NUTRIENT MANAGEMENT AND STARTER FERTILIZER FOR NO-TILL CORN

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ABSTRACT

No-till corn acreage has steadily increased in Illinois. No-till presents unique problems of nutrient stratification, increased surface residue, and cool, wet soils which may influence nutrient availability. Two experiments were initiated in 1993 at 4 locations to evaluate the response of no-till corn to: 1) primary N applications of anhydrous ammonia preplant, UAN broadcast preplant, and ammonia sidedressed at V6; 2) starter fertilizers with factorial combinations of N, P, and K banded 2 inches beside and 2 inches below the seed (2X2); and 3) seed-placed fertilizers with various N, P, and K rates and sources, as well as a comparison of liquid and dry fertilizers. Experimental sites differed in climate, soil type, and soil test values. Grain yields were highest when ammonia preplant was used as the primary nitrogen source. Sidedressed ammonia performed nearly as well as preplant ammonia. Broadcast UAN did poorly when post-application weather was dry and warm, resulting in yield losses of 10-25 bu/A. When early season soil test levels of P and K were adequate, 2X2 starter containing N+P increased yields by 14 bu/A at the two northern locations, regardless of previous crop. This combination of N+P increased yields by 9 bu/A at 1 of 2 southern locations in 1993. Banding N+P consistently increased V6 plant weights of late-planted 1995 corn at all locations. Plant growth and yield were more consistently increased when starter fertilizer was banded instead of seed-placed; however, yield benefits from some seed-placed fertilizer treatments were observed at the same locations showing responses to 2X2 placement. Both seed-placed liquid and dry fertilizers with similar nutrient contents provided similar yield responses. Dry fertilizers with high salt contents or ammonia-liberating compounds slowed emergence. When yield responses to dry fertilizers were observed, the seed-placed fertilizer usually contained at least 10 lbs/A of N and P_2O_5. However, these rates slowed emergence at some locations in 1994 and 1995. The liquid products 10-34-0 and 9-18-9 applied at rates of 10-20 lbs/A of N+K_2O did not significantly slow emergence. In summary, better yield responses occurred when N was injected and 2X2 starter containing N+P was used.

NO-TILL NITROGEN MANAGEMENT

Illinois no-till corn producers have three options for applying the majority of their N. These are preplant injection, surface applications of urea-based compounds, or sidedressed injected N. Preplant anhydrous ammonia has been a popular method for applying N due to

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low costs per unit N applied and consistent yield responses to injected N. However, surface applications of UAN or urea are becoming increasingly popular for those who believe that the benefit of speedy application offsets the extra cost of N. Surface applications have an added benefit of preserving surface residue in erodible areas. Sidedressing N improves N availability and fertilizer use efficiency while reducing early-season N losses from denitrification and leaching in some situations.

Large amounts of surface residue, as well as increased immobilization in the top 2 inches can reduce the effectiveness of surface-applied N sources. Surface application of UAN for no-till corn has been shown to reduce yields in cases where urea is converted to volatile NH_3. In southern Illinois, surface applications of UAN yielded 18 bu/A less than injected UAN (Varsa et al., 1994). In Indiana, Mengel et al. (1982) reported a 33% yield increase when UAN was injected instead of broadcast.

Ammonia volatilization is highest when urea is applied to a warm, moist soil with high surface residue (Bouwmeester et al., 1985; Burch and Fox, 1989; Clay et al., 1990). Soil type can affect NH_3 volatilization, because NH_3 losses increase on soils with low cation exchange capacity (Keller and Mengel, 1986; Reynolds and Wolf, 1987). Keller and Mengel (1986) measured peak NH_3 losses 23 hours after fertilizer application. Rainfall must occur shortly after urea application to avoid N losses from ammonia volatilization in no-till. Keller and Mengel (1986) reported that a 1-inch rain stopped NH_3 volatilization. Bouwmeester et al. (1985) found similar results, and Fox et al. (1986) reported that the number of days until 2 inches of rain fell determined potential for NH_3 volatilization.

Applying sidedress N maximizes fertilizer use efficiency (Fox et al., 1986), increases N availability to plants (Howard and Tyler, 1989), and may increase grain yield (Stecker et al., 1993). Sidedressing N has limitations, though. Farmers face the risk of not getting N applied in a wet spring, an increased chance of crop injury, and conflicts with other spring work such as herbicide application.

2X2 STARTERS

Starter fertilizers offer the potential to increase nutrient availability on cool, wet, no-till soils, particularly where P and K have become stratified. Several studies have demonstrated that 2X2 banding is a safe, effective way to supply starter fertilizer. In Indiana, Mengel (1990) reported an average yield increase of 10 bu/A at 10 of 11 sites. All sites in this study were high in fertility, where starter wouldn't have been recommended for conventional tillage. In Wisconsin, Shulte and Bundy (1994) saw responses to starter fertilizer in high-testing soils that were cold at planting. Fixen and Lohry (1993) and Randall and Hoeft (1988) reviewed results from using starter fertilizer in Midwestern corn experiments with both no-till and conventional tillage. They reported yield responses to starter fertilizer in states surrounding Illinois, but found that responses to specific nutrients varied from state to state.

In warmer soils, however, responses to starter fertilizer may not occur as consistently as in cool soil. In southern Illinois, Kapusta and Varsa (1990) did not find yield benefits from application of a portion of fertilizer as 2X2-banded compared to all fertilizer being broadcast.

SEED-PLACED FERTILIZER

Applying fertilizers in a 2X2 band requires equipping planters with an extra coulter, and may slow planting speeds. These drawbacks, plus the availability of "low-salt" fertilizers, have resurfaced an interest in seed-placed (pop-up) fertilizers for no-till. It is recommended that no more than 10-15 lbs/A of N+K_2O be applied with the seed because of the risk of salt injury (Fixen and Lohry, 1993; Randall and Hoeft, 1988). It is unclear whether seed-placed fertilizers might provide a yield benefit in Illinois no-till corn.

Mortvedt (1976) cited desirable properties of seed-placed fertilizers: high water solubility, low salt index, high analysis (especially P), and absence of NH_3-liberating products (urea and DAP). Ammonium nitrate and potassium chloride are considered to be undesirable seed-placed fertilizers because of their high salt content. Fluid ammonium polyphosphates (such as 10-34-0) supply N without the hazard of NH_3 toxicity (Mordtvedt, 1976). Baweja and Bates (1971) and Waters (1972) reported that liquid fertilizers are less toxic to corn seedlings than dry fertilizers applied at rates providing the same total quantities of plant nutrients because the water contained in liquid fertilizers dilutes the salts. However, the amount of water in the fertilizer is small compared to the amount of water in the soil, so these liquid sources probably also benefitted from low salt contents.

