O/A using potassium chloride.

Weed control measures included broadcasting Paraquat (1, 1'-dimethyl-4, 4'-bipyridinium ion) at 1 qt/A plus Bicep II [atrazine(6-chloro-N-ethyl- N'- (1methylethyl)-1, 3,5-triazine-2,4- diamine) plus metolachlor 2-chloro-N-(2-ethyl-6-me thylpheny1)-N-(2-methoxy- 1-methylethyl) acetamide] applied at 2 qt/A and atrazine (6-chloro-N-ethyl- N'- (1methylethyl)- 1, 3,5-triazine-2,4-diamine) at 1pt/A for residual weed and seedling johnsongrass control. The broadcast application contained 0.5% (v/v) nonionic surfactant. One month after emergence, Accent (2-(((((4,6-Dimethoxypyrimidin- 1-yl)aminocarbonyl)) aminosulfonyl))-N,N-dimethyl-3-pyridinecarboxamine) was applied at 2/3 oz/A for rhizome johnsongrass control. Carbofuran (2, 3-dihydro-2, 2- dimethyl -7-benzofuranyl methylcarbamate) was applied I-F at 1lb/A for insect control.

Twenty ear leaves were collected from the two middle rows at mid-silking (1st week of July), dried, ground, and stored until N analysis. The N concentrations were evaluated using a Leco CNS-2000, Leco Cooperation, St. Joseph MI. Yields were determined by harvesting the two center rows and adjusting grain moisture to 15.5%.

Statistical analyses of yield and ear-leaf N concentrations were performed utilizing mixed model SAS procedures (SAS Ins., 1997). The mixed model procedure provides Type III F statistical values but does not provide mean square values for each element within the analyses or the error terms for mean separation. Therefore, mean separation was evaluated at a probability level of 0.05 through a series of protected pair-wise contrasts among all treatments (Saxton, 1998).

RESULTS AND DISCUSSION

Yields and leaf N concentrations of NT corn on each soil were affected by N treatments (Table 2). The treatment effects were inconsistent across the 3 years on both soils as indicated by the significant treatment-by-year interactive effect of yields and leaf N concentrations. Results are described by year and soil type.

Memphis silt loam yields

Injecting N at planting in 1996 and 1998 increased NT corn yields compared with broadcasting urea or UAN at planting (Table 3). Treatment differences in 1997 were limited to two treatments, broadcasting 150 lb N/A as UAN at planting and delayed injecting 150 lb N/A as UAN. No-till yield differences due to application methods have been reported (Howard and Tyler, 1989b; Howard and Essington, 1998). The effect of rainfall (amount and frequency of events after surface N application) on yearly treatment yield differences has been reported (Fox and Hoffman, 1981).

Delaying the 150 lb N/A application until the 6- to 8-leaf growth stage increased yields in 1996 (Table 3). Injecting 150 lb N/A at planting produced comparable yields with delayed injection of either 130 or 110 lb N/A plus starter. The increased yields from the delayed 150 lb N/A injection application compared with injecting 150 lb N/A at planting allow additional comparisons with delayed N rate injections. Yield increases from delaying the N application were not evident for 1997 or 1998 even though mean yields for 1997 were higher for the delayed applications. The lower overall yields in 1998 may have restricted the full expression of the treatment on yields.

The 3-year average yields need to be considered since N recommendations are based on multi-year data. For the 3 years, injecting UAN at planting resulted in higher yields than broadcasting the two N sources. The higher yields from broadcasting UAN compared with broadcasting urea agrees with earlier research (Howard and Essington, 1998; Howard and Tyler, 1989a). Yields were higher for injecting 150 lb N/A as UAN at the 6- to 8-leaf growth stage than for injecting at planting. The data suggest that over the 3 years, delayed injection of 110 lb N/A (plus 10 lb N/A starter) resulted in comparable yields with injecting 150 lb N/A at planting. Averaged across 3 years, delayed injection of 150 lb N/A increased yields by 7% over injecting N at planting. The data also indicate that, without lowering yields, the N rate can be reduced by 20% by delaying the application. These two observations should be worthy of consideration for producers seeking methods to improve yields through management or reducing N rates either during a time of restricted capital or for production close to environmentally sensitive areas.

