STRATEGIES FOR SPLIT N APPLICATIONS IN 2004

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Split application of nitrogen (N) is a management strategy for corn that has been practiced on a limited basis for years. Coarse-textured, sandy soils have often received split applications to improve N uptake and efficiency and reduce leaching loss. Some N (less than half) is generally applied prior to or at planting and the rest (usually more than half) is sidedress applied prior to tasseling. The sidedress applications may consist of either a single application or multiple applications, which are usually associated with irrigation. Because a greater portion of the N is applied closer to the time of maximum N uptake, split application strategies are often considered as being more efficient and environmentally sound. For these reasons and others, split application of N is becoming more popular on medium and fine-textured soils. Additionally, as the price of N increases, growers will give greater consideration to N management practices that are more efficient and save money. The purpose of this paper is to present information and recommendations on split N application strategies, based on more than 60 site-years of field data with corn on medium and fine-textured soils in southern Minnesota.

RESULTS AND DISCUSSION

Preplant vs. Split Application, 1989-1992

Experiments comparing spring preplant N with split N application for corn were conducted at 32 sites in southern Minnesota from 1989-1992. The sites were located on 14 fine-textured glacial till soils, 11 medium-textured loess soils, and 7 coarse-textured, outwash (sandy) soils. Previous crops at these sites included primarily soybean, but also corn, oats and rye. Urea at rates of 0, 30, 60, 90, 120, 150, and 180 lb N/A was broadcast-applied and incorporated by field cultivation or disking just prior to planting. The split N application treatments included 60 lb N/A preplant-applied as urea in 1989 and 1990 and 30 lb N/A preplant-applied as urea in 1991 and 1992. Sidedress rates of 30, 60, and 90 lb N/A were then knifed in 4 inches deep midway between the rows at the V5 to V6 stage. Thirty-year normal precipitation at the sites ranged from 24 to 32 inches per year. However, during this 4-year study, growing season rainfall ranged from 36% below normal to 59% above normal, giving a wide range of rainfall conditions upon which to evaluate the treatments.

Yield differences between the preplant and split application strategies are summarized in Table 1. Corn grain yield responded to N at 28 of the 32 sites (88%). Preplant application was equal to split application at 16 of the 28 responding sites (58%). Split application was superior to preplant application at 8 sites (28%). In all cases, excessive growing season rainfall and/or sandy soils occurred where split N application outyielded preplant application. Preplant application was superior to split application at 4 sites (14%). The disadvantage for split application generally occurred on the glacial till soils when above-normal, early season rainfall accompanied insufficient preplant N (30 lb N/A) or when growing season rainfall was below normal. Apparently the 30-lb N

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rate was insufficient under the wetter conditions to meet the plant's early-season demand until N applied at V5-V6 became available. Under drier-than-normal growing season conditions, insufficient sidedress-applied N may have moved into the active part of the root system where water was being taken up. A portion of the N applied midway between the corn rows apparently remained positionally unavailable.

Table 1. Comparing preplant N to split N application using corn grain yield response as an indicator at 32 sites in southern Minnesota.

Sites	Total	Glacial till	Loess	Outwash
Number	32	14	11	7
N responsive	28	14	9	5
Preplant yield = Split yield	16	7	7	2
Preplant yield < Split yield	8	4	1	3
Preplant yield > Split yield	4	3	1	0

Examples of how rainfall affected corn yield response to method of application on fine-textured soils in south-central Minnesota are shown in Table 2. Soybean was the previous crop on both sites. In 1991 at a site in Waseca County where May-September rainfall was 56% above normal, yields were increased an average of 11 bu/A by the split-applied treatments. It is likely that a significant portion of the broadcast preplant-applied N was denitrified in this wet year. In 1992, at a site in Blue Earth County where rainfall was only 16% above normal, yields were decreased an average of 11 bu/A by the split-applied treatments. Under these conditions, some N-deficient corn was visible at the time of the sidedress application (12-inch tall corn). Apparently the initial 30-lb preplant broadcast rate was insufficient to sustain an adequate supply of N to the plant early in the season. The plants never seemed to recover completely. In addition, rainfall later in the season did not appear adequate to move sufficient N into the active root zone to overcome the early-season deficiency.

Table 2. Corn yield as affected by method of N application on fine-textured glacial till soils.

