Efficient Fluid Fertilizer Management for Corn Producers with Automatic Guidance Systems: Three Year Summary

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ABSTRACT

The most precise GPS-controlled automatic guidance system currently available for agricultural equipment is the RTK system. This technology provides new opportunities for varying crop row position relative to recent (or older) nutrient bands and prior crop rows. Our objective in this research was to evaluate optimum corn row positions following pre-plant UAN fertilizer application at various N rates. Field research was conducted at three Purdue University research farms in NC and NW Indiana from 2006 to 2008. We applied UAN bands on 30" centers with 3 N rates (50, 100 and 200 pounds N per acre) at a depth of 4" and seeded corn the same day in parallel rows positioned 0, 5 or 10 inches from these bands. A split-plot comparison of starter-banded 10-34-0 (applied in the traditional 2"x2" placement) versus no starter was present in two locations. All plots, including a no pre-plant UAN control, received the same total 200 pounds per acre of N by adjustments in side-dress UAN rates after corn emergence. Corn plant populations and yields were reduced significantly at the 100 pound and 200 pound pre-plant N rates with planting directly over the UAN band at 2 of 3 locations (TPAC and PPAC). At the third location (ACRE), corn yield reductions were only evident with the 0" displacement treatment at the 200 pound pre-plant N rate with starter fertilizer. Lower plant populations (aggravated by limited rainfall following planting) seemed to be the primary cause of the latter yield reductions, though stunted early growth was also evident. Corn yield reductions for the 0" versus 5" row displacement following the 200 pound N rate (and when starter fertilizer was present) averaged 11 bushels per acre at ACRE (2006-2008), 24 bushels per acre at TPAC (2007-2008) and 50 bushels per acre at PPAC (2006-2008). Planting directly over the UAN bands (at all N rates) increased corn plant N concentrations in whole plant samples taken approximately 1 month after seeding at each location. Micronutrient concentrations of Mn and/or Zn tended to be higher as corn rows were positioned closer to pre-plant UAN bands. Starter fertilizer application had little effect on corn population, height or yield response to proximity of the pre-plant UAN bands, but starter did increase early season heights and plant N and P concentrations as expected. We conclude that RTK guidance is highly advantageous when planting no-till or tilled corn soon after pre-plant banded UAN application, and that the optimum corn row position for a "safe" response shortly after UAN application at high rates is at least 5 inches from, and parallel to, the UAN band.

INTRODUCTION

Recent developments in GPS-guided automatic steering systems have opened up many new management options for corn producers. Automatic guidance devices have provided benefits in terms of improved timeliness of field operations, less operator fatigue, reductions in overlapping applications of pesticides and fertilizers, controlled traffic system opportunities, as well as reduction in capital expenses (such as the possible elimination of row markers on corn planters, or the use of strip tillage tools that are only ½ to 2/3 of the corn planter width). The economic merits of automatic steering devices are still being debated, as are the relative merits of automatic guidance systems with various degrees of accuracy. Many farmers question the extra cost associated with the RTK system, which provides up to 1 inch accuracy.

However, until now, there has been very little research or extension emphasis on the possible benefits of automatic steering systems for improved efficiencies in fertilizer application and crop utilization. About

the only generalization to have emerged from the discussion thus far is that automatic guidance systems should lessen the total fertilizer applied because of less overlap (associated with more precision of the driving patterns of wide applicators, especially in non-rectangular fields). Clearly, there are many more new opportunities to be explored as possible fertilizer efficiency gains and improved profitability for corn producers who can now purchase various GPS automatic guidance systems for their tractors (and soon for the implements that are pulled behind the GPS guided tractors to correct for side-slopes), and who may also want to be capable of integrating their corn planting row placement with their own, or custom, band fertilizer applications.

Our interest in combining no-till and strip tillage operations with liquid fertilizer banding grew over years of researching and promoting strip tillage and deep banding of dry fertilizers for high yield corn production systems. When the Cropping Systems Research Division of John Deere was able to loan us RTK equipment in the fall of 2005, and with funding from both the Fluid Fertilizer Foundation and the Mary S. Rice Farm Fund at Purdue University, we were able to initiate research related to fluid fertilizer placement and corn row position.

The objectives of this research were to:

1. Determine the realistic joint benefits associated with automatic guidance systems for both UAN fertilizer banding and planting systems in no-till corn production.
2. Quantify the effects of various degrees of planter precision - relative to pre-planting UAN fertilizer bands - on corn nutrient uptake, growth and yield.
3. Determine whether the combination of automatic guidance systems and pre-plant banded UAN fertilizer application would circumvent the need for liquid starter fertilizer applicators on corn planters.

