By-Plant Nitrogen Response as a Function of Delayed Emergence in Corn (*Zea mays* L.)

By

M. Cody Daft

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(*Zea mays* L.)

Thesis Approved:

Dr. William Raun

Thesis Adviser

Dr. John Solie

Dr. Randy Taylor

Dr. A. Gordon Emslie

Dean of the Graduate College

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By-Plant Nitrogen Response as a Function of Delayed Emergence in Corn

Abstract

Crops with homogenous stands have the capability of producing higher grain yields under good growing conditions and management systems than crops with heterogeneous stands. Determining the correct nitrogen (N) rate for plants of uneven emergence should prove to be beneficial for increasing nitrogen use efficiency and crop yields. This study was investigated at two experimental sites established in the spring of 2007, near Stillwater, OK at the Lake Carl Blackwell Agronomy Research Farm under irrigation using conventional tillage management practices. The delayed plants were planted 4, 7, and 10 days after initial planting to simulate various delayed emergence scenarios, as well as receiving varying amounts of by-plant N fertilizer to assess nitrogen response. At site year Lake Carl Blackwell (1), 2007, for each day delay in planting (assuming emergence was equally delayed) corn grain yields decreased by 1,034 kg ha^{-1}, when 67 kg N/ha was applied preplant. At site year Lake Carl Blackwell (2), 2007, a yield reduction of 178 kg ha^{-1} for every day delay in planting for the 67 kg N/ha preplant N rate was observed. When sidedress N was applied, in addition to preplant N, yield reductions due to delayed planting were less pronounced. Over all sites evaluated in this work, delayed emergence decreased average grain yields thus highlighting the need to homogenize plant stands and corresponding emergence.

CHAPTER I

INTRODUCTION

Homogeneity in crop production stands is extremely important to corn producers throughout the world. Achieving stand homogeneity in cropping systems is directly related to environmental factors as well as profits. The absence of homogeneity due to spatial and temporal variability in crops must be minimized in order to capitalize on profits while decreasing inputs. Schmidt et al. (2002) found that current nitrogen recommendations for corn have been developed for large geographic regions and have traditionally been employed without considering in-field variability. One example of such variability can be seen as uneven emergence in corn.

Uneven emergence may result in a decision to replant the crop before supplementary amendments are made, or to treat the field entirely as if no variability were present which could ultimately lead to over-fertilization, over-irrigation, and over-application of pesticides to certain areas of the field. Late emerging plants may act as weeds by competing for nutrients while producing minimal or no yields. A decision whether to destroy the late-emerging plants then becomes necessary (Nafziger et al., 1991). Poor management decisions based on uneven emergence can easily cause a significant decrease in profit. Intensive management strategies such as crop monitoring show the dynamics of variability within crop stands and growth, while also providing useful information on crop development aiding in the expansion of soil nutrient management and efficiency strategies (Machado et al., 2002).

Delayed emergence and complete failure of seed emergence are causes of uneven crop stands early in the season. Crops with uniform stands have the advantage of producing higher grain yields under good growing conditions and management systems than crops with poor stands. Martin et al. (2005) noted that methods which homogenize corn plant stands and emergence may decrease plant-to-plant variation and could lead to increased grain yields. It has been found that uneven crop stands in corn production systems may occur due to plant residue, compaction of the soil, soil moisture content, and irregular planting depths (Ford and Hick, 1992). Because many variables contribute to uneven crop stands, producers are faced with challenging decisions to alter management practices such as fertilization, preparation of seedbeds, and or replanting. The decision of whether or not to replant and to treat the entire field in an identical manner may result in costly over-fertilization of delayed emerging plants which may give rise to interplant competition. Advancements in agricultural technologies and intensive management strategies have facilitated improved crop performance, however, completely overcoming difficulties related to seed emergence and uneven crop stands is not yet obtainable.

CHAPTER II

REVIEW OF LITERATURE

The price of nitrogen fertilizer has increased dramatically over the past several years. As demands increase, and the price of nitrogen fertilizer continues to rise, it is imperative to increase world nitrogen use efficiency (NUE). Raun and Johnson (1999) explain that only 33% of the total N applied for worldwide cereal production is actually removed in the grain. Raun et al. (2002) further explain that the 67% of N which is lost via volatilization, surface runoff, soil denitrification, and leaching is estimated to be worth more than $15 billion annually. This number will undoubtedly escalate as demands for petroleum based products such as natural gas continue to climb.

Conventional uniform applications of nitrogen fertilizers have the tendency to over or under-fertilize due to spatial variability found within fields. In order to maximize grain yields, producers must be cognizant of in-field variability. Factors such as soil type, tillage, irrigation, nitrogen rate and placement, crop emergence, yield potential, as well as the interaction among them vary greatly from one field to the next, making the determination of an optimum nitrogen rate for maximum crop yields very difficult (Gehl et al., 2005). Scharf et al. (2005) reported the importance of increasing NUE by understanding the variability within fields, assessing the need for nitrogen fertilizer at high resolutions, and how these are of utmost importance in order to satisfy crop needs as well as decreasing production costs by minimizing N inputs and losses. The presence of variability can be seen at many scales and levels throughout cropping systems. Distinct differences can be seen in yield potential and nitrogen availability at a scale of 1-m^2 or smaller, requiring sub-meter resolution to accurately and independently treat spatial variability at this level (Raun et al., 2005). It is near impossible to visualize these differences in soil properties with the naked eye, but once plant growth is initiated these differences become more and more apparent. The differences seen at this level are often categorized as by-plant differences.

Plant to plant variation within fields can be the result of environmental factors as well as management practices. Liu et al. (2004) found that producers and agronomists have recently given considerable attention to the variability found within plant spacing as well as plant emergence in order to enlarge grain yields. Hodgen et al. (2007) found that a delay in relative emergence of 4 days can potentially show a yield reduction of over 15% in a single plant. The plants which were delayed in emergence were shorter and had less ear leaf area measured during grain fill, thus allowing the earlier emerging plants to absorb more incident solar radiation and resulting in an increased demand for applied nitrogen fertilizer. They also found that specifically treating the late emerged corn plants with larger amounts of nitrogen fertilizer did not rectify the reduction in potential yield due to the interplant competition of larger neighboring corn plants for access to solar radiation. These results show the need to homogenize plant emergence and plant spacing variability, as well as the recognition of differences in yield potential that can be found at the by-plant level.

Martin et al. (2005) reported that grain yield variability within corn plants can be expected across a range of environments. They further noted that as yield levels increased the yield range increased accordingly, and despite yield levels the by-plant differences averaged more than 2765 kg ha^{-1} over 7 sites and 2 years. This data shows there are large differences in the fertilizer N requirements from plant to plant, and also identifies the need for more precise placement of nitrogen fertilizer. Plant spacing variability was reviewed by Nielsen (2001), showing a decrease in grain yields of 156 kg ha^{-1} for every 2.54 cm increase in the standard deviation within plant-to-plant spacing. Liu et al. (2004) reported dissimilar results where corn response to variation in plant emergence resulted in a loss of yield, while variation within-row spacing showed no significant effect on yield.

Knowledge of variability occurring at the by-plant level has led to the development of management tools and practices to treat such variation. Raun and Johnson, (1999) reported that maximum NUE and nitrogen fertilizer savings are dependant upon management decisions made at the appropriate field element size. Solie et al. (1996) defined the field element size as the resolution or area providing the most accurate measure of the available nutrient where the level of that specific nutrient changes with distance. In many instances this field element size occurs at the sub-meter or by-plant level. Management at resolutions larger than the field element size are likely to be less effective due to the existence of independent variation of nutrient levels all under one blanket treatment (Martin et al., 2005). To treat such variability at 1-m^2 resolution, differences can be detected by the computation of Normalized Difference Vegetative Index (NDVI) through the use of hand held multispectral reflectance optical sensors designed at Oklahoma State University and treated accordingly, resulting in an overall increase in NUE (Raun et al., 2002). In order to apply nitrogen fertilizer at the 1-m^2 resolution, optical sensor measurement should work in conjunction with variable rate applicators. Variable rate application of nitrogen fertilizer has the ability to increase nitrogen use efficiency by managing spatial variability (Inman et al., 2005).

Nitrogen use efficiency may also be increased by better managing nitrogen application timing. It is typical in corn production systems to apply nitrogen fertilizer in its entirety in the fall. While this practice may be convenient for some farmers due to the time of year and the fewer number of tasks at hand during the fall, it is not the most efficient method of nitrogen use. The application of nitrogen in the fall can lead to an increase in nitrogen loss due to factors such as denitrification and leaching, thus effecting the environment as well as profits. When nitrogen is applied after plant emergence, there is considerably less time for leaching and denitrification to occur (Vetsch and Randall, 2004). This is especially important to corn production in the Midwest due to excessive amounts of NO_3 leaching from tile-drained fields. Binder et al. (2000) reported that the delayed application of nitrogen can more accurately supply nitrogen as it is needed by the crop, thus further increasing NUE. Midseason application of nitrogen fertilizer will also allow farmers to take advantage of nitrogen additions provided by environmental interactions such as lightning and rainfall during the growing season. Additional nitrogen should be applied at mid-season, or around V-8, when the plant is taking up the most nitrogen (Binder et al., 2000). This will not only help to meet the plant's high demand for nitrogen at this time, but also increase NUE.

Producers are often slow to adopt new technologies. While some producers are using sensor based technology and variable rate applicators, others adopt new management practices in a stepwise fashion and work their way up to the adoption of newer technology. One management practice that aids producers in understanding the presence of variability within their fields is the utilization of site specific management zones (SSMZs). In order to characterize spatial variability in SSMZs, Inman et al. (2005) found that mean nitrogen uptake increased as the productivity potential of SSMZs increase, also showing significant differences in N uptake between SSMZs for multiple N application rates and site-years. They concluded that SSMZs exhibited less yield and N uptake variability within individual zones when compared to whole fields. Koch et al. (2004) found similar results showing the identification of SSMZs reduced nitrogen fertilizer applications and increased nitrogen use efficiency when variable rate nitrogen applications with a variable yield goal were used compared with uniform nitrogen management.

Farming by management zones can be beneficial in order to more accurately apply nitrogen fertilizers. While management zones express less variability as compared to whole fields, yearly variations in climate may result in over or under-application of nitrogen fertilizers. Schepers et al. (2004) found it successful to break fields into management zones and farm them independently, but due to temporal variability across spatial patterns in yields it may be beneficial to group the use of management zones with in-season remote sensing systems. Nitrogen use efficiency can be increased by utilizing in-season remote sensing along with variable rate fertilizer applications. These management practices have the ability to more accurately apply and determine the amount of nitrogen needed within a specific area, which is temporally dependent.

CHAPTER III

OBJECTIVES

The objectives of this study were to determine corn (*Zea mays* L.) nitrogen responsiveness as a function of interplant competition arising from delayed emergence and to assess nitrogen requirements with and without delayed emergence. The null hypothesis, Ho, states that: There is no advantage of modifying nitrogen fertilization rates on plants that are delayed in emergence by more than four days when compared to neighboring plants. The alternative hypothesis, Ha, states that: There is an advantage of varying nitrogen fertilization rates on plants that are delayed in emergence by more than four days when compared to neighboring plants.

CHAPTER III

METHODOLOGY

Site Description

Two experimental sites were established in the spring of 2007: both near Perry, OK at the Lake Carl Blackwell irrigated research station. The Lake Carl Blackwell research station soil series is classified as a Pulaski fine sandy loam (Fine Sandy Loam, Coarse-loamy, mixed, nonacid, thermic Typic Ustifluvent). Results from composite, preplant soil sample analysis are reported in Table 1.

Treatment Structure and Measurements

Dekalb (DKC 66-23) Bt corn hybrid was planted late March or early April at a seeding rate of 73779 plants ha at the Lake Carl Blackwell irrigated research station. With corn planted at 76.20 cm row spacing, the interplant distance was 17.78 cm. This 17.78 cm row spacing was achieved by hand planting. Equal inter-row spacing is essential for the analysis of this experiment, thus requiring hand planting.

A planting device was made from 3.81 cm square tubing to ensure that a planting depth of 5.08cm and proper interplant spacing (17.78 cm apart) was achieved. Bolts positioned 0.95cm deep were placed every 17.78 cm apart along the tube. This was then used to create fixed depressions in the soil and ensuring specific planting points for each of the seeds.

The experiment employed a randomized complete block design (RCBD) with 14 treatments and 3 replications. The employed treatment structure is reported in Table 2. Fifteen plants were planted in each row, which were further divided into five subgroups. The subgroups containing three plants had two plants planted on the same day and a delayed plant planted in the middle of the two plants. The delayed plant was planted 4, 7, and 10 days after the neighboring 2 plants (to simulate various delayed emergence scenarios) according to treatment. Each plot consisted of 1 row that was hand planted with 1 border row on each side. Hand planting ensures that each plant occupies an area of 0.13548 m^2, therefore yields can be determined accurately across each plot. Row and plant configuration are illustrated in Figure 2. Border rows were machine planted on the same day on each side of the rows which contained the delayed plants at a similar population.

A preplant fertilizer rate of (67 kg N ha^{-1}) was applied using streamer nozzle before planting using UAN (28-0-0). Each location was side-dress fertilized at the V8 growth stage using UAN (28-0-0). Varvel et al. (1997) noted that yield potentials for corn appear to be set during the early growth stages prior to V8, thus additional nitrogen applications to the crop should take place very near the V8 growth stage. Three side-dress fertilizer rates of UAN (28-0-0) (44.8, 67.2, and 89.6 kg ha^{-1}) were applied by plant according to treatment.

The subgroups within each row were tagged in sets of three and hand harvested. For each treatment three of the five subgroups were selected for harvest. For each of the three subgroups, each plant was be harvested and bagged separately. Each bag was individually weighed wet, dried in an air forced oven at 66^0 C and weighed again for moisture determination. Percent moisture will be determined by taking the wet weight minus the dry weight and dividing by the wet weight. Grain yield for all treatments was expressed using 15.0% moisture. Grain yields from each plant was determined and collected for analyses. Analysis of variance to determine treatment effects was determined using SAS (2001). Significant differences between treatments was evaluated using the standard error of the difference (SED) between two equally replicated means. Furthermore, non-orthogonal single-degree-of-freedom contrasts were performed to further evaluate treatment effects.