These data indicate that N efficiency, 3-year average (yield/N rate) x 100, was affected by N source applied at planting, method of application at planting, delaying the N application, and reducing the delayed N rate (Table 3). Injecting UAN at planting increased N efficiency from 68 to 77% compared with broadcasting N. The efficiency was greater for broadcasting UAN than for broadcasting urea. Delaying the 150 lb N/A application increased N efficiency from 77 to 82%. Nitrogen efficiency was increased from 82 to 109% by reducing the delayed N rate from 150 to 90 lb N/A. Fowler et al. (1990) reported maximum N use efficiency at low N rates and decreased efficiency as N rates increased.

Collins silt loam yields

Injecting 150 lb N/A at planting in 1996 resulted in higher yields than broadcasting urea (Table 4). Delaying the 150 N rate increased yields 6.6% when compared with injecting UAN at planting. By delaying the N application, the N rate could be reduced by 6.6% to 130 lb N/A plus starter or by 20% to 110 lb N/A plus starter while maintaining comparable yields. In 1997, injecting N at planting increased yield relative to broadcasting the two N sources. In 1998, injecting N at planting generally resulted in higher yields than delaying applications.

The 3-year average yields indicate no significant differences for delaying the N application when compared with injections made at planting. Injecting N at planting resulted in 22% higher yields when compared with broadcast N applications. Nitrogen efficiency for applications at planting ranged from 75 to 87% whereas the efficiency ranged from 91 to 122% for the delayed applications.

Memphis silt loam leaf N concentrations

In 1996, injecting UAN at planting produced higher leaf N concentrations than broadcasting UAN, but broadcasting UAN produced higher leaf N concentrations than the broadcast urea treatment (Table 5). Injecting 150 lb N/A 51 DAP resulted in higher leaf N concentrations than was observed for injecting UAN at planting. Leaf N differences were not observed between injecting 150 lb N/A at planting and delayed injection of the three lower N rates. In 1997, there were no differences in leaf N concentrations among treatments applied at planting. These data are possibly responsible for the year-by-treatment interaction since differences were evident in 1996. Delaying the N applications resulted in higher leaf N concentrations than treatments applied at planting. In 1998, treatment effects on leaf N concentrations were similar to the 1996 data. Injecting UAN resulted in higher N concentrations than broadcasting either urea or UAN. Leaf N concentrations were not increased by delaying the application.

Averaged across years, delayed injection of the three high N rates resulted in higher leaf N concentrations than injecting N at planting. These data indicate that injecting 150 lb N/A as UAN at planting resulted in leaf N concentrations comparable with injecting 90 lb N/A plus starter at the 6- to 8-leaf growth stage. These data closely resemble the yield data except that yield differences were slightly less than leaf N concentration differences. For the 3 years, leaf N concentrations were greater for delayed injecting 110, 130, and 150 lb N/A rates relative to injecting 150 lb N/A at planting. Three-year average yield differences were limited to the 150 lb N/A rate applied at planting or delayed (Table 3).

Collins silt loam leaf N concentrations

Leaf N concentration in 1996 was greater for injecting UAN at planting than for broadcasting UAN at planting (Table 6). Leaf N concentrations with delayed N application varied with application rate, as would be expected. Differences were not significant for delayed injection of the lowest N rate and applying N at planting. In 1997, delayed injection of the three highest N rates increased leaf N compared with applying N at planting. Delayed injection of N in 1998 increased leaf N relative to applying N at planting.

Averaged across years, delayed injection of the three highest N rates resulted in higher leaf N concentrations than N injected at planting. Based on leaf N concentrations, delayed injection of 90 lb N/A plus a starter resulted in N concentrations comparable with injecting 150 lb N/A at planting. These data are similar to the leaf N concentrations for the Memphis silt loam.

