# MAIZE (*ZEA MAYS* L.) GRAIN YIELD RESPONSE TO VARIABLE ROW NITROGEN FERTILIZATION


By

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Bachelor of Science in Plant and Soil Sciences

Oklahoma State University

Stillwater, Oklahoma

2006


Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
May, 2008

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VARIABLE ROW NITROGEN FERTILIZATION

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ACKNOWLEDGEMENTS

I thank Oklahoma State University, the Graduate College, the College of Agricultural Sciences and Natural Resources, the Department of Plant and Soil Sciences, and the Soil Nutrient Management/Soil Fertility project for the support I have received in completing this step in my educational career. I thank my adviser, Dr. Bill Raun for the guidance and help he has given me. His guidance has been invaluable to me in the completion of this degree. I thank my committee members, Dr. John Solie and Dr. Randy Taylor who have aided me with their knowledge and expertise. I thank all of the former and fellow graduate and undergraduate students I have been privileged to have worked with during my degree studies - Dr. Kefyalew Girma, Dr. Brenda Tubaña, Dr. Byungkyun Chung, Kyle Lawles, Clint Mack, Brian Arnall, Olga Walsh, Cody Daft, Brandon England, Pam Turner, Starr Holtz, Birehane Desta, Sudeep Sidhu, Yumiko Kanke, Jared Crain, Yuriko Mori, Bee Kim, Jake Halverson, and Rachel Crocker. The dedicated work with these fellow students of sample collection, data processing, field help, and travels has created memories that will last a lifetime. I express a special thanks to my family – David & Carolyn, Dr. Janica, Andrew & Star, Audrey, and Adreonna, Matthew, Shaun & Jill Raley and Sierra, David, Jalynda, Joanna, Jonathan, Juliann, Jenna, and Benjamin, Cecil & Dorothy, and Donna Hill – who have encouraged and supported me in my educational endeavors, in keeping my faith in God, and for the strength and resolve to complete this important step in my educational career.

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## ABSTRACT

Crop yields are affected by the amount and application of nitrogen fertilizer. This study was conducted to determine the effect of variable nitrogen rate and row application on maize grain yields. The effects of variable rate and row application were investigated at the R.L. Westerman Irrigation Research Facility near Stillwater, Oklahoma on a Port-Oscar silt loam (fine-silty, mixed, super active, thermic Cumulic Haplustolls) and at Hennessey, Oklahoma on a Bethany silt loam (fine, mixed, thermic Pachic Paleustolls). In 2005 the highest yields were produced for the entire duration of the study. Significant yield differences occurred in non-fertilized rows adjacent to N (67, 100, 134 kg N $ha^{-1}$) fertilized rows, but not when adjacent to low N (34 and 67 [some cases] kg N $ha^{-1}$). In 2006, which had a dry growing season, grain yields were significantly lower than those produced in 2005. With a few exceptions, rows receiving N did not produce significantly higher yields in 2006. In 2007, trends were similar to those observed in 2005. Excluding 2006, all site-years showed a significant reduction in yield when fertilizer was not applied to each row. Row by row differences were observed, indicating that lateral movement of N is variable from year to year and from row to row, suggesting the need for application of N by individual row to obtain optimum yields.

# CHAPTER I

## INTRODUCTION

All forms of life require essential nutrients to maintain proper health. Of all nutrients, water is the most limiting. Additional nutrients required by life include, but are not limited to, nitrogen (N), phosphorus, potassium, calcium, etc. Of these additional nutrients, N is the most limiting for agronomic production (Malhi et al., 2001).

Curley (1988) suggests that profitable crop production is directly related to the availability of N, and thus the application of N. However, high levels of continuous application of N has led to concern for nitrate pollution in ground and surface waters (Di and Cameron, 2002). As a result, crop production practices, aesthetic qualities, economical analysis, and environmental stewardship must be integrated to effectively mitigate this problem and benefit agronomic production, aesthetics, and the environment.

Researchers at Oklahoma State University (OSU) have devoted efforts to improve nitrogen use efficiency (NUE) for both cereal and non-cereal crops. With NUE for the world estimated at 33% for cereal grain production (Raun and Johnson, 1999), practices that mitigate the loss of applied N are needed. It will be essential to utilize resources efficiently in order to keep agricultural production ahead of the human population growth curve. The world's human population is estimated at more than 6.6 billion (U.S. Census Bureau, 2006) people with 1.25 percent growth per year. Although there is a 2.2 percent increase in overall worldwide agricultural production per year, the growth for cereal production is only 0.8 percent per year (FAO, 2007). If these rates continue, cereal consumption needs of the human population will surpass the production of cereal grains in the forseeable future. Of all the cereals grown in the world, maize is one of the most widely cultivated.

# CHAPTER II

## OBJECTIVE

The objective of this study was to determine maize (*Zea mays L.*) grain yield response to variable row N fertilization at varying rates when liquid N fertilizer is placed at the base of each maize row. The null hypothesis, $H_o$: There is no advantage to fertilizing each row and the resultant grain yields will not differ with variable row N fertilization. The alternative hypothesis, $H_a$: There is an advantage to fertilizing each row and grain yields will significantly differ with variable row N fertilization.

# CHAPTER III

## LITERATURE REVIEW

Maize is an important crop grown as food for humans and feed for livestock in the United States and the world. Under current production, maize is the largest crop produced in the world with 695,228,280 metric tons (MT) produced in 2006 (FAO, 2007). For 2006, production in the United States (U.S.) was 267,598,000 MT, placing maize as the largest crop grown in the U.S. (FAO, 2007). Compared to 1996, these values represent an increase in maize production of 105,768,241 MT (18 percent) and 234,527,008 MT (14 percent) in the world and the U.S., respectively. Production increases can be attributed to increased land under maize cultivation in the world, higher yields per land area (FAO, 2007), improved hybrids, management and fertilization strategies (Pingali, 2000). Because of the importance of maize to the U.S. and the world, it is important to evaluate production inputs, i.e. fertilizer, irrigation, pesticide applications, etc., that may increase production or decrease the cost of production. After water, N fertilizer is considered to be the most limiting factor for crop production, including the production of maize.

The fertilizer component that plants require in greatest amounts and whose availability often limits plant productivity is N (Bloom et al., 2003). In addition, the greatest competition between plants is usually for N, and thus it is the major nutrient input farmers utilize to increase crop yield (Patterson, 1995; Raun and Johnson, 1999).

Consumption of N fertilizer for 2005 in the world was 94,233,396 MT and in the U.S. was 10,926,100 MT (FAO, 2007). Maize accounts for 40 percent (Daberkow and Huang, 2006) of N fertilizer consumed in the U.S., i.e. 4,370,440 MT. With NUE estimated to be 42 percent for cereal production in developed nations (Raun & Johnson, 1999), 1,835,585 MT of N fertilizer is recovered in maize grain in the U.S. However, 50 percent of the N recovered in the grain comes from N supplied by the environment (Keeney, 1982), i.e.917,792 MT, resulting in an estimated 3,452,648 MT of N fertilizer lost in maize production in the U.S.

Nitrogen fertilizer losses are the result of plant N losses, denitrification, surface runoff, leaching, and/or volatilization. In maize, plant N losses have accounted for up to 73 percent of the total $^{15}N$ (Francis et al., 1993). Denitrification losses can be greater than ten percent (Hilton et al., 1994), surface runoff losses up to 13 percent (Blevins et al., 1996), leaching losses up to 23 percent (Drury et al., 1996), and volatilization losses up to 40 percent (Fowler and Brydon, 1989) of the total N applied. Generally, N losses only occur when N is present in excess of plant needs (Johnson and Raun, 1995). As a result of N losses, contamination of surface and ground water has become a major issue and ways to reduce such losses have become an important focus of the agricultural sector.

Nitrogen has been identified as a major contaminant of ground and surface waters (Daberkow and Huang, 2006). The U.S. Geological Survey (1999) estimates about 90 percent of N contaminants originate from nonpoint sources, which includes fertilizers and animal waste applied to croplands. As a result of such contamination, or nutrient loading, eutrophication and hypoxia can occur, as is the case in the Gulf of Mexico at the mouth of the Mississippi River (Mitsch et al., 2001). A majority of the nutrient loading causing hypoxia in the Gulf region can be traced to N fertilization in the upper mid-west, i.e. maize belt of the U.S. In this regard, measures have to be taken at the farm level to reduce nutrient loading, and that will in turn reduce the risk on ground and surface waters.

A measure that would reduce N losses is to apply N to a crop at the proper rate and time. Nitrogen losses can be reduced by management decisions in terms of the form, method, and timing of N application (Durst and Beegle, 1999). The application of "insurance" N, which could be as high as 67 kg N $ha^{-1}$ $yr^{-1}$ (Legg et al., 1989), should be limited and the use of reference strips implemented to eliminate excessive N applications. Application timing of N fertilizer is important for both agronomic and environmental reasons. For maize, a common practice is to apply N in the fall because producers have more time to make the application, N fertilizer prices tend to be lower compared to the spring, and field conditions are better (Randall and Schmitt, 1998). However, Buzicky et al. (1983) showed when N fertilizer was applied in the fall, N losses were 36 percent greater and maize yields eight percent less than when N fertilizer was applied in the spring. Applying N fertilizer at the optimum time and correct rate has been shown to substantially reduce N losses when compared to excessive N applications at non-optimum times (Mitsch et al., 2001). Application placement, i.e. fertilization zone of N fertilizer is also of importance when considering measures to reduce N losses in maize.

The importance of N fertilizer placement varies with crop yield potential, soil N levels, the amount and timing of rainfall, tillage systems, and environmental conditions (Blackshaw et al., 2002). With such influential factors, placing N fertilizer in the fertilization zone at the correct rate and optimum time should limit the impact of each input feature. As a result, NUE would be expected to increase through the appropriate placement of N fertilizer through split applications (Lehrsch et al., 2000). For maize, N fertilization occurs on a variety of scales – surface broadcasting, sidedressing between rows, banding, knife injection, etc. – for preplant, starter, and topdressing applications. Of the various application methods, banding and sidedressing are particularly advantageous when producing maize in N depleted soils; however, if adequate N is present in the soil as a starter fertilizer for growth through mid-season, then 100 percent of the additional N fertilizer needed applied as a sidedress application may increase NUE and yield (Lehrsch et al., 2000). Banding resolution of N in maize, i.e. every row, between row, every other row, etc. has been shown to be satisfactory in producing no reduction in yield by applying N in the middle of every other row instead of every inter-row (Durst and Beegle, 1999; Hefner and Tracy, 1995; Murrell, 2006; Lehrsch et al., 2000; Stecker, 1993; Vitosh et al., 1995). Durst and Beegle (1999) and Stecker (1993) considered this application best practiced as a sidedress application when maize rows are visible so that the bands of N can be precisely placed between the rows to eliminate the potential decline in yield to the row furthest from the N source. However, this is contradictory to work by others.

In maize, N is predominantly used by the individual row to which it is applied when spatial diversity is minimized near the point of application (Johnson and Kurtz, 1974; Joleka and Randall, 1987; Sanchez et al., 1987; Blaylock et al., 1990). Further, studies conducted in Iowa, U.S. showed labeled N was recovered chiefly by the row to which it was applied with little N recovery observed in either adjacent maize row, suggesting that maize derives little of its N from that applied to adjacent rows

(Ghaffarzadeh et al., 1998). From a logical standpoint, this makes incredible sense because the roots of a maize plant occupy a relatively small area in comparison to the width of a normal row spacing of 0.76 m.

Maize plants obtain the majority of N through root absorption of the inorganic ions ammonium ($NH_4^+$) and nitrate ($NO_3^-$) from the soil solution (Bloom et al., 2003) of which the availability to plant roots can be a limitation for plant growth (Miller and Cramer, 2004). Nitrogen uptake by maize is determined by the N influx rate at the root surface and the size and morphology of the root system (Mackay and Barber, 1986); therefore, N is mostly delivered to the roots through a combination of diffusion and mass flow properties where diffusion relies on concentration gradients and mass flow relies on transpiration to draw water to the roots (Miller and Cramer, 2004). Miller and Cramer (2004) further note that for maize, N supplied by mass flow has been estimated to be four-fold greater than that supplied by diffusion. Therefore, it is important to realize the type of roots that absorb and translocate nitrate ($NO_3^-$) to the growing maize plant (Lazof et al., 1992) and the proximity of those roots in relation to the above-ground plant and in relation to N fertilizer application.

