EFFECT OF NITROGEN FERTILIZER

RATE AND PLACEMENT ON

CORN GRAIN YIELD

By

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EFFECT OF NITROGEN FERTILIZER RATE AND PLACEMENT ON CORN GRAIN YIELDS

Abstract

By-plant application of nitrogen (N) fertilizer has the potential to increase N use efficiency in corn (*Zea mays* L.). This study was conducted to evaluate the use of directed stream application at the base of the plant using UAN (urea ammonium nitrate) versus dribble surface bands applied in the middle of the row, and to evaluate the use of directed stream application by-plant using UAN versus dribble surface bands applied in the middle of the row. The experiment was conducted at the Robert L. Westerman Irrigated Research Station at Lake Carl Blackwell, OK (LCB), and at the Eastern Research Station at Haskell, OK for three years. The experimental design was a randomized complete block with three replicates. Treatments were three N placement methods and applied in three different methods; 1. stream at the base of the row; 2. by plant at the base of the plant; and 3. stream between the rows. Each treatment method had four N rates split applied, and three N rates applied all pre-plant. At the Irrigated LCB site, in 2005, 2006, and 2007 an increase in grain yields from by-plant N application at lower rates when compared to commonly applied N in the middle of the row. Similarly, at the non-irrigated site at Haskell, by-plant fertilization showed improved grain yields at lower N rates in 2005. At Haskell in 2006 the middle two N rates (90 and 135 kg N ha^{-1}) resulted in slightly higher yields when fertilizing by-plant. In 4 of 6 site years , there was a slight advantage associated with applying N by-plant at lower N rates compared with N applied uniformly in the middle of the row. The benefits of fertilizing by-plant tended to be more evident when yields were lower and the production cycle was characterized by moisture stress.

I. INTRODUCTION

Today's agricultural producers must concern themselves with how to make an economical profit as well as how to conserve and protect the resources on their land so that those resources will be there for the future. All producers must concern themselves with the environmental impact of their farming practices. Excess N application can cause contamination of both ground and surface water. This contamination can lead to eutrophication of water supplies and oxygen depletion of aquatic plant and animal life.

Higher yields are the goal of agricultural producers; however, inputs must be kept at an economical level in order to make a profit. Results indicate that wheat yield potential is more strongly influenced by previous crop, fertilizer N rate, and N placement method than by tillage system (Kelley and Sweeney, 2005).

Martin et al. (2005) showed that over all sites in all countries and states, plant to plant variation in corn grain yields averaged 2765 kg ha^{-1}, (44 transects in Ohio, Argentina, Mexico, Nebraska, Iowa, Oklahoma, and Virginia). This data documented that there are likely large differences in the fertilizer requirements between one corn plant and the adjacent corn plant, thus indicating the need for more precise placement of N fertilizer. Martin et al. (2008) further showed that plant height could be used as a quantitative estimate of plant competition, and an equation was developed that incorporated linear distance occupied by each plant to obtain an in-season estimate of yield.

Precision application equipment developed at OSU allows variable nitrogen rate (VRT) application in corn, wheat, soybeans, sorghum, canola, and bermudagrass. This unit is capable of applying herbicides/insecticides while simultaneously applying N in liquid streams (http://nue.okstate.edu/Precision_Ag_Equipmentx.htm, 2006). This technology has made it possible to apply fertilizer only where it is needed. Although the variable rate applicator was initially developed for winter wheat, it can also be used for other crops (corn and other row crops) where by-plant application is needed (Raun et al, 2002). Since N is primarily recovered in the row to which it is applied, by-row precision applications seem to be an appropriate management tool (Ghaffarzadeh et al, 1998).

Currently, available application equipment is capable of by-plant fertilization and it has been shown that by-row application is an effective management tool. Raun and Johnson (1999) showed that "precision agriculture practices allow timely and precise application of N fertilizer to meet plant needs as they vary across the landscape". This variation "across the landscape" is what makes variable rate fertilization necessary. Individual areas and plants within those areas produce different yields and therefore need more or less fertilizer depending on their position in the field.

Seminal roots in corn anchor the young seedling corn plant and absorb small amounts of water and nutrients for the first two to three weeks of growth. If damage occurs to these seminal roots (examples of damage can include salt injury from excessive rates of starter fertilizer) before later developing permanent roots become established, stunting or death to the plant will occur. After emergence of the seedling, the nodal or permanent roots elongate (leaf stage V2). By leaf stage V6, nodal roots are well established and have taken over the sustenance of the plant. Damage to the nodal roots in the V1 to V5 growth stages can severely stunt corn plant development (Nielsen 2007). Anderson (1987) found that root growth was observed under drought and N stress conditions when shoot growth and yield were limited.

II.REVIEW OF LITERATURE

According to Olson and Sander (1988), narrow row spacing (< 76 cm) minimizes between-plant competition within the row, and therefore it can potentially result in higher corn grain yield. Higher corn grain yields with an increased plant population (up to 76500 plants ha^{-1}) has been reported by Bruns and Abbas (2003). Aldrich et al. (1986) demonstrated that corn grain yield could be increased by 5% if the row spacing was narrowed from traditional 102-cm to 76-cm spacing. Nielsen (1988), Bullock et al. (1988), and Porter et al. (1997) found that there is a potential for increased corn grain yield when the row spacing is less than 76 cm. Hashemi et al. (2005) studied crowding effects on corn grain yield. This study was important for understanding the competition existing among plants for water, light and nutrients. They found that all yield components declined linearly in response to increased competition pressure.

Numerous researchers have published results on different N rates, placement and irrigation on corn grain yields. Lehrsch et al. (2000) evaluated the effects of N placement and row spacing in southern Idaho with different irrigation water positioning. They concluded that banding N fertilizer to the side of a furrow coupled with the irrigation of the other side of the row resulted in higher corn grain yields, silage yields, and increased N uptake over broadcast application. This work was important for making recommendations on fertilizer N placement, and on adjusting sidedress N fertilizer application rates and techniques to minimize the amounts of residual N left in soil post-harvest. The excess N during the cold periods of fall and winter leads to leaching of nitrate (NO_3-N). One of the main advantages of banding fertilizer N is that the growing root system expands around the fertilizer and potentially minimizes leaching by increasing N uptake.

Benjamin et al. (1997) achieved higher yields by fertilizing every mid-row, while placement of N fertilizer only to non-irrigated middle rows resulted in lower N availability and N uptake. These results did not agree with those of Hefner and Tracy (1995). They concluded that, with irrigation of every second furrow, knife application of ammonium nitrate (NH_4NO_3) resulted in higher yields when applied only to the non-irrigated middle row, not to every middle row. However, some producers argue that the best result is achieved by application of irrigation water and fertilizer N (whether it is banded, side dressed or both) to the same side of the corn row to encourage lateral NO_3-N movement to supply the root systems of the nearby plants with N (Lehrsch et al., 2000).

