CORN PLANT UNIFORMITY FOLLOWING SHALLOW NH_3 PLACEMENT IN PRECISION-GUIDED, PRE-PLANT NITROGEN APPLICATIONS

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Abstract

Corn (Zea mays L.) production relies extensively on different types of N fertilizers, and anhydrous ammonia (NH_3) continues to be a dominant N source in much of the Corn Belt. Timing and placement of NH_3 fertilizer can affect plant-to-plant uniformity and yield of corn, and especially so when high N rates are applied and there is little time between spring pre-plant NH_3 application and planting. The effects of shallow pre-plant NH_3 placement on corn plant-to-plant uniformity were investigated for both no-till and spring-till tillage systems at two N fertilizer rates. A John Deere 2510H applicator and precision RTK guidance was used to apply NH_3 either diagonal to, or parallel to (but displaced 6 inches), the intended corn rows. Corn planting (also RTK guided) took place within 3 days of NH_3 application. Intensive monitoring of individual plant development in selected zones began with seedling emergence and continued through maturity. Results from the first year of the study (2010) showed that the frequency distribution of individual-plant ear weights had similar variations for corn plants in parallel versus diagonal application directions, although heavier ears (and higher overall yields) were observed in treatments with parallel versus the traditional diagonal application. Spring tillage following application increased final grain yields relative to no-till, and corn yields were also higher at 180 pounds N than at 130 pounds N acre^{-1}. More definitive conclusions concerning corn plant variability following shallow NH_3 placement are only possible with additional years of research; this project was continued in 2011. Additional research may also be necessary to verify whether a 6-inch offset is sufficient for parallel-to-row, pre-plant NH_3 with this new applicator in RTK guidance systems.

Introduction

Efficient corn (Zea mays L.) production in modern intensified agriculture relies heavily on extensive usage of N fertilizers. Anhydrous ammonia (NH_3) is one of the most widely used N fertilizers in the last few decades (Stamper, 2009 and USGS, 2011) in the United States due primarily to its lower cost (per unit of N) relative to other N sources. Farmers and researchers are always interested in how, when and where to apply the NH_3 to derive maximum benefit from this fertilizer source.

John Deere recently introduced a new line of NH_3 applicators (2510H Nutrient Applicator) to the market (John Deere, 2008) which is fundamentally different from the traditional knife type NH_3 applicators in design and also in operation. This is a single-disk opener system mounted on a high clearance frame where the applicator provides shallower nutrient placement than the traditional knife type of injectors; the constant depth is controlled by a 3-inch wide gauge wheel and maintained with active hydraulic down pressure (John Deere, 2011a). The reported advantages of the new 2510H applicators are:

- shallower nutrient placement and the disk opener enables higher-speed NH_3 application with less horsepower requirement than traditional knife type of applicators,
- reduced soil disturbance provides farmers the opportunity to apply pre-plant NH_3 in no-till and minimum tillage systems,
- higher clearance opens a longer timeframe for optimal side-dress application.

Although there has been extensive engineering testing in the design of the applicator to be able to operate wide range of soil conditions (such as soil moisture, texture and different tillage or crop rotation systems), there have been relatively few studies conducted for comparison of the opportunity of this new applicator to improve nutrient use efficiency for N in today's corn production system. Besides the on-farm evaluations conducted by dealers and farmers who are open to try new technologies, very few replicated field research studies have been conducted/published using the 2510H applicator in the United States and none in Indiana.

As Indiana's corn seeding rates have steadily increased in the last quarter century (Nielsen, 2011); the uniform availability of nutrients may have become more important. For example, Boomsma et al. (2009) reported the even more essential importance of adequate N rates for corn planted at high densities for uniform growth and higher yields. Rossini et al. (2011) reported similar inter-plant competition for resources in high plant density environment (especially with low nutrient supply).

Currently, farmers have the ability to position their tractors very accurately (within inches) and return precisely to the same track at a later time (repeatability). This real time kinetic (RTK) system, such as the John Deere's StarFire system (John Deere, 2011b) can facilitate change in NH_3 application practices (especially in pre-plant applications). Most Indiana and Illinois corn farmers currently apply NH_3 diagonal to the future corn rows in pre-plant application to avoid or minimize the possibilities of corn seedling injury for corn rows that happen to be planted right on top of the NH_3 band where growing corn roots encounter toxic N fertilizer concentrations such as those referenced in prior reports by Sawyer et al. (2009) and Fernández et al. (2011).