CHAPTER IV

FINDINGS

At the Lake Carl Blackwell sites (1) and (2), in the 2007 crop year, extreme rainfall amounts were received above the monthly and yearly averages. Large portions of this rainfall were received at planting, resulting in less than optimum plant emergence and homogeneity among treatments. In 2008, the Lake Carl Blackwell sites (1) and (2) encountered significant damage in all treatments due to feral hogs. The severity of this damage prohibited any yield data collection for the 2008 crop year.

Site Year Lake Carl Blackwell (1), 2007

The response to fertilizer N resulted in insignificant differences when comparing treatments. (Table 3). Furthermore, limited differences were noted for topdress N rates (0, 45, 90) when 67 kg ha^{-1} N was applied preplant. Analysis of variance reporting the significance of treatment effects on corn grain yield is reported in Table 4.

At the Lake Carl Blackwell (1) site in 2007, delayed planting by 7 days (treatment 10), with 67 kg ha^{-1} N rate applied preplant uniformly, and a 45 kg ha^{-1} sidedress N resulted in a higher average grain yield than any other treatment, at 12,161 kg ha^{-1} (Figure 3). Delayed planting by 10 days, with 67 kg ha^{-1} N rate applied preplant uniformly, and no sidedress application of N (treatment 12) resulted in a lower average grain yield than other treatments, at 2,723 kg ha^{-1} (Figure 3). However, both treatment means were derived from a limited data set where observations per cell were unequal to those of other treatments. Excluding the two previously mentioned treatments, all other treatment means differed only by 2,562 kg ha^{-1}. These results, along with unequal observations per cell were in part caused by uncommonly high rainfall amounts at planting times, causing uneven plant emergence and varied yields.

According to the Oklahoma Climatological Survey (http: climate.ok.gov contact) the average yearly rainfall for central Oklahoma (the region where research took place) is 940 mm, but from January 1 to December 31, 2008, this region accumulated rainfall amounts totaling approximately 1330 mm. Rainfall received during this time was 140% of the average amount received annually, of which 690 mm were received in the months of May and June. These abnormally high amounts of rainfall proved to be problematic when attempting to control plant emergence, therefore impacting overall yield differences between treatments.

Average corn grain yields within a three plant sequence over all N rates where the center plant (#2) was delayed 0, 4, 7, and 10 days after plants #1 and #3 showed that the greatest reduction in yield (of plant #2) was seen when plants were delayed by 10 days in planting (Figure 4). When the center plant (#2) was delayed by 4, 7, or 10 days after plants #1 and #3, a reduction in yield was always documented compared to plants #1 and #3, although not always significant. Over all N rates, plant #2 showed no significant difference in yield compared to plants #1 and #3 when plant #2 was planted on the same day (zero days delayed in planting). However, when averaged across all treatments, by-plant yields of neighboring plants (#1 and #3) were significantly different than the center plant (#2) at the .01 probability level (Table 5).

Yield averages, where the center plant (#2) was planted 0, 4, 7, and 10 days after plants #1 and #3 are reported in Figures 5-7, where 67 kg ha-^{1} of N was applied preplant uniformly with an additional 0, 45, and 90 kg N ha-^{1} applied sidedress at the V8 growth stage. Yield averages of the three plant sequences were greatest when the center plant (#2) was planted on the same day. When all three plants were planted on the same day, neighboring plants did not necessarily produce larger by plant grain yields as compared to other treatments. However, by-plant yields among three plant sequences where the center plant (#2) emerged on the same day as neighboring plants (#1 and #3), were commonly smaller than yields found within three plant sequences of treatments where the center plant (#2) was delayed in emergence by 4, 7, or 10 days. Findings in Table 5 outline the elevated yield levels of neighboring plants (#1 and #3) as well as the suppressed yields of plant (#2) averaged across all treatments. A statistically significant trend reported in (Table 6) shows an increase of neighboring plant (#1 and #3) yields as the center plant (#2) was delayed in emergence by an increasing number of days, regardless of the amount of N applied at sidedress. When neighboring plants (#1 and #3) yielded higher than the center plant (#2), the average yield of the entire three plant sequence often suffered dramatically. This can be attributed to the greater depression in yield of the center plant (#2) as it was delayed in emergence by 4, 7, or 10 days when compared to neighboring plants (#1 and #3). Even so, when the center plant (#2) was planted 4 or 7 days later, the average yields of each three plant sequence remained greater than the average yields of three plant sequences where the center plant (#2) was not delayed (zero days delayed in emergence).

The only situation where the average yields of three plant sequences did not out perform that of sequences where the center plant (#2) was not delayed (zero days delayed in emergence) was when three plant sequences contained a center plant (#2) delayed in emergence by 10 days. In this situation, the average yield level of the center plant (#2) was only 7% of the average yields found within three plant sequences where the center plant (#2) was not delayed in emergence (zero days delayed). This extremely large depression in yield of the center plant (#2) resulted in a substantial decline in the average yield of the three plant sequence. Yield levels of neighboring plants (#1 and #3), when the center plant (#2) was delayed in emergence by 4 or 7 days, were elevated to such an extent that the average yields of the three plant sequences were greater than when the center plant (#2) was not delayed in emergence (zero days delayed in emergence).

Determining the relative yield of a crop is not necessarily a useful predictive tool in crop research. This is due to the fact that by the time relative yields can be measured the crop season is over. However, relative yields are useful if one knows what factors influenced those yields, and can monitor the crop in order to amend such factors. Figure 8 reports the relative yield of three plant sequences, where the center plant was delayed 0, 4, and 10 days after neighboring plants, where 67 kg ha^{-1} N was applied preplant uniformly, and with no added sidedress N. The relative yield is derived by taking the center plant yield value and dividing it by the average yields of the two neighboring plants within a three plant sequence. Center plants emerging zero days after their neighboring plants within a three plant sequence resulted in the highest relative yields compared to other treatments. As expected, when the three plant sequence had even emergence, the relative yield levels were normally 100% or more of the actual yield of the three plant sequence it was derived from. Center plants whose emergence was delayed by 4 days compared to neighboring plants within a three plant sequence resulted in substantially lower relative yield levels than the previously mentioned treatments. Relative yields for the three plant sequences where the center plant was delayed in emergence by 4 days were nearly 0%. Relative yields for the three plant sequences where the center plant was delayed in emergence by 7 days were unable to be determined since only sporadic observations were available. The relative yield of three plant sequences where the center plant was delayed in emergence by 10 days had very low relative yields, at or near 0% versus the actual yield of the three plant average.

67 kg ha $^{-1}$ preplant N + 45 kg ha^{-1} N sidedress

The relative yields of treatments where the center plant was delayed 0, 4, 7, and 10 days after neighboring plants, where 67 kg ha^{-1} of N was applied preplant uniformly, and with an additional 45 kg ha^{-1} of N applied sidedress at the V8 growth stage are reported in (Figure 9). Three plant sequences where the center plant was delayed in emergence by 0 days compared to neighboring plants resulted in higher relative yields than three plant sequences where the center plants were delayed in emergence by 4, 7, or 10 days with the previously stated N amendments. The relative yield of three plant sequences where the center plant emerged 4 days after neighboring plants reached a maximum of 24% of the actual yield obtained from the three plant sequence of which it was derived. Several of the three plant sequences among the same treatment had very low relative yields. The relative yield of the center plant (#2) as compared to the average of the neighboring plants (#1 and #3) when planted 7 days after neighboring plants was 25%. The relative yield of all but one three plant sequence where the center plant was delayed in emergence by 10 days compared to neighboring plants resulted in 0% of the actual yield. One three plant sequence within this treatment had a relative yield of 11%. Within all treatments reported in Figure 9, the actual yield levels of three plant sequences were the lowest among those containing center plants delayed in emergence by 0 days compared to neighboring plants. This can be attributed to the higher yields of neighboring plants when the center plant was delayed in emergence.

67 kg ha^{-1} N preplant + 90 kg ha^{-1} N sidedress

The relative yields of treatments where the center plant was delayed 0, 4, 7, and 10 days after neighboring plants, where 67 kg ha^{-1} of N was applied preplant uniformly, and with an additional 90 kg ha^{-1} of N applied sidedress at the V8 growth stage are reported in Figure 10. Center plants emerging zero days after their neighboring plants resulted in the highest relative yields compared to other treatments. Relative yield levels were normally close to 100% or more of the actual yield with no delay in planting for the center plant. When three plant sequences contained center plants that emerged 4, 7, or 10 days after neighboring plants, relative yield levels were much lower. Center plants emerging 4 days later than neighboring plants resulted in relative yields not greater than

9% of the actual yield from the three plant sequence of which it was derived. Center plants emerging 7 days later than neighboring plants within a three plant sequence resulted in relative yields that were less than 1% of the actual yield from the three plant sequence. These three plant sequences containing center plants delayed in emergence by 7 days had the lowest relative yields of all treatments with the same N amendments. Three plant sequences where the center plant was delayed in emergence by 10 days had greater actual yields than other three plant sequences. However, this was not due to higher relative yields. The largest relative yield among three plant sequences containing center plants delayed in emergence by 10 days was 24%, with others below 10%.

When additional N was applied sidedress at levels of 0, 45, and 90 kg ha^{-1}, three plant sequences containing center plants that emerged on the same day as neighboring plants (zero days delayed in planting) resulted in higher relative yields than any other treatments (Figures 8-10). Likewise, center plants that emerged 10 days after neighboring plants resulted in the lowest relative yields. Although relative yields of plants with even emergence (zero days delayed in planting) were higher than other treatments, many three plant sequences containing center plants emerging 4, 7, or 10 days after neighboring plants had higher actual yields.

Yield Depression

The number of days a center plant was delayed in emergence compared to neighboring plants played a critical role in determining average corn grain yield depression of three plant sequences (Figure 11). When center plants were not delayed in emergence compared to neighboring plants (zero days delayed in emergence), the three plant sequence suffered a depression in yield when a treatment of 67 kg ha^{-1} N was applied preplant uniformly with an additional 45 kg ha^{-1} N applied at sidedress. It can be assumed that this yield depression was potentially caused by unfavorable weather and soil moisture conditions at planting. A negative depression in yield was recorded when center plants among a three plant sequence were not delayed in emergence compared to neighboring plants (zero days delayed in emergence), when a treatment of 67 kg ha^{-1} N was applied preplant with no additional N applied sidedress. Likewise, when an additional 90 kg ha^{-1} N was applied at sidedress, this same negative depression in yield was seen. In these situations, a negative yield depression can be viewed as an increase in average yields among three plant sequences. When center plants were delayed by 4 days in emergence compared to neighboring plants within a three plant sequence, a depression in yield was always documented. A preplant treatment of 67 kg N ha^{-1} resulted in the largest average yield depression of 8,270 kg ha^{-1} (Figure 11). Similar results in yield depression were documented when an additional 45 and 90 kg ha^{-1} of N was applied at sidedress. These treatments provided average grain yield depressions of 5,168 and 7,635 kg ha^{-1} (Figure 11). Average yield depressions of sequences where the center plant was delayed in emergence by 7 days were 12,101 kg ha^{-1} among treatments of 67 kg ha^{-1} of N preplant with an additional 45 kg ha^{-1} of N at sidedress, and 4,648 kg ha^{-1} among treatments of 67 kg ha^{-1} of N preplant with an additional 90 kg ha^{-1} of N at sidedress. Center plants emerging 10 days after neighboring plants resulted in average yield depressions of; 4,085 kg ha^{-1} from a treatment of 67kg ha^{-1} of N applied preplant, 8,867 kg ha^{-1} from a treatment of 67 kg ha^{-1} of preplant N and 45 kg ha^{-1} of N applied at sidedress, and 6,668 kg ha^{-1} from a treatment of 67 kg ha^{-1} of preplant N with an additional 90 kg ha^{-1} of N applied at sidedress. Over all treatments, neither days of delayed emergence or N rate was found to have a significant effect on yield depression. However, a numerical trend can be seen where sequences containing center plants delayed in emergence by 4, 7, or 10 days result in a substantial depression of yield.

Percent of Maximum Corn Grain Yield

The percent of maximum corn grain yield expressed as a function of planting delay in days showed significant grain yield reductions in a linear fashion as planting was delayed from 0 to 10 days (Figure 12). The percent of maximum grain yield was reduced by 5% when emergence was delayed 4 days, 59% when emergence was delayed by 7 days, and 95% when emergence was delayed by 10 days, all treated with 67 kg ha^{-1} of N preplant and an additional 45 kg ha^{-1} of N applied at sidedress (Figure 12). This treatment showed a very strong relationship between the percent of maximum corn grain yield and days of delayed emergence, with an R^2 value of 0.92 (Figure 12). Similarly, other treatments showed a linear trend in the gradual decline of the percent of maximum grain yield, but did not have quite as strong of a relationship. For sequences where emergence of the center plant was delayed by 7 days, the percent of maximum grain yield declined to less than 26% of the average of the two border plants, regardless of N fertilization amounts (Figure 12). Also, sequences where emergence of the center plant was delayed by 10 days, the percent of maximum grain yield declined to less than 12% of the average of the two border plants, regardless of N fertilization amounts (Figure 12).

When comparing the percent of maximum corn grain yields averaged over all three plant sequences among the same N treatment, days of delayed emergence proved to be significant at the 0.01 level (Table 7). The amount of variation in the percent of maximum corn grain yields is better explained by days of delayed emergence, rather than N rate. In general, there were very few differences as a result of different fertilizer N rates at this site.

Site Year Lake Carl Blackwell (2), 2007

A significant response to fertilizer N was observed when comparing treatments 3 and 4 vs. 1, and comparing 6 and 7 vs. 1 (Table 8). Significant responses were also observed when comparing treatments 5-7 vs. 8-11 (Table 8). However, limited differences were noted for topdress N rates (0, 45, 90) when 67 kg ha^{-1} N was applied preplant.