RAINFALL

The yield and leaf N concentration data show differences each of the 3 years for both soils. Both yield and leaf N concentration differences between broadcast and injection application methods may be attributed to rainfall within the first several days following N application at planting. For the Memphis soil, rainfall totals following application varied among years. In 1996, 0.1 inch of rain was recorded (not presented) within 3 days following planting with an 11-day interval between the next event of 0.2 inch. In 1997, a total 1.1 inches of rain was recorded within **5** days after planting with an additional 0.7 inch of rain the next day. In 1998, 0.1 inch of rain was recorded within 3 days after planting with an additional 0.8 inch recorded the 11th day after application. These data suggest that rainfall was sufficient to incorporate the broadcast N applications and possibly promote leaching from the injected N thus restricting yield and leaf N differences in 1997 (Table 3). For the Collins soil, 0.3 inch of rain was recorded within 4 days after planting in 1996, 0.3 inch of rain was recorded the second day after N application in 1997, and 1.0 inches of rain were recorded within 7 days following application in 1998. Apparently, 1 inch of rain within 7 days after N application was sufficient to reduce yield and leaf N concentration differences between broadcast and injected application methods while the 0.3 or less inches was insufficient in 1996 or 1997.

Generally, the greater the yield difference between applying N at planting and later (6th to 8th leaf) the greater the rainfall recorded between planting and time of the delayed application. In 1996, corn yield and leaf N concentrations on the Memphis silt loam were increased with delayed N application. During the 51-day interval between planting and applying N, 5.3 inches of rain were recorded (Table 7). The 1997 yields were not improved by delaying the N application (Table 3), but leaf N concentrations were increased by delayed applications (Table 5). This observation indicates that weather conditions between the first week of July (leaves for N evaluation collected) and harvest in September affected yields. A total of 5.9 inches of rain was recorded between planting and injecting N 52 DAP. A total of 15.8 inches of rainfall was recorded in 1997, which was approximately 2 inches less than that recorded for 1996. The 1998 data indicate that delayed applications did not increase either yields or leaf N concentrations. Thus, conditions existing before silking or at silking reduced the yields. The 1998 yields were generally one-third lower than the other two years. The 1998 weekly average high temperatures and cumulative rainfall were 94°F with 0.1 inch of rain for the week of June 24, 92°F with no rainfall for the week of July 1, 90°F with 2.1 inches of rain during the week of July 8, and 90°F with 0.2 inch of rain during the week of July 15. Pollination of corn may be hampered when air temperatures are this high and rainfall is restricted. These weather conditions would restrict yields, as indicated by the data, and thus restrict the treatment effects.

On the Collins silt loam, the 1996 and 1997 yield and leaf N concentrations indicate that delaying N application was beneficial (Tables 4 and 6). During this interval, 5.6 inches of rain were recorded in 1996 with 4.8 inches recorded in 1997. Rainfall recorded between the delayed application and the black layer formation was 15.1 inches in 1996 and 23.5 inches in 1997. The 1998 yield and leaf N data indicate that delayed application affected only N concentration. However, the rainfall data would suggest that differences in yield and leaf N concentrations should exist based on the 1996 rainfall and yields. As was pointed out with the 1998 Memphis data, factors other than rainfall may be responsible for the lack of response. The 1998 weekly average high temperatures and cumulative rainfall were 95°F with no rain during the week of June 24, 93°F with 0.7 inch of rain during the week of July 1, 90°F with 0.2 inch of rain for the week of July 8, and 90°F with **1.1** inches of rain for the week of July 15. These conditions are similar to those reported for the Memphis silt loam except that rainfall appears to be slightly less.

CONCLUSIONS

In most environments, NT corn yields, leaf N concentrations, and N efficiency can be increased by delaying N application until the corn is in the 6- to 8-leaf growth stage. However, the benefit from the delayed application is dependent upon weather conditions between planting and the delayed application. These data indicate that delaying the N application can increase yields by 5 to 15% and if rainfall is not a limitation, the N rate can be reduced by 15 to 20% without reducing yields. During certain years, leaf N concentrations were increased by delaying the N application, but yields were not increased due to drought stress between silking and black layer.

REFERENCES

Fox, R.H. and L.D. Hoffman., 1981. The effect of N fertilizer source on grain yield, N uptake, soil pH, and lime required in no-till corn. Agron. J. 73-891-895.

