CORN GROWTH AND YIELD RESPONSES TO PRE-PLANT AND IN-SEASON NITROGEN COMBINATIONS

J.A. Rutan and K. Steinke
Michigan State University, East Lansing, Michigan
ksteinke@msu.edu

ABSTRACT

In-season N applications may help synchronize N availability with corn uptake but further investigation is needed to validate different combinations of pre-plant and in-season N strategies. Field experiments were initiated in 2014 to investigate corn response to N management programs involving multiple N-placements, timings, and sources applied at a single N rate at two Michigan locations. Nitrogen management programs were grouped into three strategies utilizing broadcast pre-plant incorporated (PPI) N, starter N applied in-furrow (7 lbs N A^{-1}), or starter N banded 2 in beside and 2 in below the furrow (40 lbs N A^{-1}). Treatment combinations within the in-furrow and banded starter N strategies included sidedress at V4-6, V10-12, or 50/50 (split) V4-6 and V10-12, while PPI strategies involved 100% urea, 25/75 mix of urea with polymer-coated urea, and poultry litter applied at 1.0 ton A^{-1} plus sidedress N V10-12. At one location on an Alfisol soil, delaying sidedress N application until V10-12 decreased mean grain yield 4-8% as compared to the V4 or split sidedress N application. At a second location on a Mollisol soil, the PPI N strategy resulted in a 4-5% yield increase as compared to other strategies with similar yield reductions observed to V10-12 sidedress N applications. Due to limited N losses early in the season, first year data suggest that a lack of numerous, large (> 1 in.) precipitation events may have reduced the opportunity for positive yield gains when applying V10-12 sidedress N applications.

INTRODUCTION

Increased weather variability and concern for Great Lakes Basin water quality require improved corn (Zea mays L.) nitrogen (N) management strategies that simultaneously deliver N to the crop and reduce the risk for N loss. The greatest potential for N loss occurs 1) during wet, warm conditions, and 2) when soil nitrate is present without active crop growth (Dinnes et al., 2002; Karlen et al., 1998). The 4R approach can be utilized as a platform to guide fertility management programs reflecting the right 'rate', 'source', 'time', and 'place' of N applications that optimize plant N uptake and minimize environmental loss (Roberts, 2007).

On medium- and fine-textured soils of the northern cornbelt, spring pre-plant N applications may be considered a best-management practice in conventional tillage systems and a common strategy used by Michigan corn growers (Vetsch and Randall, 2004). However corn N uptake does not begin in earnest until V6 to V8 with maximum uptake occurring at V10-14 (Bender et al., 2013). Early spring weather in Michigan may be volatile with above-average precipitation resulting in N loss conditions and decrease the relative efficiency of N application on fine-textured poorly-drained soils (Randall and Vetsch, 2005).

Splitting N applications may be an effective strategy to increase N use efficiency and reduce overall N rates (Gehl et al., 2005; Walsh et al., 2012). Starter fertilizers applied in-furrow 'pop-up' or 2 in beside and 2 in below '2x2' the furrow are two strategies utilized by Michigan growers to increase early season growth in cool, moist soil conditions. The 2x2 offers the ability to deliver greater starter N rates without sacrificing germination while the popup has the advantage of positional availability at reduced N rates. Response to starter N has resulted in greater realization of the crop's yield potential (Bundy and Andraski, 1999), but the potential for corn to become N stressed before sidedress timings may be impacted by weather and choice of N strategy.

Delaying N applications to avoid early-season weather events may reduce opportunities for N loss, but growers can risk irreversible yield loss due to N stress (Binder et al., 2000; Scharf et al., 2002). In-season applications as late as V16 have resulted in 0-3% yield loss in Missouri but little validation of this practice has occurred in Michigan where shorter-season hybrids and a narrower growing season impact crop development (Scharf et al., 2002). Further investigations are needed to identify corn response and efficiency of current Michigan grower strategies with delayed N applications.

The objective of this study was to develop a series of N management strategies based on 4R nutrient stewardship that take into account N placement, N timing, and N source in order to increase corn N use efficiency.