Data concerning the exact date of emergence were not recorded for each plant within three plant sequences at this site. Excessive rainfall amounts at planting were less than desirable, causing soil temperatures to decline and the soil profile to be saturated. These issues seemed to slow the germination process of seeds that were previously planted, as well as prevent germination for a period of time among seeds planted during high moisture conditions, which had the potential to compromise individual treatments. However, the large number of three plant sequences collected was expected to deliver accurate estimates of the average grain yield.

At the Lake Carl Blackwell (2) site in 2007, the main effect of treatment proved to be significant (PR > F= 0.052). A treatment (6) of delayed planting by 4 days, 67 kg ha^{-1} N rate applied preplant uniformly, and a 45 kg ha^{-1} sidedress N rate resulted in a higher average grain yield than any other treatment, at 16,172 kg ha^{-1} (Figure 13). The check treatment (1) of no preplant or sidedress N applications, along with even emergence (zero days delayed) resulted in a lower average grain yield than any other treatments, at 10,611 kg ha^{-1} (Figure 13). Excluding the two previously mentioned treatments, all other treatment means differed only by 3,853 kg ha^{-1}. Analysis of variance reporting the significance of treatment effects on corn grain yields is reported in Table 9. The main effect of treatment proved to be significant.

Average corn grain yields of each plant within a three plant sequence over all N rates where the center plant (#2) was delayed in emergence 0, 4, 7, and 10 days after plants #1 and #3 showed the greatest reduction in yield (of plant #2) was seen when plants were delayed by 10 days in planting (Figure 14). Although not always significant, a reduction in yield could be seen when comparing the center plant (#2) delayed in emergence by 4, 7, or 10 days to plants #1 and #3 (Figure 14). By-plant grain yields from each three plant sequence averaged across all treatments showed that neighboring plant (#1) was significantly different than the center plant (#2) at the 0.005 probability level (Table 10). However, these by-plant yields also showed that neighboring plant (#3) was not significantly different than the center plant (#2) (Table 10). It was apparent that plant to plant variability was encountered in this study since average yields of plants (#1 and #3) differed. However, this does not negate the effect of yield depression from the center plant when compared to its neighbors (Figure 14). The difference in yield between these two plants did not prove to be significant, but is apparent within each three plant sequence. Although plant spacing was held constant between all plants, plant (#3) appeared to have more interplant competition with the center plant (#2). This could have potentially caused the significantly similar by-plant mean grain yields of plants (#2) and (#3), as well as their significant difference to plant (#1) when averaged across all N rates (Table 10).

Yield averages of three plant sequences, where the center plant (#2) was planted 0, 4, 7, and 10 days after neighboring plants (#1) and (#3) are reported in Figures 15-17. Yield averages of three plant sequences contain a uniformly applied preplant N rate of 67 kg ha^{-1} with an additional 0, 45, and 90 kg N ha^{-1} at the V8 growth stage (Figures 15-17). Among treatments of 67 kg N ha^{-1} applied uniformly preplant with no additional N at sidedress, the average yield of three plant sequences containing center plants (#2) delayed in emergence by 4 days when compared to neighboring plants (#1 and #3) was greater than other treatments at 12,891 kg ha^{-1} (Figure 15). The average yield of three plant sequences containing even emergence among all plants (zero days delayed in emergence) yielded slightly lower at 12,194 kg ha^{-1} (Figure 15). Three plant sequences where the center plant (#2) was delayed in emergence by 10 days when compared to neighboring plants (#1 and #3) resulted in the lowest average grain yield at 11,769 kg ha^{-1} (Figure 15). A slightly higher average yield was reported when center plants were delayed in emergence by 7 days compared to neighboring plants (#1 and #3) at 12,160 kg ha^{-1} (Figure 15).

Yield averages of three plant sequences with an additional 45 kg N ha^{-1} applied at sidedress showed dissimilar results compared to the previously mentioned treatments.

Three plant sequences containing center plants (#2) delayed in emergence by 4 days when compared to neighboring plants (#1 and #3) yielded higher than other sequences with 0, 7, or 10 days of delayed emergence (Figure 16). However, sequences containing 10 day delay center plants (#2) yielded just slightly lower (Figure 16). The sequences containing center plants (#2) delayed by 0 days in emergence yielded lower than all other treatments except for sequences containing a 7 day delay in center plant (#2) emergence. This could be due in part by the poor planting conditions at the original time of planting. During the original time of planting, when center plants that were to represent no delay in emergence were planted, soil moisture levels were exceptionally high. Other treatments in which center plants were planted 4, 7, and 10 days later may have potentially encountered more optimum planting conditions. Therefore, this could partially account for the exceptionally lower yields among treatments containing center plants delayed by 0 days in emergence. Center plants (#2) within three plant sequences which were planted 4 and 7 days after neighboring plants (#1 and #3) yielded noticeably less than plant #1 (Figure 16). However, the same center plant (#2) yielded higher than neighboring plant (#3) (Figure 16). A definite pattern of higher yielding neighboring plants (#1 and #3) and a lower yielding center plant (#2) was recorded for both 7 and 10 day delay three plant sequences (Figure 16). Even so, average three plant sequence yields for these two treatments differed by 1,969 kg ha^{-1}, while the range of all sequences within similar N rates differed only by 2,328 kg ha^{-1} (Figure 16).

Yield averages of three plant sequences with 67 kg ha^{-1} preplant N and 90 kg ha^{-1} N applied at V8 where center plants (#2) were delayed by 0, 4, 7, and 10 days in emergence compared to neighboring plants (#1 and #3) resulted in minimal differences between one another (Figure 17). Three plant sequences where the center plant (#2) was delayed in emergence by 4, or 7 days resulted in near identical yields (Figure 17). Both of these sequences had a noticeable depression in yield of the center plant (#2) compared to plant (#1), but yielded only slightly less than plant (#3) (Figure 17). The yield averages of three plant sequences where center plant (#2) was delayed in emergence by 10 days compared to neighboring plants (#1 and #3) showed the most drastic depression in yield of plant (#2), as well as the lowest three plant yield average of all sequences within the same N rate treatment (Figure 17). The average yield of neighboring plants (#1 and #3) was 14,240 kg ha^{-1}, while the average yield of the center plants (#2) were 8,720 kg ha^{-1} (Figure 17).

Within all N rates and days of delayed emergence, three plant sequence yield averages behaved quite unpredictably. Regardless of N rate or days of delayed emergence, many sequences showed a depression in yield of the center plant (#2) compared to neighboring plants (#1 and #3) (Figures 15-17). Some sequences showed center plants (#2) yielding higher than neighboring plant (#3) (Figures 15-17). Even so, a numerical trend can be seen that outlines a greater yield average of neighboring plants (#1 and #3) when compared to center plants (#2) (Table 11). This trend is noticed over all N rates and for differing days of delayed emergence among center plants (#2) within three plant sequences (Table 11).

Yield Depression

Average corn grain yield depression of three plant sequences is highly influenced by the number of days a center plant is delayed in emergence compared to its neighboring plants (Figure 18). When center plants were not delayed in emergence compared to neighboring plants (zero days delayed in emergence), the three plant sequence suffered a depression in yield when a treatment of 67 kg ha^{-1} N was applied preplant uniformly with an additional 90 kg ha^{-1} N applied sidedress (Figure 18). It can be assumed that this yield depression was potentially caused by unfavorable weather and soil moisture conditions at planting. A negative depression in yield was recorded when center plants among a three plant sequence were not delayed in emergence compared to neighboring plants (zero days delayed in emergence), when a treatment of 67 kg ha^{-1} N was applied preplant with no additional N applied sidedress (Figure 18). Likewise, when an additional 45 kg ha^{-1} N was applied at sidedress, a negative depression in yield was seen once again (Figure 18). A negative yield depression can be viewed as an increase in the average yields for the 0 and 4 day delayed planting at the 67 kg ha^{-1} N rate.

Averaged over all N rates, sequences containing center plants delayed in emergence by 4 days when compared to neighboring plants, where 67 kg ha^{-1} N was applied preplant uniformly also showed a negative yield depression (Figure 18). However, when an additional 45 or 90 kg ha^{-1} of N was applied at sidedress, a depression in yield was always present (Figure 18). When center plants were delayed by 7 days in emergence compared to neighboring plants within a three plant sequence, a depression in yield of no less than 1,745 kg ha^{-1} was recorded regardless of N rate (Figure 18). Average yield depressions of three plant sequences were the highest when center plants were delayed in emergence by 10 days compared to neighboring plants (Figure 18). An average yield depression of over 4,160 kg ha^{-1} could be seen across all N rates as three plant sequences contained center plants delayed in emergence by 10 days. Over all treatments, N rate was not found to have a significant effect on yield depression. However, yield depression was significantly affected by differing days of delayed emergence of center plants within a three plant sequence at the 0.05 level (Table 12). The effect of delayed emergence on yield depression noticeably intensified as the number of days a center plant was delayed in emergence increased.

Percent of Maximum Corn Grain Yield

The percent of maximum corn grain yield expressed as a function of planting delay in days indicate significant grain yield reductions in a linear fashion as planting was delayed from 0 to 10 days (Figure 19). Treatments where 67 kg N ha^{-1} were applied preplant uniformly resulted in the percent of maximum grain yield being reduced by 2% when emergence of the center plant of a three plant sequence was delayed by 4 days (Figure 19). When emergence was delayed by 7 days a 20% reduction took place, and a 38% reduction in the percent of maximum grain yield was recorded when emergence was delayed by 10 days (Figure 19). This treatment showed a very strong relationship between the percent of maximum corn grain yield and days of delayed emergence, with an R^2 value of .91 (Figure 19). Treatments where an additional 45 and 90 kg N ha^{-1} were applied sidedress at V8 showed a similar linear decline in yields as the number of days a center plant was delayed in emergence increased (Figure 19). However, these treatments did not have nearly as strong of a relationship between days of delayed emergence and the percent of maximum grain yield when compared to the 67 kg N ha^{-1} preplant treatment (Figure 19). When comparing the percent of maximum corn grain yields averaged over all three plant sequences and N rates, days of delayed emergence proved to be significant at the 0.05 level (Table 13). However, N rate did not have a significant effect on the percent of maximum corn grain yields. The percent of maximum corn grain yields can be better explained by the different days of delayed emergence, rather than N rate. This site year resulted in very few differences caused by N fertilization, where as days of delayed emergence played a significant role in altering grain yields.

Corn Grain Yield as a Function of Delayed Planting

For both Lake Carl Blackwell sites (1) and (2), the relationship between average corn grain yield and days planting was delayed, for preplant and preplant + sidedress N rate combinations are illustrated in Figures 20, and 21, respectively. For each day delay in planting (assuming emergence was equally delayed) corn grain yields decreased by 1034 kg/ha, when 67 kg N/ha was applied preplant (Figure 20, R^2 = 0.83, LCB 1). Those treatments receiving supplement fertilizer N sidedress did not result in reliable relationships that could be discussed. Similarly, yields decreased by 178 kg/ha for every day delay in planting at LCB 2 (Figure 21), for the 67 kg N/ha preplant N rate. Alternatively, results for this relationship were inconclusive when a sidedress N rate was applied on top of the 67 kg N/ha preplant N rate. It is possible that by applying added sidedress N, the reduction in yield due to the delayed planting was suppressed at Lake Carl Blackwell (2) since at this site a significant response to applied N was found (Table 8). However, this same interpretation would not be applicable at Lake Carl Blackwell (1) since the response to sidedress fertilizer N was small.

Site Year Lake Carl Blackwell (1) and (2), 2008

At the Lake Carl Blackwell sites (1) and (2), in the 2008 crop year, plant emergence and crop growth were carefully monitored throughout the growing season to ensure homogeneity among treatments. Substantial crop damage began to occur at both sites near the end of grain fill due to pressure from feral hogs. At the time of harvest upwards of 95% of the crop had been destroyed. No harvest data were able to be collected for both sites in 2008.

Field notes taken during the growing season of 2008 showed that treatments where plant (#2) was delayed by more than 4 days, regardless of fertility, were substantially shorter in height. This trend appeared to increase in severity as plant (#2) was delayed by 7 or 10 days. A substantial depression in yield could be observed from 2007 data when emergence of center plants (#2) was delayed by 4, 7, and 10 days. The amount of yield depression had no interaction with N rate, but a trend showing an increase in yield depression could be found as emergence was further delayed. Observations of vegetative growth, as well as ear development and grain fill supported this trend in 2008. In all cases, when the height of plant (#2) was shorter than its two neighboring plants, corn ears also suffered suppression in size. These plants delayed by more than 4 days were visibly smaller, capable of receiving less solar radiation, and appeared to have a smaller, less developed root system to utilize mobile nutrients such as nitrogen in the root system zone.

Uneven emergence in plant stands makes possible the rise of interplant competition, which can be documented throughout the growing season by plant height, ear size, and overall vigor, resulting in a theoretical depression of yield which can be exacerbated regardless of sidedress fertilizer amendments as plants approach an emergence date of 7 or 10 days after neighboring plants. Although grain yields were unable to be collected, the observed characteristics of plant growth and response to delayed emergence and nitrogen fertilization throughout the growing season leads to the theoretical conclusion that when plants are delayed in emergence by 7 or 10 days compared to their neighboring plants, the center plant as well as the 3 plant sequence will suffer a significant loss in yield. Furthermore, it should be noted that the addition of sidedress fertilizer N to delayed plants had either much less or little effect on grain yields for the delayed plants when compared to neighboring plants. Observed differences in plant height, leaf area, and ear size throughout the growing season in 2008 illustrated that delayed emerged plants rarely acted as a weed in relation to neighboring plants. Despite the fact that delayed plants may have competed for water and nutrients, the larger, more vigorous neighboring plants continued growth in a normal matter without losses in yield.

Solar radiation is a key factor in the interplant competition seen among delayed and normal emerging plants. The lack of sunlight, along with smaller leaf area of the plants delayed in emergence by more than 4 days to intercept light, proved to depress overall growth and development of delayed emerging plants to an extent where competition for nutrients among neighboring plants performed insignificant damage to grain yields and plant health of these neighboring plants. Root mass and development of plants where emergence was delayed 7 or 10 days lacked size and occupied less overall area than neighboring plants, therefore having less ability to obtain and compete for valuable nutrients. The inability of delayed emerging plants to acquire sufficient amounts of nutrients and sunlight throughout its lifecycle results in a less than optimum yield level, as well as a significant depression in yield when compared to neighboring plants whose emergence is even.