OBJECTIVES

The objectives of these experiments were to determine the response of no-till corn to: 1) primary N applications of anhydrous ammonia preplant, UAN broadcast preplant, and ammonia sidedressed at V6; 2) starter fertilizers with factorial combinations of N, P, and K banded 2 inches beside and 2 inches below the seed (2X2); and 3) seed-placed fertilizers with various N, P, and K rates and sources, as well as a comparison of liquid and dry fertilizers. Experimental locations and soil conditions were varied to gain a better understanding of how environment might influence these treatments.

MATERIALS AND METHODS

Experiments were established from 1993 to 1995 at four locations varying in climate, soil type, crop rotation, and soil test values (Table 1). While cooperating farmers were the same each year, the field or area within the field was different each year. In Experiment 1, three main plot treatments consisted of 160 lb N per acre supplied as ammonia preplant, UAN broadcast preplant, or ammonia sidedressed at V6. Within each main plot, 8 starter treatments (2X2 banded) were applied as factorial combinations of N, P, and K. See Table 6 for a complete list of starter treatments. Corn was planted with a 2-row planter at rates near 35,000 seeds/A, and planting dates are listed in Table 2.

Seed-placed, surface-dribbled starter, and 2X2 banded fertilizer treatments were studied in Experiment 2. Twelve treatments compared factorial combinations of N, P, and K. Thirteen seed-placed treatments were included to compare the effect of N source (urea vs. ammonium nitrate), P source (DAP vs. MAP), K source (KCl vs. K_2SO_4), and liquid source (10-34-0 vs. 9-18-9). In 1994, three additional treatments of surface-applied UAN and DAP were added. In 1995, a higher rate of surface-dribbled UAN and an additional seed-placed and 2X2 treatment were added. All plots received 160 lb N/acre as preplant NH_3. A complete list of Experiment 2 treatments can be found in Tables 19-21.

Stand counts were taken for Experiment 2 during the period from emergence to V3. About one month after planting, uniform stands of 26,000 plants/A were established by hand thinning both experiments. Above-ground whole plant samples were taken at the V6 growth stage; plant weight and tissue N, P, and K were measured. Ear leaf samples were collected at silking for N, P, and K analysis. Yield was determined by hand harvesting at maturity; grain yields were corrected to 15.5% moisture.

In 1993 and 1995, all plots at Oblong received a broadcast application of 200 lb/A of K_2O. The Gridley plots were injured by a herbicide application at the V7 stage in 1993; therefore, grain yields are not reported for Gridley in 1993. The Pana location has swales and received excessive rainfall in 1994 and 1995, thus causing stunted plants and highly variable results.

RESULTS AND DISCUSSION

There was no significant interaction between primary N source and starter fertilizers. Therefore, the results from the primary N source, 2X2-banded, and seed-placed starter fertilizers will each be discussed separately.

Nitrogen Management

In 1993, dry weights of V6 plants receiving UAN were equal to or larger than those of ammonia-fed plants. However, UAN-fed plants yielded 25 bu/A less in Oblong, and did not have higher yields than ammonia-fed plants at any location (Table 3). Oblong had high residue, a low cation exchange capacity, warm temperatures, and only 0.5 inches of rainfall within the first week after UAN was applied (Figure 1). These conditions increase NH_3 volatilization (Bouwmeester et al., 1985; Burch and Fox, 1989; Clay et al., 1990; Fox et al., 1986; Keller and Mengel, 1986; Reynolds and Wolf, 1987), so NH_3 volatilization after UAN application likely resulted in significant N losses. The sidedress NH_3 treatment yielded 8 bu/A less than UAN and preplant NH_3 at Ashton, but was similar to preplant ammonia at the other locations (Table 3).

In 1994, preplant ammonia provided consistently high V6 plant weights. Grain yields of preplant and sidedressed ammonia were not significantly different at any location. UAN-fed plants yielded at least 10 bu/A less at Pana and Oblong (Table 4). In both locations, weather following UAN application to the moist soil was warm and dry (Figure 2), which likely favored NH_3 volatilization. Because Pana was flooded, magnitude of yield reduction in UAN-fed plants should be interpreted with caution due to the large variability present (treatments differing by over 20 bu/A were not detected as statistically different).

In 1995, corn was planted late (in early June) due to excessive rainfall throughout May. Plants at V6 with preplant NH_3 consistently weighed equal to or more than with UAN broadcast (Table 5). Excessive rainfall after preplant N applications at Oblong and Pana (Figure 3) likely caused denitrification and leaching, so the sidedressed NH_3 treatment was expected to yield better than the preplant N treatments.

2X2 Starter

In 1993, plant weight at V6 was consistently increased by 2X2 treatments of 25-0-0, 25-30-0, and 25-30-20. At Ashton, a northern continuous corn location with soil testing high in P and K, starter with N+P (25-30-0 or 25-30-20) increased yields by 15-20 bu/A (Table 6). These starter combinations increased yields by 9 bu/A in Oblong. The Oblong location yielded about 60 bu/A above the average for that soil type, so it is likely that N became yield-limiting, and the N in the starter provided an extra boost.

In 1994, plants at Oblong showed a strong response to starter K fertilizer because the soil K test was low and no additional K was broadcast. Plant weight and grain yields were similar to those in 1993, in that 25-30-0 performed similarly to 25-30-20 when the soil K test was adequate. Yields at both Gridley (corn after soybean) and Ashton (corn after corn) were increased by 14 bu/A with 25-30-0 or 25-30-20 starter (Table 7). Gridley and Ashton are in the northern half of the state and have heavier, colder, wetter soils, which should increase the likelihood of a benefit from starter (Shulte and Bundy, 1994).

As in previous years, starters containing N+P provided the highest V6 plant weights in 1995 (Table 8). Because starter fertilizer leads to more vigorous early growth, and earlier maturity, yield benefits from starter are expected to be more evident in 1995.

Seed-placed Fertilizers

In 1993, seed-placed dry fertilizer rates of 10-10-0 and 10-10-10 in the N-P-K factorial portion of the experiment provided V6 plant weight and grain yield results similar to the 10-10-10 and 25-30-20 2X2 banded treatments (Table 15). At Ashton, treatments receiving at least 10 lbs N+K_2O yielded better than the check and performed similarly to the 2X2 banded starter. There were no significant differences among nutrient sources (Table 16). As with the 2X2 study, no yield differences were observed at Pana or Oblong, and Gridley was damaged by herbicide. There was no significant stand reduction by any of the seed-placed treatments, even at rates of 20 lbs N+K_2O.