Spatially and temporally, N in the soil is extremely heterogeneous (Miller and Cramer, 2004; Raun et al., 2002). Various studies have indicated that N is primarily recovered by the maize row to which it is applied and therefore, row-by-row precision applications of N fertilizer (Ghaffarzadeh et al., 1998) or finer resolutions, i.e. by plant N fertilizer application seems to be an appropriate management tool for improving NUE, increasing yield, reducing input costs, and lowering the risk of potential N losses to lower the detrimental impacts to the environment caused by excess N applications.

# CHAPTER III

# MATERIALS AND METHODS

## Site Description

Experimental sites were established at the R.L. Westerman Irrigation Research Center at Lake Carl Blackwell (LCB), west of Stillwater, OK, in 2005 and at Hennessey (HEN), OK in 2007. The site at the irrigation research center is located on a Port-Oscar silt loam (fine-silty, mixed, super active, thermic Cumulic Haplustolls) and the Hennessey site is located on a Bethany silt loam (fine, mixed, thermic Pachic Paleustolls). Initial soil test results (0-15 cm) for each location are reported in Table 1. Each site was planted to maize (*Zea mays* L.), using Pioneer® 33B51 (2005 and 2006) and DeKalb® DKC 66-23 (2007) at LCB and DeKalb® 50-20 at HEN. The irrigated site was planted at a population of 79,000 seeds $ha^{-1}$ for all years and the rainfed Hennessey site was planted at a population of 53,100 seeds $ha^{-1}$. Both sites were planted with a row spacing of 0.76 m.

## Treatment Structure and Measurements

The study consisted of 11 treatments arranged in a completely randomized block design with three replications (LCB 2005 and 2006) and modified for the 2007 season to 11 treatments arranged in a completely randomized design consisting of three replications in four ranges. The treatment structure employed at LCB for 2005 and 2006 (Table 2) was modified slightly in 2007 (Table 3) to allow for better interpretation of change in yield and influence of N fertilizer applied to specific rows and its lateral movement, if any. Plots were 3 meters long by seven rows (0.76 m row spacing). Nineteen liters of 10-15-0 starter liquid fertilizer was applied at time of planting at the irrigated site for 2006 and 2007. No starter or pre-plant fertilizer was applied at the rain-fed site. Top-dress N rates of 34, 67, 100, and 134 kg N $ha^{-1}$ were applied at V6- V8 growth stages to individual rows based on treatment structure. The V6-V8 growth stages are known as the time when the tassel/growing point comes above the soil surface. Rapid growth of the plant and ear shoot initiation and kernel row determination begins (Hanway, 1963). Syringes were used to apply the N fertilizer at the base of the plant in each fertilized row.

At harvest, the ears from each plant of the first five rows (2005 and 2006) and the five middle rows (2007) of each plot were hand harvested by individual row. The ear weight (grain on cob) of each row was recorded. Ears were dried at 75° C for seven days using a forced air drying oven, reweighed, and kernels shelled using a hand mechanical sheller. Grain weight for each row was recorded and a sub-sample taken for further analysis. Sub-sample grain was ground to pass through a 0.125 mm (120-mesh) sieve and processed for N analysis using a Carlo-Erba (Milan, Italy) NA-1500 dry combustion analyzer using the procedure outlined by Schepers et al. (1989). Statistical analysis at the 0.05 probability level, using Duncan's Multiple Range Test was performed using SAS (SAS, 2003).

# CHAPTER V

# RESULTS

## Site Year LCB 2005

At LCB, in 2005, significant yield differences occurred in non-fertilized rows adjacent to mid to higher N fertilized rows receiving 67, 100, or 134 kg N $ha^{-1}$; lower rates of 34 and 67 (some cases) kg N $ha^{-1}$ did not result in significant yield differences in adjacent rows receiving no N (Table 4). For each treatment, fertilized rows produced higher yields than non-fertilized rows (Figure 1) even though this difference in yield was not always significant.

Differences in yield by row can be attributed to the rate of N received by each row. For treatments one, three, six, and seven, in which the first three rows received N and the next two rows received no N (Table 2), the resultant grain yields showed different yields between fertilized and non-fertilized rows (Figure 1). In each case, the first three rows (border row, row one, row two) produced yields that were not significantly different; however, row two's yield was depressed from that of the border row and row one. Row two's yield was not significantly different than rows three or four, but rows three and four were significantly different than the border row and row 1 (Table 4). In each scenario, row two's yield depression may be attributed to competition from row three which received no N, indicating some lateral movement of N fertilizer.

Treatment eight consisted of the first two rows (border row and row 1) and the last two rows (row 3 and row 4) receiving no N and the middle row (row 2) receiving 67 kg N $ha^{-1}$ (Table 2). The one fertilized row produced a higher grain yield, indicating the benefit of N fertilizer; however the increase in yield was not significantly different than the yield from rows receiving no N (Table 4). Treatment eleven which consisted of the first two rows and the fourth row (Border row, row one, row three) receiving N (134 kg $ha^{-1}$) and the third and fifth rows (row 2 and row 4) receiving no N (Table 2), resulted in grain yields depressed in the non-fertilized rows (Figure 1). However, the grain yield in row four was the only yield significantly different (Table 4). The yield for row two was depressed from that of either of its neighbor rows, but indicates that some lateral movement may have occurred to allow this yield to be higher than that of row four.

According to the National Agricultural Statistics Service (NASS) (http://www. nass.usda.gov/) average maize yields for Payne county (LCB located within county) for 2005 were 4.4 Mg $ha^{-1}$, which is well below the yields produced at the irrigated LCB location. There is no data reported by NASS on irrigated maize for Payne county.

**Site Year LCB 2006**

At LCB, in 2006, yields were significantly lower than those produced in 2005. For 2006, response to mid-season application of N fertilizer was limited and as a result rows receiving N (34, 67, 100, and 134 kg N $ha^{-1}$) did not produce significantly higher yields when compared to rows receiving no N fertilizer (Table 4). The few instances where significant yield differences occurred did not follow the same trend as 2005. Significant yield differences occurred in treatments one, two, seven, and eleven. For treatment one, rows one, two, and three were significantly different than the border row even though row one and row two each received the same N rate (134 kg N $ha^{-1}$) as the border row. Row three received no N fertilizer, but produced the same yield as row two which had received the highest N rate (134 kg N $ha^{-1}$) (Table 4).

The check treatment (treatment nine – all five rows received 0 kg N $ha^{-1}$) on average yielded more than four of the fertilized treatments (treatments three, four, five, and six), and produced yields nearly identical to two other fertilized treatments (treatments two and eight) (Figure 2). This illustrates a limited response to N except for isolated cases (border row of treatments one and seven, and row one of treatment eleven) (Table 4); however, the depressed yields produced for this site year show that yield was less impacted with rate of N applied and more with moisture availability and high temperatures.

The National Agricultural Statistics Service (NASS) (http://www. nass.usda.gov/) reported average maize yields for Payne county (LCB located within county) for 2006 at 2.7 Mg $ha^{-1}$, which is below the yields produced at the irrigated LCB location. There is no data reported by NASS on irrigated maize for Payne county.

**Combined Site Years LCB 2005 and 2006**

Combining site years 2005 and 2006 resulted in trends similar to those found for 2005; however, overall yields were depressed due to low yields obtained in 2006. Significant yield differences occurred between non-fertilized rows adjacent to rows receiving higher rates of N (67, 100, and 134 kg N $ha^{-1}$); low rates of N (34 kg N $ha^{-1}$) did not result in significant yield differences when compared to adjacent rows (Table 5). Fertilized rows yielded more than non-fertilized rows across treatments (Figure 3).

Treatments one and six, in which the first three rows received N and the next two rows received no N (Table 2), the resultant grain yields were significantly different for the first two rows (border row and row one) when compared to all other rows (Table 5). The middle row's (row two) yields were significantly different from the border row but not row one, nor rows three or four, indicating a depression in yield possibly due to competition from the adjacent rows three and four which received no N. Additionally rows three and four produced yields significantly lower than row one. Treatment seven is similar, other than the middle row's (row two) yield was not significantly different than any of the other rows of either higher or no N; however, rows receiving no N (rows three and four) produced yields significantly different than those yields produced by rows (border and one) receiving 134 kg N $ha^{-1}$ (Table 5).

Treatment two, in which the first three rows received 100 kg N $ha^{-1}$ and the next two rows received no N (Table 2), a significantly lower yield was obtained in the fourth row (row three) which was immediately adjacent to the fertilized row (Figure 3). Similarly, for treatment three, rows receiving no N (rows three and four) produced significantly lower yields than rows receiving N except for the row immediately adjacent (row 2) to the non-fertilized row (Table 5). Yield for this row was not significantly different from any other row, but was depressed from that obtained from adjacent fertilized rows, but higher than that obtained from adjacent non-fertilized rows, suggesting that competition for N from the non-fertilized rows may have resulted in the yield depression. As a result, row three's yield was depressed from that of row two, but higher than that of row four (Figure 3).

Treatment eleven's grain yields were lower in the non-fertilized rows than in the fertilized rows (Figure 3). Row two and four received no N and yields for those rows were significantly different than the yield for the border row and row one (Table 5). Row three, which received the same rate as the border row and row one (134 kg N $ha^{-1}$) produced a yield lower than the other fertilized rows, but higher than the non-fertilized rows (Figure 3). Row two, between two fertilized rows, produced a higher yield than row four which had only the one adjacent fertilized row, indicating that some lateral movement of N may have occurred to produce the obtained yield.

**Site Year LCB 2007**

With slight modifications to the treatment structure for 2007, results for LCB are more revealing of variable row N fertilization. Yield differences of significance occurred between N fertilized rows (67, 100, 134 kg N $ha^{-1}$) and non-fertilized rows. However, at the lower N rate, rows fertilized with 34 kg N $ha^{-1}$ did not produce yields significantly different than non-fertilized rows (Table 6). For all treatments, excluding treatment four, fertilized rows produced higher yields than non-fertilized rows (Figure 4).

Treatments one, two, and three had the same row treatment sequencing structure at different N rates (134, 100, 67 kg N $ha^{-1}$). The first two rows were fertilized and the next three rows were non-fertilized (Table 3). Treatment one results show a significant yield difference from the first three rows (rows one, two, and three) compared to the last two rows (rows four and five) (Table 6). Row three, having received no N, had a depressed yield from that of either row one or two, but a higher yield than those of either rows three or four, suggesting that some lateral movement of N may have occurred as this row was in competition for nutrients with row two, a fertilized row (Figure 4). For treatments two and three every non-fertilized row had a significantly lower yield than the fertilized rows (Table 6). The two rows fertilized (one and two) had significantly higher yields than the non-fertilized rows (three, four, and five), suggesting in this case that no lateral movement of N occurred, nor were rows at this spacing (0.76m) in competition with one another for nutrients. Likewise, treatment five further substantiates this. Row one was the only fertilized row, receiving 134 kg N $ha^{-1}$. The four subsequent rows (two, three, four, and five) received no N fertilizer. Each of the non-fertilized rows produced a significantly lower yield than the fertilized row. Additionally, the non-fertilized row immediately adjacent to the fertilized row did not have a higher yield than the non-fertilized row adjacent on the other side (Table 6). Results from treatment ten concurred. Rows one through four were fertilized (134 kg N $ha^{-1}$) and row five was not fertilized (Table 3). Row five's yield was significantly lower than that of the fertilized rows (Table 6), indicating that no lateral movement of N occurred.

Treatment seven showed that some competition for nutrients or lateral movement of N occurred. Rows four and five (0 kg N $ha^{-1}$) had significantly lower yields than rows one or two which received 134 kg N $ha^{-1}$, but not row three which received no N. Row two's yield was depressed from that of row one, but higher than that of row three; likewise, row three's yield was higher than that of rows four and five (Figure 4). Treatment eight showed that a non-fertilized row between two fertilized rows may help to increase the yield of the non-fertilized row. Treatment eleven yield results concurred with this. In both treatments, the non-fertilized row between two fertilized rows (67 or 134 kg N $ha^{-1}$) resulted in a higher yield in the non-fertilized row when compared to the other non-fertilized rows within the treatment (Table 6). Treatment eight further showed that any non-fertilized row adjacent to a fertilized row benefits from the fertilizer applied. Only those rows not adjacent to a fertilized row resulted in significantly lower yields. However, treatment eleven disagreed, showing that only rows between two fertilized rows (i.e. row 2) benefit from fertilizer application, while adjacent rows (rows four and five), even to fertilized rows, if not between two fertilized rows produced significantly lower yields (Table 6).