CHAPTER V

CONCLUSION

Limited response to applied fertilizer N was found at Lake Carl Blackwell (1), 2007. Also, small differences were noted for topdress N rates (0, 45, 90) when 67 kg N ha^{-1} was applied preplant. For each day delay in planting (assuming emergence was equally delayed) corn grain yields decreased by 1034 kg ha^{-1}, when 67 kg N ha^{-1} was applied preplant. While no significant response to fertilizer N was achieved at Lake Carl Blackwell (1), 2007, delayed planting proved to have a significant effect on corn grain yields at both sites. At site year Lake Carl Blackwell (2), 2007, a yield reduction of 178 kg ha^{-1} for every day delay in planting for the 67 kg N ha^{-1} preplant N rate was observed. Similar to Lake Carl Blackwell (1), 2007, site year Lake Carl Blackwell (2), 2007 resulted in limited differences for topdress N rates (0, 45, 90) when 67 kg N ha^{-1} was applied preplant. However, a significant response to fertilizer N was observed when comparing treatments within this site. Conflicting response to applied fertilizer N when comparing sites reinforces the variability of fertilizer N from site to site and year to year. Over both sites and years, average by-plant corn grain yields within three plant sequences regardless of sidedress N rates where the center plant (#2) was delayed in planting by 0, 4, 7, and 10 days after neighboring plants #1 and #3 showed the greatest reduction in yield (of the delayed plant #2) among treatments where planting was delayed by 10 days. The effect of sidedress N varied from site year to site year, as did days of delay in planting. When sidedress N was applied, in addition to preplant N, yield reductions due to delayed planting were less pronounced. Over all sites evaluated in this work, delayed emergence decreased average grain yields thus highlighting the need to homogenize plant stands and corresponding emergence.

Knowledge of by-plant corn grain yields and interplant interactions are vital for the progression of treating variability within corn production systems. This research should assist researchers and producers to better understand by-plant differences such as interplant competition arising due to uneven emergence among corn stands. The ability to quantify the effects of variability within corn emergence will aid producers in management decisions such as replanting later emerging areas of a field, or possibly treating these areas independently at a resolution that will allow fertilizer rates to be adjusted by-plant. Future research should be conducted to better understand the response of treating corn at the by-plant level, as well as fine tuning the methodology to treat fields at this resolution.

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Table 1. Initial surface (0-15 cm) soil test results prior to experiment initiation at Lake Carl Blackwell, OK, 2007.

Location, depth	K mg kg	P mg kg	NH4-N mg kg	NO3-N mg kg	pH
LCB (1) 0-15 cm	105	27	17	3.2	6.15
LCB (2) 0-15 cm	144	45	28	4.3	5.63

NH_4-N and NO_3-N – 2 M KCL extract; P and K – Mehlich-3 extraction; pH – 1:1 soil:deionized water

Table 2. Treatment structure employed at Lake Carl Blackwell, 2007 and 2008 evaluating nitrogen response as a function of delayed emergence on resultant corn grain yields.

Treatment	Pre-Plant Nitrogen (kg ha $^{-1}$)	Days Delayed in Emergence	Side-Dress Nitrogen (kg ha $^{-1}$)
1	0	0	0
2	67	0	0
3	67	0	45
4	67	0	90
5	67	4	0
6	67	4	45
7	67	4	90
8	0	7	67
9	67	7	0
10	67	7	45
11	67	7	90
12	67	10	0
13	67	10	45
14	67	10	90

Table 3. Non-orthogonal single-degree-of-freedom contrasts evaluating treatment effects, Lake Carl Blackwell (1), 2007.

Contrast Treatments	Degrees of Freedom	Mean Squares	Pr >F
1 vs. 3 and 4	1	645	0.98
1 vs. 6 and 7	1	1054687	0.56
2-4 vs. 5-7	1	627483	0.65
2-4 vs. 8-11	1	400535	0.72
5-7 vs. 8-11	1	2910	0.97

Table 4. Analysis of variance for corn grain yields as influenced by days of delayed emergence and N rate, Lake Carl Blackwell (1), 2007.

Source of Variation	Degrees of Freedom	Mean Squares	PR > F
Rep	2	1603564	0.604
Treatment	12	40405613	0.326
Error	10	3026492	

SED=1420

Table 5. By-plant mean grain yields of each plant within a three plant sequence over all N rates and days of delayed emergence, Lake Carl Blackwell (1), 2007.

Plant Number (Orientation)	By-Plant Mean Grain Yields kg ha^{-1}
1	7010 a
2	1817 b
3	7049 a

SED=1522

Means in a column followed by the same letters are not significantly different at .01 probability levels

Table 6. Average by-plant grain yields of each plant within a three plant-sequence over all preplant and topdress N rates where the center plant (#2) was delayed 0, 4, 7, and 10 days after plant (#1) and (#3), Lake Carl Blackwell (1), 2007.

Days of Delayed Emergence	Neighboring Plant Yield Average kg ha^{-1} Plant (#1)	Center Plant Yield Average kg ha^{-1} Plant (#2)	Neighboring Plant Yield Average kg ha^{-1} Plant (#3)	Neighboring Plant Yield Average kg ha^{-1} Plant (#1 and #3)	Three Plant Sequence Yield Average kg ha^{-1} Plant (#1, #2, #3)
0	4191	4706	5208	4700	4874
4	8053	876	7748	7900	5422
7	8203	1364	9083	8643	6216
10	7595	322	6157	6876	4174

SED=1522

Table 7. Percent of maximum grain yields of three plant sequences expressed as a function of delayed emergence in days, averaged over all N rates, Lake Carl Blackwell (1), 2007.

Days of Delayed Emergence	Average Percent of Maximum Grain Yields
0	95 a
4	21 b
7	8 b
10	5 b

SED=21

Means in a column followed by the same letters are not significantly different at the 0.01 probability level.

Table 8. Non-orthogonal single-degree-of-freedom contrasts evaluating treatment effects, Lake Carl Blackwell (2), 2007.

Contrast Treatments	Degrees of Freedom	Mean Squares	Pr >F
1 vs. 3 and 4	1	18632544	0.03
1 vs. 6 and 7	1	30740341	0.01
2-4 vs. 5-7	1	7100998	0.17
2-4 vs. 8-11	1	1445480	0.53
2-4 vs. 12-14	1	655952	0.67
5-7 vs. 8-11	1	16410925	0.04
5-7 vs. 12-14	1	11307050	0.08
12-14 vs. 8-11	1	80779	0.88

Table 9. Analysis of variance for corn grain yields as influenced by days of delayed emergence and N rate, Lake Carl Blackwell (2), 2007.

Source of Variation	Degrees of Freedom	Mean Squares	PR > F
Rep	2	15397105	0.03
Treatment	13	7616195	0.05
Error	25	3607770	

SED=1550

Table 10. By-plant mean grain yields of each plant within a three plant sequence over all N rates and days of delayed emergence, Lake Carl Blackwell (2), 2007.

Plant Number (Orientation)	By-Plant Mean Grain Yields kg ha^{-1}
1	15124 a
2	11721 b
3	12540 b

SED=833

Means in a column followed by the same letters are not significantly different at the 0.01 probability level.

Table 11. Average by-plant grain yields of each plant within a three plant-sequence over all preplant and topdress N rates where the center plant (#2) was delayed 0, 4, 7, and 10 days after plant (#1) and (#3), Lake Carl Blackwell (2), 2007.

Days of Delayed Emergence	Neighboring Plant Yield Average kg ha^{-1} Plant (#1)	Center Plant Yield Average kg ha^{-1} Plant (#2)	Neighboring Plant Yield Average kg ha^{-1} Plant (#3)	Neighboring Plant Yield Average kg ha^{-1} Plant (#1 and #3)	Three Plant Sequence Yield Average kg ha^{-1} Plant (#1, #2, #3)
0	14398	11739	11462	12930	12604
4	15637	13761	13171	14404	14525
7	15022	10852	12273	13647	12739
10	15440	10535	13255	13997	12837

SED=833

Table 12. Yield depression of three plant sequences as influenced by delayed emergence, averaged over all N rates, Lake Carl Blackwell (2), 2007.

Days of Delayed Emergence	Yield Depression kg ha^{-1}
0	259 a
4	643 a
7	2131 ab
10	4163 b

SED=1094
Means in a column followed by the same letters are not significantly different at the 0.05 probability level.

Table 13. Percent of maximum grain yields of three plant sequences expressed as a function of delayed emergence in days, averaged over all N rates, Lake Carl Blackwell (2), 2007.

Days of Delayed Emergence	Average Percent of Maximum Grain Yields
0	102 a
4	98 a
7	88 ab
10	74 b

SED=7
Means in a column followed by the same letters are not significantly different at the 0.05 probability level.

Figure 1. Planting device constructed to establish fixed depths, and distances between plants for all sites, 2007-2008.

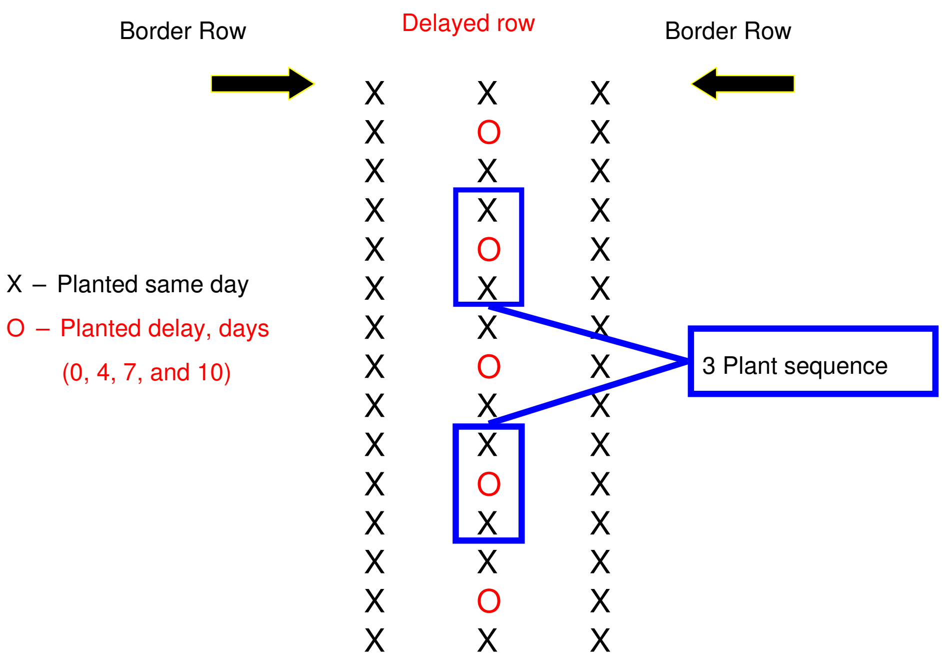


Figure 2. Schematic diagram demonstrating a single plot whereby the center row had 5, 3-plant sequences between two border rows. Each treatment was replicated three times, thus, 15, 3-plant sequences were used to determine each treatment average.

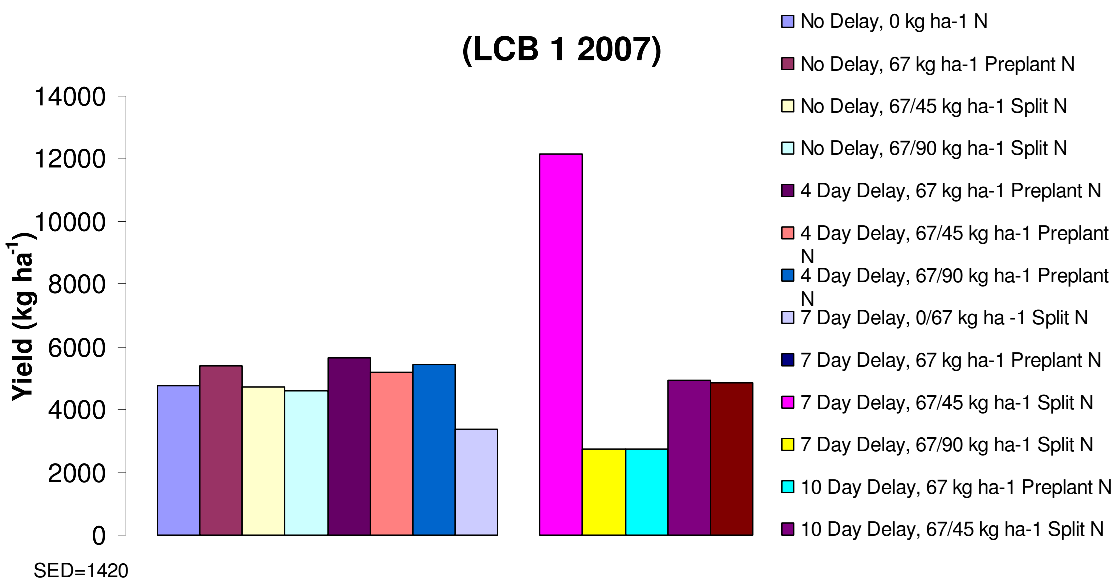


Figure 3. Treatment means expressed as corn grain yields in kg ha^{-1}, Lake Carl Blackwell (1), 2007.

