Nitrogen Timing and Sidedress Placement Strategies in Michigan

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ABSTRACT

Nitrogen (N) timing and placement methods are key components to improve corn (*Zea mays* L.) N management. Studies were initiated in Richville and Lansing, MI in 2017 utilizing four N timing strategies including 100% N broadcast after planting (PRE); 50% N pre-plant incorporated with 50% N sidedressed (SD) at V6 (50/50); no pre-plant N with 100% N SD V6 (0/100); and 40 lbs N A^{-1} applied 2-in below and to the side of the seed (2x2) with remaining N SD V6. The PRE strategy was also applied with and without a urease inhibitor (UI). Sidedress (V6) placement methods included coulter-inject 15-in from the row, Y-drop surface application, and Y-drop surface application with a UI. The 0/100 and 2x2 N timing strategies increased grain yield and economic return in Richville. No differences in grain yield or agronomic efficiency (AE) were observed among N timing, SD placement, or UI effects in Lansing, but the 50/50 N timing strategy decreased economic return. Y-drop surface application decreased yield 16 bu A^{-1} and economic return \$55 bu A^{-1} in Richville compared to coulter-inject. Agronomic efficiency increased with the 0/100 and 2x2 N timing strategies and coulter-inject SD placement in Richville. Preliminary 2017 data suggest delaying N applications until V6 may improve grain yield and AE while surface N application adjacent to the plant resulted in similar or reduced grain yield and AE.

INTRODUCTION

The United States (U.S.) produces approximately 14.6 billion bushels of corn annually accounting for 36% of world production (USDA-FAS, 2018). Chlorophyll production and grain yield are dependent on N supply making N an essential nutrient for crop production (Smith et al., 1990; Schelgel and Grant, 2006). Globally, nitrogen use efficiency (NUE) was estimated at 33-47% indicating large quantities of N were lost to the environment (Lassaletta et al., 2014). Volatile spring weather patterns have placed greater emphasis on N placement and timing strategies as N losses can be greatly affected by environmental conditions encountered immediately after N application (Bock, 1984).

Maximum N uptake occurs after V10 with less than 15% of N accumulation occurring prior to V6 (Bender et al., 2013). Nitrogen applications prior to peak uptake periods may increase the potential for N loss while delaying N applications until mid to late-season may result in unrecoverable yield reductions (Binder et al., 2000; Dinnes et al., 2002). Ruiz Diaz et al. (2008) observed yield reductions when split-applying N at planting and late-vegetative stages as compared to applying all of the N at planting. In contrast, Rutan and Steinke (2018) observed yield increases up to 16.1% with split N applications rather than applying 100% of N at planting. Split N applications may be beneficial in Michigan as additional climatic variability due to proximity within the Great Lakes Basin may increase N loss potential between planting and sidedress (Warncke et al., 2009).

Corn accumulates a significant percentage of nutrients from a 15 inch radius around the base of the plant (Hodgen et al., 2009). Precise fertilizer placement may mitigate environmental impacts associated with nutrient runoff while increasing grain yield (Bruulsema et al., 2009). Surface-applied fertilizer may be beneficial as producers often combine fertilizer applications with weed control programs but must consider potential volatilization N losses (Fox and Piekielek, 1993; Stecker et al., 1993). Subsurface starter applications placed 2 inches below and to the side of the seed may increase early-season nutrient accumulation and consistency in grain yield and profitability but require additional equipment installation on planters and require slower planting speeds (Niehues et al., 2004; Rutan and Steinke, 2018). Starter N fertilizer applications may also increase early-season root growth and prove beneficial for water and nutrient accumulation during stressful environmental conditions (Mullock, 2014).