**Site Year HEN 2007**

The HEN site produced significantly different yields between fertilized and non-fertilized rows (Table 6). Treatment rows with higher N rates (100 and 134 kg N $ha^{-1}$) produced yields significantly different than rows receiving no N, while lower N rates (34 and 67 kg N $ha^{-1}$) did not produce significantly different yields when compared to rows receiving no N. With the exception of treatment six, all treatments followed a similar trend. All fertilized rows yielded higher, although not always significantly, than non-fertilized rows (Figure 5).

Treatments five, seven, eight, and eleven suggest some lateral movement or competition for N among rows. In treatment five, row two, having received no N, produced a higher yield than the other three rows (three, four, and five) receiving no N, but yielded lower than the adjacent row one which received 134 kg N $ha^{-1}$ (Figure 5). This suggests that row two received some benefit from the fertilizer applied to row one. For treatment seven, rows two, three, four, and five yielded significantly lower than row one (134 kg N $ha^{-1}$) even though row two also received some N (67 kg N $ha^{-1}$). The yield of row two was higher than that of rows three, four, and five suggesting a response to the N applied (Table 6). Treatment eight showed that a non-fertilized row between fertilized rows may receive some benefit from the fertilized rows. The yield of the non-fertilized row was lower than that of the fertilized, but higher than that of the other non-fertilized rows (Figure 5). However, in the same treatment, the non-fertilized row adjacent to the fertilized row yielded significantly lower than the fertilized rows (Table 6). Treatment eleven suggests a similar trend. The non-fertilized row between fertilized rows and adjacent to fertilized rows produced a lower yield, though not significantly lower. However, the non-fertilized row five next to the non fertilized row four produced a significantly lower yield than either of the fertilized rows (Table 6), suggesting that the non-fertilized rows between or adjacent to fertilized rows may receive some benefit from the N applied.

The National Agricultural Statistics Service (NASS) (http://www. nass.usda.gov/) reported average maize yields for Payne county (LCB located within county) for 2007 at 6.3 Mg $ha^{-1}$, which is equivalent to yields produced at the irrigated LCB location. There is no data reported by NASS on irrigated maize for Payne county. For Kingfisher county (HEN located within county) for 2007, NASS reported average maize yields of 5.6 Mg $ha^{-1}$, which is lower than the average yields produced in this study at the HEN site. Additionally, at the LCB site, disease pressure resulted in lower yields, with some rows having up to forty percent of the ears damaged (data not shown).

**Combined Site Years for LCB and HEN 2007**

Combining site years LCB and HEN 2007 resulted in trends similar to those found for each site year. Significant yield differences occurred between non-fertilized rows adjacent to rows receiving higher rates of N (67, 100, and 134 kg N $ha^{-1}$); low rates of N (34 kg N $ha^{-1}$) did not result in significant yield differences when compared to adjacent rows (Table 7). Fertilized rows yielded more than non-fertilized rows across all treatments (Figure 6).

Treatment one indicates some competition or lateral movement between fertilized and non-fertilized rows. Row three (0 kg N $ha^{-1}$) produced a yield not significantly different than either the fertilized or the other non-fertilized rows. The yield of row three was lower than the fertilized rows, but higher than the other non-fertilized rows (Figure 6). The other non-fertilized rows (four and five) produced yields significantly lower than the fertilized rows (Table 7). Treatments two and three follow the same row treatment sequencing structure as treatment one, just at different N rates (100 and 67 kg N $ha^{-1}$). Both of these treatments showed all non-fertilized rows (three, four, and five) produced significantly lower yields (Table 7) suggesting little to no lateral movement of N or competition between rows for nutrients. However, row three, immediately adjacent to the fertilized row, produced a yield slightly higher than the subsequent non-fertilized rows. Treatment five further showed this trend. Row one (134 kg N $ha^{-1}$) is the only fertilized row (Table 3). The other rows (two, three, four, and five) all produced significantly lower yields than the fertilized row (Table 7); however, the non-fertilized row adjacent to the fertilized row did produce a higher yield than the other non-fertilized rows (Figure 6).

Treatments seven, eight, ten, and eleven further showed non-fertilized rows produced significantly lower yields than fertilized rows (Table 7). In treatment seven, all non-fertilized rows produced a significantly lower yield than the two fertilized rows even though the fertilized rows received different rates of N (134 and 67 kg N $ha^{-1}$). The row receiving the lower rate of N produced a lower yield than the row receiving the higher rate, but both yields were significantly higher than the non-fertilized rows. Treatment eight and eleven showed that non-fertilized rows, even when adjacent to fertilized rows, produced significantly lower yields (Table 7). However, non-fertilized rows between two fertilized rows seemed to benefit from the application of N. For both treatments, the between, non-fertilized row produced a higher yield than the other two non-fertilized rows, although not significantly different (Figure 6). In treatment eight, the between, non-fertilized row was not significantly different than the fertilized rows or the non-fertilized rows. However, for treatment ten, the between, non-fertilized row produced a yield significantly lower than the two adjacent fertilized rows on either side, but not significantly higher than the other non-fertilized rows. Treatment ten showed application of N by row is significant (Table 7). The first four rows received N (134 kg N $ha^{-1}$) and the last row (row five) received no N. Row five produced a significantly lower yield than all the fertilized rows suggesting little to no lateral movement of N or competition among rows for nutrients.

# CHAPTER VI

## CONCLUSIONS

Low rates of N (34 kg N $ha^{-1}$) did not produce significantly different yields for any site year when compared to the 0 kg N $ha^{-1}$ check. Even when N stress was severe, applying low N rates (34 kg N $ha^{-1}$) mid season (V6-V8) had no effect on resultant grain yields. However, at the higher N rates (>67 kg N $ha^{-1}$) yield increases were observed. For this study there were obvious minimum amounts of N that were required to effect maize grain yield changes. Higher N rates (100 and 134 kg N $ha^{-1}$) did produce significantly higher yields for all site years. The significance of the 67 kg N $ha^{-1}$ application rate varied from site year to site year. In most cases, non-fertilized rows received little to no benefit from N applied to neighboring rows; however there were instances where this benefit could be seen. Nonetheless, even if a benefit occurred, the resultant yield was depressed from that of the neighboring fertilized row(s), suggesting that the non-fertilized row's yield potential had been dampened by lack of adequate N. Row by row differences can be seen due to the N rate or lack thereof applied to each specific row, indicating that lateral movement of N is variable from year to year and from row to row, suggesting the need for application of N by individual row.

## REFERENCES


Blackshaw, R.E., G. Semach, and H.H. Janzen. 2002. Fertilizer application method affects nitrogen uptake in weeds and wheat. *Weed Sci.* 50:634-641.

Blaylock, A.D., J.G. Benjamin, and R.M. Cruse. 1990. Microplot design for determining corn recovery of nitrogen fertilizer applied in the row. *Soil Sci. Soc. Am. J.* 54:930-933.

Blevins, D.W., D.H. Wilkison, B.P. Kelly, and S.R. Silva. 1996. Movment of nitrate fertilizer to glacial till and runoff from a claypan soil. *J. Environ. Qual.* 25:584-593.

Bloom, A.J., P.A. Meyerhoff, A.R. Taylor, and T.L. Rost. 2003. Root development and absorption of ammonium and nitrate from the rhizosphere. *J. Plant Growth Regul.* 21:416-431.

Buzicky, G.C., G.W. Randall, R.D. Hauck, A.C. Caldwell. 1983. Fertilizer N losses from a tile-drained mollisol as influenced by rate and time of 15-N depleted fertilizer application. p. 213. *In* 1983 Agronomy abstracts. ASA, Madison, WI.

Curley, S. 1988. Nitrogen management. A&L Mid West Laboratories, Inc. Omaha, NE.

Daberkow, S. and W. Huang. 2006. Nutrient management. p. 117-123. *In* 2006 (ed.) Agricultural resources and environmental indicators. USDA, Washington, DC.

Di, H.J. and K.C. Cameron. 2002. Nitrate leaching in temperate agroecosystems: sources, factors, and mitigating strategies. *Nutrient Cycling in Agroecosystems* 46:237-256.

Drury, C.F., C.S. Tan, J.D. Gaynor, T.O. Oloya, and T.W. Welacky. 1996. Influence of controlled drainage-subirrigation on surface and tile drainage nitrate loss. *J. Environ. Qual.* 25:317-324.

Durst, P.T., and D.B. Beegle. 1999. Nitrogen fertilization of corn. Agron. Facts 12. Penn. State Coop. Ext., Penn. State Univ., University Park.

[FAO] Food and Agriculture Organization of the United Nations. 2007. FAOSTAT [Online]. Available at http://faostat.fao.org (verified 3 Dec. 2007).

Fowler, D.B., and J. Brydon. 1989. No-till winter wheat production on the Canadian prairies: Placement of urea and ammonium nitrate fertilizers. *Agron. J.* 81:518-524.

Francis, D.D., J.S. Schepers, and M.F. Vigil. 1993. Post-anthesis nitrogen loss from corn. *Agron. J.* 85:659-663.

Ghaffarzadeh, M., F.G. Préchac, R.M. Cruse, and M.M. Harbur. 1998. Fertilizer and soil nitrogen use by corn and border crops in a strip intercropping system. *Agron. J.* 90:758-762.

Hanway, J.J. 1963. Growth stages of corn (*Zea mays,* L.). *Agron. J.* 55:487-492.

Hefner, S.G., and P.W. Tracy. 1995. Corn production using alternate furrow nitrogen fertilization and irrigation. *J. Prod. Agric.* 8:66-69.

Hilton, B.R., P.E. Fixen, and H.J. Woodward. 1994. Effects of tillage, nitrogen placement, and wheel compaction on denitrification rates in the corn cycle of a corn-oats rotation. *J. Plant Nutr.* 17:1341-1357.

Johnson, G.V., and W.R. Raun. 1995. Nitrate leaching in continuous winter wheat: Use of a soil-plant buffering concept to account for fertilizer nitrogen. *J. Prod. Agric.* 8:486-491.

Johnson, J.W., and L.T. Kurtz. 1974. A technique for reducing 15N required for field experiments with labeled nitrogen fertilizer. *Soil Sci.* 117:315-317.

Joleka, W.E., and G.W. Randall. 1987. A nitrogen-15 microplot design for measuring plant and soil recovery of fertilizer nitrogen applied to corn. *Agron. J.* 79:322-325.

Keeney, D.R. 1982. Nitrogen management for maximum efficiency and minimum pollution. p. 605-649. *In* F.J. Stevenson (ed.) Nitrogen in agricultural soils. Agron. Monogr. 22. ASA, CSSA, and SSSA, Madison, WI.

Lazof, D.B., T.W. Rufty, and M.G. Redinbaugh. 1992. Localization of nitrate absorption and translocation within morphological regions of the corn root. *Plant Physiol.* 100:1251-1258.

Legg, T.D., J.J. Fletcher, K.W. Easter. 1989. Nitrogen budgets and economic efficiency: A case study of southeastern Minnesota. *J. Prod. Agric.* 2:110-116.

Lehrsch, G.A., R.E. Sojka, and D.T. Westermann. 2000. Nitrogen placement, row spacing, and furrow irrigation water positioning effects on corn yield. *Agron. J.* 92:1266-1275.

Malhi, S.S., C.A. Grant, A.M. Johnston, and K.S. Gill. 2001. Nitrogen fertilization management for no-till cereal production in the Canadian Great Plains: a review. *Soil & Tillage Research* 60:101-122.

Mackay, A.D., and S.A. Barber. 1986. Effect of nitrogen on root growth of two corn genotypes in the field. *Agron. J.* 78:699-703.

Miller, A.J., and M.D. Cramer. 2004. Root nitrogen acquisition and assimilation. *Plant and Soil* 274:1-36.

Mitsch, W.J., J.W. Day, J.W. Gilliam, P.M. Groffman, D.L. Hey, G.W. Randall, and N. Wang. 2001. Reducing nitrogen loading to the Gulf of Mexico from the Mississippi river basin: Strategies to counter a persistent ecological problem. *BioScience* 51:373-388.

Murrell, S. 2006. Fertilizer nitrogen BMPs for corn in the northcentral region. Better Crops 90(2):16-18.

NASS. 2008. National Agriculture Statistics Service: Statistics database. [Online] [Subset Average Grain Yield by county database] Available at http://www.nass.usda.gov (verified 19 Mar. 2008).

Patterson, D.T. 1995. Effects of environmental stress on weed/crop interactions. *Weed Sci.* 43:483-490.