In 1994, early plant emergence at Ashton was delayed by most dry fertilizer rates of 10-20 lbs/A of N+K_2O. Ashton was cold and dry (Figure 2), which slowed germination and increased the amount of time the seed was in contact with the fertilizer. Under these poor germinating conditions, liquid fertilizer forms with lower salt indices did not appear to slow emergence. Gridley was also cold and dry, and some injury from high rates of dry seed-placed fertilizers was observed, but not as consistently as at Ashton. Early emergence (VE stage) was slowed at Pana at the 2 dry seed-placed rates containing 20 lbs/A N+K_2O. Stand counts at all locations 1 week later (V3) did not reveal any consistent significant population differences between treatments. At Pana and Oblong, plant populations were reduced by seed-placed urea products.

Plant weight at V6 was similar between dry and liquid nutrient sources in 1994. Seed-placed fertilizer did not increase plant weight as much as the 2X2 starter did. Grain yield was improved at Ashton and Oblong by N+K_2O rates of 15-20 lb/A. Much of the yield response in the dry treatments was due to the presence of K (Table 17). However, liquid applications of 10-34-0 and 10-20-10 yielded similarly (Table 18). In Experiment 2, UAN or DAP surface-applied over the row at planting slightly improved yields at Ashton, but these yield increases were only about 66% of the yield increase provided by 2X2 placement.

Slower emergence with seed-placed dry fertilizers with higher salt indices was evident at all locations, particularly Gridley and Oblong, in 1995 (Table 9). Plants receiving urea were severely injured. Liquid fertilizers at rates of 10-34-0 and 10-20-10 did not significantly hinder emergence (Table 10). By V2, there were few differences in emergence, except in the treatments with urea and high salt fertilizers (Tables 12-14) At Oblong, 50 lb/A of UAN surface-dribbled also hindered emergence (Tables 11 and 14). After the late planting, little or no rainfall occurred for about 8 days, and temperatures were quite warm (Figure 3). The lack of rainfall to help dilute seed-zone salts was probably responsible for the slower emergence in 1995.

Although several fertilizer rates clearly delayed emergence in 1995, V6 plant weights of both the dry and liquid fertilizer treatments were similar to or higher than those of the check treatment (Tables 19 and 20). There were no clear, consistent differences between weight of plants receiving dry or liquid fertilizer. Urea decreased plant weight at Gridley and Oblong. Fertilizer banded 2X2 improved plant weights more than did seed-placed fertilizer (Tables 19-21). Surface applications of UAN and DAP provided plant weights similar to seed-placed rates, but significantly less than those with 2X2 starter (Table 21).

CONCLUSIONS

1. Broadcast application of unamended urea-ammonium nitrate solutions was not consistently as effective as injected anhydrous ammonia.

2. Inclusion of both N and P in a 2x2 banded starter increased early season plant growth and corn yield, particularly in cool, wet soils. Most of the increase could be attributed to N.

3. Seed placed fertilizer slowed the rate of seedling emergence, particularly in dry springs.

4. Early season plant weight (V-6) and yield increase from seed placed fertilizer were not as consistent as with 2x2 banded starter.

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TABLES AND FIGURES

Table 1. Description of experimental locations. Soils are listed from northernmost to southernmost.

					Soil Test (lb/A)	
Site	Soil	Texture	Prvs. Crop	pH	P_1	K
Ashton	Typic Argiudoll	sil	corn	6.2	91	385
Gridley	Typic Argiudoll	sil	soybean	6.4	31	245
Pana	Udollic Ochraqualf	sil	soybean	7.2	50	276
Oblong	Aeric Ochraqualf	sil	soybean	6.7	31	148

Table 2. Planting dates for all locations, 1993-1995.

	Location			
Year	Ashton	Gridley	Pana	Oblong
1993	May 20	May 18	May 26	June 1
1994	May 4	May 3	May 20	May 23
1995	June 6	June 5	June 7*	June 13

* Seed-placed experiment was planted June 12, 1995 at Pana.

Table 3. Effect of primary N source on grain yield. 1993.

	Location			
Primary N Source	Ashton	Gridley	Pana	Oblong
	bushels/A			
Ammonia Preplant	130 AB[1]	***	175 A	197 A
UAN Preplant	136 A		178 A	173 B
Ammonia Sidedress	127 B		172 A	200 A

[1]Average values followed by the same letter in the row or column are not significantly different (based on LSD at α=0.10).
*** Damaged by herbicide at V7 growth stage.

Table 4. Effect of primary N source on grain yield. 1994.

Primary N Source	Location: Ashton	Gridley	Pana	Oblong
------------------------	----------------------	bushels/A	----------------------	
Ammonia Preplant	186 A[1]	147 A	167 A	140 A
UAN Preplant	184 A	138 A	110 B	129 B
Ammonia Sidedress	185 A	134 A	146 A	147 A

[1]Average values followed by the same letter in the row or column are not significantly different (based on LSD at α=0.10).

Table 5. Effect of primary N source on plant weight at V6. 1995.

Primary N Source	Location: Ashton	Gridley	Pana	Oblong
------------------------	----------------------	g/plant	----------------------	
Ammonia Preplant	5.14 A[1]	4.27 A	6.41 AB	6.59 A
UAN Preplant	4.90 A	4.10 B	6.76 A	6.82 A
Ammonia Sidedress	5.00 A	4.08 B	5.93 B	5.94 B

[1]Average values followed by the same letter in the row or column are not significantly different (based on LSD at α=0.10).

Table 6. Effect of 2X2 banded starter fertilizer on grain yield. 1993.

Starter N	P_2O_5	K_2O	Location: Ashton	Gridley	Pana	Oblong
-------	lb/acre	-------	----------------------	---------------------- bushels/A	----------------------	
0	0	0	122 E[1]	***	171 A	187 BC
25	0	0	131 BCD		175 A	194 AB
0	30	0	126 DE		175 A	183 C
25	30	0	142 A		185 A	196 A
0	0	20	128 CDE		171 A	184 C
25	0	20	136 ABC		175 A	193 AB
0	30	20	126 DE		170 A	187 BC
25	30	20	138 AB		178 A	196 A

[1]Average values followed by the same letter in the row or column are not significantly different (based on LSD at α=0.10).
*** Damaged by herbicide at V7 growth stage.

Table 7. Effect of 2X2 banded starter fertilizer on grain yield. 1994.

Starter N	Starter P_2O_5	Starter K_2O	Location: Ashton	Gridley	Pana	Oblong
------- lb/acre -------			----- bushels/A -----			
0	0	0	177 D[1]	128 C	136 C	136 BC
25	0	0	189 AB	139 ABC	152 A	129 C
0	30	0	185 BC	132 BC	134 C	130 C
25	30	0	191 A	142 AB	151 AB	136 BC
0	0	20	178 D	146 A	132 C	150 A
25	0	20	189 AB	146 A	137 C	141 B
0	30	20	181 CD	138 ABC	143 ABC	136 BC
25	30	20	189 AB	146 A	141 BC	150 A

[1]Average values followed by the same letter in the row or column are not significantly different (based on LSD at α=0.10).