The objectives of the study are to determine the effects of the direction of NH_3 application on the variability in plant growth, development, and N access among adjacent plants within rows (including the effect on ear weight consistency from plant-to-plant within rows) and to determine whether plant-to-plant uniformity in corn depends on the post-application tillage practices and the applied N rates.

Materials and Methods

The study was conducted on a Chalmers silty clay loam soil (a dark prairie soil with approximately 4% organic matter) at Purdue University's Agronomy Center for Research and Education (ACRE) near West Lafayette, IN (40.4855246, -87.0006963). The study was a split-plot design where the direction of the application was the whole plot and tillage system and applied N rates were the subplots. Anhydrous ammonia was pre-plant applied with the JD 2510 shallow nutrient applicator at a 15° angle to the intended corn row (traditional application), or parallel to the corn row but offset 6 inches, followed by either no-till or conventional spring tillage treatments. In all cases, the 2510 applicator was set to apply NH_3 to a 4.5" depth. The

RTK guided tractor was kept to the same wheel tracks in parallel NH_3 application and in the subsequent planting by adjusting the toolbar position of the 2510H row units. The N fertilizer rates were the Purdue's recommended N rate (180 lbs acre^{-1} for corn following soybean at this location) and 50 lbs acre^{-1} less, but all treatments also included a common side-banded starter fertilizer (10-34-0) with 12.5 gallon acre^{-1} rate at planting. Pioneer 1367XR was seeded at 34,000 plants acre^{-1} on April 17th, 2010 (about 3 days following NH_3 application).

A 17.5 feet section of row was selected in each plot after planting, and all individual plants in these zones were intensively monitored from their seedling emergence date to their individual plant yield at harvest; individual plant growth and development measurements (i.e. emergence date, plant height, leaf chlorophyll (SPAD) content, and silking and tassel emergence times) were taken during the growing season. Individual plants in no-till and spring-till systems were categorized as "early" silking if they were among the first 10% of plants for that tillage system to achieve silk emergence, and were categorized as "late" silking if they were among the last 10% of plants to achieve silking. The "normal" silking plants were the approximately 80% of the plants between "early" and "late" silking. Mean overall silk emergence was 1-2 days earlier in the spring-till system.

Plants from the selected zones were individually hand harvested. Grain yield and yield components (kernel number and kernel weight) were recorded for each plant. Kernel weights were adjusted to 15.5% moisture content. Plots were also harvested for bulk yield response. The center 6 rows of each 12-row plot was harvested by a JD 9400 combine with a 6-row header and a separate weigh buggy system; all grain yields were adjusted to 15.5% moisture content.

Results

Neither NH_3 application position/rates, nor subsequent tillage systems affected final plant populations. Overall mean seedling emergence times were also unaffected by N and tillage treatments (data not presented). Combine harvested yields were numerically, but not statistically significantly higher, in 3 of 4 treatments when NH_3 was parallel applied but offset from the corn row (Table 1). Both N rates and the tillage system significantly influenced the final grain yield.

Table 1. Effects of anhydrous ammonia placement with the John Deere 2510H on combine harvested yield, on corn grain weight and kernel number per plant, and kernel weight based on 6 replications in 2010 at the Agronomy Center for Research and Education, West Lafayette, IN.

Pre-plant NH_3 Placement, N Rate (pounds/acre), and Tillage Treatment Combination	Combine harvested yield	Mean kernel weight per plant	Mean kernel number per plant	Mean kernel weight per kernel
	(Bu/A)	(g)	(kernels/plant)	(g)
Diagonal, 180 N, No-till	217.8 c[1]	160.4 abc[1]	460.7 b[1]	0.358 a[1]
Diagonal, 130 N, No-till	185.4 d	145.9 d	474.2 ab	0.309 d
Diagonal, 180 N, Spring-till	231.3 ab	166.4 ab	503.7 a	0.333 bc
Diagonal, 130 N, Spring-till	210.1 c	159.0 bc	502.5 a	0.319 cd
RTK 6" from row, 180 N, No-till	215.5 c	168.4 ab	487.2 ab	0.360 a
RTK 6" from row, 130 N, No-till	195.6 d	151.2 cd	467.9 ab	0.329 bc
RTK 6" from row, 180 N, Spring-till	238.5 a	172.7 a	501.9 a	0.346 ab
RTK 6" from row, 130 N, Spring-till	221.8 bc	165.7 ab	496.7 ab	0.336 bc