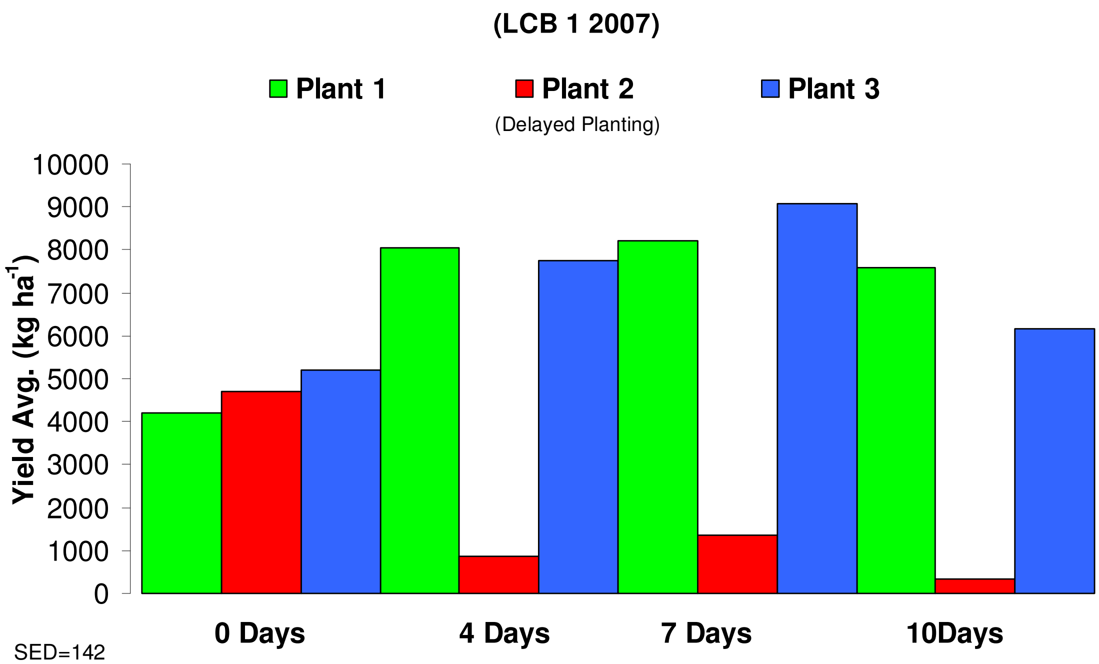


Figure 4. Average corn grain yields of each plant within a three plant sequence over all N rates where the center plant (#2) was delayed 0, 4, 7, and 10 days after plants #1 and #3, Lake Carl Blackwell (1), 2007.

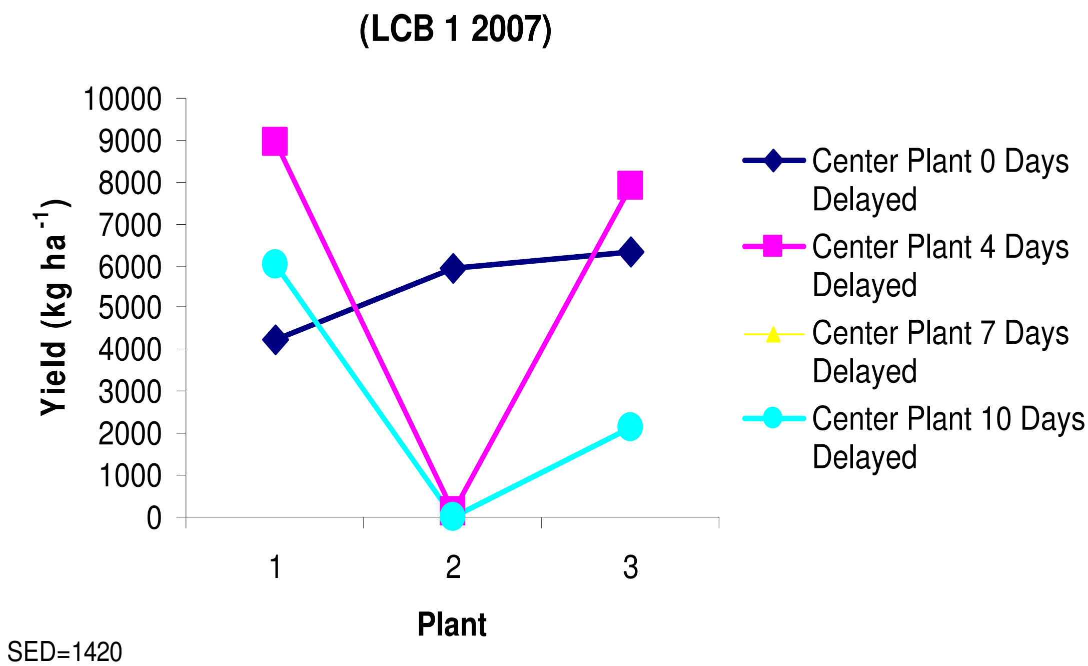


Figure 5. Average corn grain yield of three plant sequences, where the center plant (#2) was planted 0, 4, 7, and 10 days after plants #1 and #3, where 67 kg ha^{-1} of N was applied preplant uniformly, and with no added sidedress N, Lake Carl Blackwell (1), 2007.

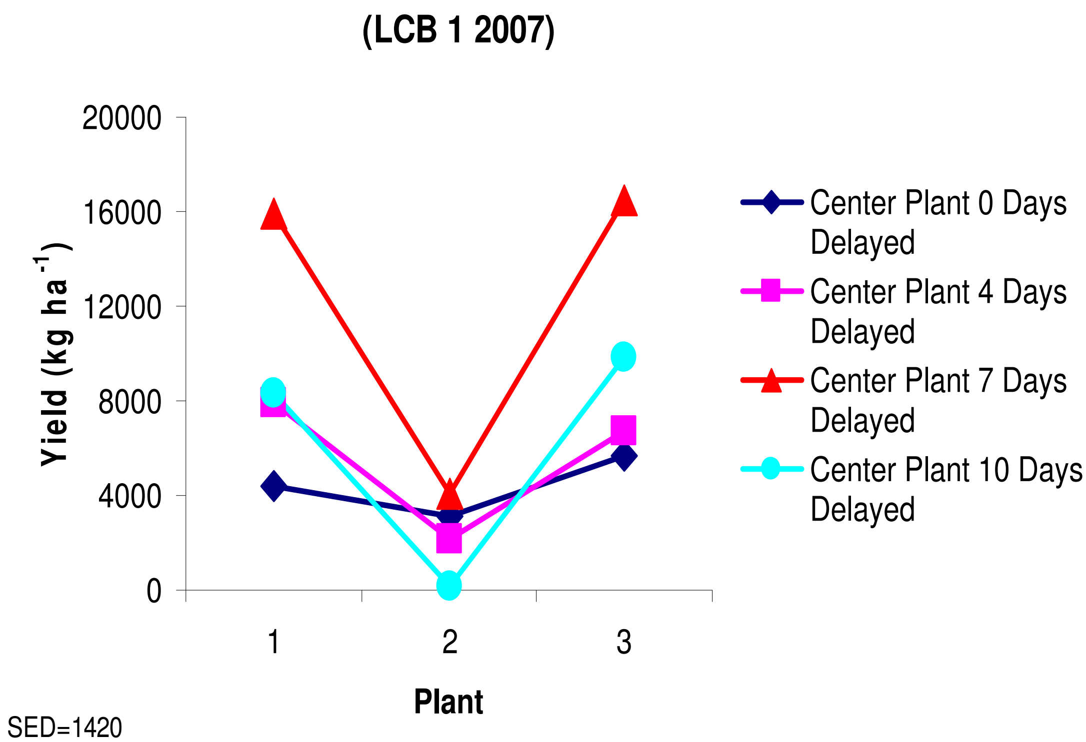


Figure 6. Average corn grain yield of three plant sequences, where the center plant (#2) was planted 0, 4, 7, and 10 days after plants #1 and #3, where 67 kg ha^{-1} of N was applied preplant uniformly, and with an additional 45 kg ha^{-1} of N applied sidedress at the V8 growth stage, Lake Carl Blackwell (1), 2007.

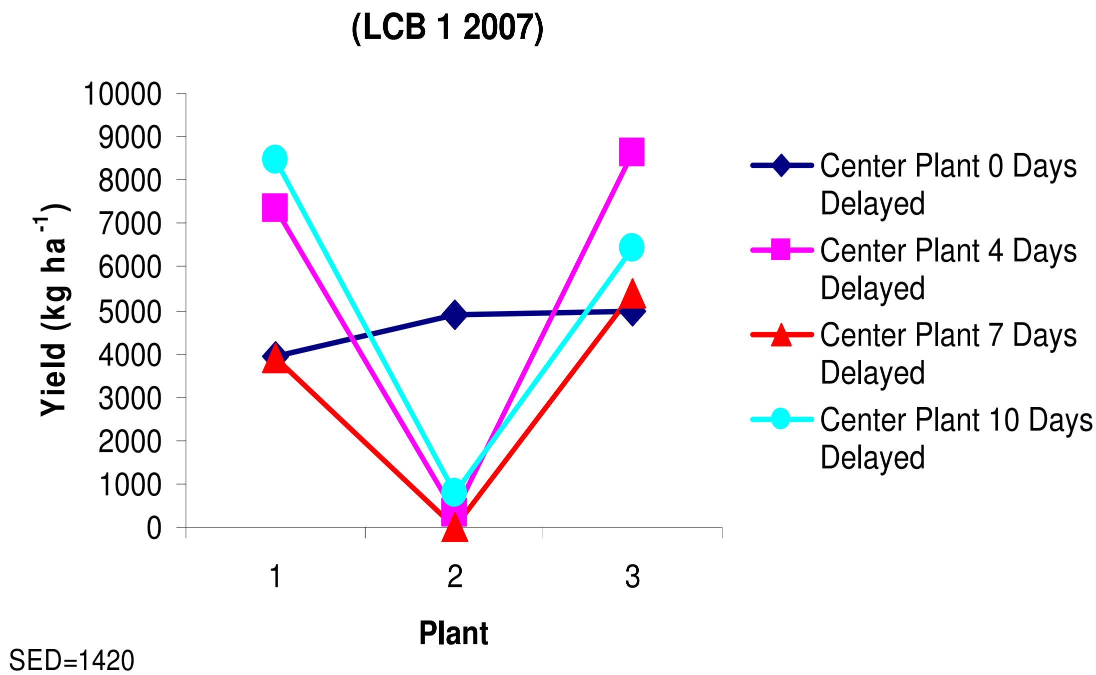


Figure 7. Average corn grain yield of three plant sequences, where the center plant (#2) was planted 0, 4, 7, and 10 days after plants #1 and #3, where 67 kg ha^{-1} of N was applied preplant uniformly, and with an additional 90 kg ha^{-1} of N applied sidedress at the V8 growth stage, Lake Carl Blackwell (1), 2007.

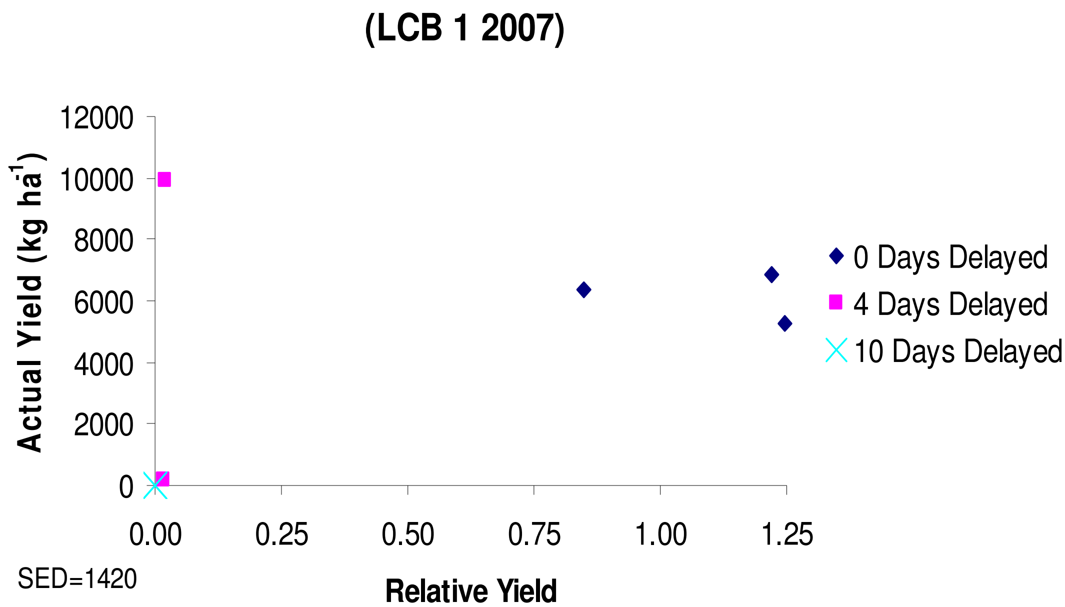


Figure 8. Relative yield of the center plant versus the average of neighboring plants (1 and 3) when the center plant was planted 0, 4, and 10 days after the neighboring plants, with 67 kg ha^{-1} of N applied preplant, and with no additional N applied, Lake Carl Blackwell (1), 2007.

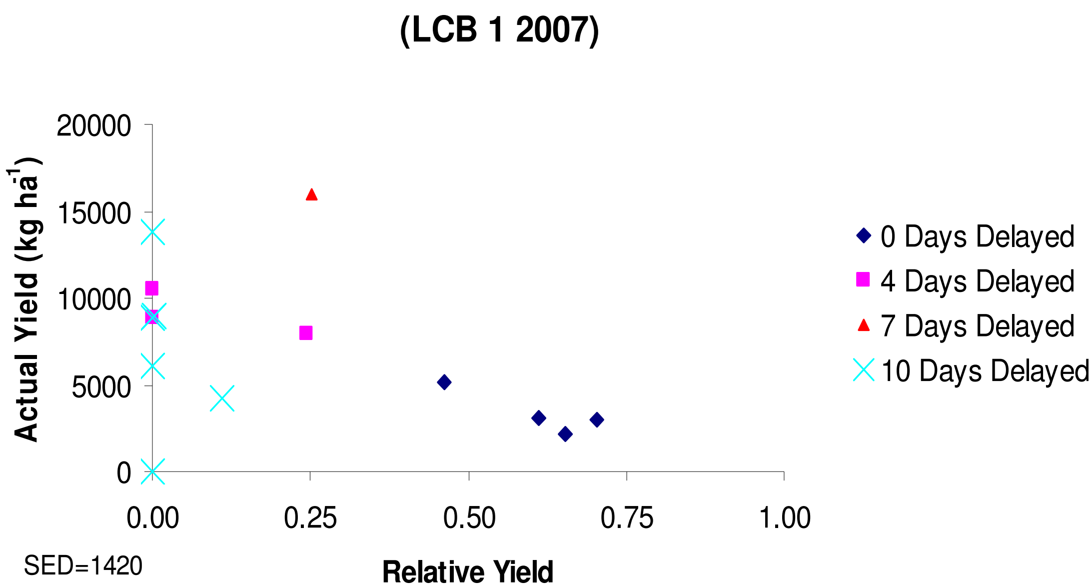


Figure 9. Relative yield of the center plant versus the average of neighboring plants (1 and 3) when the center plant was planted 0, 4, 7, and 10 days after the neighboring plants, with 67 kg ha^{-1} of N applied preplant, and with an additional 45 kg ha^{-1} of N applied sidedress at the V8 growth stage, Lake Carl Blackwell (1), 2007.