METHODS AND MATERIALS

A field experiment was initiated on 8 May 2014 on a Mollisol soil at the Saginaw Valley Research and Extension Center in Richville, Michigan, on a Tappan-Londo loam soil (fine-loamy, mixed, active, calcareous, mesic Typic Epiaquolls). A second field experiment was initiated on 19 May 2014 on an Alfisol soil at the MSU Agronomy Farm in Lansing, Michigan, on a Capac loam soil (fine-loamy, mixed, active, mesic Aquic Glossudalf). Nine N management programs and an untreated control were arranged in a randomized complete block design with four replications. Programs were grouped into three strategies utilizing broadcast pre-plant incorporated (PPI) N, starter N applied in-furrow (popup), or starter N applied 2 in beside and 2 in below the furrow (2x2) reflecting MI grower practices. Treatment combinations of N placement, N timing, and N source were equalized to a total N rate based on the site-specific maximum return to nitrogen rate (MRTN) (180 and 140 pounds N A^{-1} for Richville and Lansing, respectively) (Table 1). The corn hybrid used over both study sites was Dekalb DKC48-12 RIB (98 d relative maturity) (Monsanto Co., St. Louis, MO) in 30 in rows to achieve a final plant population of 34,000 seeds A^{-1}. Fields were previously cropped to soybean at both study sites and received conventional tillage.

Soil properties at the Richville, MI location included 2.8% O.M., 7.7 pH, 24 ppm P, and 164 ppm K. Soil properties at the Lansing, MI location included 2.8% O.M., 6.5 pH, 47 ppm P, and 114 ppm K. Observations included plant tissue samples collected for total N analysis at V6, R1, and R6. Fifteen basal stalk samples were collected per plot to evaluate stalk nitrate concentration 1 to 3 weeks after black layer. Soil samples (0-12 in) were collected per plot 1 to 3 weeks after black layer to evaluate treatment effects on soil residual nitrate levels. Optical canopy sensors were used to assess treatment effects at V6 and R1. Sensor measurements included chlorophyll meter readings taken using the Minolta SPAD chlorophyll meter, and NDVI readings taken using the Greenseeker® red band sensor (Trimble Navigation Ltd., Sunnyvale, CA). Plant height measurements were collected from 25 plants per plot at V6 and R2. Grain moisture, test weight, and yield were taken at harvest and adjusted to 15.5% moisture.

Statistical analyses were performed using SAS. Least significant difference tests were used to separate means. Multiple degree of freedom (df) contrasts were constructed using the mean of three treatment combinations within each N strategy and used to compare effects of N strategies. Due to a significant effect of location, data are presented separately for each site (Table 2).

PRELIMINARY RESULTS AND DISCUSSION

Richville, MI. Total rainfall accumulations of 2.6 in. within 1 week after planting may have diluted effects of popup treatments resulting in a significant yield decrease of 11 bu A^{-1} as compared to PPI strategies (Table 3). However, below-average total May and June rainfall may have decreased further N loss opportunities for strategies utilizing PPI N. Yields were increased 10-15 bu A^{-1} when utilizing a single PPI application as opposed to a starter + V4-6 sidedress combination.

Starter N applications followed by V4-6 or V4-6+V10-12 (split 50/50) sidedress N applications resulted in greater corn yield whereas significant yield reductions occurred when the majority of N was applied V10-12 (Table 3). The ability of at-plant N applications to realize and maintain yield potential illustrates the risks and rewards associated with late-season N applications. Significant regression data observed at V6 indicate yield potential was affected early, thus N delivery to the plant may impact levels of N stress incurred prior to sidedress timings (Table 4).

Lansing, MI. Contrasting corn N strategies utilizing either popup, 2x2 starter applications, or PPI N applications resulted in similar grain yields in 2014 (Table 3). A lack of early-season heavy rainfall events may have prevented some degree of N loss in pre-plant incorporated applications and may have hindered the effectiveness of substituting urea with PCU. However June rainfall was 38% above the 30 yr average and when poultry litter was followed with a V10-12 sidedress application, a significant 19 bu/a yield increase was observed vs. treatments 5 and 6 (Table 3). Fewer growing degree days (GDD) later in summer may have reduced test weight (Table 3) across all N strategies as July was 126 GDD’s below average (data not shown).