Applying N mid-season allows producers to supply N closer to peak uptake periods and reduce the risk for N loss (Warncke et al., 2009; Bender et al., 2015). Coulter-injecting N 4 inches deep and 15 inches from the base of the plant is a common SD placement strategy but root pruning can be a cause for concern. However, corn root densities may be two-fold higher directly below the plant compared to 14 inches away from the plant as corn root density decreases with distance from the plant (Mengel and Barber, 1974). In no-till corn production, Fox and Piekielek (1993) reported mid-season coulter-inject N and surface-band N produced similar yields but observed greater NUE with coulter-inject N applications. Woodley et al. (2018) observed similar results and reported an average yield reduction of 11% when surface streaming N as compared to coulter-inject. Surface band N applications increase the risk for N loss by volatilization and require precipitation to move N into the root zone for nutrient accumulation (Stecker et al., 1993). Limited data exists evaluating sidedress N placement directly adjacent to the base of the plant with coulter-inject N applications at the same timing or growth stage. The objective of this study was to evaluate grain yield and economic return to multiple N timing and placement combinations in Michigan.

MATERIALS AND METHODS

Field studies were initiated in Richville, MI on 28 April 2017 on a Tappan-Londo (fine-loamy, mixed, active, calcareous, mesic Typic Epiaquolls) loam soil and in Lansing, MI on 12 May 2017 on a Capac (fine-loamy, mixed, active, mesic Aquic Glossudalf) loam. Previous crops consisted of wheat (*Triticum aestivum* L.) in Richville and soybean (*Glycine max* L. Merr.) in Lansing. Preplant soil samples were collected at an 8 inch depth prior to fertilization and analyzed for soil chemical properties which included 7.9 pH, 3.1% organic matter (OM), 14 ppm P, and 196 ppm K in Richville and 7.2 pH, 2.3% OM, 27 ppm P, and 108 ppm K in Lansing. Broadcast P and K fertilizers were applied prior to planting based on MSU fertilizer recommendations (Warncke et al., 2009).

Experiments were designed as a randomized complete block design with four replications. Four N timing strategies were utilized including a non-fertilized control, 100% of N broadcast after planting (PRE), 50% of N pre-plant incorporated (PPI) with 50% of N sidedressed (50/50), 0% of N PPI with 100% of N sidedressed (0/100), and 40 lbs N A^{-1} applied 2 in below and to the side of the seed with the remainder of N sidedressed (2x2). The PRE strategy was applied with and without a urease inhibitor (UI). Sidedress N methods consisted of coulter-inject 4 inches deep and 15 inches from the row, Y-drop surface application adjacent to the base of the plant, and Y-drop application with a UI. Sidedress application were made at V6 on 6 June 2017 in Richville and 9 June 2017 in Lansing. Nitrogen rates were determined using maximum return to nitrogen

(MRTN) recommendations and were consistent across N strategies at 170 and 145 lbs N A^{-1} in Richville and Lansing, respectively (Warncke et al., 2009).

Plots measuring 15 ft in width and 40 ft in length were planted with the hybrid DKC51-38 (Monsanto Co., St. Louis, MO) in 30 inch rows to achieve a seeding rate of 34,000 seeds A^{-1}. A Minolta SPAD 502 chlorophyll meter (CM) (Konica Minolta, Tokyo, Japan) was used to indicate ear leaf N status. Ten random plants were selected and one reading from each plant collected from the ear leaf (Scharf et al., 2006). The center two rows were harvest on 12 October 2017 in Richville and 10 October 2017 in Lansing to determine grain yield. Grain yield was adjusted to and reported at 15.5% moisture. Economic analyses were performed using cost estimates of \$183 UAN A^{-1}, \$305 urea A^{-1}, and \$130 gal^{-1} Agrotain Advanced 1.0 (Koch Agronomic Services, LLC, Wichita, KS) A^{-1}. Application costs of \$12, \$11.12, \$13.61, \$1.88, and \$6.54 A^{-1} were estimated for Y-drop application, coulter-inject application, urea incorporation, 2x2 starter application, and urea broadcast application. Gross profits were calculated as input costs subtracted from the product of yield and grain price received (\$3.10 bu^{-1}). Agronomic efficiency (AE) was determined as the change in yield of treatments with N from the non-fertilized control divided by N rate (Sawyer et al., 2017).

Statistical analyses were performed using PROC GLIMMIX in SAS 9.4 (SAS Institute, Cary, NC) at $\alpha = 0.10$ to determine the effects of nitrogen timing and placement methods on corn grain yield, economic return, and agronomic efficiency. Means across N timing strategies, SD methods, and the effect of a UI were performed using multiple degree of freedom (*df*) contrasts. Coefficients of determination (r^2) were determined using PROC REG to investigate the relationship between SPAD measurements with grain yield.