Pingali, P.L. 2000. 1999/2000 World maize facts and trends, meeting world maize needs: technological opportunities and priorities for the public sector. CIMMYT, Mexico.

Randall, G.W., and M.A. Schmitt. 1998. Advisability of fall-applying nitrogen. Proc. Wisconsin Fertilizer, Aglime, and Pest Management Conf. Middleton, WI.

Raun, W.R., J.B. Solie, G.V. Johnson, M.L. Stone, R.W. Mullen, K.W. Freeman, W.E. Thomason, and E.V. Lukina. 2002. Improving nitrogen use efficiency in cereal grain production with optical sensing and variable rate application. *Agron. J.* 94:815-820.

Raun, W.R., and G.V. Johnson. 1999. Improving nitrogen use efficiency for cereal production. *Agron. J.* 91:357-363.

Sanchez, C.A., A.M. Blackmer, R. Horton, and D.R. Timmons. 1987. Assessment of errors associated with plot size and lateral movement of nitrogen-15 when studying fertilizer recovery under field conditions. *Soil Sci.* 144:344-351.

SAS Institute. 2003. SAS/STAT User's Guide. Release 9.1 ed. SAS Inst., Cary, NC.

Schepers, J.S., D.D. Francis, and M.T. Thompson. 1989. Simultaneous determination of total C, total N and $^{15}N$ on soil and plant material. *Commun Soil Sci Plant Anal* 20:949-959.

Stecker, J.A. 1993. Nitrogen management for no-tillage systems in Missouri [Online]. Available at http://extension.missouri.edu/explore/agguides/soils/g09175.htm (verified 6 Dec. 2007).

U.S. Census Bureau. 2006. U.S. and world population clocks [Online]. Available at http://www.census.gov/main/www/popclock.html (verified 19 Mar. 2008).

U.S. Geological Survey. 1999. The quality of our nation's waters: Nutrients and pesticides. U.S. Geological Survey Circular 1225. USGS, Washington, DC.

Vitosh, M.L., J.W. Johnson, and D.B. Mengel. 1995. Tri-state fertilizer recommendations for corn, soybeans, wheat and alfalfa. Ext. Bull. E-2567. Mich. State Ext., East Lansing.

**Table 1.** Initial soil test results (0-15 cm) for LCB 2005 and HEN 2007.

| | | | mg $kg^{-1}$ | | | |
|---|---|---|---|---|---|---|
| **Location** | **Year** | **pH** | **$NH_4$-N** | **$NO_3$-N** | **P** | **K** |
| LCB | 2005 | 5.54 | 22.6 | 3.8 | 33.6 | 129 |
| | Classification: Port-Oscar silt loam (fine-silty, mixed, super active, thermic Cumulic Haplustolls) | | | | | |
| HEN | 2007 | 5.26 | 2.03 | 3.2 | 63.1 | 391 |
| | Classification: Bethany silt loam (fine, mixed, thermic Pachic Paleustolls) | | | | | |
| * pH - 1:1 soil:water; P and K - Mehlich III; $NH_4$-N and $NO_3$-N - 2 M KCL | | | | | | |

**Table 2.** Treatment structure employed for N row study at Lake Carl Blackwell 2005 and 2006 on resultant maize grain yields.

| Treatment | Sidedress Application kg N ha$^{-1}$ | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Border** | **Row 1** | **Row 2** | **Row 3** | **Row 4** | **Row 5** | **Border** |
| **1** | 134 | 134 | 134 | 0 | 0 | 0 | 0 |
| **2** | 100 | 100 | 100 | 0 | 0 | 0 | 0 |
| **3** | 67 | 67 | 67 | 0 | 0 | 0 | 0 |
| **4** | 34 | 34 | 34 | 0 | 0 | 0 | 0 |
| **5** | 134 | 134 | 0 | 0 | 0 | 0 | 0 |
| **6** | 134 | 134 | 34 | 0 | 0 | 0 | 0 |
| **7** | 134 | 134 | 67 | 0 | 0 | 0 | 0 |
| **8** | 0 | 0 | 67 | 0 | 0 | 0 | 0 |
| **9** | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **10** | 134 | 134 | 134 | 134 | 134 | 0 | 0 |
| **11** | 134 | 134 | 0 | 134 | 0 | 0 | 0 |

**Table 3.** Treatment structure employed for N row study at Lake Carl Blackwell, and Hennessey, 2007 on resultant maize grain yields.

| Treatment | Sidedress Application kg N ha$^{-1}$ | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Border** | **Row 1** | **Row 2** | **Row 3** | **Row 4** | **Row 5** | **Border** |
| **1** | 134 | 134 | 134 | 0 | 0 | 0 | 0 |
| **2** | 100 | 100 | 100 | 0 | 0 | 0 | 0 |
| **3** | 67 | 67 | 67 | 0 | 0 | 0 | 0 |
| **4** | 34 | 34 | 34 | 0 | 0 | 0 | 0 |
| **5** | 134 | 134 | 0 | 0 | 0 | 0 | 0 |
| **6** | 134 | 134 | 34 | 0 | 0 | 0 | 0 |
| **7** | 134 | 134 | 67 | 0 | 0 | 0 | 0 |
| **8** | 67 | 67 | 0 | 67 | 0 | 0 | 0 |
| **9** | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **10** | 134 | 134 | 134 | 134 | 134 | 0 | 0 |
| **11** | 134 | 134 | 0 | 134 | 0 | 0 | 0 |

**Table 4.** Treatment mean grain yields for LCB, 2005 and 2006.

| Treatment Means by Row | | | Grain Yield Mg ha$^{-1}$ | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Year** | **LOC** | **TRT** | **Border Row** | | **Row 1** | | **Row 2** | | **Row 3** | | **Row 4** | |
| 2005 | LCB | **1** | 12.4 | | 11.6 | | 10.3 | | 7.4 | a,b | 5.6 | a,b,c |
| | | **2** | 10.2 | | 10.5 | | 11.0 | | 7.3 | c | 7.5 | c |
| | | **3** | 10.5 | | 10.3 | | 8.7 | | 6.8 | a,b | 6.0 | a,b |
| | | **4** | 8.4 | | 8.3 | | 8.4 | | 7.9 | | 7.9 | |
| | | **5** | 8.8 | | 8.5 | | 5.3 | a | 5.6 | | 5.6 | |
| | | **6** | 13.0 | | 13.0 | | 9.5 | a,b | 8.5 | a,b | 8.5 | a,b |
| | | **7** | 11.1 | | 11.6 | | 9.1 | | 7.4 | a,b | 7.1 | a,b |
| | | **8** | 6.1 | | 5.7 | | 8.6 | | 6.2 | | 6.3 | |
| | | **9** | 9.4 | | 8.7 | | 9.9 | | 9.2 | | 9.8 | |
| | | **10** | 11.1 | | 11.0 | | 9.4 | | 10.3 | | 11.3 | |
| | | **11** | 12.3 | | 12.0 | | 9.6 | | 11.3 | | 8.2 | a,b |
| 2006 | LCB | **1** | 7.8 | | 5.2 | a | 4.7 | a | 4.7 | a | 5.9 | |
| | | **2** | 6.0 | | 4.6 | | 4.2 | | 3.3 | a | 4.8 | |
| | | **3** | 5.0 | | 4.6 | | 3.4 | | 3.6 | | 3.6 | |
| | | **4** | 3.2 | | 3.1 | | 3.1 | | 2.4 | | 3.0 | |
| | | **5** | 3.4 | | 3.8 | | 3.0 | | 3.0 | | 3.1 | |
| | | **6** | 4.5 | | 4.0 | | 3.9 | | 3.7 | | 3.6 | |
| | | **7** | 7.3 | | 5.7 | | 5.4 | | 5.3 | | 4.6 | a |
| | | **8** | 5.3 | | 4.9 | | 4.0 | | 4.0 | | 5.1 | |
| | | **9** | 4.0 | | 4.7 | | 5.1 | | 4.4 | | 4.4 | |
| | | **10** | 5.3 | | 5.8 | | 6.4 | | 5.1 | | 5.5 | |
| | | **11** | 4.9 | | 7.0 | | 4.7 | b | 4.4 | b | 4.6 | b |
| Means in a row followed by a letter indicate significantly different means at the 0.05 probability level using Duncan's multiple range test in the following manner: a - to border row, b - to row 1, c - to row 2 | | | | | | | | | | | | |

**Table 5.** Mean treatment grain yields over site-years LCB, 2005 and 2006.

| Treatment Means by Row | | | Grain Yield Mg ha$^{-1}$ | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Year** | **LOC** | **TRT** | **Border Row** | | **Row 1** | | **Row 2** | | **Row 3** | | **Row 4** | |
| 2005 and 2006 | LCB | **1** | 10.1 | | 8.4 | | 7.5 | a | 6.1 | a,b | 5.7 | a,b |
| | | **2** | 8.1 | | 7.5 | | 7.6 | | 5.3 | a,b,c | 6.1 | |
| | | **3** | 7.7 | | 7.5 | | 6.1 | | 5.2 | a,b | 4.8 | a,b |
| | | **4** | 5.8 | | 5.7 | | 5.8 | | 5.1 | | 5.4 | |
| | | **5** | 6.1 | | 6.2 | | 4.1 | | 4.3 | | 4.4 | |
| | | **6** | 8.7 | | 8.5 | | 6.7 | a | 6.1 | a,b | 6.1 | a,b |
| | | **7** | 9.2 | | 8.7 | | 7.2 | | 6.3 | a,b | 5.8 | a,b |
| | | **8** | 5.7 | | 5.3 | | 6.3 | | 5.1 | | 5.7 | |
| | | **9** | 6.7 | | 6.7 | | 7.5 | | 6.8 | | 7.1 | |
| | | **10** | 8.2 | | 8.4 | | 7.9 | | 7.7 | | 8.4 | |
| | | **11** | 8.6 | | 9.5 | | 7.2 | b | 7.9 | | 6.4 | a,b |

Means in a row followed by a letter indicate significantly different means at the 0.05 probability level using Duncan's multiple range test in the following manner: a - to row 1, b - to row 2, c - to row 3

**Table 6.** Treatment mean grain yields for LCB and HEN, 2007.

| Treatment Means by Row | | | Grain Yield Mg ha$^{-1}$ | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Year** | **LOC** | **TRT** | **Row 1** | | **Row 2** | | **Row 3** | | **Row 4** | | **Row 5** | |
| 2007 | LCB | **1** | 7.3 | | 6.9 | | 5.9 | | 3.7 | a,b | 4.4 | a |
| | | **2** | 9.2 | | 9.7 | | 5.1 | a,b | 4.2 | a,b | 5.2 | a,b |
| | | **3** | 7.5 | | 8.2 | | 3.6 | a,b | 3.9 | a,b | 3.4 | a,b |
| | | **4** | 5.6 | | 4.9 | | 4.4 | | 5.3 | | 4.2 | |
| | | **5** | 9.4 | | 4.8 | a | 4.4 | a | 5.5 | a | 4.0 | a |
| | | **6** | 6.2 | | 4.7 | | 3.5 | a | 4.5 | | 3.5 | a |
| | | **7** | 7.5 | | 6.6 | | 5.0 | | 3.2 | a,b | 3.5 | a,b |
| | | **8** | 7.3 | | 5.0 | | 6.5 | | 4.9 | | 4.1 | a |
| | | **9** | 5.4 | | 3.9 | | 3.4 | | 3.9 | | 4.5 | |
| | | **10** | 8.8 | | 9.1 | | 8.2 | | 8.9 | | 4.6 | a,b,c,d |
| | | **11** | 7.5 | | 4.6 | | 6.6 | | 3.3 | a,c | 2.9 | a,c |
| 2007 | HEN | **1** | 7.5 | | 8.4 | | 6.9 | | 6.1 | b | 6.2 | b |
| | | **2** | 8.7 | | 9.0 | | 6.9 | b | 6.5 | a,b | 7.0 | b |
| | | **3** | 5.4 | | 5.7 | | 5.0 | | 4.0 | | 4.0 | |
| | | **4** | 7.8 | | 7.4 | | 6.9 | | 5.7 | a | 7.1 | |
| | | **5** | 8.6 | | 7.2 | | 5.4 | a | 5.5 | a | 6.6 | a |
| | | **6** | 8.4 | | 7.0 | | 8.4 | | 6.4 | a,c | 6.7 | |
| | | **7** | 8.6 | | 6.8 | a | 5.2 | a | 5.6 | a | 5.8 | a |
| | | **8** | 7.0 | | 6.5 | | 7.3 | | 4.8 | a,c | 6.4 | |
| | | **9** | 5.4 | | 4.8 | | 4.6 | | 5.3 | | 6.1 | |
| | | **10** | 8.8 | | 9.1 | | 9.4 | | 10.1 | | 8.3 | d |
| | | **11** | 7.0 | | 5.7 | | 7.4 | | 5.9 | | 4.8 | a,c |