Data from the 2014 Lansing site suggest when utilizing pop-up and 2x2 starter N strategies, delaying the majority of corn N application until V10-12 reduced yield as compared to early season V4 sidedress (Table 3). However, late season N applications can still be used to attain greater corn yields should growers miss the opportunity to apply early-season sidedress N (Table 3). Successful sidedress N application timing can be dependent on seasonal weather patterns. Yield potential of the corn plant is realized early, and the ability of N strategies to sufficiently supply N until sidedress timings and maintain potential can influence the success of sidedress N application timings.

PROJECT CONTINUATION

A second year of research for this study is currently underway and will continue to fine tune N management strategies to improve fertilizer recommendations. The primary goal of this work is to develop scientific N recommendations based upon 4R N management that maximize N use efficiency yet may be adjusted in-season based on spring weather conditions. Multiple grower strategies are investigated to pertain to a large group of grower production systems.

REFERENCES

Bender, R.R., J.W. Haegele, M.L. Ruffo, and F.E. Below. 2013. Nutrient uptake, partitioning, and remobilization in modern, transgenic, insect-protected maize hybrids. Agron. J. 105:161-170.

Binder, D.L., D.H. Sander, and D.T. Walters. 2000. Maize response to time of nitrogen application as affected by level of nitrogen deficiency. Agron. J. 92:1228-1236.

Bundy, L.G., and T.W. Andraski. 1999. Site-specific factors affecting corn response to starter fertilizer. J. Prod. Agric. 12(4)664-670.

Dinnes, D.L., D.L. Karlen, D.B. Jaynes, T.C. Kaspar, J.L. Hatfield, T.S. Colvin, and C.A. Cambardella. 2002. Nitrogen management strategies to reduce nitrate leaching in tile-drained Midwestern soils. Agron. J. 94:153-171.

Gehl, R.J., J.P. Schmidt, L.D. Maddux, and W.B. Gordon. 2005. Corn yield response to nitrogen rate and timing in sandy irrigated soils. Agron. J. 97:1230-1238.

Karlen, D.L., L.A. Kramer, and S.D. Logsdon. 1998. Field-scale nitrogen balances associated with long-term continuous corn production. Agron. J. 90:644-650.

Randall, G.W., and J.A. Vetsch. 2005. Corn production on a subsurface-drained mollisol as affected by fall versus spring application of nitrogen and nitrapyrin. Agron. J. 97:472-478.

Roberts, T.L. 2007. Right product, right rate, right time, and right place…the foundation of BMP's for fertilizer. Better Crops 91(4):14-15.

Scharf, P.C., W.J. Wiebold, and J.A. Lory. 2002. Corn yield response to nitrogen fertilizer timing and deficiency level. Agron. J. 94:435-441.

Vetsch, J.A., and G.W. Randall. 2004. Corn production as affected by nitrogen application timing and tillage. Agron. J. 96:502-509.

Walsh, O., W. Raun, A. Klatt, and J. Solie. 2012. Effect of delayed nitrogen fertilization on maize (Zea mays L.) grain yields and nitrogen use efficiency. J. of Plant Nut. 35:538-555.

Table 1. Treatment combinations utilized and rates (lbs N A^{-1}; Lansing rates in parentheses).

Treatment	Total N Rate	PPI	Popup	2x2	V4-6	V10-12
	--lbs A^{-1}--		--------Starter--------		----Sidedress Timing----	
1	0	0	0	0	0	0
2	MRTN		AmP (7)		UAN (133)	
3	MRTN		AmP (7)			UAN (133)
4	MRTN		AmP (7)		UAN (66.5)	UAN (66.5)
5	MRTN	Urea (140)				
6	MRTN	PCU (105) + Urea (35)				
7	MRTN	Poultry Litter (54)				UAN (86)
8	MRTN			UAN (40)	UAN (100)	
9	MRTN			UAN (40)		UAN (100)
10	MRTN			UAN (40)	UAN (50)	UAN (50)

Abbreviations: AmP=ammonium polyphosphate 10-34-0; PCU=polymer coated urea; UAN=28% urea ammonium nitrate.
Lansing application dates – PPI's: 5/19/14: V4-6: 6/09/14, V10-12: 7/07/14
Richville application dates – PPI's: 5/08/14: V4-6: 6/04/14, V10-12: 6/30/14

Table 2. Statistical summary for the effect of N placement, N timing, and N source combinations on relative canopy sensing observations, and yield across both study locations.