METHODOLOGY

Equipment and Locations: John Deere loaned us a RTK base station plus a 7930 or 7830 (in 2008) tractor equipped with Automatic Guidance (RTK) and front-wheel assist for research purposes at the Agronomy Center for Research and Education (referred to as ACRE, and located near West Lafayette, IN), at the Throckmorton-Purdue Agricultural Center (referred to as TPAC, and located south of Lafayette, IN) and the Pinney-Purdue Agricultural Center (referred to as PPAC, and located near Wanatah, IN). We used a 7-coulter DMI Nutri-Placr 2800 for pre-plant and side-dress UAN application on our research plots at these 2 locations. We were able to plant corn with 6-row no-till planters at all 3 locations (a JD 1780 planter, also donated by the Cropping Systems Group of John Deere in 2000), and a JD 1770 planter at PPAC. Both planters have liquid fertilizer attachments for the traditional 2”x2” placement. The soil at ACRE is a Brookston silty clay loam with about 4% organic matter, the soil at TPAC is a mixture of Lauramie silt loam and Throckmorton silt loam with about 2.4% organic matter, and the soil at PPAC is a Raub sandy loam with about 2.4 % organic matter.

Treatments, Experimental Design, and Cultural Practices: Field experiments established as either split-plot (ACRE and TPAC) or RCB (PPAC) with 6 replications involved no-till corn planting on soybean stubble shortly after (typically on the same day) pre-plant UAN application in late April or early May of each year. Individual plot lengths were 90 feet at ACRE and TPAC but 135 feet at PPAC. All plots received the same total rate of N fertilizer (i.e. 200 pounds/acre of actual N as UAN), but the amount of pre-plant UAN varied from 0 to 200 pounds actual N per acre. Pre-plant UAN was banded to a depth of approximately 4”. The side-dress UAN application rates (applied between the corn rows at approximately the V-4 stage) also varied from 0 to 200 pounds N per acre. Representative cultural practices for each location in 2008 are outlined in Tables 1 to 3, but specific details for earlier years are available in previous reports (Vyn and West, 2007, 2008).

Main treatments: Corn Row Proximity to Pre-plant UAN Fertilizer

1. Control (no pre-plant UAN band)
2. Pre-plant UAN at 50 pounds, Planter 0" (on-row)
3. Pre-plant UAN at 50 pounds, Planter ± 5"
4. Pre-plant UAN at 50 pounds, Planter ± 10"
5. Pre-plant UAN at 100 pounds, Planter 0" (on-row)
6. Pre-plant UAN at 100 pounds, Planter ± 5"
7. Pre-plant UAN at 100 pounds, Planter ± 10"
8. Pre-plant UAN at 200 pounds, Planter 0" (on-row)
9. Pre-plant UAN at 200 pounds, Planter ± 5"
10. Pre-plant UAN at 200 pounds, Planter ± 10"

Sub-treatments: Starter at planting (at ACRE and TPAC only)

1. No 2" x 2" starter-band placement of 10-34-0 at 20 gallons/acre
2. With 2" x 2" starter-band placement of 10-34-0 at 20 gallons/acre

Table 1. Cultural Practices Used, Field 117, ACRE, 2008

Field Operation	Date	Application Details
Hybrid planted	4/29	Pioneer 32T85 (RR2, LL, HXX). No-till seeding. Air vacuum at 9.8 psi.
Seeding rate		34,000 seeds/ac. Planting speed was 5.6 mph.
Starter fertilizer/planter		10-34-0 @ 20 gallons/ac, 2-inches to the side and 2-inches below seed.
Insecticide/planter		None.
Weed control	4/30	Pre-emergence:
		Harness Extra 5.6 at 5 pts/ac
		Atrazine at ½ lbs/ac
		Post-emergence:
	6/2	Roundup Original Max at 22 oz/ac
		Ammonium sulfate at 8 lbs/100 gallons water
	6/18	Roundup Original Max at 22 oz/ac
		Ammonium sulfate at 8 lbs/100 gallons water
Nitrogen fertilizer	4/29	Pre-plant UAN per treatment.
	6/11	Post-plant UAN per treatment.
Soil sampled	5/20	Soil samples taken to a 12 inch depth. Analyzed for nitrate and ammonium.
Plant samples	6/6	10 whole plant samples per plot for nutrient analyses.
Harvest	10/29	Machine harvest 2 rows of each 6 row plot, 90 feet, with Kincaid plot combine.