[1] means with different lowercase letter indicate statistically significant difference at P=0.05

Consistently heavier individual plant grain weights were measured in the RTK-parallel plots than in the diagonal plots, but direction differences within a N rate and tillage system were not significant (Table 1). The no-till system had somewhat lower kernel numbers per plant than spring-till, and lowest kernel numbers per plant were observed in in the diagonal no-till plots at the higher N rate. The 180 lbs N acre^{-1} fertilizer rate resulted in higher individual kernel weights relative to the 130 N rate, and RTK treatments tended to result in higher individual kernel weights (except in the no-till 180 N rate).

Individual ear (grain only) weights were assigned into groups based on successive 25 gram increments (i.e. 0-25g, 25-50g etc.). The distribution of the frequency of ear weight groups showed more occurrence of higher grain weight regardless of tillage or applied N rate when NH_3 application was RTK guided parallel to the corn row (Figure 1). A shift towards heavier ear weights was also observed following spring tillage versus no-till system regardless of the direction of application. Higher N fertilizer rate increased the frequency of bigger ears within the same tillage system in both application directions. Plant-to-plant variation was not improved too much in any of the treatment combinations, but the higher incidence of heavier individual-plant grain weights favored RTK guided, parallel application.

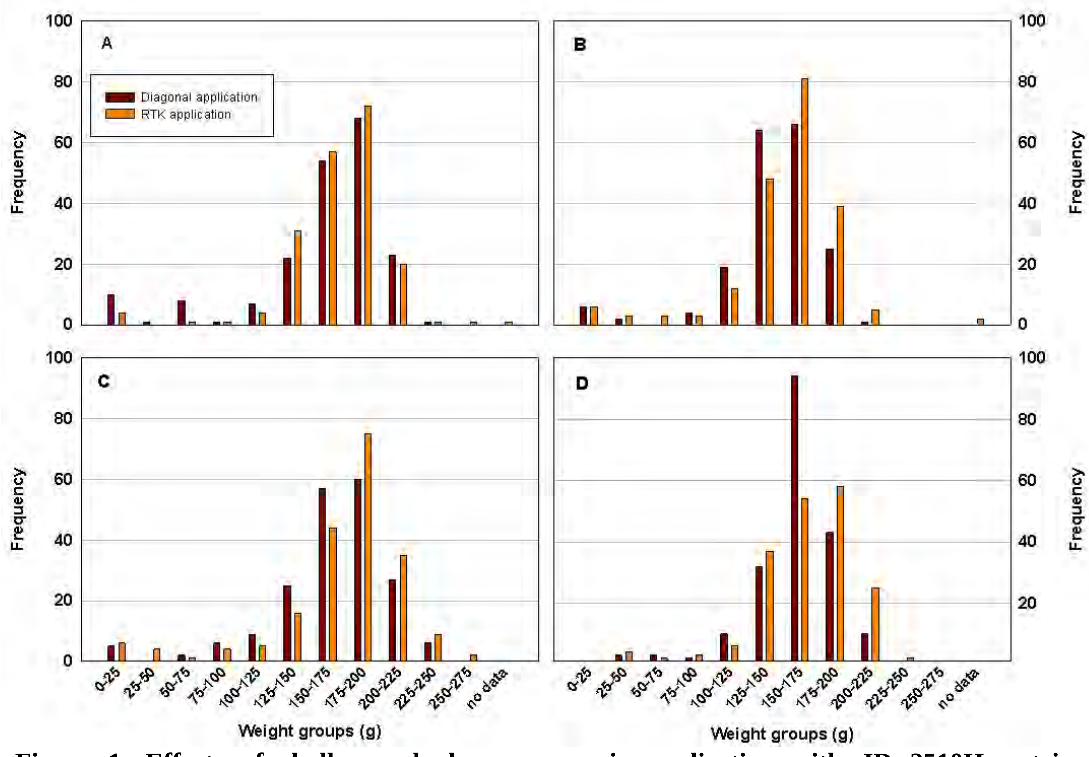