Means in a row followed by a letter indicate significantly different means at the 0.05 probability level using Duncan's multiple range test in the following manner: a - to row 1, b - to row 2, c - to row 3, d - to row 4

**Table 7.** Mean treatment grain yields over site-years HEN and LCB, 2007.

| Treatment Means by Row | | | Grain Yield Mg ha$^{-1}$ | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Year** | **LOC** | **TRT** | **Row 1** | | **Row 2** | | **Row 3** | | **Row 4** | | **Row 5** | |
| 2007 | HEN and LCB | **1** | 7.4 | | 7.6 | | 6.4 | | 4.9 | a,b | 5.3 | a,b |
| | | **2** | 8.9 | | 9.3 | | 6.0 | a,b | 5.3 | a,b | 6.1 | a,b |
| | | **3** | 6.5 | | 6.9 | | 4.3 | a,b | 3.9 | a,b | 3.7 | a,b |
| | | **4** | 6.7 | | 6.2 | | 5.6 | | 5.5 | | 5.6 | |
| | | **5** | 9.0 | | 6.0 | a | 4.9 | a | 5.5 | a | 5.3 | a |
| | | **6** | 7.3 | | 5.8 | | 5.9 | | 5.4 | a | 5.1 | a |
| | | **7** | 8.1 | | 6.7 | | 5.1 | a,b | 4.4 | a,b | 4.6 | a,b |
| | | **8** | 7.2 | | 5.7 | | 6.9 | | 4.8 | a,c | 5.3 | a,c |
| | | **9** | 5.4 | | 4.4 | | 4.0 | | 4.6 | | 5.3 | |
| | | **10** | 8.8 | | 9.1 | | 8.8 | | 9.5 | | 6.4 | a,b,c,d |
| | | **11** | 7.2 | | 5.2 | a | 7.0 | b | 4.6 | a,c | 3.9 | a,c |

Means in a row followed by a letter indicate significantly different means at the 0.05 probability level using Duncan's multiple range test in the following manner: a - to row 1, b - to row 2, c - to row 3, d - to row 4

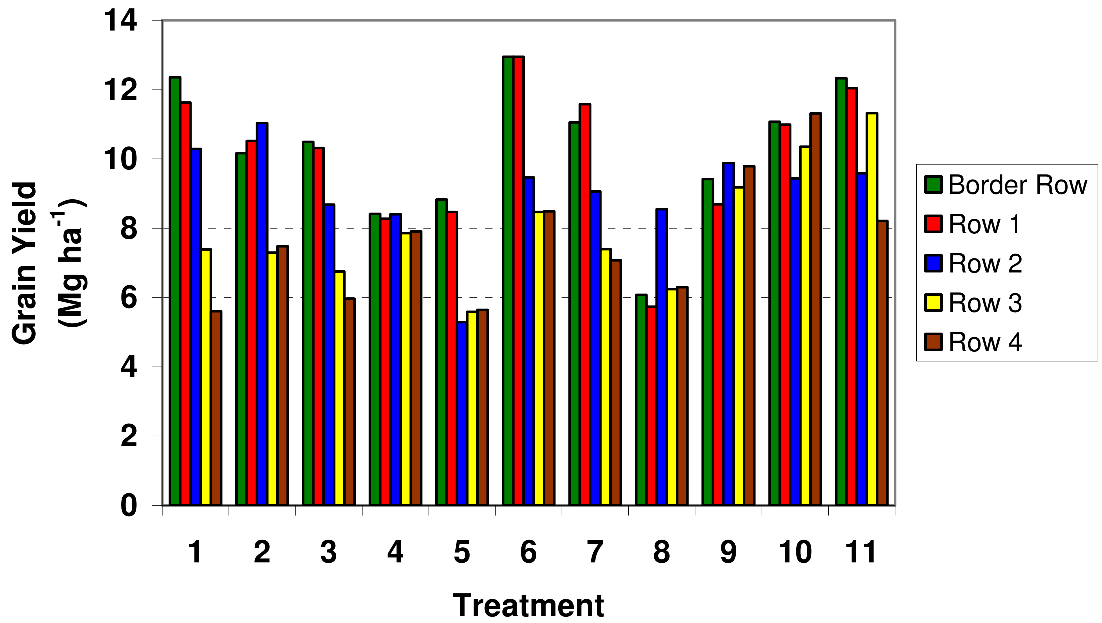



**Figure 1.** Grain yield for five harvested rows with varying N rate treatments per row, LCB 2005.

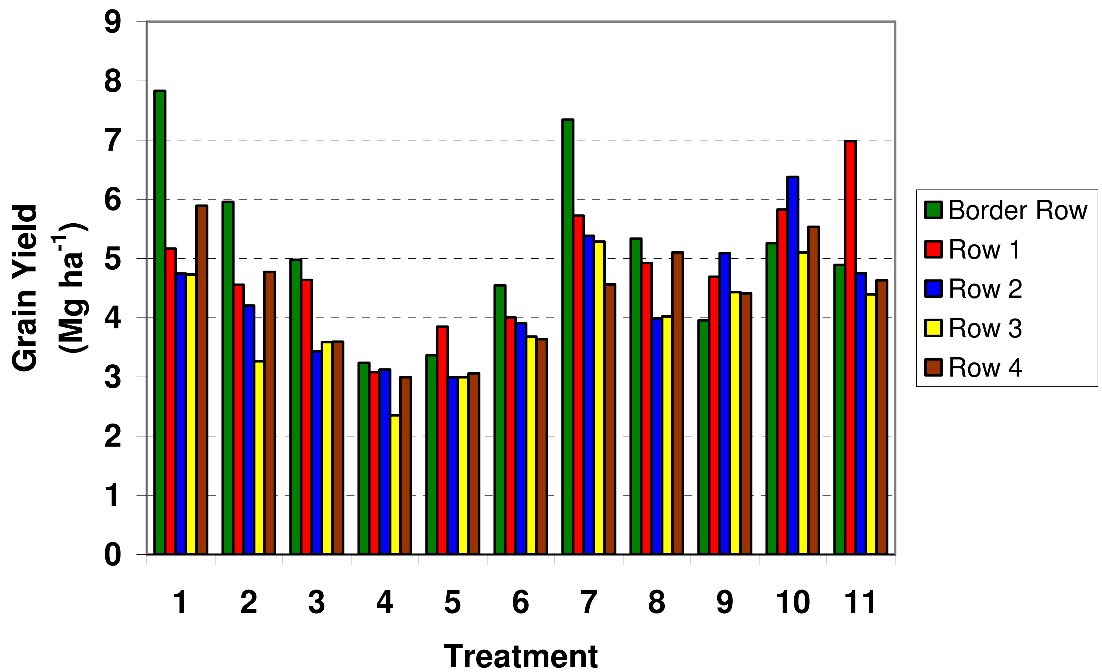



**Figure 2.** Grain yield for five harvested rows with varying N rate treatments per row, LCB 2006.

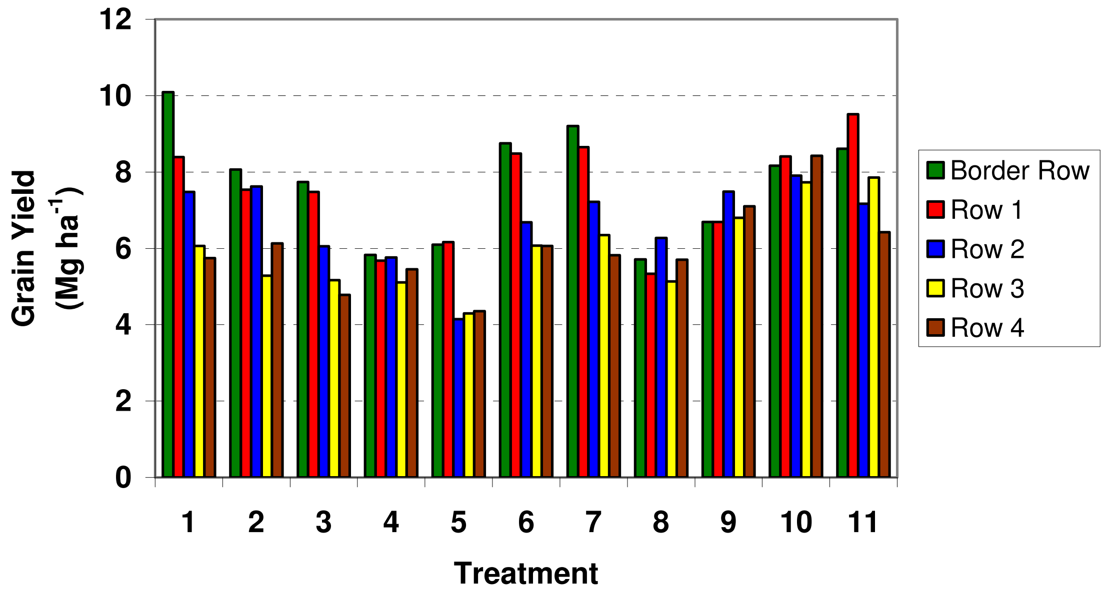



**Figure 3.** Combined treatment means grain yield for five harvested rows with varying N rate treatments per row, LCB 2005 and 2006.