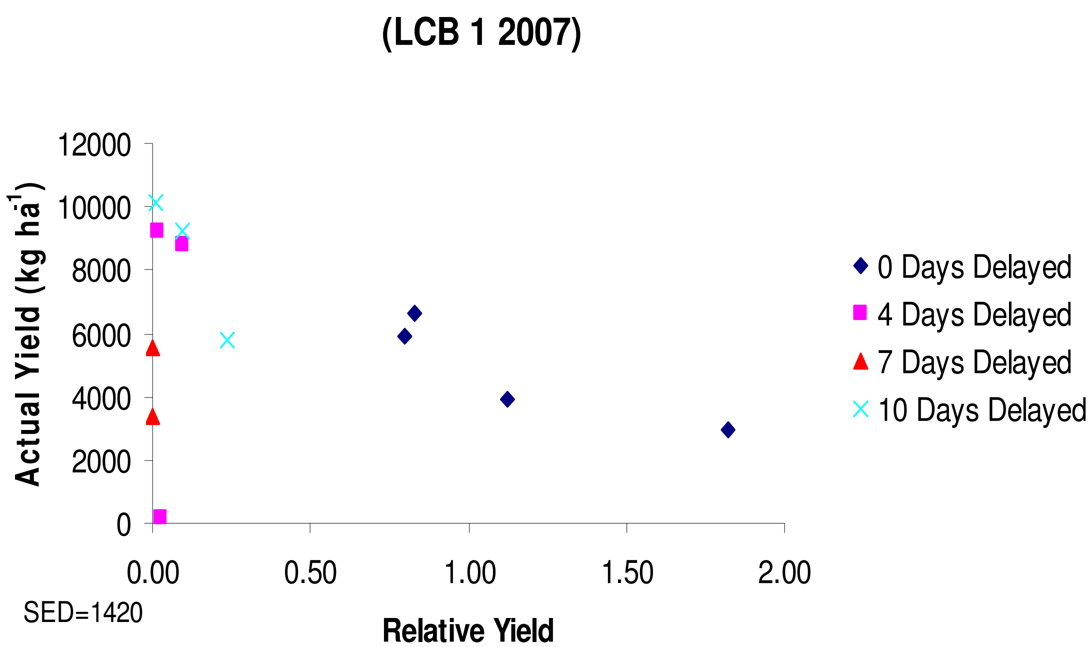


Figure 10. Relative yield of the center plant versus the average of neighboring plants (1 and 3) when the center plant was planted 0, 4, 7, and 10 days after the neighboring plants, with 67 kg ha^{-1} of N applied preplant, and with an additional 90 kg ha^{-1} of N applied sidedress at the V8 growth stage, Lake Carl Blackwell (1), 2007.

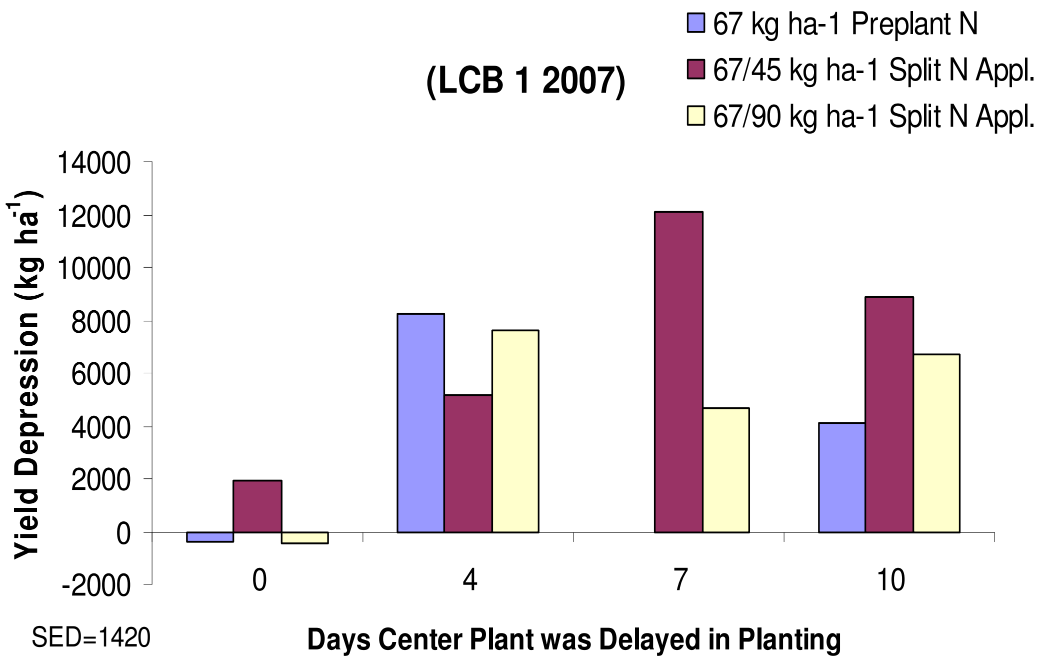


Figure 11. Average corn grain yield depression of three plant sequences, where the center plant was delayed by 0, 4, 7, and 10 days after its neighboring plants, Lake Carl Blackwell (1), 2007.

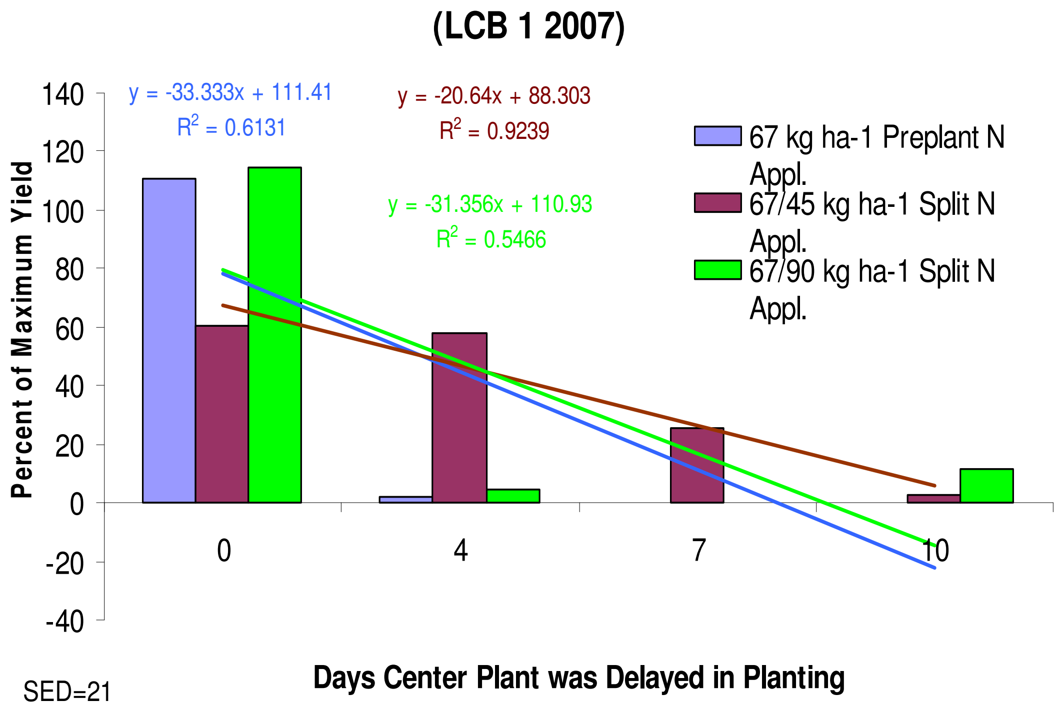


Figure 12. Three plant average where the center plant was delayed 0, 4, 7, 10 days, expressed as percent of maximum yield, Lake Carl Blackwell (1), 2007.

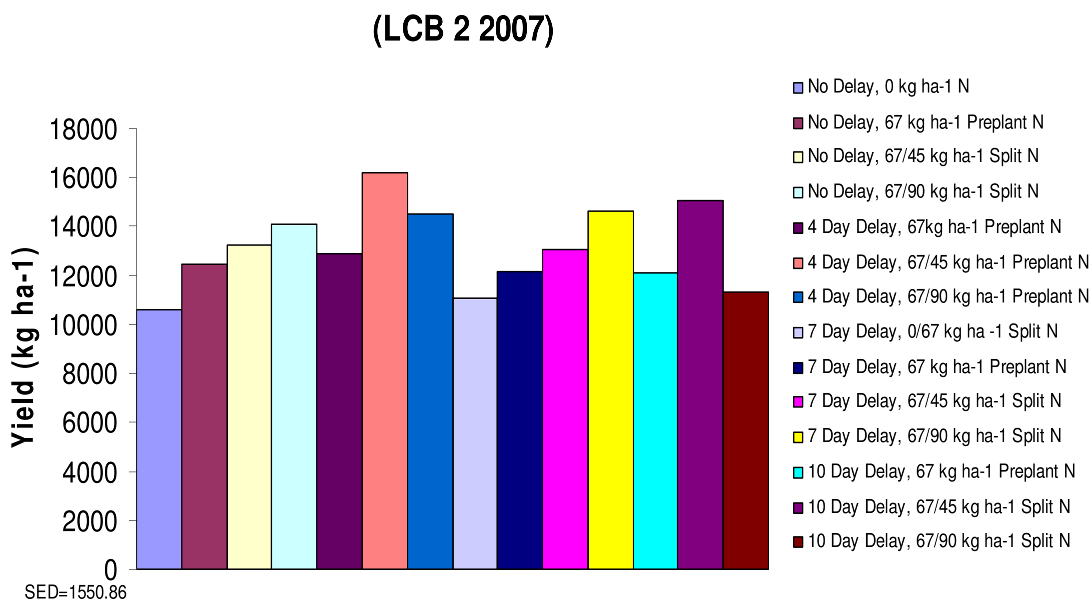


Figure 13. Treatment means expressed as corn grain yields in kg ha^{-1}, Lake Carl Blackwell (2), 2007.

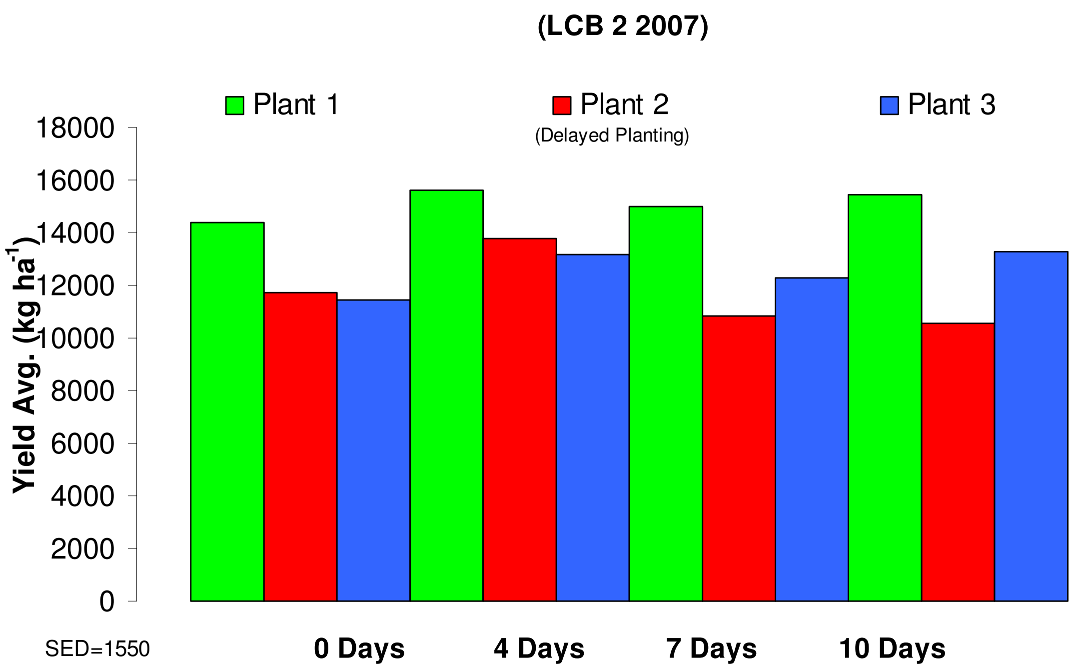


Figure 14. Average corn grain yields of each plant within a three plant sequence over all N rates where the center plant (#2) was delayed 0, 4, 7, and 10 days after plants #1 and #3, Lake Carl Blackwell (2), 2007.