Forage production can also benefit from understanding soil nutrient status by identifying the best fertilizer rate and placement strategy. A study by Harmoney and Thompson (2005) was conducted to determine the most appropriate strategy for N and P fertilizer rate and placement for increasing the forage yield and quality of triticale (*Triticosecale rimpaui* Wittm.). After comparing 14 different N and P rate and placement combinations, the authors concluded that banding N fertilizer with the seed resulted in highest forage production and better forage quality. Harapiak et al. (1993) found that in wheat, N banded with the seed often has a great advantage over broadcast N application in areas with adequate soil moisture and higher grain yield potentials. In areas with dryer soil conditions and lower yield potentials, application of seed-placed fertilizer N is considered to be less effective because it might lead to the loss of significant amount of moisture, and therefore, cause decreased seed-bed quality. The authors underline the importance of considering the effectiveness of various fertilizer N placement techniques with the whole complex economic, logistical and personal factors in order to make the most favorable management decision for a particular crop production system. Recent work by Kelley and Sweeney (2005) showed that choice of fertilizer N rates and N placement applied to wheat has a much greater effect on grain yield compared to the effects of tillage system used or the crop grown prior to wheat. They found subsurface fertilizer N application to be superior compared to surface N application methods as it resulted in more effective N utilization by the crop and, consequently, in higher grain yield. Numerous authors published results showing the advantages of broadcast-applied liquid urea ammonium nitrate (UAN) over injected UAN as well as other N–sources used, coupled with various placement techniques in winter wheat and in no-till corn (Touchton and Hargrove 1982; Stecker et al. 1993; Fox and Piekielek 1993). Application of N fertilizer at the base of a plant should allow for the maximum N uptake as well as minimize leaching. The rational use of residual N and fertilizer N results in higher NUE, higher NUE results in more money in farmers' pockets and less contamination of our groundwater.

III. OBJECTIVES

The objectives of this study were to evaluate the use of directed stream application at the base of the plant using UAN versus dribble surface bands applied in the middle of the row, and to evaluate the use of directed stream application by-plant using UAN versus dribble surface bands applied in the middle of the row. The null hypothesis, Ho: There is no advantage of placing N at the base of the plant, and placement of N at the base of corn plants will not affect the range of by-plants yields in that row. The alternative hypothesis, Ha: There is an advantage of placing N at the base of the plant, and it will affect the by-plant yield range.

IV. MATERIALS AND METHODS

Site Description

Two experimental sites were established in the spring of 2005: one near Perry, OK at the Robert L. Westerman Irrigated Research Station (LCB), and one near Haskell, OK at the Eastern Research Station (a dryland location). The LCB research station soil series is a Pulaski fine sandy loam (Coarse-loamy, mixed, nonacid, thermic Typic Ustifluvent) and the soil at the Haskell site is classified as Taloka silt loam (fine, mixed, thermic, Mollic Albaqualf). Results from composite, pre-plant soil sample analysis from each site is reported in Table 1.

Treatment Structure and Measurements

Table 2 summarizes the treatments that were evaluated in this experiment. The experimental design employed was a randomized complete block (RCBD) with three replications at both locations. At both locations, 15 treatments (combinations of N placement methods and rates) were included. Three sidedress N placement methods were considered (Figure 1). The first method consisted of sidedressing each plant at the base individually. The actual rate applied to each plant was determined by dividing the N rate for a row by the number of plants in the row. The second placement method was distribution of sidedress N in each row at the base of the plant, but in a continuous fashion. The third method was identical to the second method except sidedress N was applied in the middle of two adjacent rows instead of at the base of each plant. Sidedress

N rates were 0, 22.5, 45, 90, and 180 kg N ha^{-1} applied as urea ammonium nitrate (28 % N). Prior to fertilization, the number of plants per row were determined. This was subsequently used to determine the amount of UAN to place at the base of each plant when implementing a particular method of application. Sidedress N was applied with 60 ml syringes when corn was between the V8 and V10 growth stages at all locations and in all years. Pre plant N treatments consisted of 0, 45, and 225 kg N ha^{-1} applied as urea (46-0-0).

At LCB, phosphorus (P) was banded with the seed at a rate of 9.72 kg P ha^{-1} in all years. Haskell had no P or K applied in 2005, 2006 or 2007. Initial soil test for Haskell and LCB is reported in Table 1.

At both locations, plot size was 3 x 6 m. In 2005, the irrigated LCB location was planted to Pioneer (33B51 Pioneer HI-Bred, Des Moines, Iowa) Bt corn hybrid at a seeding rate of 83,980 plants ha^{-1} on April 12th. The same year the dryland Haskell location was planted to the same corn hybrid on April 4th at a rate of 61,750 plants ha^{-1}. In 2006, LCB was planted on April 3rd with Pioneer (33B51 Pioneer HI-Bred, Des Moines, Iowa) Bt corn hybrid at a seeding rate of 79,040 plants ha^{-1}, and Haskell was planted on April 13th with the same corn hybrid at a rate of 59,280 plants ha^{-1}. In 2007, LCB was planted on March 21st with Dekalb (DKC66-23 Monsanto Company, St. Louis, Missouri) Bt corn hybrid at a seeding rate of 79,040 plants ha^{-1}, and Haskell was planted with Pioneer (33B54 Pioneer HI-Bred, Des Moines, Iowa) Bt corn hybrid at a seeding rate of 61,750 plants ha^{-1}. Both locations had row spacing of 76 cm for all three years.

Annual weed control was accomplished with Bicep Magnum Lite II herbicide at a 3501 ml ha^{-1} (Active ingredients 1.12 kg ha^{-1} atrizine and 1.4 kg ha^{-1} S-metalachlor) application rate at both locations at planting. At harvest, corn ears were collected by-plant, and the fresh and dry weight of ears from each plant were determined. Oven-dried ears (dried for 7 days at 60°C) were shelled and grain collected was then weighed. These by-plant data were used to determine the yield range in each row. The sum of the ears per plot was used to calculate yield on a plot basis. Grain sub-samples from each plot were processed prior to N analysis. Grain sub samples were collected and oven dried at 70°C for 14 days. Samples were then processed to pass through a 140-mesh screen for total N analysis using a Carlo Erba NA dry combustion analyzer (Fisons Instruments Beverly, MA) (Schepers et al., 1989). Total N uptake was determined by multiplying percent grain N by grain yield. Nitrogen use efficiency was calculated by dividing increase in grain N uptake due to N fertilization by the amount of N applied. Yield in Mg ha^{-1}, grain N uptake in kg ha^{-1} and percent nitrogen use efficiency were calculated from the data.

Statistical data analysis was performed using procedures in SAS (SAS, 2001)**.** This included analysis of variance using a replication treatment model (15 treatments), and using the full factorial of treatments of N rate (4 levels) and method of placement (3 strategies). The standard error of the difference between two equally replicated means was calculated for each dependent variable analyzed and that is included for determining treatment differences.

V. RESULTS

At the LCB site, in both 2006 and 2007, significant plant stand damage was encountered within the experimental area that was primarily due to wild hogs. Although no data was collected to substantiate as much, this damage was sometimes greater in high N plots.