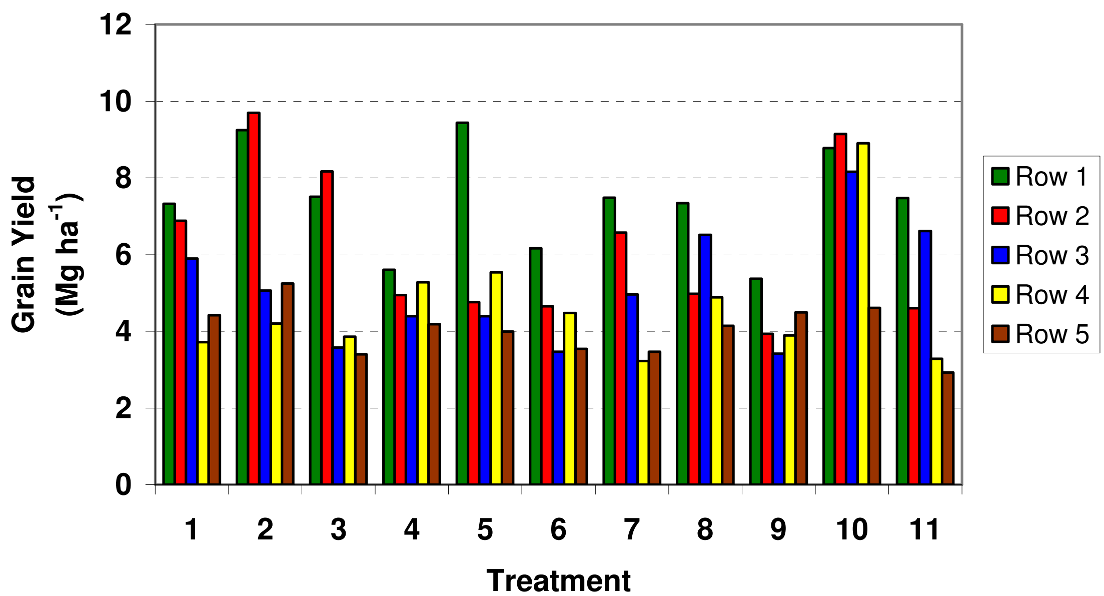



**Figure 4.** Grain yield for five harvested rows with varying N rates per row, LCB 2007.

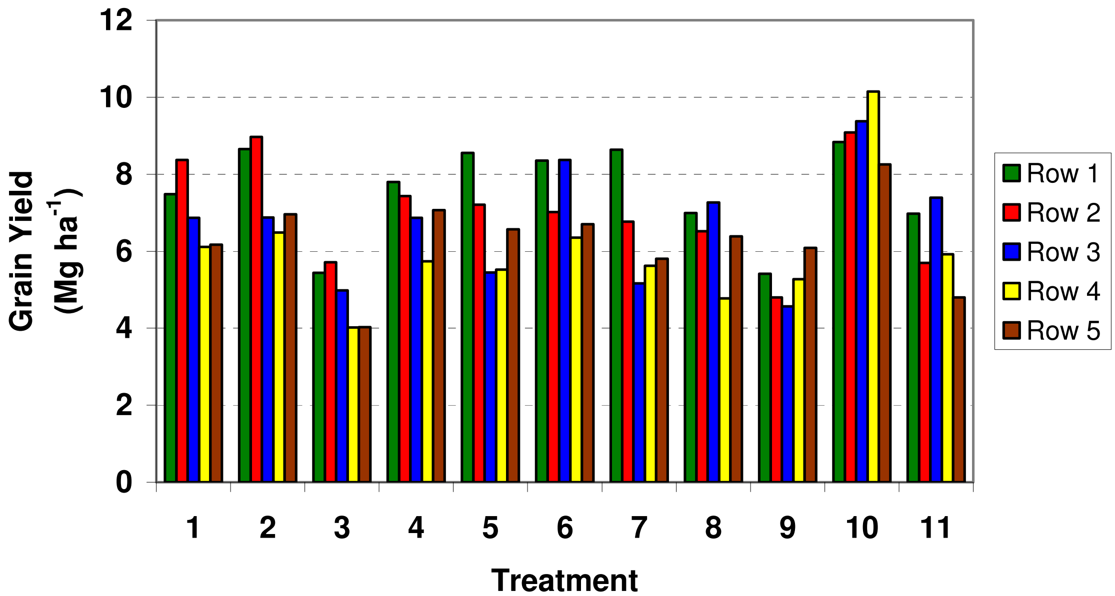



**Figure 5.** Grain yield for five harvested rows with varying N rates per row, HEN 2007.

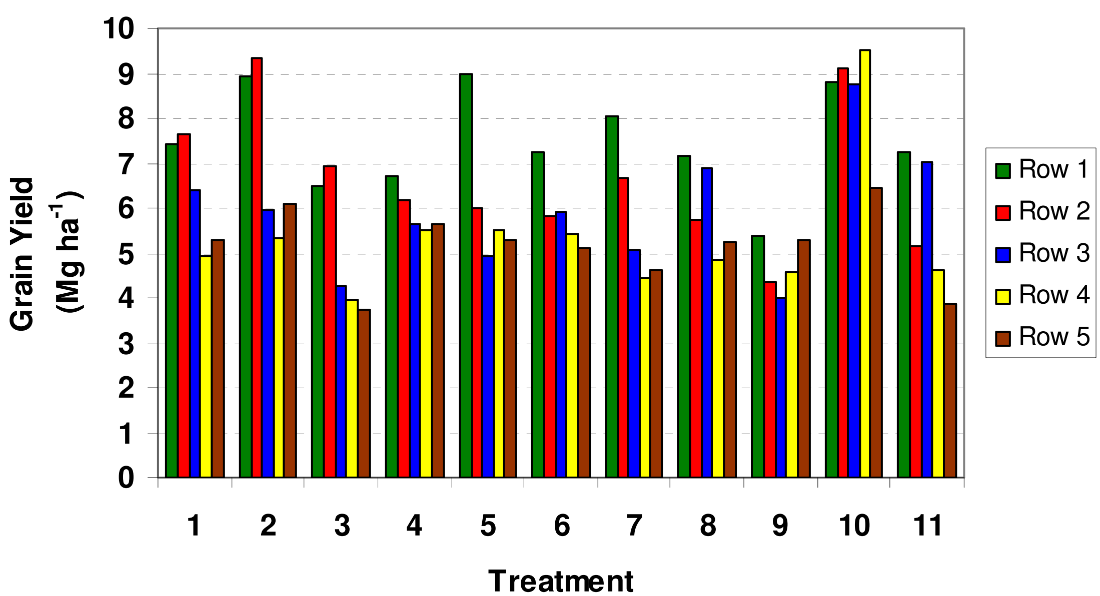
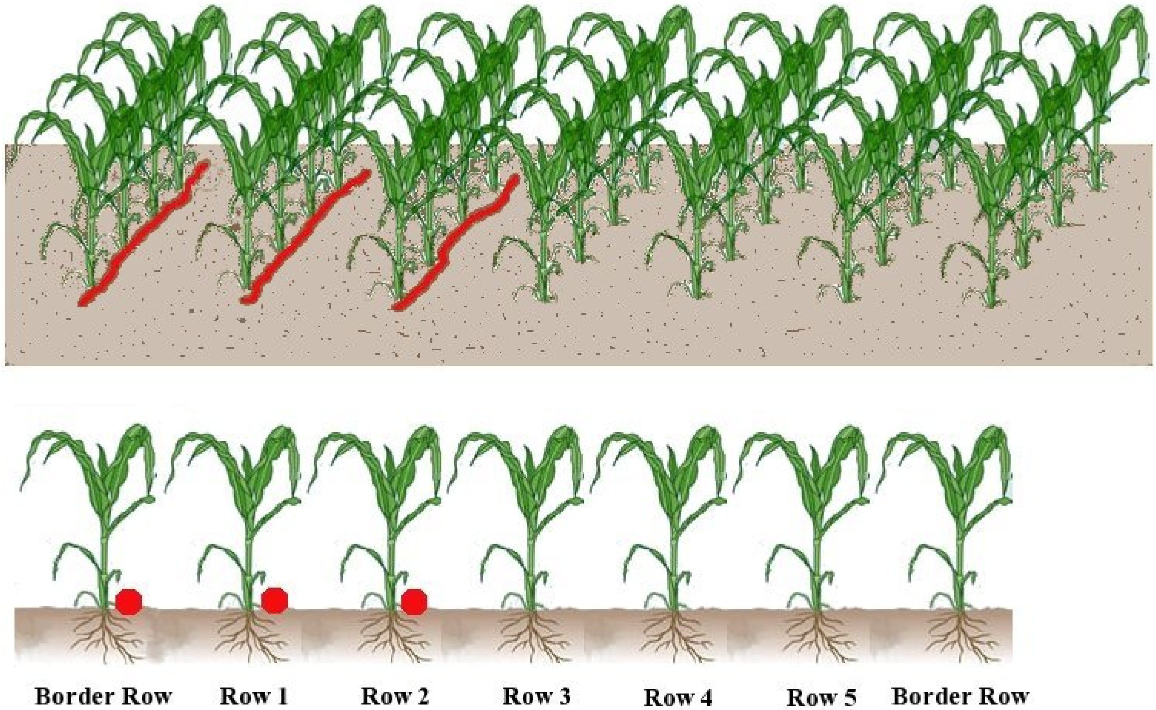
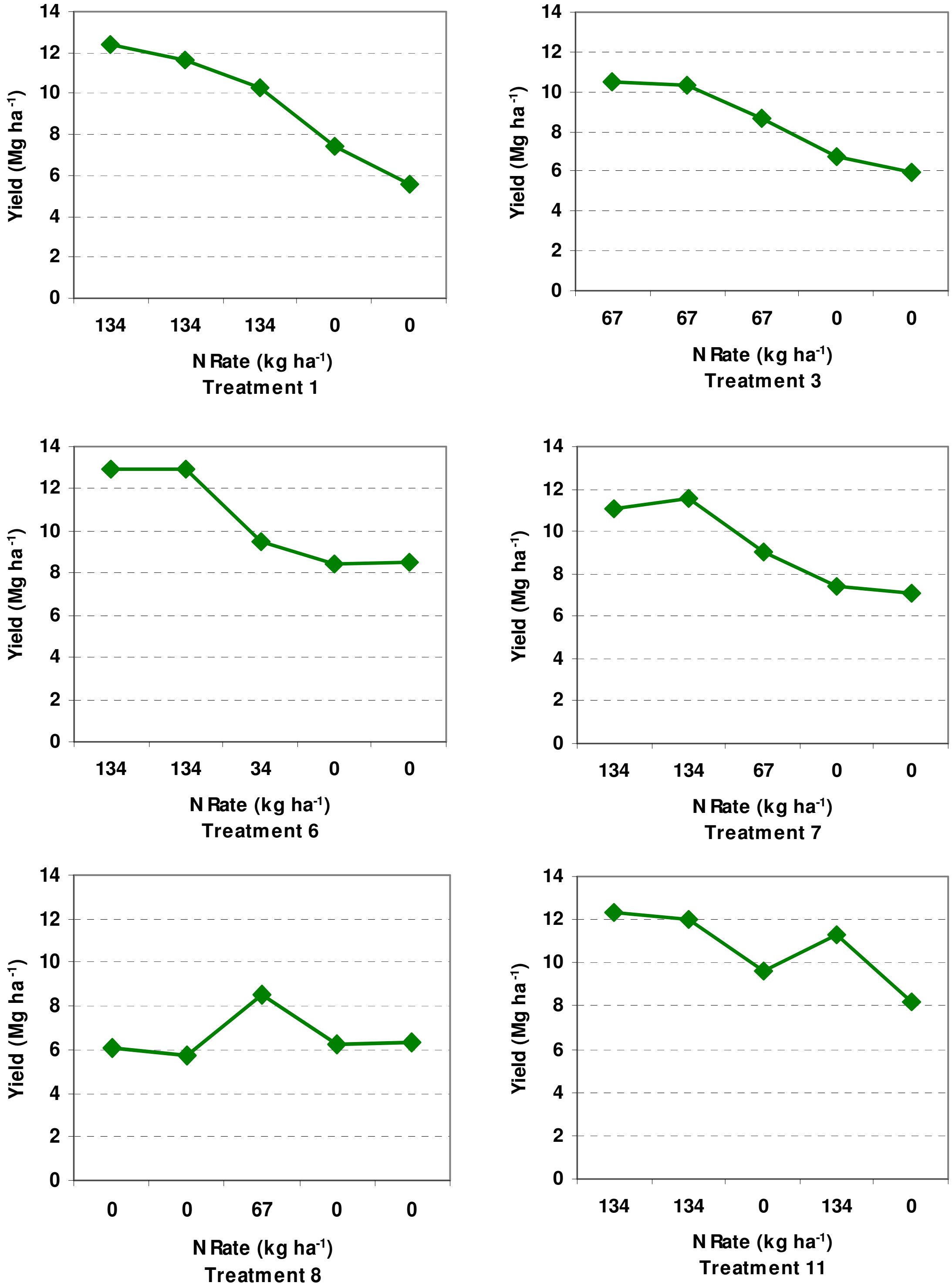



**Figure 6.** Combined treatment means grain yield for five harvested rows with varying N rate treatments per row, HEN and LCB 2007.