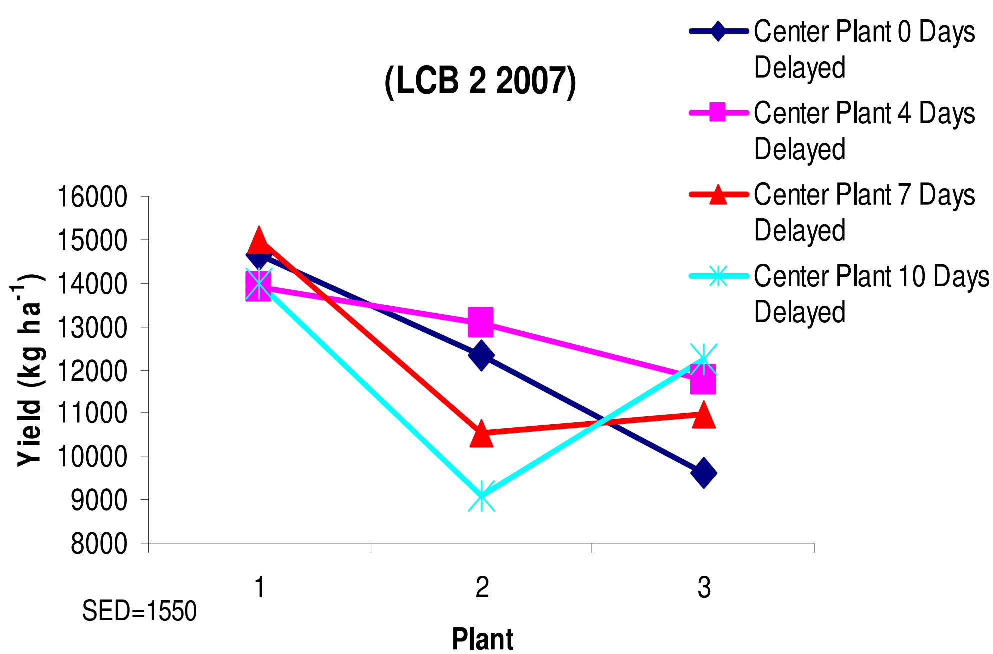


Figure 15. Average corn grain yield of three plant sequences, where the center plant (#2) was planted 0, 4, 7, and 10 days after plants #1 and #3, where 67 kg ha^{-1} of N was applied preplant uniformly, and with no added sidedress N, Lake Carl Blackwell (2), 2007.

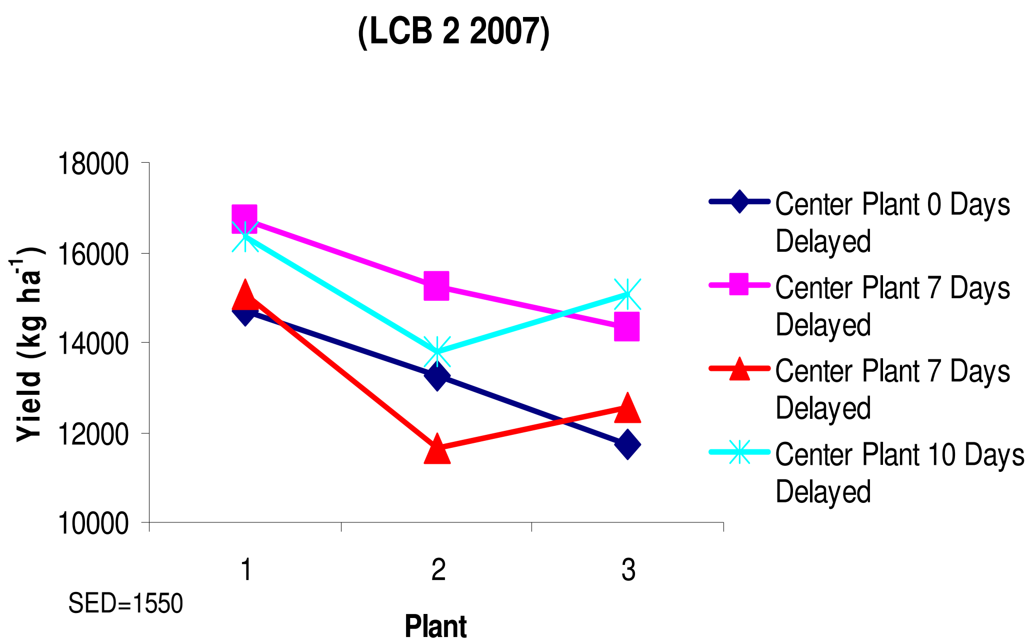


Figure 16. Average corn grain yield of three plant sequences, where the center plant (#2) was planted 0, 4, 7, and 10 days after plants #1 and #3, where 67 kg ha^{-1} of N was applied preplant uniformly, and with an additional 45 kg ha^{-1} of N applied sidedress at the V8 growth stage, Lake Carl Blackwell (2), 2007.

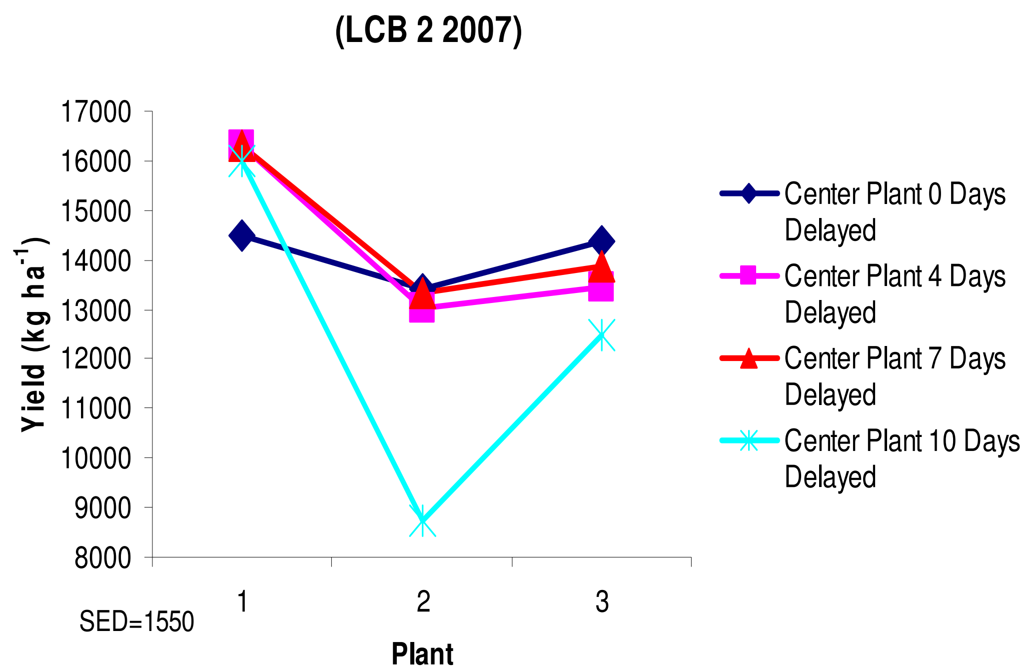


Figure 17. Average corn grain yield of three plant sequences, where the center plant (#2) was planted 0, 4, 7, and 10 days after plants #1 and #3, where 67 kg ha^{-1} of N was applied preplant uniformly, and with an additional 90 kg ha^{-1} of N applied sidedress at the V8 growth stage, Lake Carl Blackwell (2), 2007.

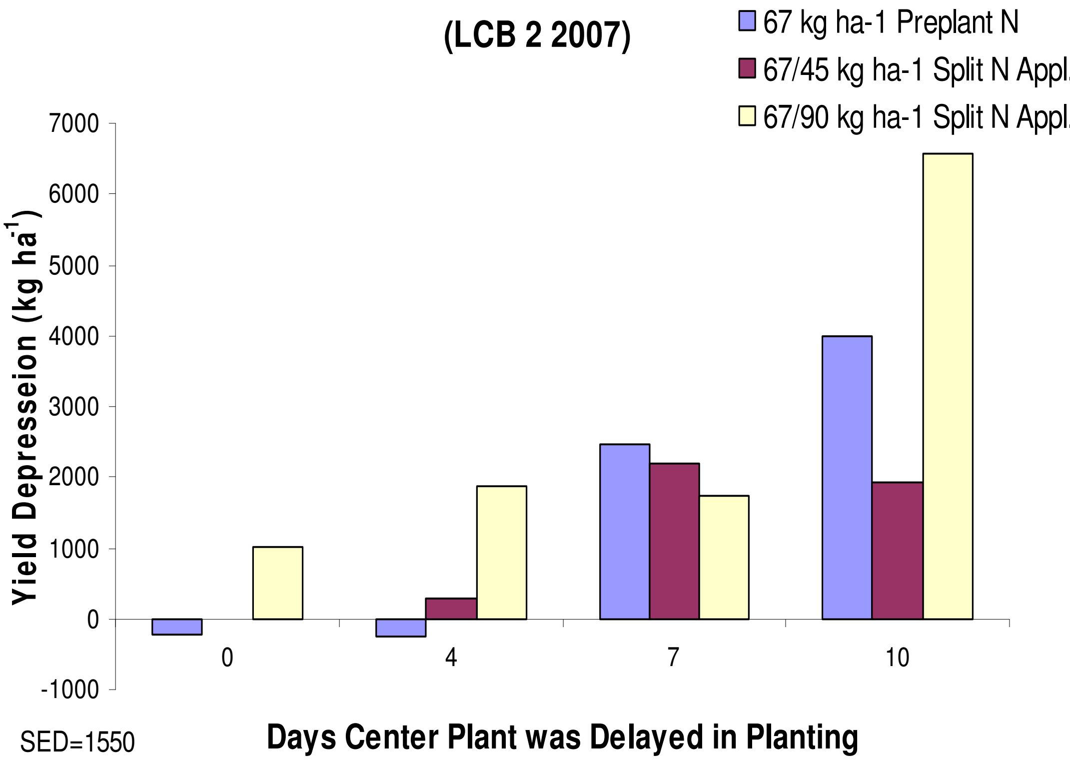


Figure 18. Average corn grain yield depression of three plant sequences, where the center plant was delayed by 0, 4, 7, and 10 days after its neighboring plants, Lake Carl Blackwell (2), 2007.

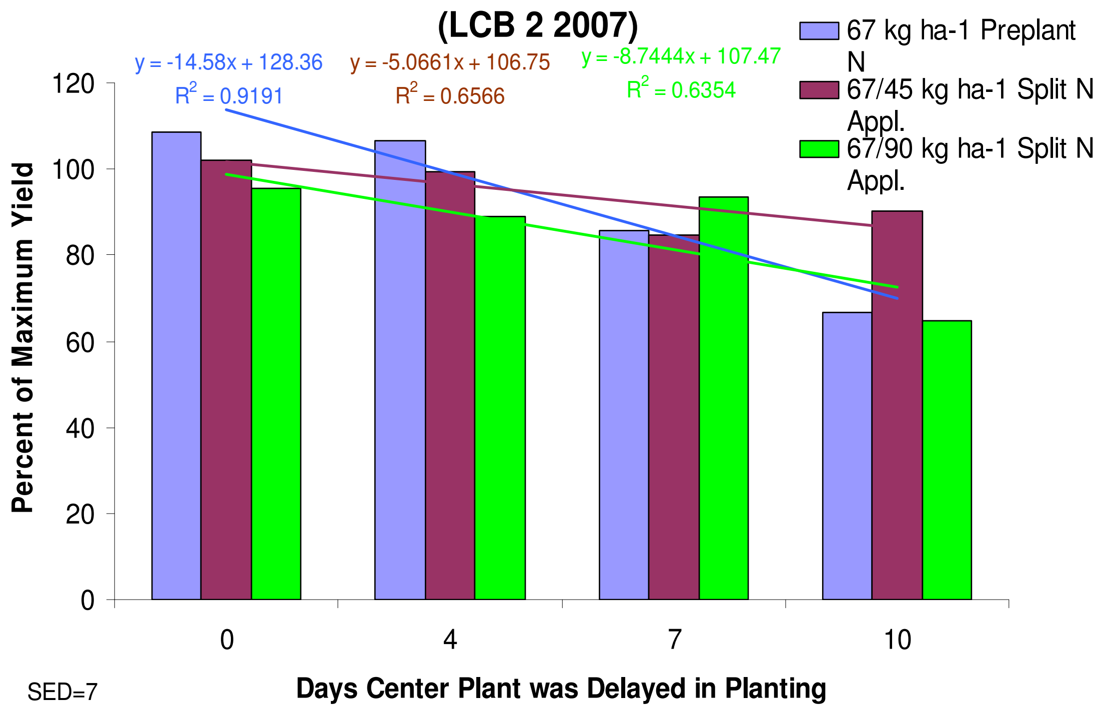


Figure 19. Three plant averages where the center plant was delayed 0, 4, 7, 10 days, expressed as percent of maximum yield, Lake Carl Blackwell (2), 2007.

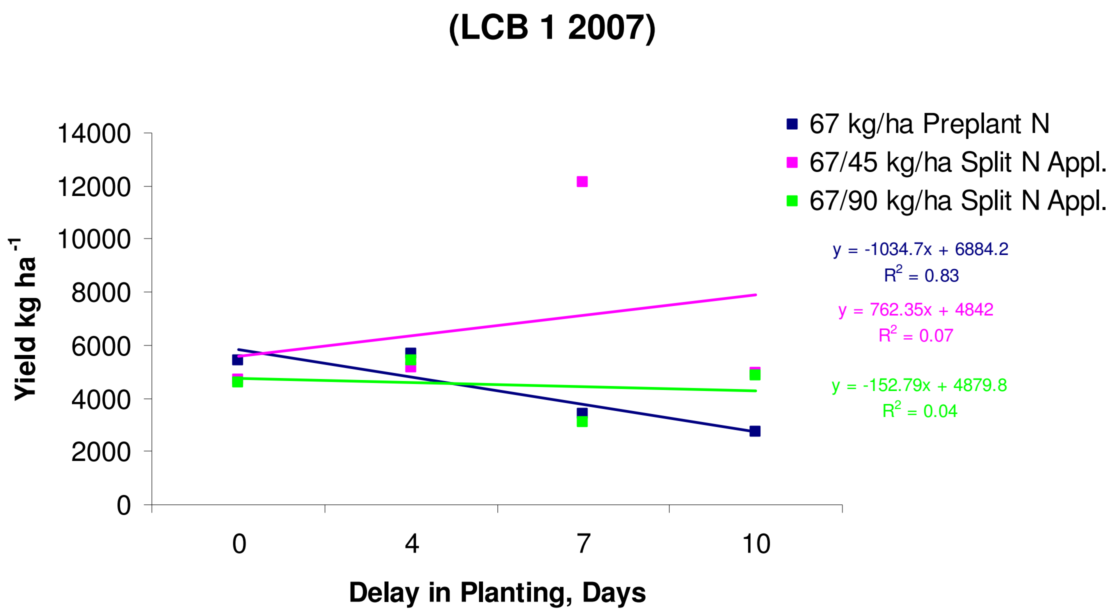


Figure 20. Average corn grain yield levels from three-plant sequences when the center plant was delay planted, 0, 4, 7, and 10 days, Lake Carl Blackwell (1), 2007.