Figure 1. Effects of shallow anhydrous ammonia application with JD 2510H nutrient applicator on ear weight distribution in 2010 at West Lafayette, IN. Diagonal and parallel-RTK guided directions are paired in the following treatment combinations: No-till 180 N rate (A), No-till 130 N rate (B), Spring-till 180 N rate (C), and Spring-till 130 N rate (D).

Seedling emergence and silking times (expressed in Growing Degree Days) were plotted against their respective individual-plant ear weights in each treatment combination (the two example treatments from each application direction are presented in Figure 2 andFigure 3). Deviation amongst plants within rows for seedling emergence time had very little influence on the final ear weights, while deviation in silking time had much more influence on grain yield. Individual plants that silked earlier had heavier ears, while late silking plants had a higher percentage of lower ear weights. Individual-plant grain weights were also little affected by individual plant spacing in the row (Figure 4). Less than 10% of the individual-plant variation in grain yield was explained by either relative seedling emergence GDD, or by plant spacing. (Figures 2-4, plus non-reported data from other treatment combinations). The dominant influence on individual plant grain weights came not from variation in seedling emergence or plant spacing but from inter-plant competition for resources in later vegetative and early reproductive stages.

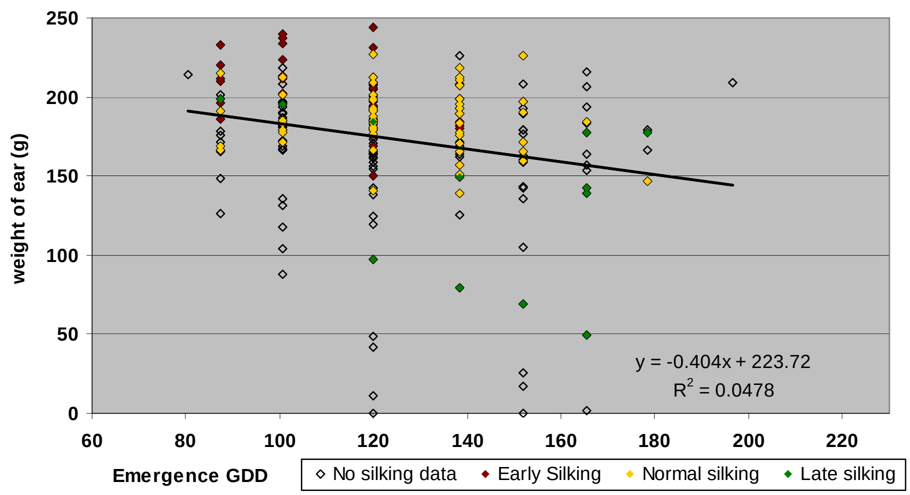

Figure 2. Relationship of seedling emergence (in GDD) to silking time and individual-plant corn ear weights in RTK parellel applied NH_3 at 180 N pounds acre^{-1} rate in spring-tilled plots near West Lafayette, IN (2010).