At Haskell in 2005 with the application of the 67.5 and 90 kg N ha^{-1} sidedress N rates, the by-plant method of fertilizing each plant individually yielded higher than the other methods of application (Figure 2). At the higher levels of fertilization (135 and 225 kg N ha^{-1}), the fertilization between two adjacent rows had slightly higher yields. The average number of ears per plot was 40 over all treatments and there was little to no damage to the plots. The average weight of an ear harvested at this site was 80.6 grams, with the highest average ear weight (107 grams) coming from the lowest N rate treatment (67.5 kg N ha^{-1}). Similarly, at LCB in 2005 the lower sidedress N rates (67.5 and 90 kg N ha^{-1}) were as good or better when fertilized by-plant, but the higher N rates yielded better when fertilized along the base of the row (Figure 3). The average number of ears per plot was 53, and the average ear weight was 173 grams.

According to the National Agriculture Statistics Service (http://www.nass.usda .gov) average corn grain yields for 2005 and 2006 in Muskogee county (the county of the Haskell location) were 6.49 and 6.27 Mg ha^{-1}, respectively. This dryland corn grain yield is consistent with grain yields found at Haskell for the study reported here (Table 3). Statistics for Payne county Oklahoma (the county for the LCB site) showed that average grain yield for 2005 and 2006 was only 4.07 and 2.69 Mg ha^{-1}, respectively. This dryland yield average is well below the irrigated harvested yields at LCB. There was no irrigated corn yield data for Payne county in 2005 or 2006.

At Haskell in 2006, the by-plant treatment at the 90 kg N ha^{-1} rate yielded higher than any other treatment or rate except the 135 kg N ha^{-1} treatment between rows (Figure 4). The check out yielded all but the previous two mentioned treatments and rates illustrating the limited response to applied N. The varied yields that came out of this site year showed that yield had less to do with treatment method or rate of N applied and more to do with moisture and hot temperatures. The average number of ears per plot was 35, and the average ear weight was 95 g with most of the plots yielding between 90 and 100 g per ear.

Methods did not respond the same over the different N rates evaluated at Lake Carl Blackwell in 2006. This was evidenced in having varied response over method of application, and that is illustrated in Figure 5. The interaction of method and N rate at this location showed that the two middle N rates (90 and 135 kg N ha^{-1}) responded positively to by-plant fertilization (5.8 and 6.1 Mg ha^{-1}), but that was not observed at 67 and 225 kg N ha^{-1}. The average number of ears per plot was 65, and the average weight of the ears was 85 g per plot.

At Haskell in 2007, grain yield increased with N rate, although the rate of increase was small. The 67.5 kg N ha^{-1} showed an average yield over all placement methods of 5.8 Mg of grain ha^{-1}, while the high N rate of 225 kg N ha^{-1} showed an average yield of 7.0 Mg of grain ha^{-1}(Figure 6). This is more than a three-fold increase in N rate with only a 1.2 Mg ha^{-1} increase in grain yield, and could suggest that residual soil N may have been higher than in previous years. Alternatively, this could simply mean that maximum yields were achieved at lower rates. Rainy conditions throughout the growing season (site was twice flooded during growing season) may have contributed to excess N movement in the soil. Average number of ears per plot at this site in this year was 62, and the average ear weight was 109 grams.

At LCB in 2007, at the lower N rates (67.5 and 90 kg N ha^{-1}) the by-plant method of fertilizing yielded higher than the other methods of application. At the 135 kg N ha^{-1} rate, sidedressing at the base of the row had higher yields (5.9 Mg ha^{-1}**)** than fertilizing in the middle of adjacent rows or at the base of the plant (Figure 7). Alternately, the 225 kg N ha^{-1} rate resulted in a grain yield of 6.5 Mg ha^{-1} when N was sidedressed in the middle of adjacent rows. Average number of ears per plot at this site was 36, with numbers ranging from 17 ears in the 225 kg N ha^{-1} by plant fertilization plot to 51 ears in the 67.5 kg N ha^{-1} plot that was fertilized along the base of the rows.

The relationship between grain yield and ears per square meter for both locations, over three years is reported in Figure 8. The data reported here encumbered rather diverse environments and where the planting densities ranged from 59 to 83 thousand seeds per hectare. There was no clear yield benefit of having resultant plant densities in excess of 6 per square meter or 60,000 plants per hectare (Figure 8). Although ears were the dependent variable, with few exceptions, all plants had only one ear. Although this data is not conclusive, for the environmental conditions included in this study, the advantages of having extremely high populations (>80,000 plants per hectare) was not evident.

We did not collect any data to determine whether or not the high N rates used in the study resulted in root burn. However, this is a possibility, especially since the by-plant methods placed all of the N at the base of each plant. A trend for decreasing yields at the high N rates was in fact observed and that would support possible root burn, but this was not substantiated. Consistent with work by Nielsen (2007) showing that nodal root damage could take place early on in the corn life cycle (V1 to V5), sidedress treatments in this experiment were applied between the V8 and V10 growth stages, therefore reducing the chance of early root damage from high N rates.

VI. CONCLUSIONS

Varying rates and placement of N fertilizer were used in this experiment to determine the correct N sidedress recommendations for corn. Many farmers apply excess N as insurance, hoping to produce high yields in all years. For this study, applying excess N was not altogether advantageous. Over all site years the more moderate N rates of 45, 67 and 90 kg ha^{-1} produced higher yields with significantly lower N inputs. Only Haskell in 2007 and LCB in 2005 had higher grain yields at the highest N rate of 225 kg N ha^{-1}. These results should assist those interested in fertilizing their crops by-plant, and those people who are interested in varying the amount of N they apply to their crop as they fertilize across the field. Over sites and years, maximum grain yields were achieved at a density of 6 plants per square meter. When evaluating all three-site years, for each different average N rate, grain yields ranged from 2.6 to 11.4 Mg ha^{-1}. By-plant sidedress applications resulted in either higher or comparable yields at most sites and years when N rates were 67.5 kg ha^{-1}. Furthermore, the benefit of fertilizing by-plant tended to be more evident when yields were lower and the production cycle was characterized by moisture stress. Root proliferation into the middle of the row would likely be less under drought than when moisture was non-limiting, and by-plant strategies would result in N application nearer to the seminal root system .

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Table 1. Initial soil test results LCB and Haskell, OK 2005

Location	pH	NH_4-N	NO_3-N	P	K	Total N	Organic C
		mg kg $^{-1}$				g kg $^{-1}$	
Lake Carl Blackwell	6.3	7.92	8.72	24.75	98.74	0.75	8.93
Classification: Pulaski fine sandy loam (Coarse-loamy, mixed, nonacid, thermic, Typic Ustifluvent).							
Haskell	5.8	8.59	6.14	41.80	122.25	0.76	9.87
Classification:Taloka silt loam (Fine, mixed, thermic, Mollic Albaqualf).							

* pH – 1:1 soil: water; K and P – Mehlich III; NH_4-N and NO_3-N – 2 M KCl, Total N and Organic C – dry combustion.