Table 2. Cultural Practices Used, Meigs North, Throckmorton PAC, 2008

Field Operation	Date	Application Details
Tillage	4/28, 4/29	Disk, field cultivate.
Hybrid planted	4/30	Pioneer 32T85 (RR2, LL, HXX). Air vacuum at 9.8 psi.
Seeding rate		34,000 seeds/ac. Planting speed was 5.6 mph.
Starter fertilizer/planter		10-34-0 @ 20 gallons/acre, 2-inches to the side and 2-inches below seed.
Insecticide/planter		None.
Weed control	4/29	Pre-emergence: Degree Xtra 3 pt/acre
	6/12	Post-emergence: Cornerstone at 22 ozs/acre
Nitrogen fertilizer	4/30	Pre-plant UAN per treatment.
	6/16	Post-plant UAN per treatment.
Soil sampled	5/21	Soil samples taken to a 12 inch depth. Analyzed for nitrate and ammonium.
Plant samples	6/6	Whole plant samples for subsequent nutrient analyses.
Harvest	11/4	Machine harvest all 6 rows of each plot, 90 feet, with TPAC's combine and our weigh buggy.

Table 3. Cultural Practices Used, Field I-6, Pinney PAC, 2008		
Field Operation	Date	Application Details
Hybrid planted	5/6	Pioneer 34A20 (RR2 LL HXX PO250). No-till seeding.
Seeding rate		34,238 seeds/acre. Planting speed was 5.6 mph. PPAC's planter, our tractor.
Starter fertilizer/planter		19-17-0 @ 125 lbs/acre, 2-inches to the side and 2-inches below the seed
Insecticide/planter		Force 3G @ 5.5 oz/1000 row feet
Weed control		Burn-down:
	4/23	2,4-D @ 1 pt/acre
		Roundup @ 2 pt/acre
		Pre-emergence:
	5/6	Degree Extra @ 7 pts/acre
		Balance Pro @ 1.5 oz/acre
Nitrogen fertilizer	5/5	Pre-plant UAN per treatment.
	6/3	Post-plant UAN per treatment. PPAC's applicator.
Soil sampled	5/19	Soil samples taken to a 12 inch depth. Analyzed for nitrate and ammonium.
Plant samples	6/5	10 whole plants per plot for nutrient analyses
Harvest	11/3	Machine harvest center 6 rows of each 12 row plot, 135 feet. PPAC's combine and our weigh buggy.

RESULTS and DISCUSSION

Location 1 (ACRE)

We will discuss the 2008 results first and then the 3-year results for this location. The overall negative effects of on-row planting on early plant establishment after pre-plant UAN banding at high N rates were as expected at this location (Table 4). Delayed emergence was apparent at both the 100 and 200 pound N rates with on-row planting. Corn plant populations recovered at this location (data not shown) and overall differences in plant population were not apparent later on in the season. Neither early nor final plant populations were affected by starter fertilizer. Early plant heights were generally taller with starter fertilizer than without, but in both situations corn plant means were lowest when corn seeds were placed directly over the pre-plant UAN application at the highest rate. Later season plant heights were still positively affected by starter fertilizer, but on-row planting of corn with starter resulted in shortest plants at the 200 pound pre-plant N rate.

Corn yields in 2008 were very high (Table 4) because of the very favorable weather conditions. Grain yields with no starter were lowest when the corn rows were planted 10 inches to the side of the lowest pre-plant N rate (i.e. 50 pounds). However, when starter fertilizer was present, there were no significant differences among the pre-plant N and planter row position treatment combinations (Table 4). There was no significant reduction in corn yield associated with on-row plant at any rate in 2008. Grain moisture concentrations at harvest were quite low in all treatments because of our delayed harvest, but it is interesting that there was a small, but significant, reduction in grain moisture concentrations with starter fertilizer, as well as a significant increase in grain moisture when there was no pre-plant UAN applied.

For this environment and year, it seems that there was no yield advantage to starter fertilizer and no yield disadvantage to planting corn directly over the UAN band. The latter contrasted with the results in 2007, when on-row planting reduced corn yields at pre-plant N rates of 100 and 200 pounds per acre (Vyn and West, 2008). However, the 2008 final yield results are similar to those of 2006, when there was no yield disadvantage from seeding over a UAN band at any N rate (Vyn and West, 2007). In 2006, starter fertilizer resulted in a 13 bushel/acre yield boost. Starter fertilizer presence had little impact on yields in

either 2007 (Vyn and West 2008) or 2008 (this report). Soil-test P concentrations (Mehlich 3 extraction) averaged 34 ppm in 2008, so soil-test P was well above the critical level.