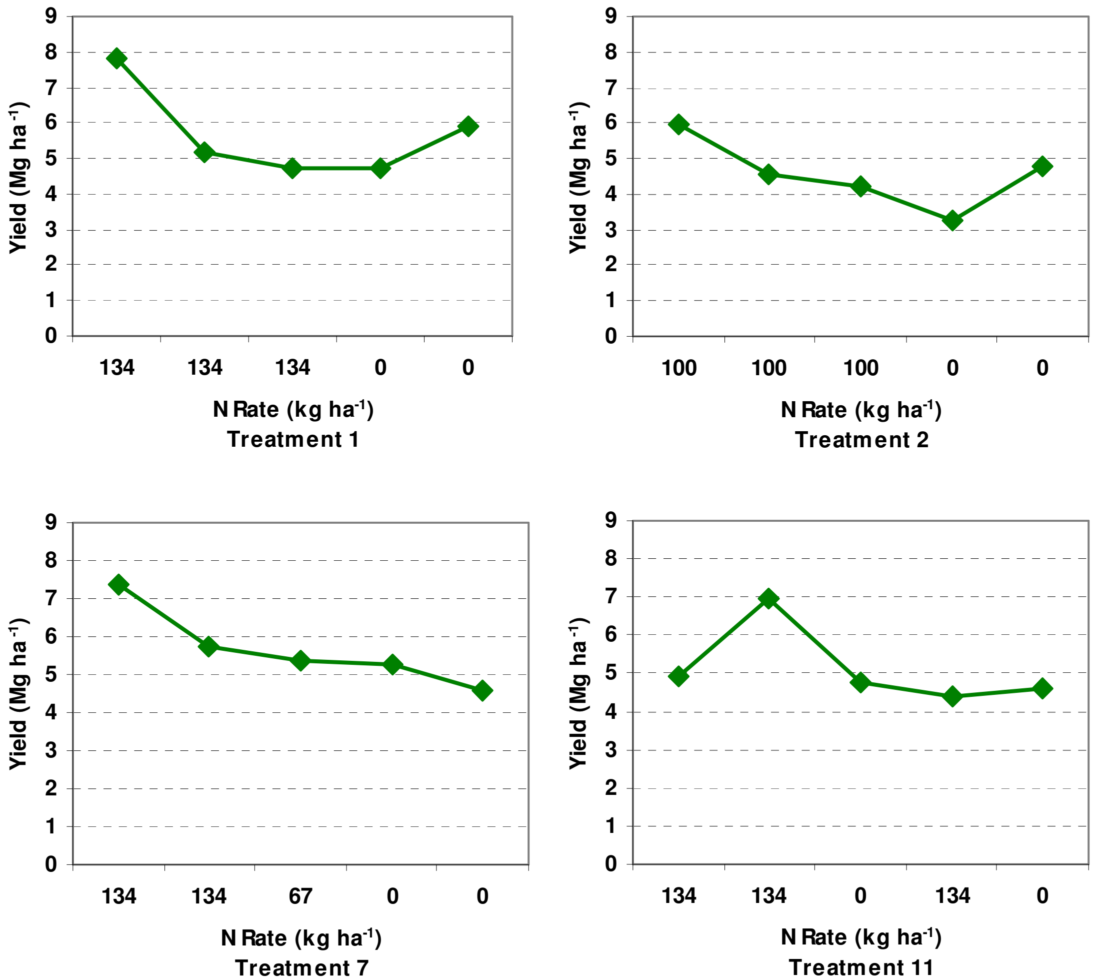
**APPENDIX**



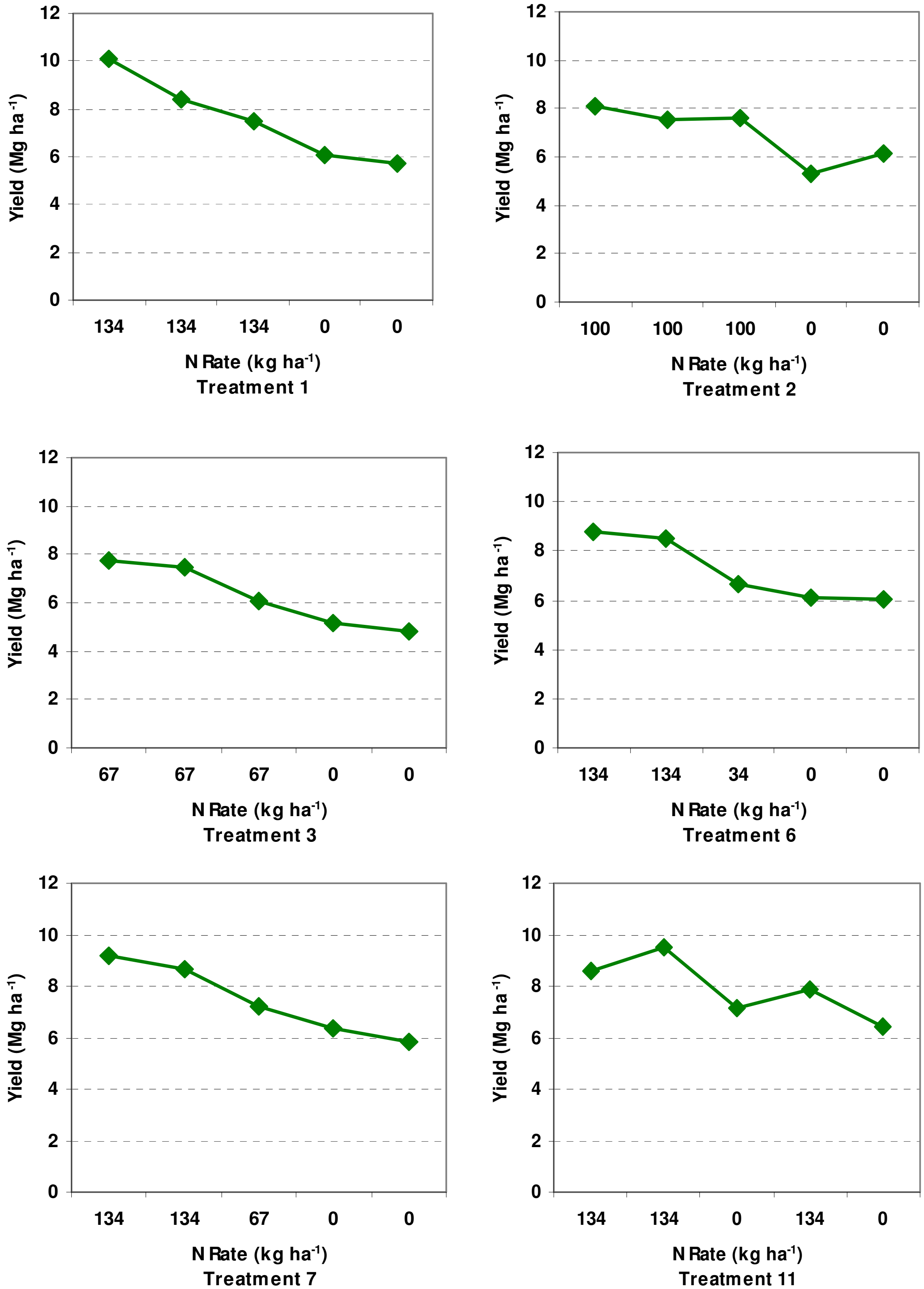

**Appendix Figure 1.** Nitrogen fertilization placement employed for this study to determine maize grain yield response to variable row N fertilization.