Table 2. Treatment structure employed for N rate and placement study at Lake Carl Blackwell, and Haskell, 2005, 2006 and 2007 on resultant corn grain yields**.**

Treatment	Pre-plant, kg N ha^{-1}	Sidedress, kg N ha^{-1}	Total N rate, kg ha^{-1}	Method
1	45	22.5	67.5	1
2	45	22.5	67.5	2
3	45	22.5	67.5	3
4	45	45	90	1
5	45	45	90	2
6	45	45	90	3
7	45	90	135	1
8	45	90	135	2
9	45	90	135	3
10	45	180	225	1
11	45	180	225	2
12	45	180	225	3
13	0	0	0	N/A
14	45	0	45	N/A
15	225	0	225	N/A

Methods of sidedress application: 1- treat each plant; 2- treat each row at the base of the plant; 3- treat each row but in the center of the row.

Table 3. Effect of N rate on grain yield for Haskell and LCB, 2005, 2006 and 2007. grain yields are expressed as Mg ha^{-1}

N rate	Haskell 2005	LCB 2005	Haskell 2006	LCB 2006	Haskell 2007	LCB 2007
0	3.5	10.1	6.5	3.1	2.6	3.1
45	4.2	11.3	5.7	4.5	5.7	4.3
67	4.8	11.0	5.2	5.4	5.8	5.3
90	4.5	11.4	6.5	5.5	6.1	4.4
135	3.9	11.2	6.4	5.4	6.7	4.6
225	4.3	11.4	5.8	4.9	7.9	4.9
N-rate Lin	NS	*	NS	*	**	NS
N- rate Quad	NS	NS	NS	**	**	NS

*, **- Significant at the 0.05 and 0.01 probability levels respectively
NS-Not Significant/ All data is the result of N-rate and grain yield contrast.

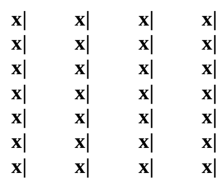
Table 4. Averaged over rates, grain yield, number of ears per plot, and average ear weight for each method of treatment by plant, along the base of the plants, between the rows and broadcast pre-plant. LCB and Haskell, OK 2005, 2006 and 2007.

Year	**Location**	**Application method**	**Grain yield Mg ha^{-1}**	**Ears per plot**	**Avg. ear Wt. (g)**
2005	Haskell	By Plant,V8	4.7a	41a	95a
		Along the base,V8	4.2a	39a	88a
		Middle of the row,V8	4.3a	40a	88a
		Broadcast pre-plant	4.0a	38a	86a
		Check	3.5	39	71
		SED	0.7	3	13
2005	LCB	By Plant, V8	11.1a	53a	173a
		Along the base, V8	11.4a	53a	176a
		Middle of the row, V8	11.2a	54a	171a
		Broadcast pre-plant	11.7a	53a	182a
		Check	10.1	53	155
		SED	0.9	3	16
2006	Haskell	By Plant,V8	6.0a	36a	93a
		Along the base,V8	5.8a	35a	95a
		Middle of the row,V8	6.3a	36a	99a
		Broadcast pre-plant	5.3a	31a	93a
		Check	6.5	37	97
		SED	1.3	4	11
2006	LCB	By Plant, V8	5.5a	65a	94a
		Along the base, V8	4.9ab	64a	83ab
		Middle of the row, V8	5.7a	66a	94a
		Broadcast pre-plant	4.4b	65a	74b
		Check	3.1	69	49
		SED	1.2	5	19
2007	Haskell	By Plant,V8	6.4b	64a	108a
		Along the base ,V8	6.3b	61b	111a
		Middle of the row,V8	6.6b	61b	115a
		Broadcast pre-plant	8.0a	67a	127a
		Check	2.6	53	54
		SED	1.2	4	18
2007	LCB	By Plant,V8	4.4a	31a	156a
		Along the base,V8	5.2a	40a	143a
		Middle of the row,V8	4.9a	37a	144a
		Broadcast pre-plant	4.5a	32a	154a
		Check	3.1	46	74
		SED	1.5	13	27

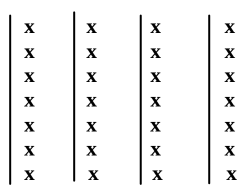
SED-standard error of the difference between two equally replicated means
Means in a column followed by the same letter are not significantly different at 0.05 probability levels.

Figure 1. Illustration of how fertilizer N was placed either by plant or by row for each respective treatment evaluated.

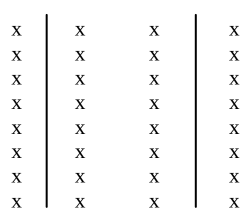
Method 1: Treat each plant. Calculate by dividing the amount of fertilizer needed for a row by the number of plants in that row, and then that amount was applied to the base of each plant.



Method 2: Treat each row. This treatment is the amount of fertilizer needed for a row evenly distributed down that row but at the base of the plants.



Method 3: Treat between two rows. Calculate amount needed for four rows and apply that amount between the rows.



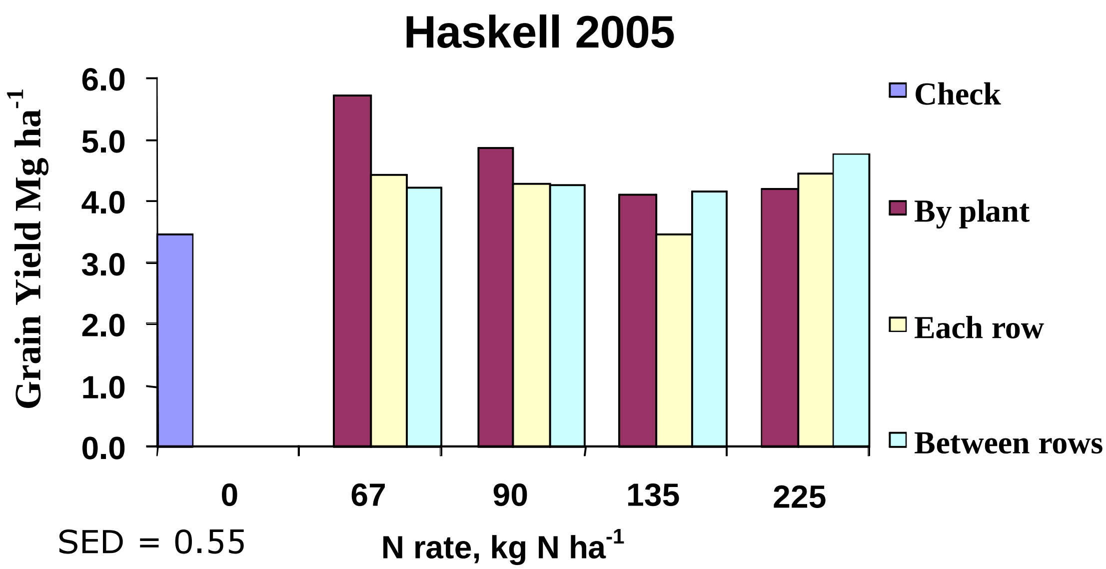


Figure 2. Grain yield for four N rate treatments where each N rate was applied by-plant, at the base of the row and in the middle of the row, Haskell 2005.