Table 8. Effect of 2X2 banded starter fertilizer on plant weight at V6. 1995.

Starter N	Starter P_2O_5	Starter K_2O	Location: Ashton	Gridley	Pana	Oblong
------- lb/acre -------			----- g/plant -----			
0	0	0	4.18 D[1]	3.90 C	5.81 B	5.70 D
25	0	0	5.06 B	4.19 B	6.20 B	5.87 BCD
0	30	0	4.34 CD	3.87 C	6.23 B	6.16 BC
25	30	0	6.68 A	4.57 A	7.23 A	8.15 A
0	0	20	4.26 CD	3.87 C	6.06 B	5.80 CD
25	0	20	4.82 BC	4.25 B	5.95 B	5.97 BCD
0	30	20	4.48 CD	3.93 C	6.15 B	6.20 B
25	30	20	6.28 A	4.63 A	7.30 A	7.78 A

[1]Average values followed by the same letter in the row or column are not significantly different (based on LSD at α=0.10).

Table 9. Effect of dry seed-placed fertilizer on emergence evaluated at VE. 1995. Seed-placed nutrient sources are NH_4NO_3, CSP, and KCl. Seeding rate was 32 seeds/row.

Treatment			Location			
N	P_2O_5	K_2O	Ashton	Gridley	Pana	Oblong
---------lb/acre---------			---------plants emerged/30 ft row---------			
Seed Placed Fertilizer						
0	0	0	23	27	26	25
5	0	0	21	27	23	25
10	0	0	16	22	17	16
0	10	0	19	28	26	20
5	10	0	19	21	18	19
10	10	0	16	15	12	15
0	0	10	20	21	22	19
5	0	10	17	18	15	19
10	0	10	13	11	13	13
0	10	10	15	19	18	20
5	10	10	16	14	18	14
10	10	10	12	9	7	10
Banded Fertilizer						
10	10	10	19	30	27	26
25	30	20	25	30	27	26
		$LSD_{0.10}$	4	4	5	3
N rate averages						
0			19	24	23	21
5			18	20	19	19
10			14	14	12	13
		Significance	*	*	*	*
P rate averages						
	0		18	21	19	19
	10		16	18	16	16
		Significance	*	*	*	*
K rate averages						
		0	19	24	20	20
		10	16	15	16	16
		Significance	*	*	*	*

Table 10. Effect of nutrient source of seed-placed fertilizer on emergence evaluated at VE. 1995. Seeding rate was 32 seeds/row.

Treatment						Location			
N	P_2O_5	K_2O	Source[1]			Ashton	Gridley	Pana	Oblong
------- lb/acre --------			------------------------			-------- plants emerged/30 ft row ---------			
Dry forms									
0	0	0				23	27	26	25
10	10	10	AN	CSP	KCl	12	9	7	10
10	10	10	U	CSP	KCl	9	2	6	9
10	10	10	U	CSP	KS	10	2	7	6
10	10	10	AN	CSP	KS	11	9	7	11
10	10	10	AN	DAP	KCl	12	11	15	13
5	13	0	DAP			20	25	20	19
10	26	0	DAP			11	12	9	7
10	44	0	MAP			7	12	10	5
Liquid forms									
3	6	3	9-18-9			19	31	24	26
5	10	5	9-18-9			22	24	26	27
10	20	10	9-18-9			19	27	23	19
5	17	0	10-34-0			22	25	23	22
10	34	0	10-34-0			20	27	27	23
			$LSD_{0.10}$			**4**	**4**	**5**	**3**
Ammonium nitrate						12	9	7	10
Urea						10	2	7	7
			Significance			NS	*	NS	*
Potassium chloride						12	6	7	9
Potassium sulfate						12	5	7	8
			Significance			NS	NS	NS	NS
Source	**Rate**								
MAP	10-44-0					7	12	7	5
DAP	10-26-0					11	12	5	7
			Significance			*	NS	NS	NS
9-18-9	10-20-10					19	27	19	19
10-34-0	10-34-0					20	27	22	23
			Significance			NS	NS	NS	*

[1] AN = ammonium nitrate, CSP = concentrated superphosphate, KCl = potassium chloride, KS = potassium sulfate, DAP = diammonium phosphate, MAP = monoammonium phosphate, U = urea.

Table 11. Effect of surface broadcast, surface banded, seed-placed, and 2X2 banded fertilizer on emergence evaluated at VE. 1995. Seeding rate was 32 seeds/row.

Treatment				Location			
N	P_2O_5	K_2O	**Application**	Ashton	Gridley	Pana	Oblong
---------lb/acre---------			**Method**	-------------- plants/30 ft row ----------			
0	0	0		23	27	26	25
10	34	0	Seed-placed liquid	20	27	27	23
10	20	10	Seed-placed liquid	19	27	23	19
10	10	0	Seed-placed dry	16	16	12	15
10	10	10	Seed-placed dry	12	9	7	10
25	30	0	Seed-placed dry	4	2	1	2
25	0	0	UAN Dribble	27	28	26	25
50	0	0	UAN Dribble	22	27	23	18
25	0	0	UAN Broadcast	23	29	27	25
25	64	0	DAP Broadcast	21	30	27	22
10	10	10	2X2 Banded	19	30	27	25
25	30	0	2X2 Banded	25	30	27	26
25	30	20	2X2 Banded	24	31	26	26
		$LSD_{0.10}$		**4**	**4**	**5**	**3**

Table 12. Effect of dry seed-placed fertilizer on emergence evaluated at the V2 growth stage. 1995. Seed-placed nutrient sources are NH_4NO_3, CSP, and KCl. Seeding rate was 32 seeds/row.

Treatment			Location			
N	P_2O_5	K_2O	Ashton	Gridley	Pana	Oblong
---------lb/acre----------			----------plants emerged/30 ft row---------			
Seed Placed Fertilizer						
0	0	0	26	31	28	28
5	0	0	27	30	27	30
10	0	0	24	28	27	28
0	10	0	25	32	29	27
5	10	0	26	29	26	28
10	10	0	25	29	22	29
0	0	10	27	28	28	26
5	0	10	26	30	26	28
10	0	10	24	29	28	30
0	10	10	23	29	27	29
5	10	10	26	29	27	28
10	10	10	26	29	26	28
Banded Fertilizer						
10	10	10	25	30	28	29
25	30	20	28	30	29	31
		$LSD_{0.10}$	**4**	**3**	**3**	**2**
N rate averages						
0			25	30	28	27
5			26	30	27	28
10			25	29	25	28
		Significance	NS	NS	*	NS
P rate averages						
	0		25	29	27	28
	10		25	29	26	28
		Significance	NS	NS	NS	NS
K rate averages						
		0	25	30	27	28
		10	25	29	27	28
		Significance	NS	NS	NS	NS

Table 13. Effect of nutrient source of seed-placed fertilizer on emergence evaluated at the V2 growth stage. 1995. Seeding rate was 32 seeds/row.