Table 4. Corn response to pre-plant banded UAN application and RTK-guided corn row placement at ACRE, 2008.†

Starter Fertilizer?	Pre-plant N rate and Placement	Stand 2 Weeks	Stand 4 Weeks	Plant Height 1	Plant Height 2	Harvest Moisture	Yield @ 15.5%
		ppa		in	in	%	bu/ac
None	0 pre-plant UAN	19625a‡		7.0abc	38.5ab	17.0a	248.0a
	50 lbs on row	17958ab		7.2ab	42.2ab	15.6c	247.2a
	50 lbs 5 inches	20917a		7.3a	40.8ab	15.8bc	238.5ab
	50 lbs 10 inches	16958ab		7.0ab	40.2ab	15.8bc	226.6b
	100 lbs on row	12833b		7.0abc	44.6a	15.7bc	249.4a
	100 lbs 5 inches	18333a		7.0ab	40.9ab	15.2c	245.3ab
	100 lbs 10 inches	19208a		6.4bcd	43.5ab	15.7c	234.3ab
	200 lbs on row	6958c		6.1d	38.5ab	16.5ab	244.8ab
	200 lbs 5 inches	21292a		6.8abcd	40.3ab	15.8bc	248.3a
	200 lbs 10 inches	18458a		6.2cd	37.5b	16.0bc	249.1a
	LSD (5%)	5384		.09	6.3	0.8	20.2
Yes	0 pre-plant UAN	19542ab		8.3a	43.4abc	16.1a	236.4
	50 lbs on row	22625a		8.5a	45.6ab	15.7ab	243.2
	50 lbs 5 inches	21042ab		8.6a	45.3abc	15.4ab	240.0
	50 lbs 10 inches	18958ab		8.0ab	42.6bc	15.3b	240.7
	100 lbs on row	17792bc		8.0ab	45.4ab	15.3ab	247.9
	100 lbs 5 inches	18833ab		8.5a	45.9a	15.2b	250.1
	100 lbs 10 inches	22208ab		8.0ab	43.9abc	15.5ab	240.9
	200 lbs on row	13375c		7.1b	42.3c	15.9ab	248.1
	200 lbs 5 inches	22500a		8.5a	46.0a	15.5ab	245.4
	200 lbs 10 inches	19917ab		7.9ab	43.8abc	15.5ab	251.0
	LSD (5%)			1.0	3.1	0.9	16.0
None	Mean of 10 treat.	17254b		6.8b	40.7b	15.9a	243.1
Yes	Mean of 10 treat.	19679a		8.1a	44.4a	15.5b	244.4

† Average of 6 replications

‡ Means with the same letter are not significantly different.

Over the 3-year period, corn plant heights following pre-plant UAN application were most stunted if the corn rows were planted directly over the UAN band at the 200 pound N rate (Table 5). Mean corn plant populations for 2006-2007 were not lowered dramatically by on-row planting at this location because of relatively moist soils, its high silt plus clay content, and timely rains after planting. But there is some evidence of lower final stands with corn planted directly over the 50 and 200 pound N rates when starter fertilizer was present. All plant populations were reduced by soil crusting in 2007. Overall grain yields for the 3-year period without starter were lowest when corn was planted 10 inches away from the UAN band at the low (50 pound) N rate. However, when both pre-plant N and starter fertilizer were applied, overall grain yields were lowest with a zero inch displacement of the corn rows from the UAN band at the 200 pound N rate. Corn yields with the latter treatment combination were similar to that following the treatment with starter but with no pre-plant UAN. The overall starter benefit was a yield gain of 4 bushels per acre and a reduction of 0.6 % in mean grain moisture content at harvest. Highest corn yields occurred with the combination of corn planted 5" away from the 200 pound pre-plant N rate with starter fertilizer. The 3-year data confirm the benefits of a minimum displacement of the corn rows from high rates of recently applied pre-plant UAN.

Corn plant nutrient analyses over the last 2 years confirmed that plant N concentrations were highest when corn rows were planted directly over the pre-plant UAN bands at the 100 and 200 pound N rate (Table 6). Lowest plant N concentrations occurred in the control plots which had no pre-plant UAN. The addition of the 10-34-0 starter increased plant N and P concentrations (as expected). The starter influence on whole-plant N and P concentrations was strongest in the treatment with zero pre-plant UAN (Table 6). Plant N, but not plant P, concentrations were affected by proximity of the corn rows to the UAN bands. In a somewhat odd development, plant K concentrations were lowest with on-row planting at the 200 pound N rate when there was no starter fertilizer, but plant K concentrations were highest for the same treatment when the N-P starter was present.