Time of application		Year	
Preplant	12" Corn	1991	1992
- - - - N rate (lb N/A) - - - -		- - - - bu/A - - - -	
0	0	84	107
30	0	129	132
60	0	143	**144**
30	30	**161**	141
90	0	158	**156**
30	60	**157**	137
120	0	165	**164**
30	90	**182**	153
	Advantage for split =	**+11**	-11

<u>Continuous Corn, Loess (Silt Loam) Soils</u>

Experiments were conducted in southeastern Minnesota from 1987 through 1997 to determine the optimum N application method for continuous corn. Anhydrous ammonia was the N source at all sites. An experiment on a Port Byron sil in Olmsted Co. from 1987-90 provided information on N efficiency and water quality in addition to corn production (Table 3). Yields were optimized at the 150-lb N rate. Highest yield and N efficiency and lowest nitrate-N concentration in the soil water at a 5-foot depth in Sept. 1990 were obtained with the spring preplant treatment. Fall or split application of N did not improve corn yield and N efficiency, but did increase the potential for greater leaching losses of nitrate. Similarly, using excess N (225 N/A) did not increase yields or N efficiency but increased nitrate leaching potential.

Table 3. Continuous corn yields as affected by time, rate, and method of application in Olmsted Co., 1987-90.

N treatment		Grain	N recovery in		NO_3-N in*
Rate	Time/method	yield	Grain	Silage	soil water
lb N/A		bu/A	- - - - - - - - %	- - - - - - - -	ppm
0	--	84	--	--	1
75	Spr. preplant	156	69	86	11
150	"	**172**	50	67	29
150	Fall	169	48	65	43
150	½ Spr. + ½ SD at V6	168	46	60	47
225	Spr. preplant	167	33	45	43

* At a 5-ft depth on 9/5/90.

Split applications of N did not improve corn yield compared to a single preplant application on a Port Byron sil in Goodhue Co. or a Seaton sil in Winona Co. (Table 4). A single sidedress application at the V4 stage produced a slightly lower yield compared to the preplant and split applications in Winona Co, but did not negatively affect grain yields in Goodhue Co.

Table 4. Continuous corn yields as affected by time and method of N application in Goodhue and Winona Counties, 1987-90.

N treatment		County	
Rate	Time/method	Goodhue	Winona
lb N/A		- - - - - Yield avg. (bu/A)	- - - - -
0	--	89	127
150	Spr. preplant	147	158
150	1/3 Spr. + 2/3 at V7	146	160
150	2/3 Spr. + 1/3 at V7	148	--
150	Sidedress at V4	146	152

Another study in Olmsted Co. compared various combinations of preplant and sidedress applications of N from 1992-97 (Table 5). In these wetter-than-normal years, the 7-yr average yield was 2-5 bu/A higher with split applications compared to a single preplant application. Applying a single sidedress application at the V6 to V7 stage reduced grain yield slightly.

Table 5. Continuous corn yield as affected by rate, time and method of N application in Olmsted Co., 1992-97.

N treatment		7-yr
Rate	Time/method	yield avg.
lb/A		bu/A
0	--	63
90	Spr. preplant (PP)	129
90	2/3 PP + 1/3 Sidedress (V6-7)	**134**
90	Sidedress (V6-7)	127
120	Spring preplant (PP)	135
120	½ PP + ½ Sidedress (V6-7)	137
	LSD (0.10) =	3

Continuous Corn, Glacial Till (Clay Loam) Soils

A 3-year (1985-87) study on a Webster cl at Waseca was conducted to determine if corn yield was affected by different placement methods and time of application of anhydrous ammonia (AA) and UAN (urea-ammonium nitrate). Soil pH ranged from 6.7 to 6.9, and moldboard plow tillage was used each year. Yields shown in Table 6 are averaged across the 60, 120, and 180-lb N rates for each treatment except the check (0 lb N/A). Averaged across the three years, split application with 2/3 of the N applied sidedress as AA increased corn yield 4 bu/A compared with a single preplant (PP) application of AA. Yields were reduced dramatically (23 bu/A) when 2/3 of the N was sidedress dribbled as UAN and incorporated with cultivation. In 1986 and 1987 injecting the sidedress UAN 4" deep gave corn yields that were 7 to 32 bu/A bu/A greater compared to the dribble-applied sidedress UAN. In general, split applications of N where 2/3 was AA and 1/3 was UAN were generally better than where all of the N for both applications was UAN.

Table 6. Continuous corn yields as affected by N source and placement method at Waseca, 1985-87.