Treatment						Location			
N	P_2O_5	K_2O	Source[1]			Ashton	Gridley	Pana	Oblong
------- lb/acre --------			------------------------			-------- plants emerged/30 ft row ---------			
Dry forms									
0	0	0				26	31	28	28
10	10	10	AN	CSP	KCl	26	29	26	28
10	10	10	U	CSP	KCl	20	13	23	26
10	10	10	U	CSP	KS	22	9	24	26
10	10	10	AN	CSP	KS	23	27	26	28
10	10	10	AN	DAP	KCl	24	27	25	28
5	13	0	DAP			26	29	27	29
10	26	0	DAP			22	25	24	25
10	44	0	MAP			20	27	29	27
Liquid forms									
3	6	3	9-18-9			23	30	27	30
5	10	5	9-18-9			25	23	29	31
10	20	10	9-18-9			26	26	27	27
5	17	0	10-34-0			26	28	27	27
10	34	0	10-34-0			26	29	28	27
			$LSD_{0.10}$			**4**	**3**	**3**	**2**
Ammonium nitrate						25	28	26	28
Urea						21	11	24	26
			Significance			*	*	NS	*
Potassium chloride						23	21	25	27
Potassium sulfate						22	18	25	27
			Significance			NS	*	NS	NS
Source		**Rate**							
MAP		10-44-0				20	27	29	27
DAP		10-26-0				22	25	24	25
			Significance			NS	NS	*	*
9-18-9		10-20-10				26	26	27	27
10-34-0		10-34-0				26	29	28	27
			Significance			NS	*	NS	NS

[1] AN = ammonium nitrate, CSP = concentrated superphosphate, KCl = potassium chloride, KS = potassium sulfate, DAP = diammonium phosphate, MAP = monoammonium phosphate, U = urea.

Table 14. Effect of surface broadcast, surface banded, seed-placed, and 2X2 banded fertilizer on emergence evaluated at the V2 growth stage. 1995. Seeding rate was 32 seeds/row.

Treatment				Location			
N	P_2O_5	K_2O	**Application**	Ashton	Gridle	Pana	Oblon
---------lb/acre---------			**Method**	--------------- plants/30 ft row --------			
0	0	0		26	32	28	28
10	34	0	Seed-placed liquid	26	29	28	27
10	20	10	Seed-placed liquid	26	26	27	27
10	10	0	Seed-placed dry	25	29	22	29
10	10	10	Seed-placed dry	26	29	26	28
25	30	0	Seed-placed dry	19	20	19	26
25	0	0	UAN Dribble	30	30	26	28
50	0	0	UAN Dribble	26	27	26	21
25	0	0	UAN Broadcast	27	32	29	28
25	64	0	DAP Broadcast	26	30	28	28
10	10	10	2X2 Banded	25	30	28	29
25	30	0	2X2 Banded	28	30	29	31
25	30	20	2X2 Banded	27	31	28	31
		$LSD_{0.10}$		**4**	**3**	**3**	**2**

Table 15. Effect of seed-placed fertilizer on corn grain yield. 1993. Seed-placed nutrient sources are NH_4NO_3, CSP, and KCl.

Treatment			Location			
N	P_2O_5	K_2O	Ashton	Gridley	Pana	Oblong
---------lb/acre----------			--------------- bushels/acre ---------------			
Seed Placed Fertilizer						
0	0	0	111	***	165	186
5	0	0	110		167	191
10	0	0	127		177	190
0	10	0	106		160	192
5	10	0	118		171	205
10	10	0	125		174	192
0	0	10	121		171	185
5	0	10	118		168	194
10	0	10	129		156	194
0	10	10	115		166	198
5	10	10	125		174	205
10	10	10	132		178	200
Banded Fertilizer						
10	10	10	132		167	197
25	30	20	127		167	189
		$LSD_{0.10}$	**15**		**NS**	**NS**
N rate averages						
0			113		166	190
5			117		170	199
10			128		171	194
		Significance	*		NS	NS
P rate averages						
	0		119		165	190
	10		120		171	199
		Significance	NS		NS	NS
K rate averages						
		0	116		169	193
		10	123		168	196
		Significance	*		NS	NS

*** = Herbicide damage at V7 stage at Gridley, 1993.

Table 16. Effect of nutrient source of seed-placed fertilizer on corn grain yield. 1993.

Treatment			Source[1]			Location			
N	P_2O_5	K_2O				Ashton	Gridley	Pana	Oblong
------- lb/acre --------			-----------------------			---------------- bushels/acre ---------------			
Dry forms									
0	0	0				111	***	165	186
10	10	10	AN	CSP	KCl	132		178	200
10	10	10	U	CSP	KCl	134		158	195
10	10	10	U	CSP	KS	134		164	196
10	10	10	AN	CSP	KS	128		163	190
10	10	10	AN	DAP	KCl	131		166	188
5	13	0	DAP			129		175	192
10	26	0	DAP			137		170	201
10	44	0	MAP			133		167	199
Liquid forms									
3	6	3	9-18-9			116		168	191
5	10	5	9-18-9			126		175	194
10	20	10	9-18-9			127		161	195
5	17	0	10-34-0			123		169	201
10	34	0	10-34-0			136		178	198
			$LSD_{0.10}$			**15**		**NS**	**NS**
Ammonium nitrate						130		170	195
Urea						134		161	196
			Significance			NS		NS	NS
Potassium chloride						133		168	198
Potassium sulfate						131		164	193
			Significance			NS		NS	NS
Source	**Rate**								
MAP	10-44-0					133		167	199
DAP	10-26-0					137		170	201
			Significance			NS		NS	NS
9-18-9	10-20-10					127		161	195
10-34-0	10-34-0					136		178	198
			Significance			NS		*	NS

[1] AN = ammonium nitrate, CSP = concentrated superphosphate, KCl = potassium chloride, KS = potassium sulfate, DAP = diammonium phosphate, MAP = monoammonium phosphate, U = urea.
*** = Herbicide damage at V7 stage at Gridley, 1993.

Table 17. Effect of seed-placed fertilizer on corn grain yield. 1994. Seed-placed nutrient sources are NH_4NO_3, CSP, and KCl.