Table 5. Corn response to pre-plant banded UAN application and RTK-guided corn row placement at ACRE, 2006-2008.†

Starter Fertilizer?	Pre-plant N rate and Placement	Stand 4 weeks‡	Plant Height	Harvest Moisture	Yield @ 15.5%
		ppa	in	%	bu/ac
None	0 pre-plant UAN	27111ab*	17.0d	22.3a	218.1a
	50 lbs on row	26763ab	19.5a	21.5c	218.8a
	50 lbs 5 inches	27798ab	19.6a	21.6bc	215.7ab
	50 lbs 10 inches	26833ab	18.7abc	21.9abc	207.2b
	100 lbs on row	27437ab	19.5a	21.69bc	214.3ab
	100 lbs 5 inches	27138ab	18.7abc	21.8abc	214.8ab
	100 lbs 10 inches	27243ab	18.7abc	21.4c	214.3ab
	200 lbs on row	27854a	18.0c	22.2ab	214.8ab
	200 lbs 5 inches	28048a	19.2ab	21.8abc	218.7a
	200 lbs 10 inches	26270b	18.4bc	21.9abc	216.1ab
	LSD (5%)	1561	1.0	0.6	10.0
Yes	0 pre-plant UAN	27076ab	21.5ab	21.4	215.9b
	50 lbs on row	25791b	22.0a	21.1	220.9ab
	50 lbs 5 inches	27687a	22.2a	21.0	217.0ab
	50 lbs 10 inches	26569ab	21.7ab	21.1	216.9ab
	100 lbs on row	26687ab	21.4ab	21.1	216.7ab
	100 lbs 5 inches	26694ab	21.9a	21.1	221.4ab
	100 lbs 10 inches	27027ab	22.1a	21.0	218.1ab
	200 lbs on row	25534b	20.7b	21.5	215.5b
	200 lbs 5 inches	27520a	21.7ab	21.2	226.7a
	200 lbs 10 inches	26277ab	21.5ab	21.3	225.3ab
	LSD (5%)	1626	1.1	0.7	10.2
None	Mean of 10 treat.	27250a	18.7b	21.8a	215.3b
Yes	Mean of 10 treat.	26686b	21.7a	21.2b	219.5a

† Average of 6 replications
‡ Includes years 2006 and 2007 only.
*Means with the same letter are not significantly different.

Micronutrient concentrations were also affected by fertilizer treatments and planter positions (Table 6). Plant Zn concentrations were significantly lower (i.e. about 4.6 ppm) in the presence of starter fertilizer. Plant Mn concentrations were lowest when no pre-plant UAN was applied or when the corn rows were positioned 10” away from the pre-plant N bands. It is possible that UAN band influences on localized soil pH may have had something to do with the variation in plant available Mn concentrations at this location. Mean soil pH was about 6.5 at this location.

Table 6. Corn plant nutrient concentration response to pre-plant banded UAN application and RTK-guided corn row placement at ACRE, 2007-2008.†

Starter Fertilizer?	Pre-plant N rate and Placement	Nitrogen	Phosphorus	Potassium	Zinc	Manganese
		%	%	%	ppm	ppm
None	0 pre-plant UAN	3.55e‡	0.36	4.02ab	33.9	39.6c
	50 lbs on row	4.64ab	0.38	3.49b	39.3	53.5abc
	50 lbs 5 inches	4.12cd	0.39	4.14a	33.7	62.5a
	50 lbs 10 inches	3.92d	0.39	3.69ab	35.1	45.4bc
	100 lbs on row	4.69ab	0.37	3.78ab	36.7	57.5ab
	100 lbs 5 inches	4.39bc	0.36	3.87ab	38.2	50.8abc
	100 lbs 10 inches	4.00d	0.37	3.87ab	36.6	47.5abc
	200 lbs on row	4.74a	0.37	3.55b	39.9	54.8abc
	200 lbs 5 inches	4.48ab	0.37	3.97ab	36.3	52.6abc
	200 lbs 10 inches	4.08cd	0.35	3.92ab	39.0	39.5c
	LSD (5%)	0.32	0.04	0.57	7.0	15.8
Yes	0 pre-plant UAN	4.11e	0.43	3.76ab	27.2b	37.6e
	50 lbs on row	4.59b	0.44	3.81ab	34.9a	54.1abc
	50 lbs 5 inches	4.49bc	0.43	3.86ab	31.6ab	45.0cde
	50 lbs 10 inches	4.22de	0.45	3.60ab	31.8ab	39.6de
	100 lbs on row	4.89a	0.44	3.97a	35.0a	58.4ab
	100 lbs 5 inches	4.55bc	0.44	3.67ab	32.2ab	50.7bc
	100 lbs 10 inches	4.32cde	0.44	3.51ab	33.2a	48.9bcd
	200 lbs on row	5.04a	0.46	3.99a	32.9a	62.6a
	200 lbs 5 inches	4.83a	0.45	3.73ab	34.5a	54.3abc
	200 lbs 10 inches	4.45bcd	0.46	3.35b	30.1ab	46.6cde
	LSD (5%)	0.24	.04	0.56	5.5	9.9
None	Mean of 10 treat.	4.3b	0.37b	3.8	36.9a	50.4
Yes	Mean of 10 treat.	4.5a	0.44a	3.7	32.3b	49.8

† Average of 6 replications

‡ Means with the same letter are not significantly different.