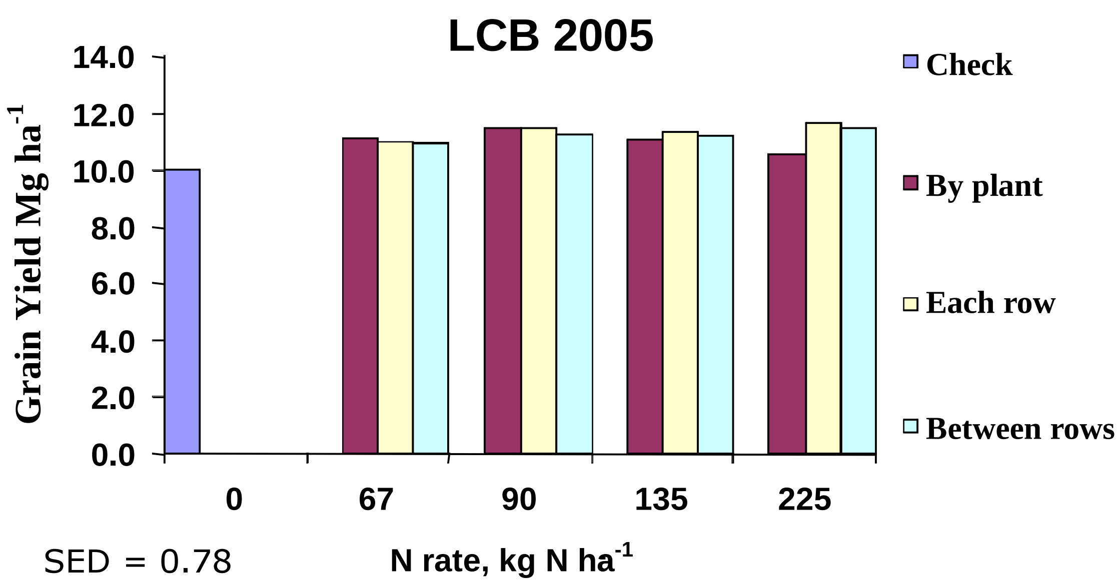


Figure 3. Grain yield for four N rate treatments where each N rate was applied by-plant, at the base of the row and in the middle of the row, LCB 2005.

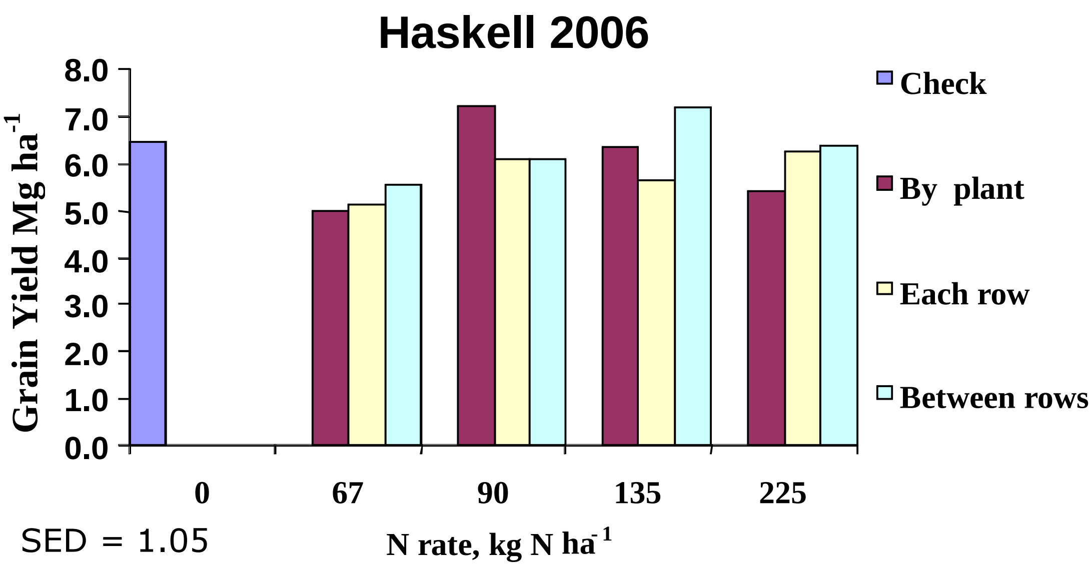


Figure 4. Grain yield for four N rate treatments where each N rate was applied by-plant, at the base of the row and in the middle of the row, Haskell 2006.

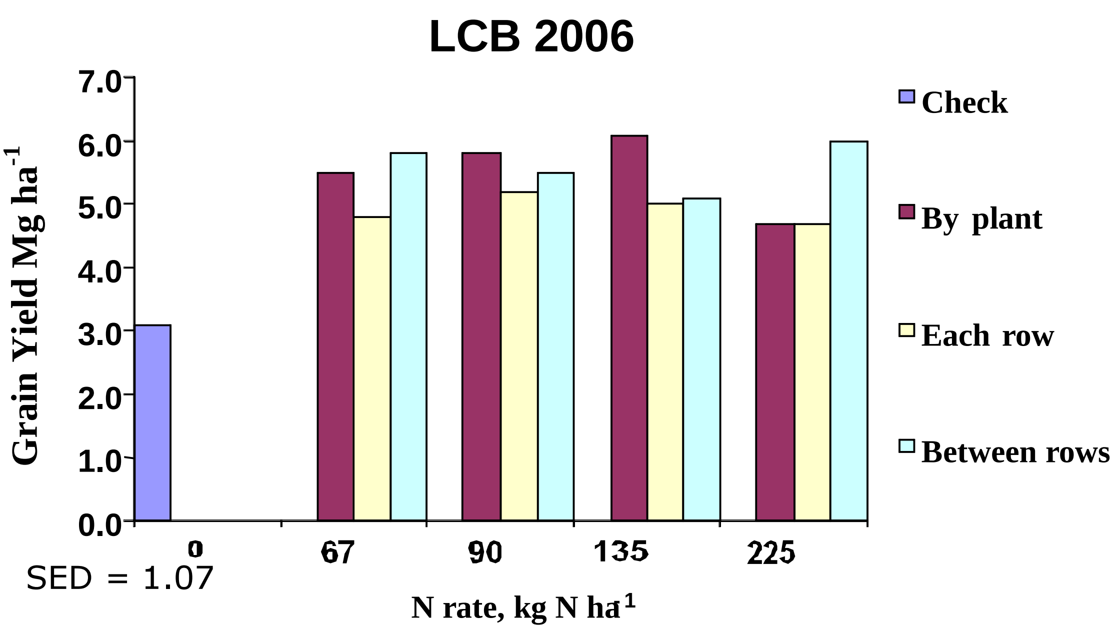


Figure 5. Grain yield for four N rate treatments where each N rate was applied by-plant, at the base of the row and in the middle of the row, LCB 2006.