Treatment			Location			
N	P_2O_5	K_2O	Ashton	Gridley	Pana	Oblong
---------lb/acre---------			-------------- bushels/acre --------------			
Seed Placed Fertilizer						
0	0	0	169	143	181	125
5	0	0	177	145	160	126
10	0	0	174	151	177	132
0	10	0	176	139	177	126
5	10	0	180	148	168	130
10	10	0	183	137	176	128
0	0	10	182	143	133	137
5	0	10	183	129	167	144
10	0	10	189	139	179	133
0	10	10	183	134	157	133
5	10	10	187	146	163	137
10	10	10	181	140	165	137
Banded Fertilizer						
10	10	10	190	146	168	135
25	30	20	187	147	166	137
		$LSD_{0.10}$	**NS**	**NS**	**NS**	**12**
N rate averages						
0			177	140	162	130
5			182	142	164	134
10			182	141	174	132
		Significance	NS	NS	NS	NS
P rate averages						
	0		179	141	166	132
	10		182	141	168	133
		Significance	NS	NS	NS	NS
K rate averages						
		0	176	144	173	128
		10	184	139	161	137
		Significance	*	NS	*	*

Table 18. Effect of nutrient source of seed-placed fertilizer on corn grain yield. 1994.

Treatment						Location			
N	P_2O_5	K_2O	Source[1]			Ashton	Gridley	Pana	Oblong
lb/acre						bushels/acre			
Dry forms									
0	0	0				169	143	181	125
10	10	10	AN	CSP	KCl	181	140	166	137
10	10	10	U	CSP	KCl	179	150	181	138
10	10	10	U	CSP	KS	183	151	181	150
10	10	10	AN	CSP	KS	190	137	163	129
10	10	10	AN	DAP	KCl	180	148	175	141
5	13	0	DAP			176	141	163	130
10	26	0	DAP			179	138	156	134
10	44	0	MAP			185	150	169	126
Liquid forms									
3	6	3	9-18-9			175	137	162	130
5	10	5	9-18-9			173	147	173	134
10	20	10	9-18-9			185	146	144	139
5	17	0	10-34-0			184	142	164	127
10	34	0	10-34-0			187	136	168	138
			$LSD_{0.10}$			**NS**	**NS**	**NS**	**12**
Ammonium nitrate						185	139	164	133
Urea						181	150	181	144
			Significance			NS	NS	NS	*
Potassium chloride						180	145	174	138
Potassium sulfate						186	144	172	139
			Significance			NS	NS	NS	NS
Source	**Rate**								
MAP	10-44-0					185	150	169	126
DAP	10-26-0					179	138	156	134
			Significance			NS	NS	NS	NS
9-18-9	10-20-10					185	146	144	139
10-34-0	10-34-0					187	136	168	138
			Significance			NS	NS	NS	NS

[1] AN = ammonium nitrate, CSP = concentrated superphosphate, KCl = potassium chloride, KS = potassium sulfate, DAP = diammonium phosphate, MAP = monoammonium phosphate, U = urea.

Table 19. Effect of seed-placed fertilizer on plant weight at V6. 1995. Seed-placed nutrient sources are NH_4NO_3, CSP, and KCl.

Treatment			Location			
N	P_2O_5	K_2O	Ashton	Gridley	Pana	Oblong
---------lb/acre---------			------------------ g/plant ------------------			
Seed Placed Fertilizer						
0	0	0	3.96	3.71	4.94	5.37
5	0	0	4.65	3.78	5.73	5.65
10	0	0	4.42	3.70	5.71	5.64
0	10	0	3.93	3.64	4.94	5.77
5	10	0	4.34	3.87	6.18	6.85
10	10	0	5.24	3.75	6.77	6.55
0	0	10	4.11	3.49	5.42	5.22
5	0	10	4.59	3.81	5.56	5.49
10	0	10	4.39	3.97	5.22	4.74
0	10	10	4.00	3.36	5.11	5.87
5	10	10	4.50	3.66	5.53	6.08
10	10	10	4.46	3.49	5.46	6.09
Banded Fertilizer						
10	10	10	5.29	4.51	6.46	7.11
25	30	20	6.61	4.81	7.25	7.69
		$LSD_{0.10}$	**0.88**	**0.34**	**0.90**	**0.55**
N rate averages						
0			4.00	3.55	5.10	5.56
5			4.52	3.73	5.75	6.02
10			4.63	3.78	5.79	5.76
		Significance	*	*	*	*
P rate averages						
	0		4.35	3.74	5.43	5.35
	10		4.41	3.63	5.66	6.20
		Significance	NS	NS	NS	*
K rate averages						
		0	4.42	3.74	5.71	5.97
		10	4.34	3.63	5.38	5.58
		Significance	NS	NS	NS	*

Table 20. Effect of nutrient source of seed-placed fertilizer on plant weight at V6. 1995.

Treatment						Location			
N	P_2O_5	K_2O	Source[1]			Ashton	Gridley	Pana	Oblong
------- lb/acre --------			-----------------------			-------------------- g/plant --------------------			
Dry forms									
0	0	0				3.96	3.71	4.94	5.37
10	10	10	AN	CSP	KCl	4.46	3.49	5.46	6.09
10	10	10	U	CSP	KCl	4.12	3.30	5.84	6.17
10	10	10	U	CSP	KS	4.69	3.18	5.66	5.28
10	10	10	AN	CSP	KS	4.51	3.63	6.21	6.62
10	10	10	AN	DAP	KCl	4.61	3.68	6.01	6.56
5	13	0	DAP			5.27	3.88	6.23	6.78
10	26	0	DAP			5.29	3.64	6.31	6.03
10	44	0	MAP			4.35	3.53	6.31	6.03
Liquid forms									
3	6	3	9-18-9			5.29	3.53	5.58	6.30
5	10	5	9-18-9			4.26	3.43	5.92	6.54
10	20	10	9-18-9			4.57	3.70	5.91	6.56
5	17	0	10-34-0			4.20	3.58	5.98	6.63
10	34	0	10-34-0			4.23	3.42	6.26	6.62
			$LSD_{0.10}$			**0.88**	**0.34**	**0.90**	**0.55**
Ammonium nitrate						4.48	3.56	5.84	6.35
Urea						4.40	3.24	5.75	5.73
			Significance			NS	*	NS	*
Potassium chloride						4.29	3.39	5.65	6.13
Potassium sulfate						4.60	3.41	5.94	5.95
			Significance			NS	NS	NS	NS
Source	**Rate**								
MAP	10-44-0					4.35	3.53	6.31	6.03
DAP	10-26-0					5.29	3.64	6.31	6.03
			Significance			*	NS	NS	NS
9-18-9	10-20-10					4.57	3.70	5.91	6.56
10-34-0	10-34-0					4.23	3.42	6.26	6.62
			Significance			NS	NS	NS	NS

[1] AN = ammonium nitrate, CSP = concentrated superphosphate, KCl = potassium chloride, KS = potassium sulfate, DAP = diammonium phosphate, MAP = monoammonium phosphate, U = urea.