Location 2 (TPAC):

We will only discuss the mean results for the 2 years (2007 and 2008) that this experiment was conducted at this location. Corn plant establishment at TPAC was negatively affected by placing corn rows directly over some pre-plant UAN bands (Table 7). Considerable plant death occurred with on-row planting at N rates of 100 pounds and 200 pounds per acre, but not with on-row planting at the 50 pound rate (Table 7). Less than 90% of the plants survived with on-row planting at 100 pounds N, and less than 75% of the plants survived at the 200 pound rate of N. The reduction in plant stand because of N toxicity was more dramatic in 2007 because of dry weather conditions prevailing after planting (Vyn and West 2008). Corn plants that did survive were somewhat shorter in the 200 pound N rate treatment relative to other row placement treatments. Plant populations were also lower when the corn rows were 5" away from the 200 pound N rate and no starter fertilizer was applied, but the same detrimental effect was not observed with starter.

Grain yields were dramatically affected by corn row position relative to the pre-plant UAN bands, but not by starter treatment (Table 7). At the 200 pound N rate, planting on-row with starter fertilizer reduced corn yields by an average 34 bushels per acre relative to planting 5" from the pre-plant bands, and by 41 bushels per acre relative to planting 10" away from the pre-plant N band. For the same 200 pound N rate, corn yield reductions with on-row planting were smaller after planting without starter (just 10 and 23

bushel yield loss relative to the 5 inch and 10 inch row displacements. There was no significant effect of on-row planting on corn growth at the 50 pound N rate. The addition of starter fertilizer resulted in faster early growth, but no increase in final corn yields at this location. Overall soil-test P (Mehlich 3 extractant) at this location averaged 31 ppm and 23 ppm, and soil-test K was only 77 ppm and 116 ppm in 2007 and 2008, respectively.

Whole plant nutrient analyses confirmed that plant N and P concentrations were significantly increased by starter fertilizer application as expected (Table 8). Plant N concentrations at this location were lowest when no pre-plant UAN was applied, but plant N concentrations were not highest for the on-row planting situation following UAN application at high rates. In fact, there were no significant differences in plant N concentrations between the 0" and 5" inch displacements following any of the 3 pre-plant UAN rates. Thus the N concentration results of Table 8 are in contrast to those at the ACRE site (Table 6), where plant N concentrations were highest following on-row planting.

Plant micronutrient concentrations were also affected by the various N and row placement treatments (Table 8). Plant Zn concentrations in the no starter treatments were lowest without pre-plant UAN and highest when corn rows were positioned 5" away from the 200 pound N rate. Plant Mn concentrations were also lowest without pre-plant UAN and highest following the 200 pound N rate when the rows were either 0" or 5 inches away from the UAN bands. In general, higher N rates were beneficial to achieving higher Mn concentrations, though one could argue that Mn concentrations > 100 ppm are not beneficial.

Table 7. Corn response to pre-plant banded UAN application and RTK-guided corn row placement at TPAC, 2007-2008.†

Starter Fertilizer?	Pre-plant N rate and Placement	Stand 4 weeks	Plant Height	Harvest Moisture	Yield @ 15.5%
		ppa	in	%	bu/ac
None	0 pre-plant UAN	30479a	28.4ab	17.5a	212.7abc
	50 lbs on row	30813a	28.5ab	17.0ab	213.4abc
	50 lbs 5 inches	31250a	30.7a	16.7b	215.5ab
	50 lbs 10 inches	30917a	29.1ab	17.2ab	226.2a
	100 lbs on row	27042b	28.4ab	16.9ab	216.5ab
	100 lbs 5 inches	29771a	28.5ab	16.9ab	219.8ab
	100 lbs 10 inches	31104a	28.3ab	16.9ab	206.5bc
	200 lbs on row	22479c	26.8b	17.0ab	196.1c
	200 lbs 5 inches	27188b	27.2b	17.2ab	206.5bc
	200 lbs 10 inches	31208a	28.2ab	17.1ab	219.0ab
	LSD (5%)	2370	2.6	0.6	17.4
Yes	0 pre-plant UAN	30792a	31.8abc	17.0ab	215.0ab
	50 lbs on row	30313a	32.6abc	16.9ab	212.6ab
	50 lbs 5 inches	30792a	33.4ab	16.6b	220.8a
	50 lbs 10 inches	30563a	33.6a	16.9ab	220.2ab
	100 lbs on row	25479b	31.4abc	16.6b	204.7b
	100 lbs 5 inches	29667a	33.1ab	16.8ab	222.1a
	100 lbs 10 inches	31313a	33.6a	16.8ab	210.9ab
	200 lbs on row	20771c	30.2c	16.9ab	179.6c
	200 lbs 5 inches	30250a	30.9bc	16.9ab	213.6ab
	200 lbs 10 inches	30604a	32.3abc	17.1a	220.5ab
	LSD (5%)	2133	2.6	0.5	16.0
None	Mean of 10 treat.	29225	28.4b	17.0a	213.2
Yes	Mean of 10 treat.	29054	32.3a	16.8b	212.0

† Average of 6 replications. Grain moisture and yield is average of 5 replications in 2008.
‡ Means with the same letter are not significantly different.