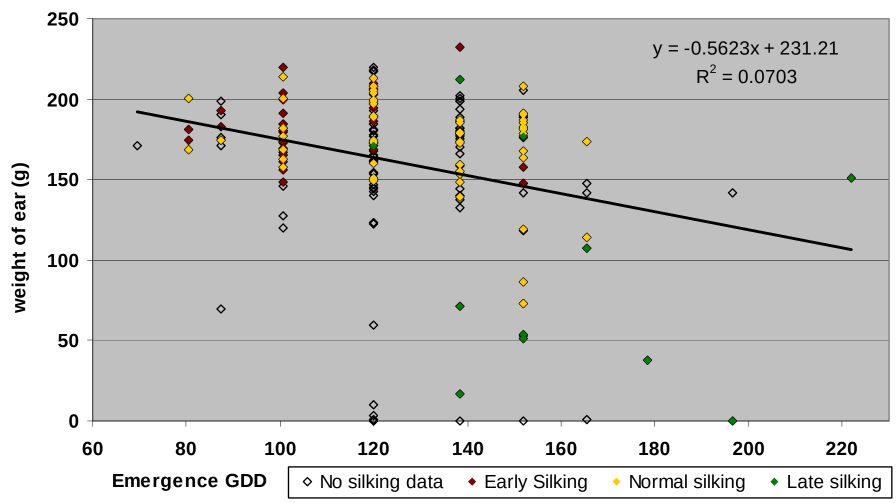

Figure 3. Relationship of seedling emergence time (in GGD) to silking time and individual-plant corn ear weights in diagonally applied NH_3 at 180 N pounds acre^{-1} rate in no-till plots near West Lafayette, IN (2010).

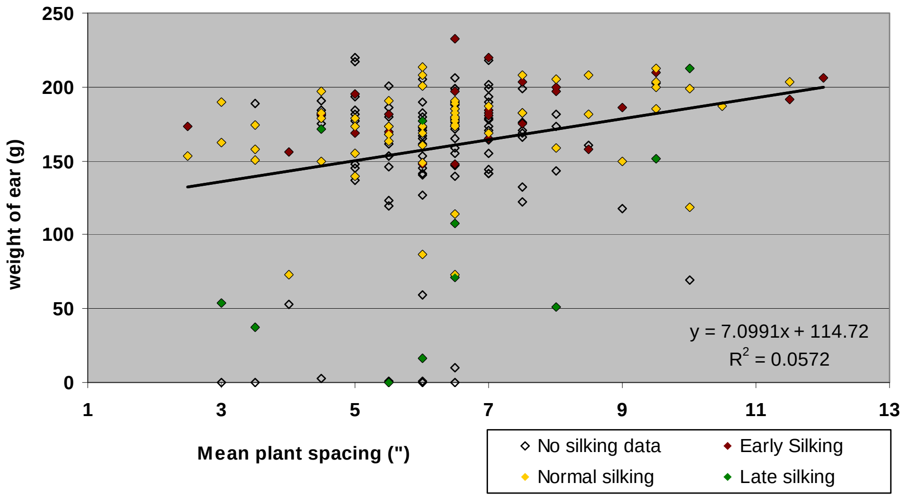

Figure 4. Relationship of mean plant spacing, silking time and individual-plant corn ear weights in diagonally applied NH3 at 180 N pounds acre^{-1} rate in no-till plots near West Lafayette, IN (2010).

Parallel applied NH_3 helped to improve mean ear weights, but certainly factors other than just the placement or rate of the NH_3 fertilizer influenced final ear weights.

These results are from the first year of research conducted in one location and using one hybrid. To have a better understanding of the effect of shallow NH_3 placement on plant-to-plant uniformity, continued study is required. We are not entirely certain that the 6-inch displacement from the intended corn row provides a sufficient safety buffer when there is little time between pre-plant NH_3 application and planting. Although a 5-inch displacement provided a sufficient corn safety buffer for pre-plant banded (and shallow 4") UAN application of rates as high as 200 lb N/acre when corn was planted within 24 hours of UAN application (Vyn and West, 2009), it is possible that a wider NH_3 offset would be even safer. In that respect, shallow pre-plant NH_3 application may require a different offset from the corn row than the traditional deeper applications.

Summary

The first year of our shallow NH_3 placement study demonstrated a small grain yield advantage for parallel (but offset 6 inches) pre-plant NH_3 relative to the traditional diagonal pre-plant NH_3 application. The yield advantage was more associated with a higher incidence of heavier ears in the RTK-parallel applied treatments rather than the achievement of more uniform adjacent plants within the rows. Variation in corn seedling emergence time or spacing explained less than 10% of the variation in individual plant yields. Controlling factors (including nutrient availability) that contribute to plant-to-plant variability in later-season growth and development is more important to final yield than minor plant-to-plant differences due to seedling emergence or spacing uniformity. It is important to optimize NH_3 management (timing, placement, and rate) to achieve consistency in individual plant growth, and the best possible corn yields, with this new shallow application system.

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