PRELIMINARY RESULTS AND DISCUSSION

Cumulative precipitation between 1 April and 31 August 2017 was 0.6 and 2.3 inches below normal for Richville and Lansing, respectively. Early-season cumulative precipitation (Apr.-May) was excessive (≥ 20% above 30 yr mean) resulting in 1.5 and 1.4 inches above normal in Richville and Lansing, respectively. Mid-season cumulative precipitation (Jun.-Aug.) was 8% and 23% below normal in Richville and Lansing, respectively, but considered normal in Richville and dry (≥ 20% below 30 yr mean) in Lansing. Average daily air temperatures in April were 4.5˚F and 4.6˚F above normal in Richville and Lansing, respectively. Temperatures were ±1.5˚F at both locations in May, June, and July with cooler temperatures than the 30 yr mean in August (2.1˚F below in Richville and 3.0˚F below in Lansing).

Grain yield was significantly affected by N timing and placement strategies in Richville while no differences existed in Lansing (Table 1). Dry soil conditions during May-August in Lansing may have limited overall N movement throughout the root zone (Venterea and Coulter, 2015). Delaying 100% of N (0/100) until SD increased grain yield in Richville compared to PRE and 50/50 N timing strategies. Grain yield was 195 bu A^{-1} for the 0/100 treatment while the PRE and 50/50 N timing strategies reduced yield to 176 and 181 bu A^{-1}, respectively (Table 1). Excessive rainfall (i.e. greater than 20% of the 30 yr mean) in April-May may have induced N loss conditions with N applied prior or at planting (Hatfield and Parkin, 2014). In Richville, similar yields were achieved with the 0/100 N timing strategy as compared to the 2x2 N timing strategy which yielded 188 bu A^{-1}. While no differences in grain yield existed at the Lansing location, the 2x2 N strategy resulted in greater yield consistency across locations and environments. Similar results were observed by Rutan and Steinke (2018) where 2x2 N applications produced greater consistency in grain yield and profitability across years, locations, and environmental conditions.

Nitrogen placement closer to the plant (i.e. Y-drop surface application) had no effect on grain yield in Lansing and reduced yield in Richville. Coulter-inject SD placement method resulted in a yield of 199 bu A^{-1} in Richville and 181 bu A^{-1} in Lansing while Y-drop surface application resulted in a yield of 183 and 172 bu A^{-1} in Richville and Lansing, respectively (Table 1). Under dry mid-season environmental conditions (i.e. Lansing), N placement above the root zone may be positionally unavailable to the crop as moisture is needed to convert urea into plant-available N and for N mobilization into the root zone (Venterea and Coulter, 2015). Lack of rainfall events within eight days of SD application may have limited nutrient movement into the root zone with surface N applications at the Richville location resulting in a significant 16 bu A^{-1} yield reduction for the Y-drop surface applied treatment compared to coulter-inject. However, no differences in grain yield were observed when comparing all treatments without a UI to all treatments with a UI (multiple *df* contrast) at either location indicating environmental conditions were not dry enough to induce volatilization N losses.

Economic return was significantly affected by N timing strategies at both locations while SD placement methods affected economic return in Richville. The 0/100 and 2x2 N strategies resulted in an economic return of \$533 and \$512 A^{-1} in Richville and \$491 and \$515 A^{-1} in Lansing, respectively (Table 1). The 50/50 N timing strategy reduced economic return at both locations while the PRE strategy reduced economic return in Lansing. Dry soil conditions in Lansing likely negated any potential differences due to SD N placement. Y-drop surface application reduced economic return \$55 A^{-1} in Richville while economic return was not affected by UI at either location (Table 1).