Source of Variation	**Yield**
	$P_r > F$
Fixed effects	
Location	0.0272
Treatment	0.0037
Location x Treatment	0.0388
Location x Treatment Sliced	
Popup + V4-6 SD	0.3063
Popup + V10-12 SD	0.5468
Popup + V4-6 + V10-12 SD (1:1 split)	0.8405
PPI (100% Urea)	0.0022
PPI (75% PCU + 25% Urea)	0.0013
PPI (1 T A^{-1} Poultry Manure + V10-12 SD)	0.6101
2x2 + V4-6 SD	0.2910
2x2 + V10-12 SD	0.3952
2x2 + V4-6 + V10-12 SD (1:1 split)	0.3850

Table 3. N placement, N timing, and N source combination effects on corn grain yield, moisture, and test weight across locations, 2014.

		Yield (bu A^{-1})		**Moisture (%)**		**Test Weight(lbs bu^{-1})**	
Treatment	N Strategy	Lansing	Richville	Lansing	Richville	Lansing	Richville
No.							
2	Pop-up	231 a*	224 cd	18.8 ab	16.7 cd	52.9 a	52.1 a
3	Pop-up	213 c	217 d	17.2 c	18.3 a	52.6 a	53.7 a
4	Pop-up	229 ab	230 abc	18.7 ab	17.7 ab	52.2 a	52.6 a
5	PPI	217 bc	239 a	17.6 bc	16.3 d	52.0 a	52.8 a
6	PPI	212 c	234 ab	18.0 bc	16.8 cd	52.2 a	52.9 a
7	PPI	234 a	230 abc	19.6 a	17.9 a	52.1 a	52.8 a
8	2x2	222 abc	229 bc	19.4 a	17.1 bc	52.4 a	53.4 a
9	2x2	213 c	218 d	19.3 a	16.8 cd	52.4 a	53.1 a
10	2x2	227 ab	233 abc	19.5 a	16.7 cd	51.7 a	54.6 a
Pr > F		0.0289	0.0141	0.0424	0.0013	0.2726	0.1639
Untreated Control§		115	96	16.7	18.3	49.5	50.2
Multiple *df* Contrasts							
Popup Strategy		224 a	224 b	18.3 b	17.5 a	52.6 a	52.8 b
PPI Strategy		221 a	235 a	18.4 b	17.0 b	52.1 a	52.8 b
2x2 Strategy		220 a	227 b	19.4 a	16.9 b	52.2 a	54.3 a
Pr > F		0.6080	0.0102	0.0367	0.0220	0.1262	0.0956

*values with the same lower case letter are not significantly different (α=0.1).
§not included in statistical analysis

Table 4. Linear regression analysis of NDVI and SPAD at V6 and R1 to yield as well as height at V6 to yield.

Site, Year		**Yield vs. NDVI**		**Yield vs. SPAD**		**Yield vs. Height**
	Stage	V6	R1	V6	R1	V6
Lansing, 2014	Slope	90.2	-270.4	0.9	4.9	2.7
	Intercept	178.1	412.3	181.1	-41.1	181.6
	$r^{2\dagger}$	0.16*	0.14*	0.03	0.29**	0.14*
Richville, 2014	Slope	103.8	-81.1	0.9	1.6	6.2
	Intercept	178.9	287.7	186.7	142.4	133.4
	r^2	0.19**	0.01	0.06	0.16*	0.34**

† When followed by an asterisk, * = significant at $Pr \leq 0.05$, ** = significant at $Pr \leq 0.01$. No asterisk denotes model was not significant ($Pr > 0.05$).

PROCEEDINGS OF THE

45th

NORTH CENTRAL
EXTENSION-INDUSTRY
SOIL FERTILITY CONFERENCE

Volume 31

November 4-5, 2015
Holiday Inn Airport
Des Moines, IA

PROGRAM CHAIR:

John E. Sawyer
Iowa State Univ
Ames, IA 50011
(515) 294-7078
jsawyer@iastate.edu

PUBLISHED BY:

International Plant Nutrition Institute
2301 Research Park Way, Suite 126
Brookings, SD 57006
(605) 692-6280
Web page**: www.IPNI.net**

ON-LINE PROCEEDINGS:

http://extension.agron.iastate.edu/NCE/