Fowler, D.B., J. Brydon, B.A. Darroch, M.H. Entz, and A.M. Johnson. 1990. Environment and genotype influence on grain protein concentration of wheat and rye. Agron. J. 82:655-664.

Howard, D.D., and B.N. Duck. 1987. Corn production on loess soils: nitrogen rates and times of application. Tennessee Farm and Home Science 144:31-35.

Howard, D.D., and M.E. Essington. 1998. Effects of surface-applied limestone on the efficiency of urea-containing nitrogen sources for no-till corn. Agron. J. 90:523-528.

Howard, D.D., and D.D. Tyler. 1989a. Comparison of time and methods of application of nitrogen solution to no-till corn. J. Fert. Issues 6:32-35.

Howard, D.D., and D.D. Tyler. 1989b. Nitrogen source, N rate and application method for no-till corn. Soil Sci. Soc. Am. J 53:1573-1577.

Roberts, R.K., D.D. Howard, D.C. Gerloff, and L.A. Johnson. 1995. Economic analysis of nitrogen sources and placement methods in no-tillage corn. J. Prod. Agric. 8:575-580.

SAS Institute. 1997. SAS/STAT Software: Changes and enhancements through release 6.12. Cary, NC.

Saxton, A.M. 1998. A macro for converting mean separation output to letter groupings in Proc Mixed. pp. 1243-1246. Proceedings of the 23rd Annual SAS Users Group Inter. Conf., SAS Institute. Cary, NC.

Table 1. Treatments applied to no-till corn to evaluate N source, application rate, application method, and timing.

Nitrogen			Application	
Source	Rate	Starter	Method	Timing
	----- lb/A --------			
Urea	150	0	Broadcast	Planting
UAN	150	0	Injection	Planting
UAN	150	0	Broadcast	Planting
UAN	150	0	Injection	6- to 8-leaf
UAN	130	10	Injection	6- to 8-leaf
UAN	110	10	Injection	6- to 8-leaf
UAN	90	10	Injection	6- to 8-leaf

Table 2. ANOVA of N treatments on yield and ear-leaf N concentration of NT corn produced on two soils.

Source	df	Memphis silt loam				Collins silt loam			
		Yield		Leaf N		Yield		Leaf N	
		'F'	Pr >F	'F'	Pr >F	'F'	Pr>F	'F'	Pr>F
Year (Y)	2	253.3	0.0001	39.8	0.001	98.3	0.0001	137.9	0.0001
Error a	10								
Nitrogen (N)	6	15.8	0.0001	55.1	0.0001	16.0	0.0001	28.4	0.0001
Y*T	12	3.1	0.001	4.6	0.0001	10.9	0.0001	4.8	0.0001
Error b	88								

Table 3. Effect of N source, application method, and time and rate of N application on no-till corn Memphis silt loam.

N source	A M†	ToA‡	N Rate	Star§	Yield 1996	Yield 1997	Yield 1998	Yield Avg.	N Effic.¶
					lb/A				%
Urea	B	P	150	0	91e#	136ab	57c	95e	63
UAN	I	P	150	0	123bc	133ab	87a	115bc	77
UAN	B	P	150	0	114d	123b	70b	102d	68
UAN	I	D	150	0	135a	144a	88a	123a	82
UAN	I	D	130	10	129ab	142a	88a	120ab	86
UAN	I	D	110	10	115cd	142a	83a	113bc	94
UAN	I	D	90	10	112d	132ab	81a	109cd	109

† Application method - B=broadcast; I=Injection.
‡ Time of N application - P=applied at planting; D=delayed until 6- to 8-leaf growth stage.
§ Starter application - in direct contact with the seed.
¶ Efficiency of N (yield/lb N x 100) for three-year mean yields.
# Within a yield column, means followed by the same letter are not significantly different at a = 0.05.

Table 4. Effect of N source, application method, and time and rate of N application on no-till corn yields on a Collins silt loam.