Table 21. Effect of surface broadcast, surface banded, seed-placed, and 2X2 banded fertilizer on plant weight at V6. 1995.

Treatment				Location			
N	P_2O_5	K_2O	**Application Method**	Ashton	Gridley	Pana	Oblong
---------lb/acre----------				------------------ g/plant ------------------			
0	0	0		3.96	3.71	4.94	5.37
10	34	0	Seed-placed liquid	4.23	3.42	6.26	6.62
10	20	10	Seed-placed liquid	4.57	3.70	5.91	6.56
10	10	0	Seed-placed dry	5.24	3.75	6.77	6.55
10	10	10	Seed-placed dry	4.46	3.49	5.46	6.09
25	30	0	Seed-placed dry	4.67	3.27	5.86	5.88
25	0	0	UAN Dribble	4.01	3.76	5.29	5.83
50	0	0	UAN Dribble	4.93	3.59	5.65	6.16
25	0	0	UAN Broadcast	4.45	3.51	5.44	5.81
25	64	0	DAP Broadcast	4.08	3.74	5.48	6.21
10	10	10	2X2 Banded	5.29	4.51	6.46	7.11
25	30	0	2X2 Banded	7.11	4.39	7.25	7.85
25	30	20	2X2 Banded	6.61	4.81	5.33	7.69
		$LSD_{0.10}$		**0.88**	**0.34**	**0.90**	**0.55**

Figure 1. Daily precipitation and minimum temperature from preplant N application to sidedress N. 1993.

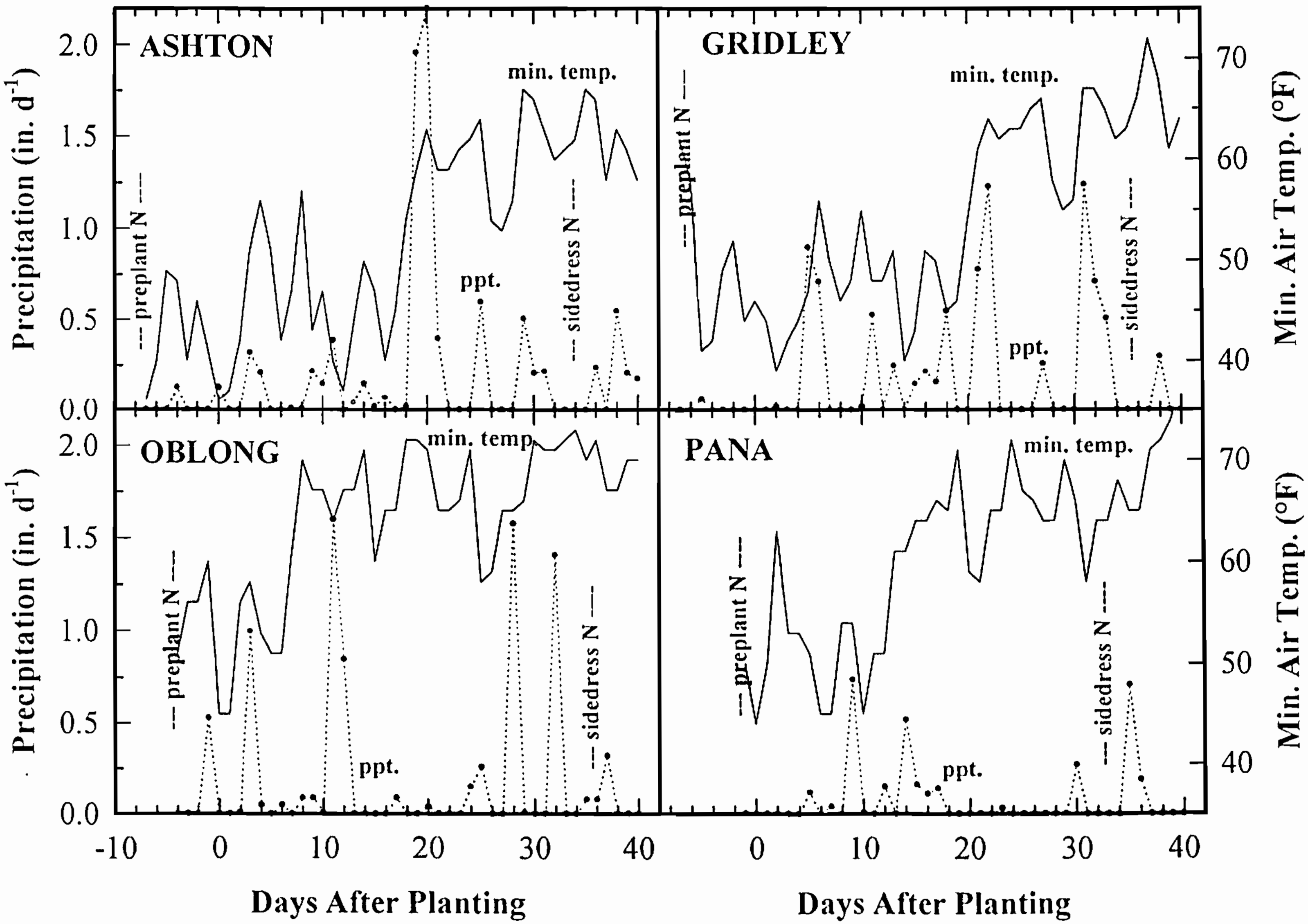


Figure 2. Daily precipitation and minimum temperature from preplant to sidedress N application. 1994.