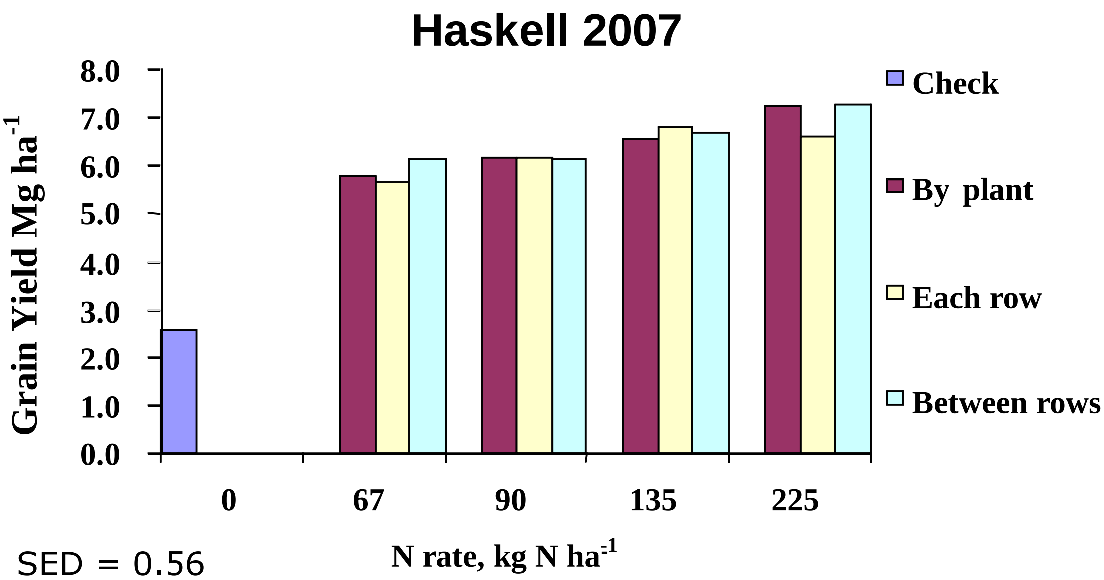


Figure 6. Grain yield for four N rate treatments where each N rate was applied by-plant, at the base of the row and in the middle of the row, Haskell 2007

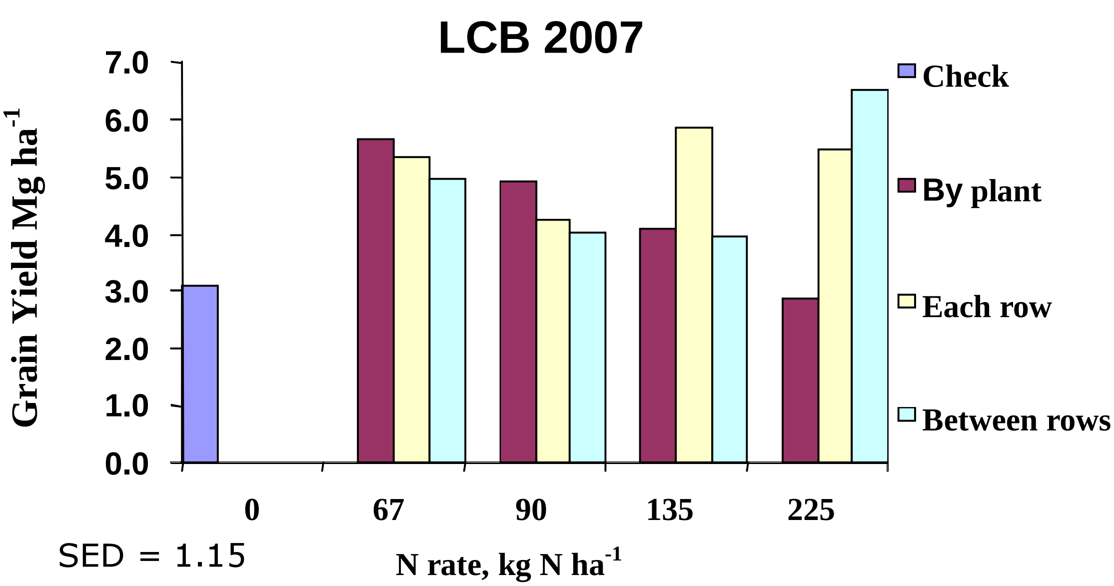


Figure 7. Grain yield for four N rate treatments where each N rate was applied by-plant, at the base of the row and in the middle of the row, LCB 2007.