N treatment	Year			3-yr
Source and time	1985	1986	1987	avg.
	- - - - - - - - Yield (bu/A) - - - - - - - -			
Check (0 lb N/A)	66	51	87	68
AA -- PP	140	117	139	132
1/3 UAN (PP) + 2/3 AA (SD)	143	119	146	**136**
1/3 UAN (PP) + 2/3 UAN (D-SD)[†‡]	130	99	110	113
1/3 UAN (PP) + 2/3 UAN (I-SD)[‡]	--	106	142	--
2/3 AA (PP) + 1/3 UAN (D-SD)[‡]	--	113	141	--
LSD (0.05) =	4	7	5	

[†] SD UAN applied at V6-7; not incorporated in 1985, incorporated by cultivation 1 d & 2 d after application in 1986 and 1987.

[‡] D-SD = surface dribble-sidedress; I-SD = inject 4"-sidedress.

Corn After Soybeans, Glacial Till (Clay Loam) Soils

A 7-yr (1987-93) study was conducted on a Canisteo cl (pH=7.6) to determine the effect of fall, spring preplant (PP), and split application of anhydrous ammonia on corn yield, N recovery in the grain and leaching loss of nitrate into tile lines. The split application treatment consisted of 40% applied spring PP and 60% sidedress at the V8 stage. The N rate was 135 lb N/A for all N treatments. Seven-year yield average and N recovery shown in Table 7 were highest for split application (145 bu/A), intermediate for the spring PP and fall N + nitrapyrin treatments (139 bu/A), and lowest when the N was applied late in October without nitrapyrin (131 bu/A). The greatest response to split N tended to occur in the wet years (1990-93). Nitrate losses in subsurface tile drainage water averaged across the four corn-soybean cycles (1990-93) were greatest for fall N without nitrapyrin, intermediate for split N application, and least for the fall N + nitrapyrin and spring PP treatments. Nitrate losses in the soybean year following corn tended to be slightly greater for the spring and split application treatments compared to the fall treatments (data not shown) (Randall et al., 2003).

Table 7. Corn yield, N recovery in the plant, and nitrate-N loss to tile drainage as affected by N application time at Waseca, 1987-93.

Application time	N-Serve	7-yr avg. yield	N recovery	NO_3-N loss in drainage
		bu/A	%	lb/inch of drainage
Check (0 lb N/A)	-	95	-	-
Fall (late Oct.)	No	131	31	3.8
“ “	Yes	139	37	3.1
Spring PP	No	139	40	3.1
40% PP + 60% SD (V8)	No	**145**	44	3.3
LSD (0.10):		4		

A study was conducted on a Webster clay loam at Waseca in 2001 and 2002 to compare fall, spring preplant, planting time, and sidedress application times along with associated N sources and methods of application in a “one-pass” tillage system (Randall and Vetsch, 2003). All N treatments, except the control, received a total of 100 lb N/A. This rate is about 15% less than the University of Minnesota recommends for an expected yield of 150-174 bu/A, but was used so that differences in application method/timing could be identified more clearly. All plots were field cultivated following broadcast application of preplant urea and UAN. Dribble treatments were applied to the soil surface within 2” of the seed row with the planter. Sidedress treatments of UAN were coulter-injected 4” deep midway between the rows at the V3 stage.

Averaged across both of these wetter-than-normal growing seasons, grain yield and N recovery were greatest when a majority of the N (60 lb N/A) was sidedress applied as UAN (Table 8). Yields were not statistically lower when a combination of either 20 or 40 lb N/A was sidedressed in conjunction with 80 or 60 lb N/A as fall-applied anhydrous ammonia with N-Serve. Yields and N recovery were significantly lower when 80 or 60 lb N/A was applied in the fall and the remaining 20 or 40 lb N/A as UAN was dribbled next to the row at planting. Because phytotoxicity symptoms were not observed, we concluded that some of the surface-dribbled UAN was lost to the atmosphere (volatilized); however, we cannot dismiss the fact that some phytotoxicity may have affected early root growth, but we never observed it.

Table 8. Corn grain yield and N recovery as affected by N source and application time and method in a one-pass tillage system at Waseca, 2001-02.