Ear leaf N status can be measured through the use of a CM and indicate N deficiency (Samborski et al., 2009). Chlorophyll meter measurements at R1 and R4 were correlated with grain yield at both locations (r^2=0.7278 and 0.6943 in Richville and 0.4660 and 0.7392 in Lansing, respectively). In Richville, multiple *df* contrasts indicated no differences existed in R1 CM measurements among N timing strategies or with the use of a UI (Table 2). The use of a UI increased CM measurements in Richville at R4 from 48.6 to 51.3 indicating greater chlorophyll production was achieved later in the season with the use of a UI despite lack of differences in grain yield (Table 2). Delaying the majority of N applications until SD (i.e. 0/100 and 2x2 N timing strategies) increased CM measurements at R4 in Richville. Chlorophyll production may have been maintained later in the season by increasing N availability during peak nutrient uptake periods. No differences existed in CM measurements at the Lansing location for either measurement timing. Agronomic efficiencies were similar to R1 CM measurements where no differences were observed among N timing, N placement, or UI strategies in Lansing while the 0/100 N timing strategy increased AE compared to the PRE and 50/50 strategies in Richville. The 2x2 N strategy increased AE compared to the PRE N timing strategy in Richville (Table 3). Results indicated greater agronomic efficiency was obtained by delaying N applications until SD time. Placing N closer to the plant via Y-drop surface N application decreased AE from 38.1 to 32.8 in Richville indicating greater agronomic efficiency of N fertilizer with coulter-inject SD N applications. Greater moisture beneath the soil surface may be beneficial during drier time periods as N availability and mobility is largely influenced by environmental conditions.

PROJECT CONTINUATION

Soil moisture conditions largely dictate corn response to N timing and placement methods thus this project was continued in 2018. The authors would like to thank Andrew Chomas and

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Table 1. Influence of N strategy on corn grain yield[†] and economic return[‡], Lansing and Richville, MI, 2017.

N Strategy	Richville		Lansing	
	----bu A^{-1}----	----US$ A^{-1}----	----bu A^{-1}----	---US$ A^{-1}---
PRE	178 def[#]	$488 cde	168 a	$466 a
PRE w/ UI[§]	173 ef	$462 de	183 a	$501 a
0/100: Coulter	202 a	$561 a	185 a	$516 a
0/100: Y-Drop	192 abcd	$529 abc	171 a	$471 a
0/100: Y-Drop w/ UI[¶]	189 abcde	$510 abcd	179 a	$487 a
50/50: Coulter	195 abc	$518 abc	163 a	$428 a
50/50: Y-Drop	171 f	$443 d	157 a	$407 a
50/50: Y-Drop w/ UI[¶]	178 cdef	$459 de	161 a	$424 a
2x2: Coulter	199 ab	$549 ab	195 a	$544 a
2x2: Y-Drop	181 cdef	$491 cde	176 a	$483 a
2x2: Y-Drop w/ UI[¶]	185 bcdef	$497 bcd	188 a	$516 a
P > F	0.05	0.01	ns[††]	ns
Untreated[‡‡]	83.6	$259	94	$290
Multiple *df* contrasts				
PRE	176 c	$475 b	175 a	$483 ab
0/100	195 a	$533 a	178 a	$491 a
50/50	181 bc	$473 b	160 a	$420 b
2x2	188 ab	$512 a	186 a	$515 a
P > F	0.03	<0.01	ns	0.06
Coulter	199 a	$543 a	181 a	$496 a
Y-Drop	183 b	$488 b	172 a	$465 a
P > F	<0.01	<0.01	ns	ns
-UI	180 a	$488 a	168 a	$457 a
+UI	181 a	$482 a	178 a	$482 a
P > F	ns[††]	ns	ns	ns

† Grain yield reported at 15.5% moisture.

‡ Economic return to nitrogen rate used in Richville and Lansing were 170 and 145 lbs N ha^{-1}, respectively.

§ UI = urease inhibitor, applied with Agrotain Advanced 1.0 at 2.0 quarts/ton Urea.

¶ UI = urease inhibitor, applied with Agrotain Advanced 1.0 at 1.0 quarts/ton UAN.

Values within each column followed by the same lowercase letter are not significantly different at $\alpha = 0.1$

†† ns, not significant.

‡‡ Untreated control not included in statistical analysis.

Table 2. Nitrogen timing, N placement, and urease inhibitor strategy effects on R1 and R4 SPAD measurements, Richville and Lansing, MI, 2017.