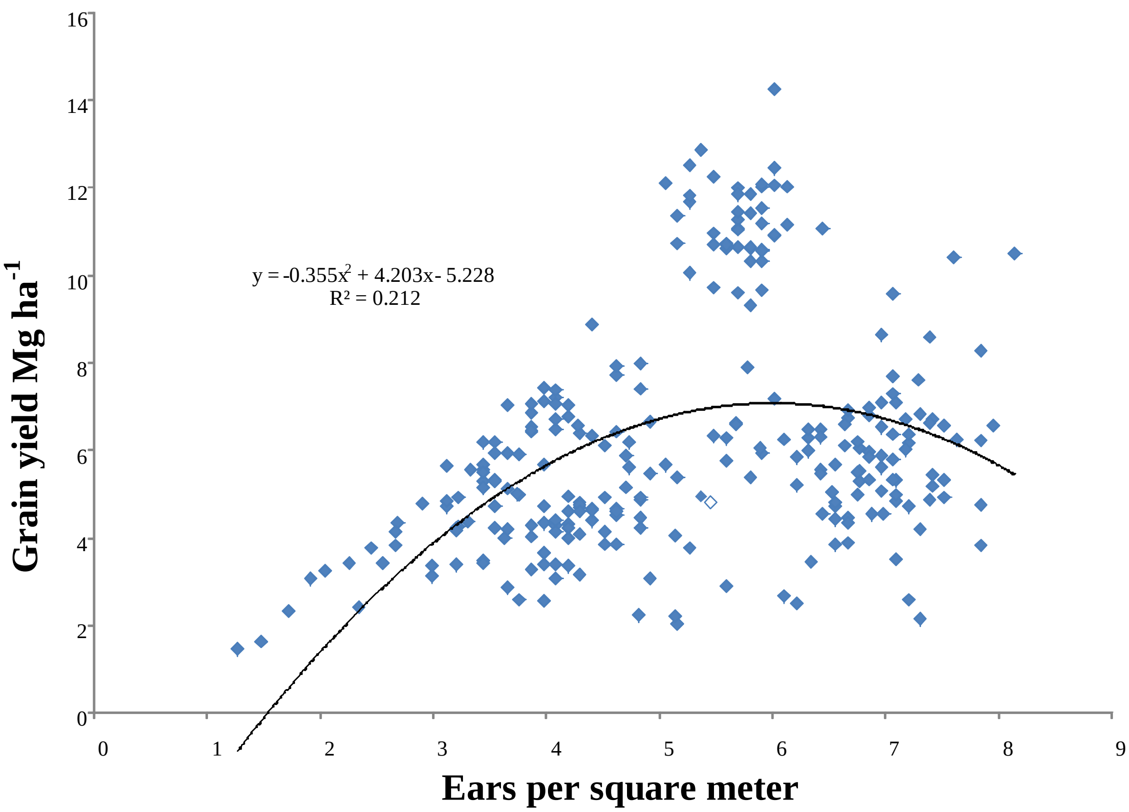
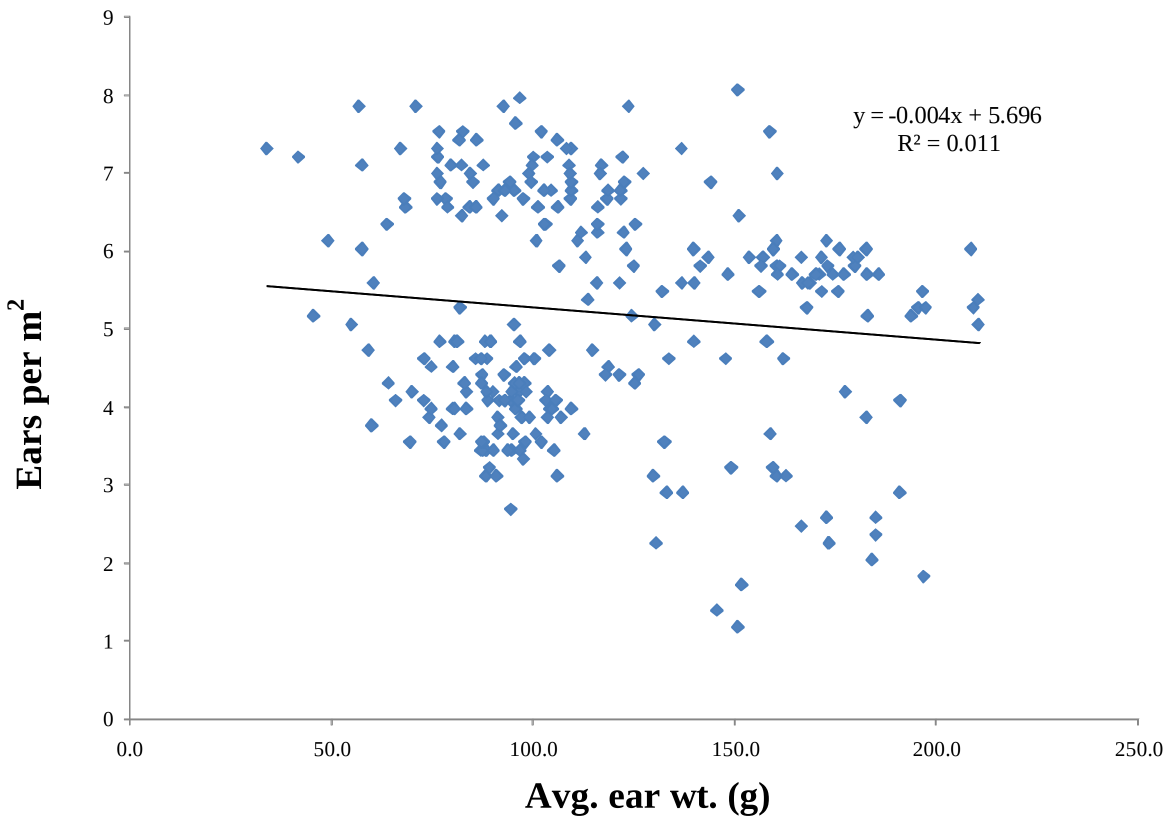
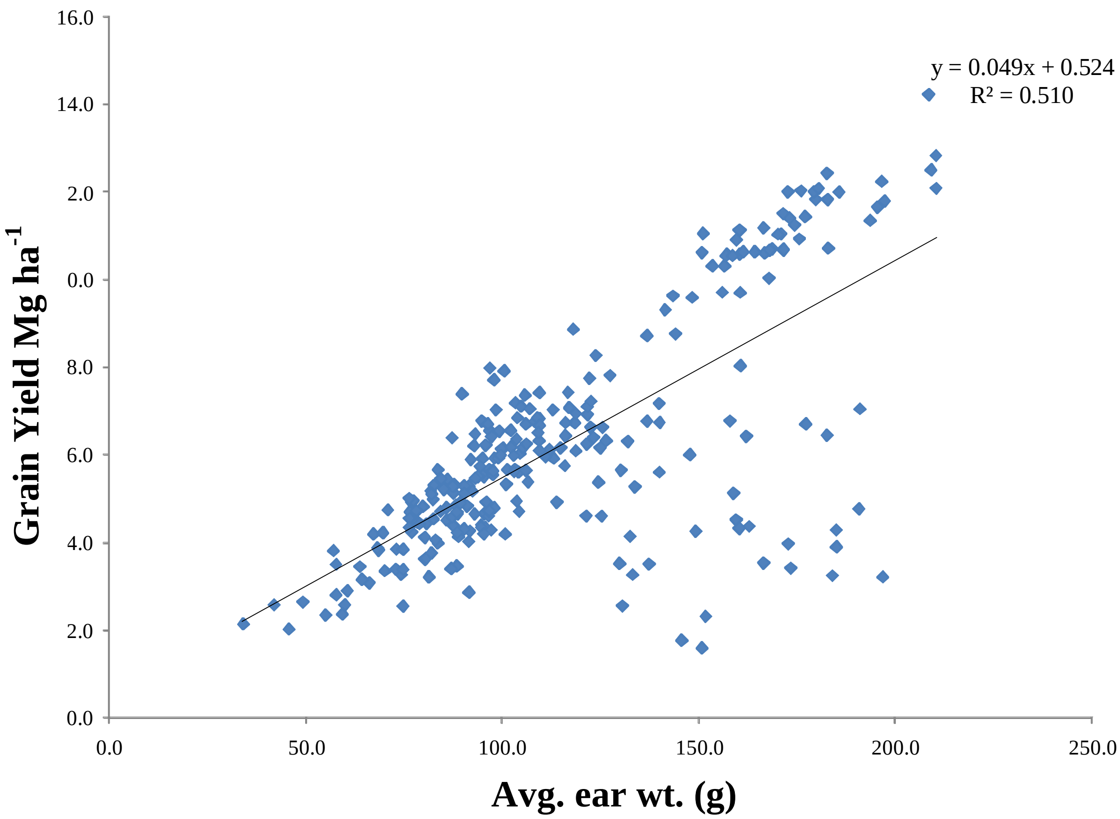


Figure 8. Relationship between corn grain yield and ears per meter squared over 2 locations and 3 years, for trials planted to different hybrids and using different seeding densities.

APPENDIX



Appendix Figure 1. Relationship between average ear weight and ears per square meter over 2 locations and 3 years, for trials planted to different hybrids and using different seeding densities.



Appendix Figure 2. Relationship between corn grain yield and average ear weight over 2 locations and 3 years, for trials planted to different hybrids and using different seeding densities.

Appendix Table 1. Mean squares from analysis of variance on corn grain yield, and associated treatment means, Haskell 2005.