Time of application and source of N					N
Fall, AA†	Preplant	Planting, UAN	Sidedress, UAN	Yield	recovery
				(bu/A)	%
None	None	None	None	118	-
w/N-S, 100				**167**	63
w/N-S, 80		Dribble, 20		154	48
w/N-S, 80			Coulter, 20	**169**	60
w/N-S, 60		Dribble, 40		155	46
w/N-S, 60			Coulter, 40	**169**	56
	AA, 100			164	60
	AA w/N-S			165	59
	Urea bdct incorp.			165	63
	UAN bdct incorp.			163	59
		Dribble, 40	Coulter, 60	**175**	**65**
		Broadcast, 40	Coulter, 60	**177**	**73**
† w/NS = with N-Serve			LSD (0.10):	10	9

SUMMARY

<u>Factors Influencing the Performance of Split-applied N</u>

Because split applications of N allow a greater proportion of the N to be applied closer to the time of rapid N uptake by corn, the common perception is that N uptake, N efficiency, and grain yield can usually be increased when split-applying N compared to fall or spring preplant applications. However, the research results presented in this paper, obtained primarily on medium- and fine-textured soils, indicate that split application increased yield and N efficiency compared to spring preplant applications in only about one-third of the more than 60 site-years of experiments. Moreover, when applied at the same rate of N, differences in potential nitrate leaching losses between preplant and split applications have not been observed. Based on the results obtained in these research trials, the following factors, conditions, and management practices seem particularly important to enhance the success of split N application:

- sandy or coarse-textured soils, particularly if irrigated
- growing season rainfall is above normal, especially during May and June.
- when the preplant portion of N is broadcast, apply 40 to 60 lb N/A. Applying less broadcast, preplant N may be insufficient to sustain plants until the sidedress portion becomes available under unusual spring rainfall conditions or when corn follows corn.
- when the preplant portion of N is applied in a band near the row with the planter, do not use more than 20 lb N/A if dribbled on the surface within 2” of the seed row.
- the sidedress portion of N should be applied prior to V4 and should be injected 4” deep. Incorporation of sidedress N by cultivation can leave the N in dry soil near the surface, resulting in poor availability in dry years.

Factors Affecting Future of Split N Application

Split application of N has not been a "first choice" of Midwest corn growers unless sandy soils and irrigation were part of the production package. Most growers have opted for spring preplant or late fall application because of time, labor, and convenience reasons. However, split application of N is likely to become much more popular in the future because of the following inter-related reasons.

- Greater environmental and economic pressures. Even though the above information does not suggest consistent or great positive environmental and economic benefits, the widely held perception that split applic ations do lead to greater efficiency and economic return and less N loss will "encourage" increased adoption of split application strategies.
- Less fall application. Because of greater environmental and efficiency concerns with fall application, shifts to spring and in-season N applications will occur.
- Less use of anhydrous ammonia (AA). Higher energy (natural gas) costs, off-shore production, transportation, safety concerns, and imported N sources are factors resulting in greater acceptance and utilization of urea and UAN and a declining market share for AA. Urea and UAN fit well into many split application strategies.
- Greater availability of "precision and farmer friendly" application equipment. As farm size grows and the desire increases for more precise application, the equipment industry is continually working to develop equipment to meet both the suppliers and growers needs. This suits split application.
- More available time due to technological development. Even though farm size continues to grow, the amount of time available to apply supplemental sidedress N has increased because less time is spent applying multiple pesticides and because larger, more efficient and precise application equipment for N is available.
- Greater emphasis on synchronizing fertilizer N availability with the timing of N uptake demand by corn. Again, this is largely due to environmental and economic concerns. However, recent developments by the fertilizer industry to produce "controlled release" fertilizers will help drive this concept.
- Greater use of remote sensing as a diagnostic tool. Remote sensing to assess the N status and N needs of a growing corn plant meshes well with strategies to obtain more precise, spatially-variable rates of sidedressed N; increased profits; and decreased environmental consequences. This technology, when fully understood, will greatly boost the use of split applications of N in the future.
- Phosphorus-based manure application. As livestock producers and growers utilizing animal manure gradually shift toward applying manure on a P-basis, supplemental N will often be needed to provide adequate N for the crop. Thus, a preplant application of manure plus a sidedress application of fertilizer N, probably based on remote sensing, will also add to the prominence of split application in the future.

CONCLUSIONS

Nitrogen timing BMPs, including split application, must be tailored to soil and climatic conditions. Factors such as extra labor/time demand, equipment needed, carryover of unused N, potential for using remote sensing or a soil test to determine rate of sidedress application, and input/output economics must be carefully considered on those soils where a yield response to split application is ***LESS*** likely. Decisions relating to time of N application are much less complicated on coarse-textured soils with irrigation or with high annual growing season rainfall.

REFERENCES

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