N Strategy	Richville		Lansing	
	R1	R4	R1	R4
PRE	56.1 a[§]	46.4 c	57.7 a	48.9 a
PRE w/ UI[†]	55.4 a	52.0 ab	54.7 a	49.7 a
0/100: Coulter	56.5 a	53.9 a	57.2 a	51.1 a
0/100: Y-Drop	56.7 a	49.3 bc	55.8 a	48.5 a
0/100: Y-Drop w/ UI[‡]	54.8 a	52.4 ab	55.7 a	53.2 a
50/50: Coulter	56.0 a	48.6 bc	55.0 a	49.7 a
50/50: Y-Drop	52.8 a	45.9 c	53.9 a	47.9 a
50/50: Y-Drop w/ UI[‡]	55.7 a	49.6 abc	52.4 a	49.6 a
2x2: Coulter	57.3 a	52.7 ab	55.0 a	47.8 a
2x2: Y-Drop	55.9 a	52.6 ab	55.2 a	52.1 a
2x2: Y-Drop w/ UI[‡]	55.5 a	51.4 ab	57.5 a	52.5 a
P > F	ns[¶]	0.05	ns	ns
Untreated[#]	36.4	24.4	42.6	25.6
Multiple *df* contrasts				
PRE	55.7 a	49.2 bc	56.2 a	49.3 a
0/100	56.0 a	51.8 ab	56.2 a	50.9 a
50/50	54.8 a	48.1 c	53.7 a	49.1 a
2x2	56.2 a	52.3 a	55.9 a	50.8 a
P > F	ns	0.02	0.09	ns
Coulter	56.6 a	51.7 a	55.7 a	49.5 a
Y-Drop	55.2 b	50.2 a	55.1 a	50.6 a
P > F	0.07	ns	ns	ns
-UI	55.4 a	48.6 b	55.7 a	49.4 a
+UI	55.3 a	51.3 a	55.0 a	51.3 a
P > F	ns	0.04	ns	ns

† UI = urease inhibitor, applied with Agrotain Advanced 1.0 at 2.0 quarts/ton Urea.

‡ UI = urease inhibitor, applied with Agrotain Advanced 1.0 at 1.0 quarts/ton UAN.

§ Values within each column followed by the same lowercase letter are not significantly different at α = 0.1

¶ ns, not significant.

Untreated control not included in statistical analysis. According to Dunnett's Test SPAD values indicate a response to N.

Table 3. Agronomic efficiency[†] (AE) of N fertilizer timing and placement combinations, Richville and Lansing, MI, 2017.

N Strategy	Richville	Lansing
	------------lb grain lb N^{-1}------------	----------lb grain lb N^{-1}-----------
PRE	31.1 def[¶]	28.8 a
PRE w/ UI[‡]	29.6 ef	34.5 a
0/100: Coulter	39.2 a	35.5 a
0/100: Y-Drop	35.9 abcd	30.0 a
0/100: Y-Drop w/ UI[§]	35.0 abcde	33.0 a
50/50: Coulter	36.9 abc	27.1 a
50/50: Y-Drop	28.9 f	24.7 a
50/50: Y-Drop w/ UI[§]	31.2 def	26.2 a
2x2: Coulter	38.2 ab	39.3 a
2x2: Y-Drop	32.0 cdef	31.8 a
2x2: Y-Drop w/ UI[§]	33.5 bcdef	36.7 a
P > F	0.0476	ns[#]
Multiple *df* contrasts		
PRE	30.4 c	31.6 a
0/100	36.7 a	32.9 a
50/50	32.3 bc	26.0 a
2x2	34.6 ab	35.9 a
P > F	0.03	ns
Coulter	38.1 a	34.0 a
Y-Drop	32.8 b	30.4 a
P > F	0.01	ns
-UI	32.0 a	28.8 a
+UI	32.3 a	32.6 a
P > F	ns	ns

† Agronomic efficiency is calculated as the change in yield of treatments with N from the non-fertilized control divided by N rate.

‡ UI = urease inhibitor, applied with Agrotain Advanced 1.0 at 2.0 quarts/ton Urea.

§ UI = urease inhibitor, applied with Agrotain Advanced 1.0 at 1.0 quarts/ton UAN.

¶ Values within each column followed by the same lowercase letter are not significantly different at α = 0.1

ns, not significant.