Table 8. Corn plant nutrient response to pre-plant banded UAN application and RTK-guided corn row placement at TPAC, 2007-2008.†

Starter Fertilizer?	Pre-plant N rate and Placement	Nitrogen	Phosphorus	Potassium	Zinc	Manganese
		%	%	%	ppm	ppm
None	0 pre-plant UAN	3.2c	0.30abc	3.3ab	27.8b	91.7c
	50 lbs on row	3.6abc	0.29bc	3.1ab	33.4ab	116.5bc
	50 lbs 5 inches	3.5abc	0.30abc	3.5a	31.7ab	112.2bc
	50 lbs 10 inches	4.0a	0.36a	3.2ab	29.4b	115.0bc
	100 lbs on row	3.8a	0.30abc	3.3ab	37.4ab	139.9ab
	100 lbs 5 inches	3.7ab	0.34ab	3.5a	35.2ab	122.5abc
	100 lbs 10 inches	3.3bc	0.29bc	3.0b	34.2ab	132.4ab
	200 lbs on row	3.7ab	0.27c	3.2ab	32.6ab	145.0ab
	200 lbs 5 inches	3.7ab	0.29bc	3.2ab	40.8a	155.8a
	200 lbs 10 inches	3.6abc	0.35ab	3.5a	33.1ab	128.1abc
	LSD (5%)	0.4	0.06	0.5	10.7	38.0
Yes	0 pre-plant UAN	3.7b	0.41ab	3.5a	25.3	98.7d
	50 lbs on row	3.8b	0.38bc	3.2ab	25.5	110.1bcd
	50 lbs 5 inches	3.9ab	0.43a	3.6a	30.0	107.7bcd
	50 lbs 10 inches	3.7b	0.40abc	3.2ab	23.5	89.5d
	100 lbs on row	3.9ab	0.39bc	3.1ab	28.8	129.4ab
	100 lbs 5 inches	3.9ab	0.44a	3.2a	32.6	126.9abc
	100 lbs 10 inches	3.7b	0.41ab	3.4a	28.7	102.9cd
	200 lbs on row	3.9ab	0.36c	2.8b	29.9	145.8a
	200 lbs 5 inches	4.4a	0.42ab	3.2ab	32.6	148.7a
	200 lbs 10 inches	3.9ab	0.44a	3.4a	31.9	125.3abc
	LSD (5%)	.03	.04	0.5	9.4	26.4
None	Mean of 10 treat.	3.6b	0.31b	3.3	33.6	126.0
Yes	Mean of 10 treat.	3.9a	0.41a	3.3	28.9	118.3

† Average of 6 replications

‡ Means with the same letter are not significantly different.

Location 3 (PPAC):

We will only discuss the mean results for the 3 years of research at this location. It is also important to emphasize that we did not split the treatments into a starter versus no starter comparison at this site because of resource constraints. Corn plant establishment at PPAC was very negatively affected by placing corn rows directly over all pre-plant UAN bands (Table 9). At the 50 pound N rate, plant populations were reduced by over 1,500 plants per acre compared to either no UAN or UAN bands at least 5" from the row. At N rates of 100 pounds and 200 pounds per acre, plant populations were reduced by over 5,000 and 12,000 plants per acre, respectively. Fewer than 65% of the plants survived at the 200 pound rate of N. At the same time, there was little detrimental impact to plant populations when corn rows were planted just 5" away from the UAN bands at even the highest N rate. Significant population reductions were observed when corn was planted directly over the UAN bands at the 100 and 200 pound N rates in all 3 years at this location (Vyn and West, 2007 and 2008).

Corn plants during the vegetative growth period were also stunted in all 3 on-row treatments (Table 9). Plant heights for on-row planting at 200 pounds were less than 3/4 as tall as those in comparable treatments planted 5" to 10" away. However, a slight reduction in plant height was observed for the corn planted 5" versus 10" away from the UAN band at the 100 and 200 pound N rates (Table 9). This marked

suppression of early plant growth was exacerbated by dry conditions following planting at this location in certain years.