N Source	A M†	ToA‡	N Rate	Star&	Yield 1996	Yield 1997	Yield 1998	Yield Avg.	N Effic.
					lb/A				%
Urea	B	P	150	0	128c#	102d	108ab	113d	75
UAN	I	P	150	0	137b	140bc	115a	130ab	87
UAN	B	P	150	0	130bc	104d	106ab	113d	75
UAN	I	D	150	0	146a	156ab	106ab	136a	91
UAN	I	D	130	10	136b	162a	103b	134a	96
UAN	I	D	110	10	136b	155ab	103b	131a	109
UAN	I	D	90	10	126c	139c	101b	122c	122

† Application method - B =broadcast; I = Injection.
‡ Time of N application - P=applied at planting; D=delayed until 6- to 8-leaf growth stage.
§ Starter application - in direct contact with the seed.
¶ Efficiency of N (yield/lb N x 100) for three-year mean yields.
# Within a yield column, means followed by the same letter are not significantly different at a= 0.05.

Table 5. Effect of N source, application method, and time and rate of N application on no-till corn ear-leaf N concentrations on a Memphis silt loam.

N Source	A M[†]	ToA[‡]	NRate	Star[&]	Leaf N concentration			
					1996	1997	1998	Avg.
			----------lb/A---------		-------------------------% N-------------------------			
Urea	B	P	150	0	1.97e[¶]	2.42c	2.42b	2.27c
UAN	I	P	150	0	2.45bc	2.48c	3.05a	2.66b
UAN	B	P	150	0	2.24d	2.35c	2.36b	2.32c
UAN	I	D	150	0	2.63a	3.00a	3.10a	2.91a
UAN	I	D	130	10	2.55ab	3.03a	3.00a	2.86a
UAN	I	D	110	10	2.58ab	2.93ab	3.06a	2.86a
UAN	I	D	90	10	2.38cd	2.81b	3.02a	2.73b

[†] Application Method - B = broadcast; I = Injection.
[‡] Time of Application - P = applied at planting; D = delayed until 6th - 8th leaf growth stage.
[§] Starter Application - in direct contact with the seed.
[¶] Within a yield column, means followed by the same letter are not significantly different at a = 0.05.

Table 6. Effect of N source, application method, and time and rate of N application on no-till corn ear-leaf N concentrations on a Collins silt loam.

N Source	A M[†]	ToA[‡]	NRate	Star[&]	Leaf N concentration			
					1996	1997	1998	Avg.
			----------lb/A---------		-------------------------% N-------------------------			
Urea	B	P	150	0	2.80c[¶]	1.84d	2.80d	2.48c
UAN	I	P	150	0	2.80c	2.35c	2.90cd	2.68b
UAN	B	P	150	0	2.61d	1.97d	2.88cd	2.49c
UAN	I	D	150	0	3.05a	2.71ab	3.17a	2.98a
UAN	I	D	130	10	3.01ab	2.71ab	3.21a	2.97a
UAN	I	D	110	10	2.89abc	2.79a	3.16a	2.95a
UAN	I	D	90	10	2.77cd	2.50bc	3.09ab	2.78b

[t] **Application Method -B=broadcast; I=injection.**
[‡] **Time of Application - P-applied at planting; D=delayed until 6- to 8-leaf growth stage.**
[&] **Starter Application - in direct contact with the seed.**
[*] **Within a yield column, means followed by the same letter are not significantly different at a = 0.05.**

Table 7. Rainfall recorded for selected periods between March and August by year.

Recorded time	Rainfall recorded					
	Memphis silt loam			Collins silt loam		
	1996	1997	1998	1996	1997	1998
Rainfall month before planting (in.)	5.3	12.1	5.1	5.5	5.2	5.2
Rainfall between planting & delayed application (in.)	5.3	5.9	13.0	5.6	4.8	12.2
Days after planting & delayed N application	51	52	44	43	42	48
No. of events for period	16	12	19	11	10	20
Largest event during period (in.)	1.6	1.1	5.3	1.3	1.1	3.3
Rainfall following delayed N application (in.)	17.9	15.9	19.2	15.1	23.5	19.0
No. of events for period	30	41	37	27	38	34