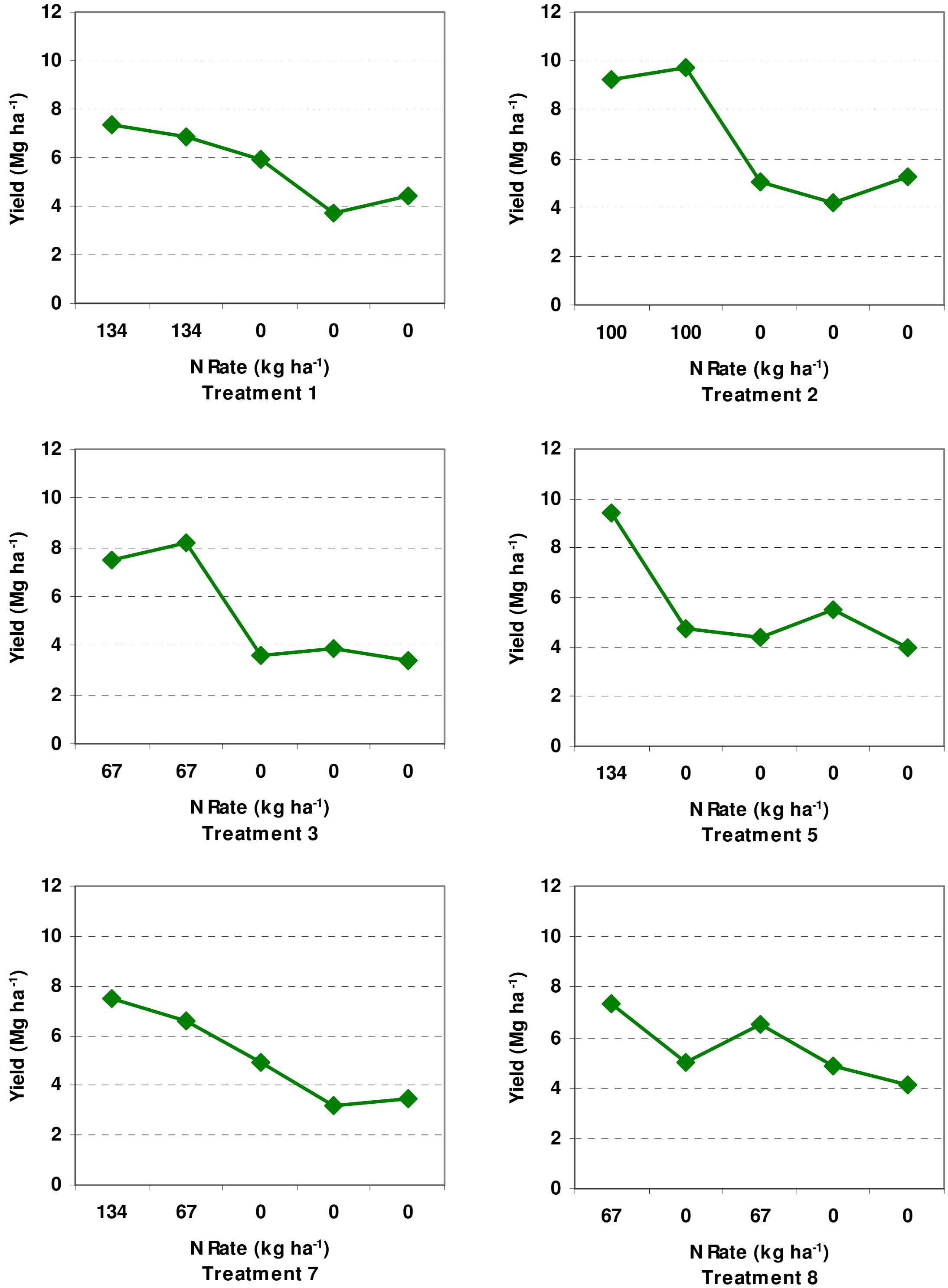

**Appendix Figure 2.** Selected individual treatment means for LCB 2005.



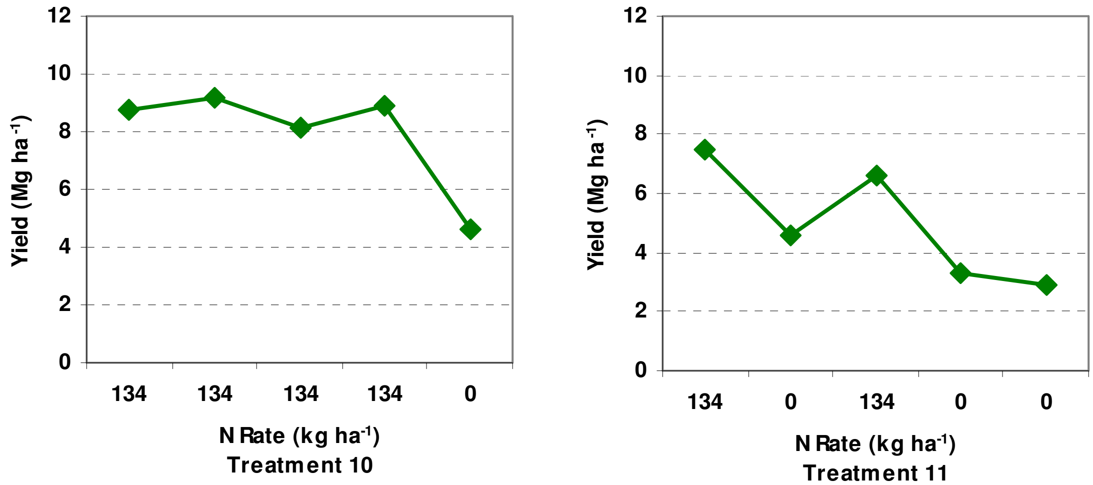

**Appendix Figure 3.** Selected individual treatment mean grain yields for LCB 2006.



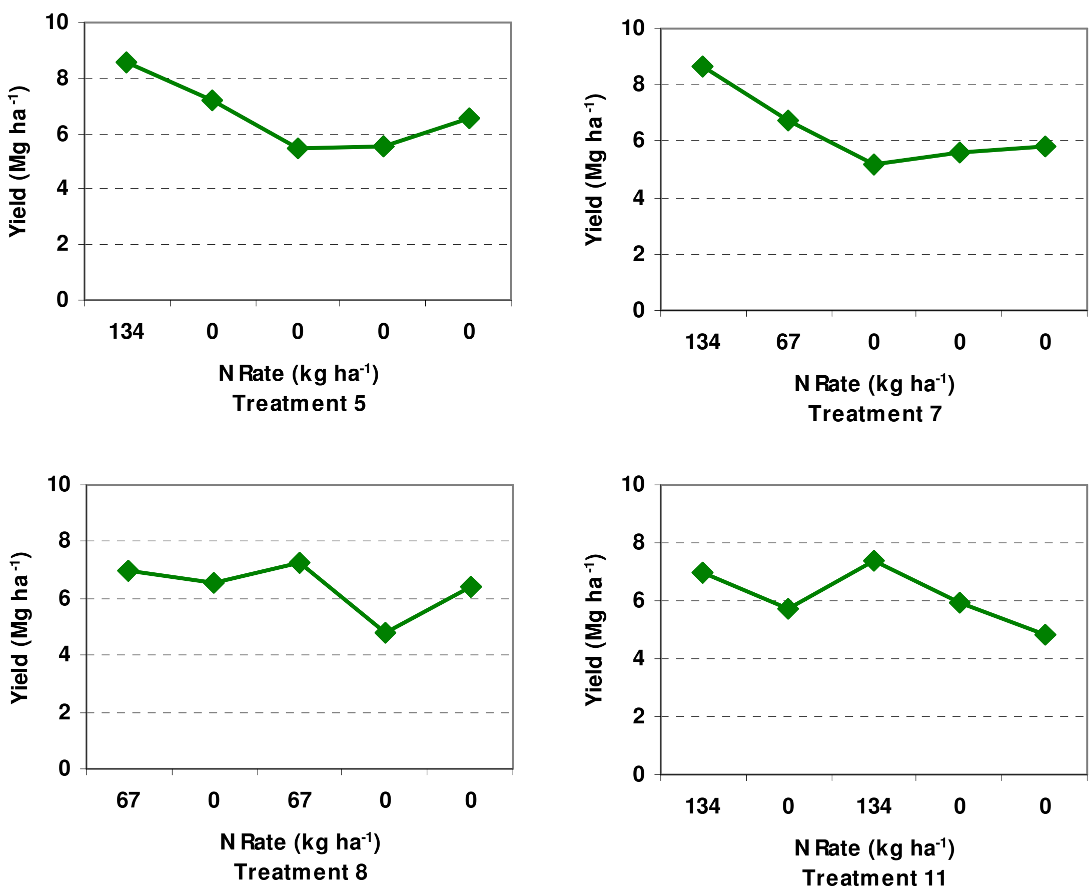

**Appendix Figure 4.** Selected individual treatment means for combined site years LCB 2005 and 2006.



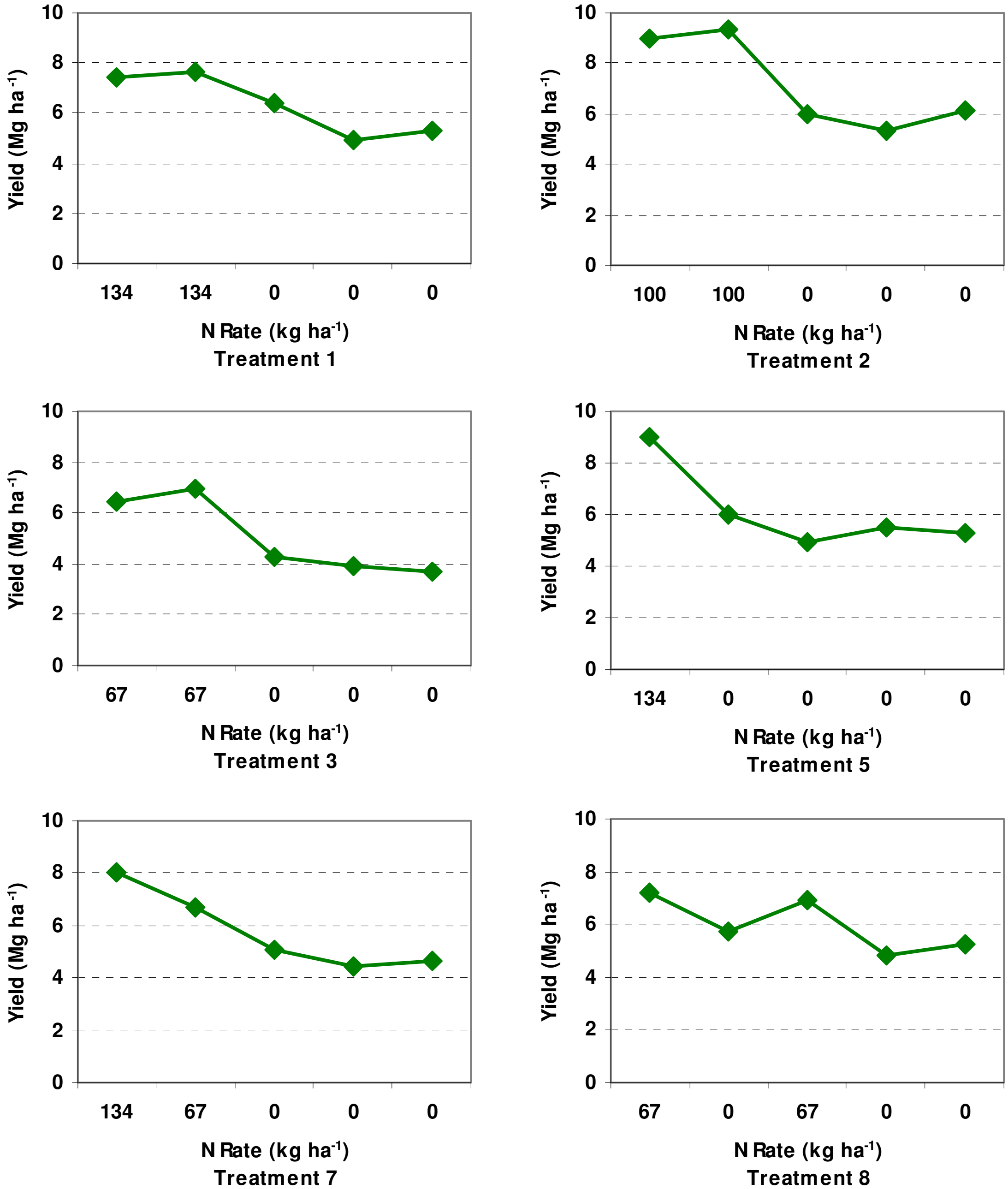

**Appendix Figure 5(a).** Selected individual treatment means for LCB 2007.



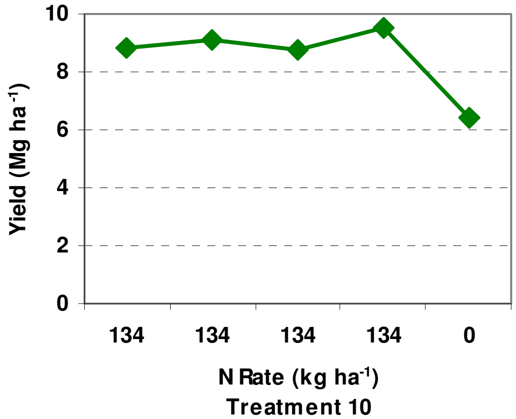

**Appendix Figure 5(b).** Selected individual treatment means for LCB 2007, continued.

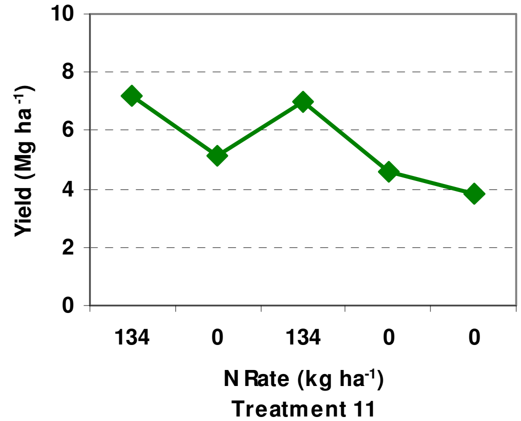



**Appendix Figure 6.** Selected individual treatment means for HEN 2007.

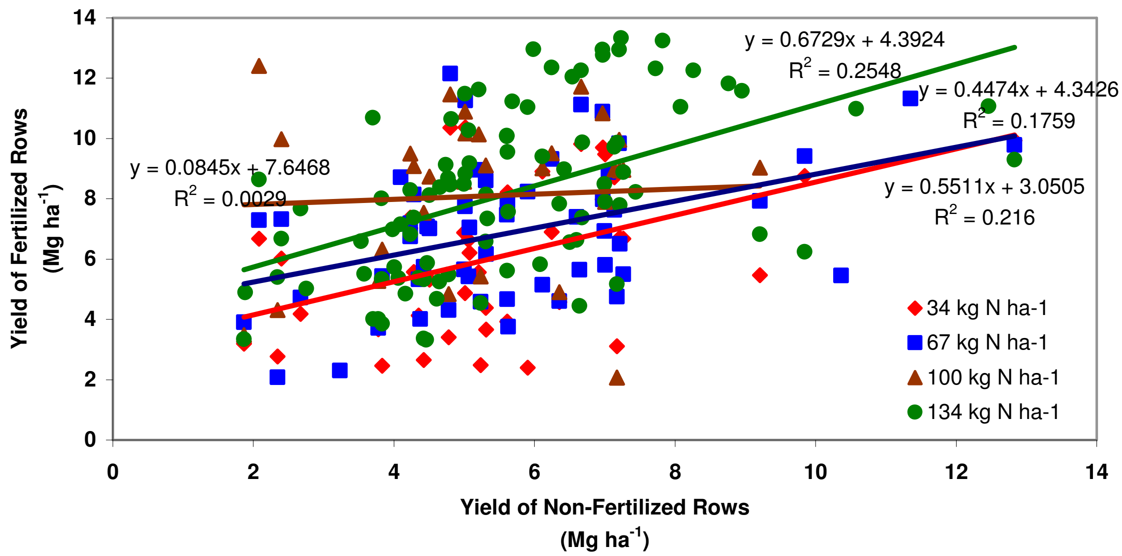



**Appendix Figure 7(a).** Selected treatment means for combined site years LCB and HEN 2007.




**Appendix Figure 7(b).** Selected treatment means for combined site years LCB and HEN 2007 continued.




**Appendix Figure 8.** Yield of fertilized rows versus the yield of non-fertilized rows for all site-years, LCB and HEN, 2005-2007.

VITA

Daniel Ethan Edmonds

Candidate for the Degree of

Master of Science

Thesis: MAIZE (*ZEA MAYS* L.) GRAIN YIELD RESPONSE TO VARIABLE ROW NITROGEN FERTILIZATION

Major Field: Plant and Soil Sciences

Biographical:

Education: Graduated from Morris High School, Morris, Oklahoma in May 2002. Received Bachelor of Science degree in Agricultural Sciences and Natural Resources, Plant and Soil Science from Oklahoma State University, Stillwater, Oklahoma, in December, 2006. Completed the requirements for Masters of Science degree in Plant and Soil Sciences at Oklahoma State University, Stillwater, Oklahoma in May, 2008.

Experience: Worked as a customer sales representative for King's Lone Tree Feeds (2001-2004); worked as an agricultural machinery operator for Dixon Farms (1998-2005); worked as an Agriculture Legislative Intern at the Oklahoma State Senate and House of Representatives (2006); worked as an Agriculture Policy Intern at the United States House of Representatives (2006); worked as an agricultural machinery operator for C.V. Ledbetter and Son, Inc. (2004-Present); employed as a Graduate Research Assistant by Oklahoma State University, Department of Plant and Soil Sciences (2007-Present).

Professional Memberships: American Society of Agronomy (ASA), Crop Science Society of America (CSSA), Soil Science Society of America (SSSA)

Name: Daniel Ethan Edmonds Date of Degree: May, 2008

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: MAIZE (*ZEA MAYS* L.) GRAIN YIELD RESPONSE TO VARIABLE ROW NITROGEN FERTILIZATION

Pages in Study: 44 Candidate for the Degree of Master of Science

Major Field: Plant and Soil Sciences


Scope and Method of Study:

This study was conducted to evaluate maize grain yield response to variable row N fertilization with varying N rates when liquid UAN (urea ammonium nitrate) fertilizer was placed at the base of each maize row. The experiment was conducted at the Robert L. Westerman Irrigation Research Center at Lake Carl Blackwell (LCB) west of Stillwater, OK for three years and at Hennessey, OK for one year. Eleven treatments, consisting of varying N rates, were used to evaluate the response of maize grain yields to variable row N fertilization and to quantify, if any, lateral movement or competition among rows for N.

Findings and Conclusions:

Low rates of N did not produce significantly different yields from non-fertilized rows for any site year. Higher N rates did produce significantly higher yields for all site years. Non-fertilized rows received little to no benefit from N applied to neighboring rows; however, there were some exceptions. Nonetheless, the resultant yields were depressed from that of the neighboring fertilized row. Row by row differences could be seen, indicating that lateral movement of N or competition among rows is variable from year to year and from row to row suggesting the need for application of N by individual row.


ADVISER'S APPROVAL: Dr. William R. Raun