Grain yields were dramatically affected by corn row position relative to the pre-plant UAN bands (Table 9). At the 100 pound N rate, planting on-row reduced corn yields by an average 20 bushels per acre relative to planting 10" from the pre-plant UAN bands. At the 200 pound N rate, planting on-row reduced corn yields by an average 58 bushels per acre relative to planting 10" from the pre-plant bands. There was no significant negative effect of on-row planting on corn growth at the 50 pound N rate. Grain moisture differences were small, but moisture levels were highest with on-row planting at the 100 and 200 pound N rates relative to planting without any pre-plant N, and this probably reflected delayed development of these corn plants (Table 9).

Table 9. Corn response to pre-plant banded UAN application and RTK-guided corn row placement at PPAC, 2006-2008. †

Pre-plant N rate and Placement	Stand 4 weeks	Plant Height	Harvest Moisture	Yield @ 15.5%
	ppa	in	%	bu/ac
0 pre-plant UAN	33449ab‡	22.4bc	21.6d	200.9ab
50 lbs on row	31972b	22.0c	21.9bcd	202.2ab
50 lbs 5 inches	33694a	23.1abc	21.6d	203.7a
50 lbs 10 inches	34326a	24.2a	21.5d	202.9ab
100 lbs on row	28092c	20.3d	22.5ab	183.0c
100 lbs 5 inches	33523ab	22.2c	21.8bcd	200.2ab
100 lbs 10 inches	34000a	24.0a	21.5d	202.8ab
200 lbs on row	20852d	16.0e	23.0a	143.4d
200 lbs 5 inches	33791a	22.0c	22.4abc	193.6b
200 lbs 10 inches	34018a	23.9ab	21.8cd	201.3ab
LSD (5%)	1716	1.5	0.7	9.4
Significance Level	.01	.01	.01	.01

†Average of 6 replications.
‡Values followed by different letters are significantly different at P=0.05.

Whole plant nutrient analyses over the 3 years confirmed that plant N concentrations were significantly increased by planting corn rows directly over the UAN fertilizer bands at all 3 N rates (Table 10). Plant N concentrations at this location were lowest when no pre-plant UAN was applied, or when the UAN bands were 10" away from the corn row. Planting corn 5" from the UAN band resulted in significantly higher plant N concentrations compared to planting 10" from the UAN band only for the 200 pound N rate. These plant N concentration results are similar to those at the ACRE site (Table 6). Plant P concentrations were highest when corn rows were 5" away from the 50 pound N rate, and plant K concentrations were highest when there was no pre-plant UAN but tended to be lower with on-row planting versus 5 or 10" away following UAN banding.

Plant micronutrient concentrations were also affected by the various N and row placement treatments (Table 10). Plant Zn concentrations tarter treatments were highest when corn was planted directly over the pre-plant UAN bands at all N rates and were significantly lower in the control treatment (i.e. no pre-plant N) or when corn rows were positioned further away from the UAN band. Plant Mn concentrations were also lowest without pre-plant UAN and highest following the 50, 100 and 200 pound N rates when the rows were either 0" inches away from the UAN bands. In general, pre-plant UAN resulted in both higher Zn and Mn concentrations, and particularly when corn rows were planted directly over the UAN band. However, one could argue that Mn concentrations above 90 ppm are so much higher than the critical levels that these are not likely to result in superior corn plant growth.

Table 10. Corn plant nutrient response to pre-plant banded UAN application and RTK-guided corn row placement at PPAC, 2006-2008. †

Pre-plant N rate and Placement	Nitrogen	Phosphorus	Potassium	Zinc	Manganese
	%	%	%	ppm	ppm
0 pre-plant UAN	3.3f‡	0.32cd	3.61a	39.6c	74.6c
50 lbs on row	4.0c	0.34ab	3.09cd	44.9ab	94.8ab
50 lbs 5 inches	3.7d	0.36a	3.48ab	41.1c	81.7bc
50 lbs 10 inches	3.5de	0.34abc	3.40abc	42.0bc	79.2bc
100 lbs on row	4.3b	0.34abc	2.85d	46.1a	94.7ab
100 lbs 5 inches	3.6de	0.33bcd	3.23bc	41.3c	87.7bc
100 lbs 10 inches	3.5ef	0.33bcd	3.52ab	40.4c	73.3c
200 lbs on row	4.7a	0.31d	3.08cd	45.8a	108.0a
200 lbs 5 inches	4.0c	0.32bcd	3.06cd	41.2c	79.2bc
200 lbs 10 inches	3.4ef	0.32bcd	3.50ab	39.3c	82.5bc
LSD (5%)	0.2	0.02	0.35	3.4	18.5
Significance Level	.01	.01	.01	.02	.01

†Average of 6 replications in 2006, average of 4 replications in 2007 and 2008.
‡Values followed by different letters are significantly different at P=0.05.

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