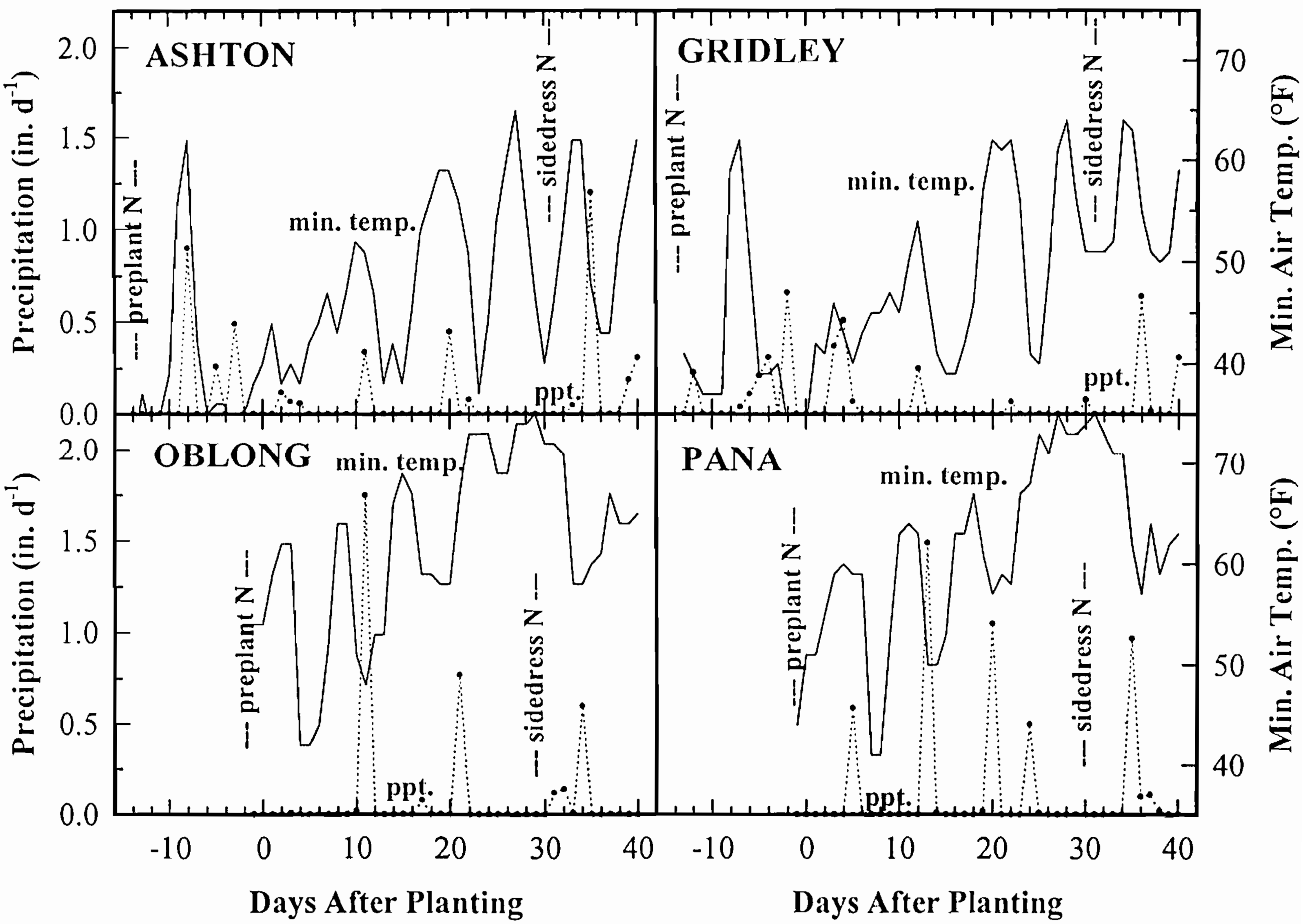
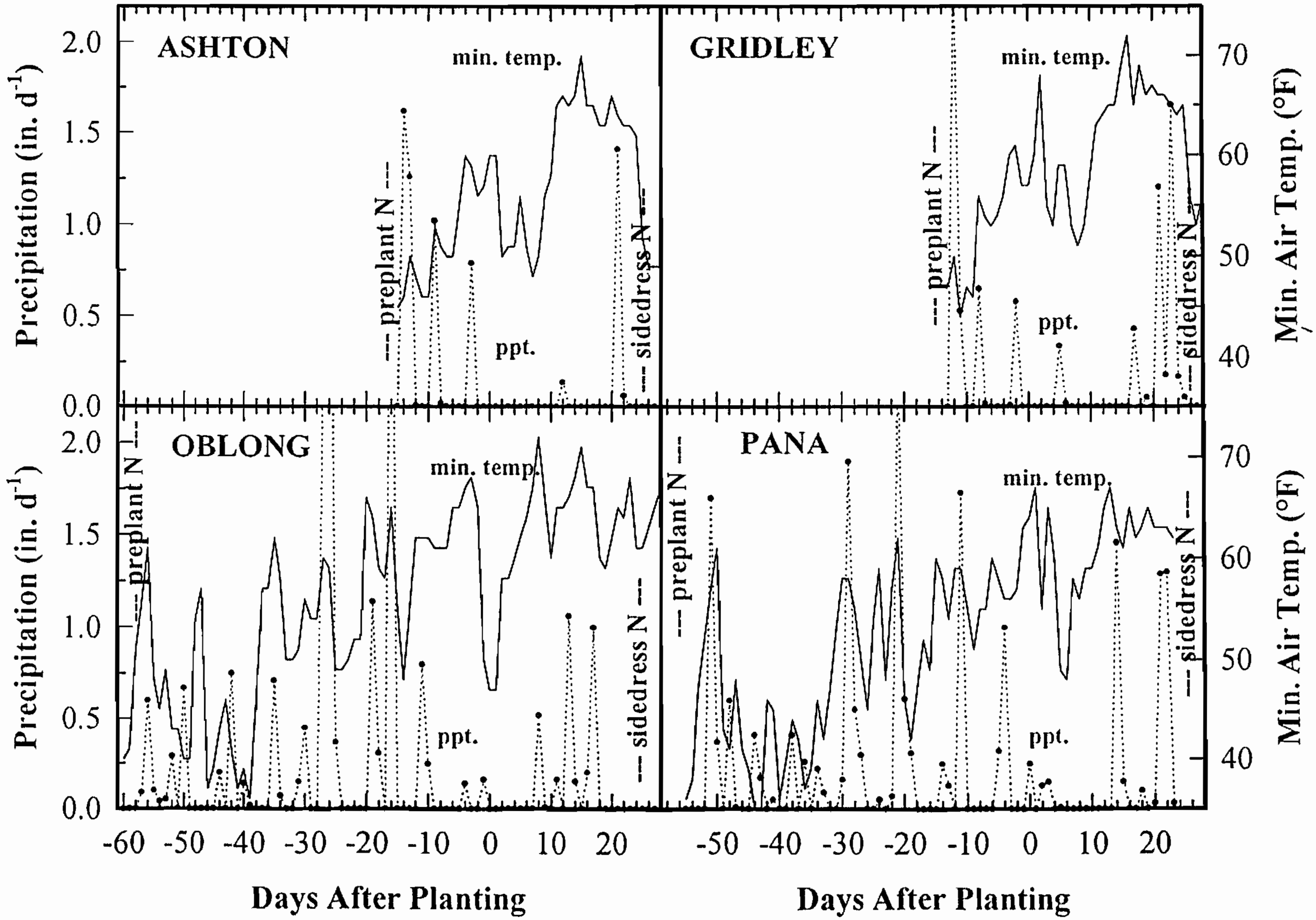


Figure 3. Daily precipitation and minimum temperature from preplant to sidedress N application. 1995.



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