Source of variation	df	Mean Squares	P value
Rep	2	0.39	0.4815
Method	2	0.97	0.1724
N rate	3	1.14	0.1135
Method x N rate	6	0.65	0.3057
Residual Error	22	0.51	
SED		0.58	

Treatment		Treatment Mean
Method	N rate kg ha^{-1}	Grain Yield, Mg ha^{-1}
By-plant	67	5.70
By-plant	90	4.87
By-plant	135	4.10
By-plant	225	4.20
Each row	67	4.43
Each row	90	4.26
Each row	135	3.50
Each row	225	4.43
Between rows	67	4.20
Between rows	90	4.26
Between rows	135	4.16
Between rows	225	4.73

Appendix Table 2. Mean squares from analysis of variance on corn grain yield, and associated treatment means, LCB 2005.

Source of variation	df	Mean Square	P value
Rep	2	1.88	0.1899
Method	2	0.29	0.7645
N rate	3	0.21	0.8984
Method x N rate	6	0.28	0.9488
Residual Error	22	1.05	
SED		0.84	

Treatment		Treatment Mean
Method	N rate kg ha^{-1}	Grain Yield, Mg ha^{-1}
By-plant	67	11.13
By-plant	90	11.46
By-plant	135	11.03
By-plant	225	10.56
Each row	67	11.03
Each row	90	11.46
Each row	135	11.30
Each row	225	11.63
Between rows	67	10.93
Between rows	90	11.26
Between rows	135	11.20
Between rows	225	11.46

Appendix Table 3. Mean squares from analysis of variance on corn grain yield, and associated treatment means, Haskell 2006.

		Mean Square	
Source of variation	df	Grain Yield, Mg ha^{-1}	P value
Rep	2	5.62	0.0580
Method	2	0.76	0.6488
N rate	3	2.97	0.1928
Method x N rate	6	1.11	0.6943
Residual Error	22	1.73	
SED		1.07	

Treatment		Treatment Mean
Method	N rate kg ha^{-1}	Grain Yield, Mg ha^{-1}
By-plant	67	4.97
By-plant	90	7.23
By-plant	135	6.37
By-plant	225	5.40
Each row	67	5.17
Each row	90	6.10
Each row	135	5.66
Each row	225	6.27
Between rows	67	5.53
Between rows	90	6.10
Between rows	135	7.17
Between rows	225	6.40

Appendix Table 4. Mean squares from analysis of variance on corn grain yield, and associated treatment means, LCB 2006.

Source of variation	df	Mean Squares	P value
Rep	2	3.22	0.2254
Method	2	1.74	0.4357
N rate	3	0.28	0.9347
Method x N rate	6	0.72	0.8980
Residual Error	22	2.02	
SED		1.16	

Treatment		Treatment Mean
Method	N rate kg ha^{-1}	Grain Yield, Mg ha^{-1}
By-plant	67	5.53
By-plant	90	5.80
By-plant	135	6.07
By-plant	225	4.67
Each row	67	4.80
Each row	90	5.23
Each row	135	5.03
Each row	225	4.67
Between rows	67	5.90
Between rows	90	5.53
Between rows	135	5.17
Between rows	225	6.00

Appendix Table 5. Mean squares from analysis of variance on corn grain yield, and associated treatment means, Haskell 2007.

Source of variation	df	Mean Square	P value
Rep	2	3.85	0.0031
Method	2	0.18	0.7104
N rate	3	2.57	0.0080
Method x N rate	6	0.17	0.9064
Residual Error	22	0.51	
SED		0.58	

Treatment		Treatment Mean
Method	N rate kg ha^{-1}	Grain Yield, Mg ha^{-1}
By-plant	67	5.73
By-plant	90	6.17
By-plant	135	6.53
By-plant	225	7.23
Each row	67	5.67
Each row	90	6.17
Each row	135	6.80
Each row	225	6.60
Between rows	67	6.13
Between rows	90	6.10
Between rows	135	6.67
Between rows	225	7.30

Appendix Table 6. Mean squares from analysis of variance on corn grain yield, and associated treatment means, LCB 2007.

Source of variation	df	Mean Square	P value
Rep	2	0.47	0.8057
Method	2	2.17	0.3844
N rate	3	1.48	0.5726
Method x N rate	6	4.26	0.1157
Residual Error	22	2.17	
SED		1.20	

Treatment		Treatment Mean
Method	N rate kg ha^{-1}	Grain Yield, Mg ha^{-1}
By-plant	67	5.67
By-plant	90	4.90
By-plant	135	4.10
By-plant	225	2.90
Each row	67	5.37
Each row	90	4.27
Each row	135	5.87
Each row	225	5.47
Between rows	67	4.93
Between rows	90	4.00
Between rows	135	3.93
Between rows	225	6.53

Vita

Clint Reed Dotson

Candidate for the Degree of

Masters of Science

Thesis: EFFECT OF NITROGEN FERTILIZER RATE AND PLACEMENT ON CORN GRAIN YIELDS

Major Field: Plant and Soil Sciences

Bibliography:

Education: Graduated from Burlington High School, Burlington, Oklahoma in May 2001. Received Bachelor of Science degree in Agribusiness from Oklahoma State University Stillwater, Oklahoma 2005. Completed the requirements for Masters of Science degree with a major in Plant and Soil Science at Oklahoma State University in December, 2007.

Experience: Worked as an assistant at a veterinary clinic and a feed yard (1999-2001); employed by USDA-ARS as a research assistant, (2002-2005). Employed by Oklahoma State University, Department of Plant and Soil Sciences, as a graduate research assistant 2006- present.

Professional Memberships: ASA CSSA SSSA

Name: Clint R. Dotson Date of Degree: December, 2007

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: EFFECT OF NITROGEN FERTILIZER RATE AND PLACEMENT ON CORN GRAIN YIELDS

Pages in Study: 37 Candidate for the Degree of Masters of Science

Major Field: Plant and Soil Science

Scope and Method of Study:

This study was conducted to evaluate the use of directed stream application at the base of the plant using UAN (urea ammonium nitrate) versus dribble surface bands applied in the middle of the row, and to evaluate the use of directed stream application by-plant using UAN versus dribble surface bands applied in the middle of the row. The experiment was conducted at the Robert L. Westerman Irrigated Research Station at Lake Carl Blackwell, OK (LCB), and at the Eastern Research Station at Haskell, OK for three years. Treatments were three N placement methods and applied in three different methods; 1. stream at the base of the row; 2. by plant at the base of the plant; and 3. stream between the rows.

Findings and Conclusions:

At the Irrigated LCB site, in 2005, 2006, and 2007 an increase in grain yields from by-plant N application at lower rates when compared to commonly applied N in the middle of the row. In 4 of 6 site years , there was a slight advantage associated with applying N by-plant at lower N rates compared with N applied uniformly in the middle of the row. The benefits of fertilizing by-plant tended to be more evident when yields were lower and the production cycle was characterized by moisture stress.

ADVISER’S APPROVAL:___Dr. Bill Raun__________________