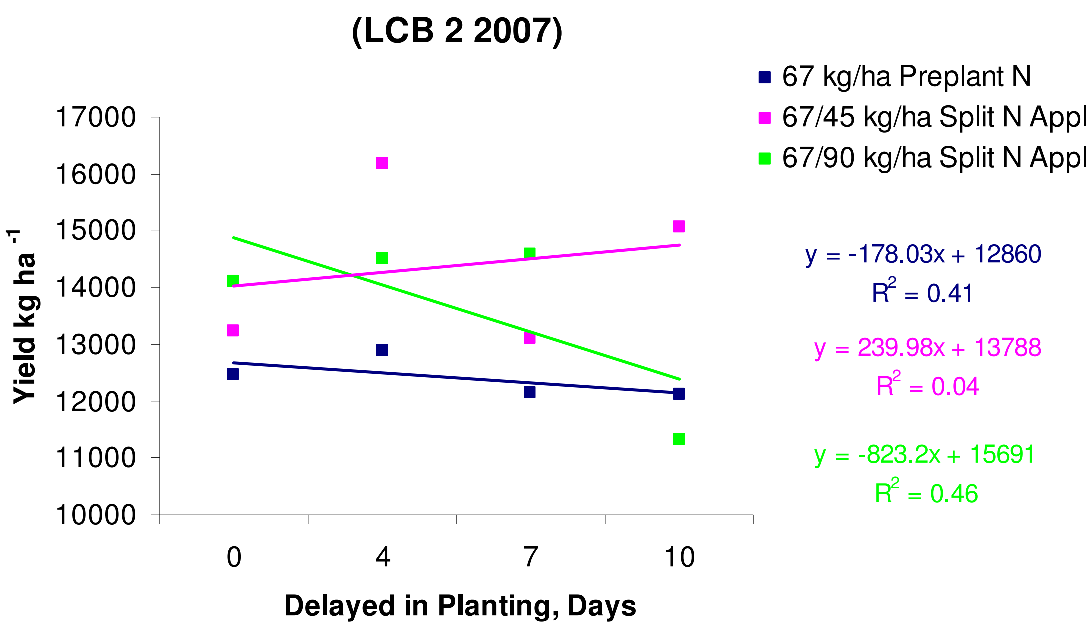


Figure 21. Average corn grain yield levels from three-plant sequences when the center plant was delay planted, 0, 4, 7, and 10 days, Lake Carl Blackwell (2), 2007.

APPENDIX

Appendix Table 1.
Treatment, days of delayed emergence, preplant nitrogen, sidedress nitrogen, and mean grain yields for Lake Carl Blackwell (1) and (2), 2007.

Treatment	Delayed Emergence Days	Preplant N kg ha^{-1}	Sidedress N kg ha^{-1}	Mean Grain Yields kg ha^{-1} LCB (1) 2007	LCB (2) 2007	Average
1	0	0	0	4328	10612	7470
2	0	67	0	5669	12194	8932
3	0	67	45	4471	13231	8851
4	0	67	90	4595	14097	9346
5	4	67	0	4550	12891	8721
6	4	67	45	5581	15417	10499
7	4	67	90	5671	14261	9966
8	7	0	67	3390	11105	7248
9	7	67	0	n a	12161	12161
10	7	67	45	12161	13089	12625
11	7	67	90	3099	14507	8803
12	10	67	0	2723	11769	7246
13	10	67	45	6126	15058	10592
14	10	67	90	5798	12404	9101
SED				1420	1550	

Appendix Table 2.
Mean grain yields of three plant sequences as affected by days of delayed emergence, over all N rates, Lake Carl Blackwell (1), 2007.

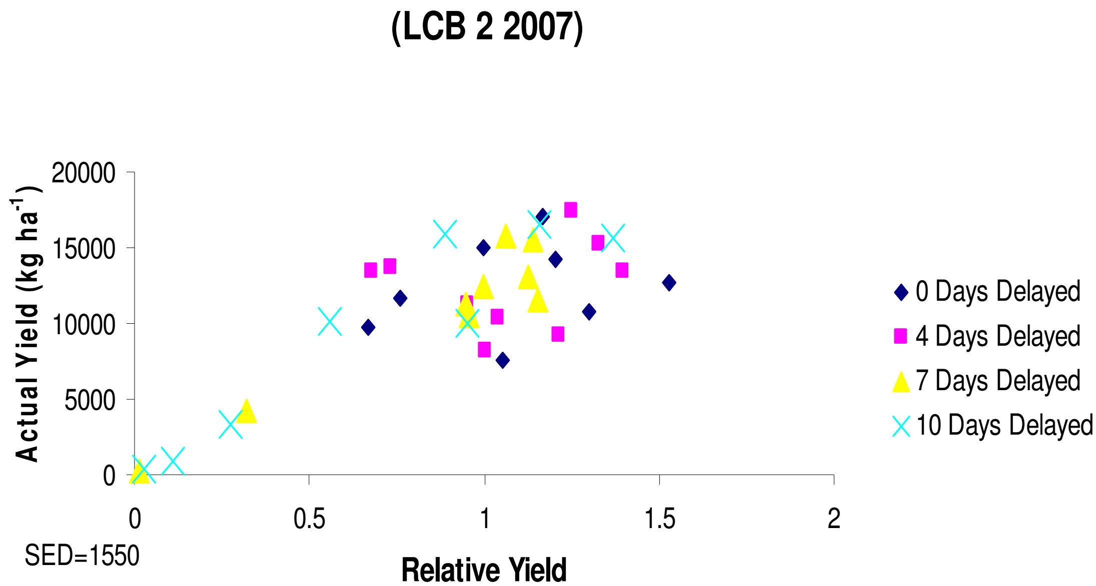
Delayed Emergence # Days	Mean Grain Yields kg ha^{-1}
0	4699 a
4	7900 b
7	8643 b
10	6876 b
SED	575

Means followed by the same letter are not significantly different at the 0.05 significance level.

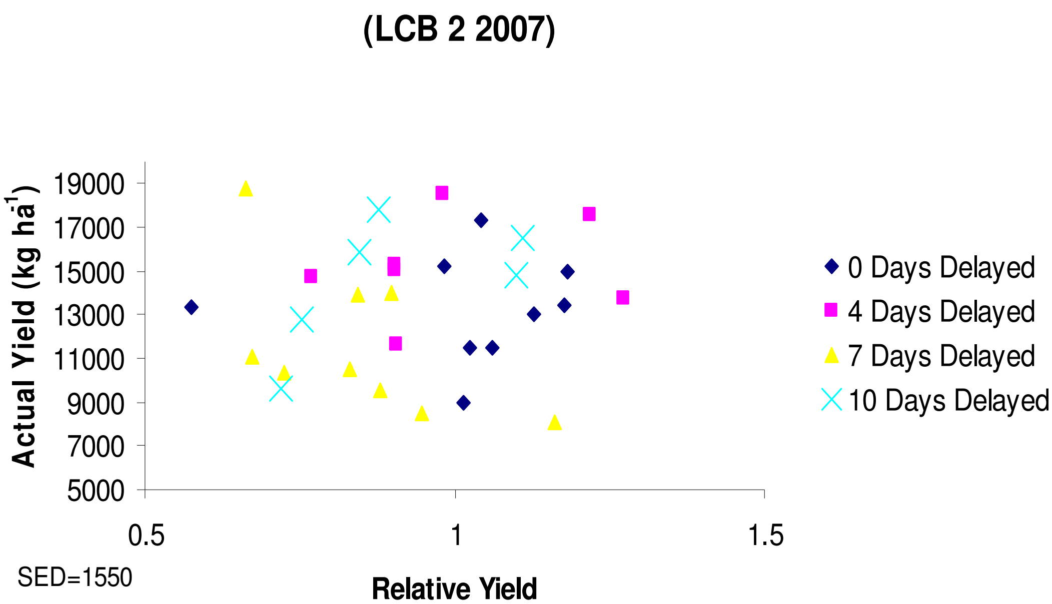
Appendix Table 3.
Mean grain yields of three plant sequences as affected by days of delayed emergence, over all N rates, Lake Carl Blackwell (2), 2007.

Delayed Emergence # Days	Mean Grain Yields kg ha^{-1}
0	12930 a
4	14404 a
7	13648 a
10	14348 a
SED	1500

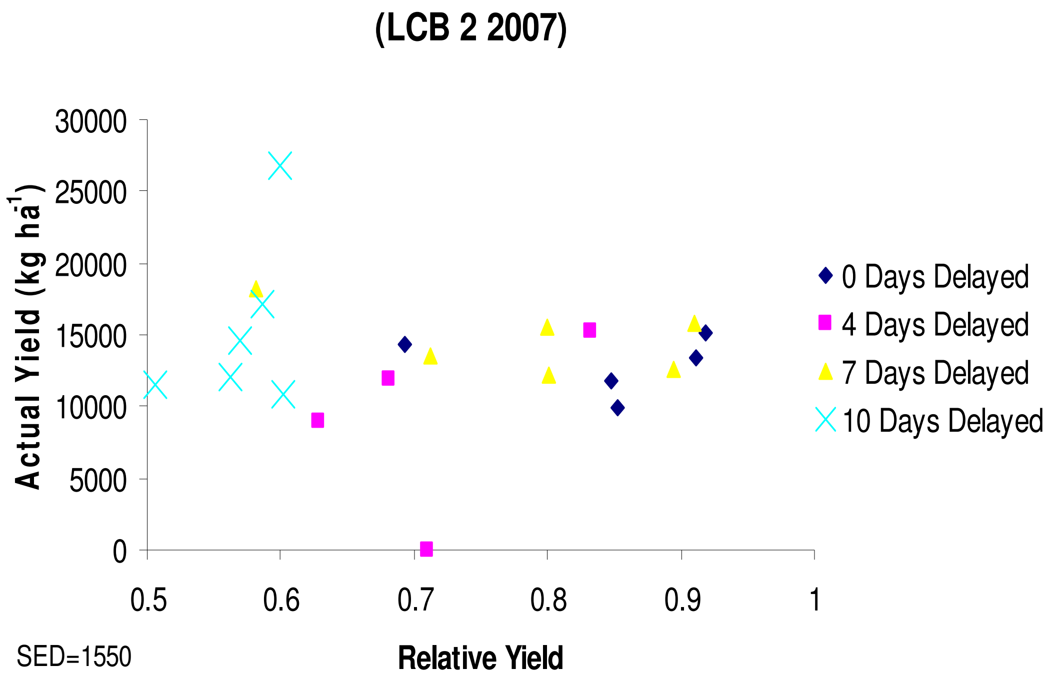
Means followed by the same letter are not significantly different at the 0.05 significance level.



Appendix Figure 1.
Relative yield of the center plant versus the average of neighboring plants (1 and 3) when the center plant was planted 0, 4, 7, and 10 days after the neighboring plants, with 67 kg ha^{-1} of N applied preplant, and with no additional N applied, Lake Carl Blackwell (2), 2007.



Appendix Figure 2.
Relative yield of the center plant versus the average of neighboring plants (1 and 3) when the center plant was planted 0, 4, 7, and 10 days after the neighboring plants, with 67 kg ha^{-1} of N applied preplant, and with an additional 45 kg ha^{-1} of N applied sidedress at the V8 growth stage, Lake Carl Blackwell (2), 2007.



Appendix Figure 3.
Relative yield of the center plant versus the average of neighboring plants (1 and 3) when the center plant was planted 0, 4, 7, and 10 days after the neighboring plants, with 67 kg ha^{-1} of N applied preplant, and with an additional 90 kg ha^{-1} of N applied sidedress at the V8 growth stage, Lake Carl Blackwell (2), 2007.

VITA

Michael Cody Daft

Candidate for the Degree of

Master of Science

Thesis: By-plant Nitrogen Response as a Function of Delayed Emergence in Corn

Major Field: Plant and Soil Sciences

Bibliography:

Education:

Graduated from Fletcher High School, Fletcher, Oklahoma in May 2002.
Received Bachelor of Science degree in Animal Science from Oklahoma State University, Stillwater, Oklahoma 2006.
Completed the requirements for the Master of Science degree with a major in Plant and Soil Science at Oklahoma State University, Stillwater, Oklahoma in December, 2008.

Experience:

Employed by Oklahoma State University as a research assistant in the area of weed science in small grains, (2003-2007). Employed by Oklahoma State University, Department of Plant and Soil Sciences, as a graduate research assistant, (2006-present).

Professional Memberships: ASA CSA SSSA

Name: Michael Cody Daft Date of Degree: December, 2008

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: BY-PLANT NITROGEN RESPONSE AS A FUNCTION OF DELAYED EMERGENCE IN CORN

Pages in Study: 70 Candidate for the Degree of Master of Science

Major Field: Plant and Soil Science

Scope and Method of Study:

The objectives of this study were to determine corn nitrogen responsiveness as a function of interplant competition arising from delayed emergence and to assess nitrogen requirements associated with 3 plant sequences, with and without delayed emergence. These variables were investigated at two experimental sites established in the spring of 2007, near Stillwater, OK at the Lake Carl Blackwell Agronomy Research Farm under irrigation using conventional tillage management practices. Fourteen treatments, consisting of varying N rates and days of delayed planting were used to evaluate by-plant nitrogen responsiveness among three plant sequences.

Findings and Conclusions:

At site year Lake Carl Blackwell (1), 2007, for each day delay in planting (assuming emergence was equally delayed) corn grain yields decreased by 1,034 kg ha^{-1}, when 67 kg N ha^{-1} was applied preplant. At site year Lake Carl Blackwell (2), 2007, a yield reduction of 178 kg ha^{-1} for every day delay in planting for the 67 kg N ha^{-1} preplant N rate was observed. When sidedress N was applied, in addition to preplant N, yield reductions due to delayed planting were less pronounced. Over all sites evaluated in this work, delayed emergence decreased average grain yields thus highlighting the need to homogenize plant stands and corresponding emergence.

ADVISER'S APPROVAL: William R. Raun