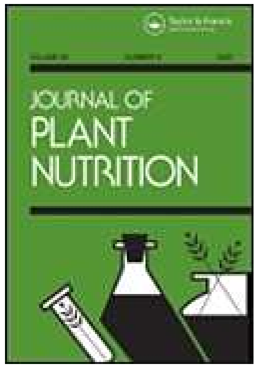

Effect of Delayed Emergence on Corn (Zea mays L.) Grain Yield

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INTRODUCTION

Homogenous plant stand establishment is important for achieving maximum corn grain yields. Spatial and temporal variability are generally common in crop fields (Solie *et al*., 1996), which inevitably leads to heterogeneous stands. Several factors have been established to cause uneven emergence of crops in the field. These include; soil temperature which affects germination and speed of coleoptile elongation (Blacklow, 1974), soil compaction (Stibbe and Terpstra, 1982; Schneider and Gupta, 1985) and presence of surface residue as a result of no-tillage practices which has been demonstrated to reduce soil temperature leading to delayed seed germination (Hayhoe and Dwyer, 1990). Variation in seed moistening, as a result of differences in seed-soil contact in a coarse seed bed (Bruckler, 1983), death after germination, excess or scarcity of water, presence of seeds unable to germinate, uneven distribution of the drill generating small skips and stand establishment in stony fields (Benson, 1990; Finck, 1997; Nielsen, 1998), are other factors that contribute significantly to uneven corn stands.

The current nitrogen (N) recommendations for corn have been developed for large geographic regions and are traditionally employed without considering in-field variability (Schmidt *et al*., 2002). In an uneven crop stand this will result in treating the whole field as if no variability were present, hence over-fertilizing the field, increasing the cost of production and reducing nitrogen use efficiency (NUE).

Past studies have demonstrated that delayed emerging plants surrounded by earlier emerging plants will show delay in leaf stage and plant height. The shading from neighboring plants will reduce light penetration and increase competition for moisture and nutrients from taller plants with more developed root systems (Weiner, 1990). This leads to decreased corn yields even if within-row plant spacing is relatively uniform (Nafziger *et al*., 1991), especially at high population densities (Ford and Hicks, 1992). Liu *et al*. (2004) demonstrated that corn yielded 4% and 8% less when one out of six plants had a delay in emergence of two leaf stages and four leaf stages respectively. Nafziger *et al*. (1991) found that if the differences in emergence times of plants in an unevenly emerged field is <2 weeks, there will be a yield loss but not significant enough to warrant replanting. If the emergence delays for some plants approach 3 weeks, then replanting may produce a yield increase of about 10% if the proportion of delayed plants exceeds 25%. Also, a growth stage difference of two leaves or greater between adjacent plants can result in the younger plant being barren at end of the season (Nielsen, 2001). This information necessitates the need to decide whether or not to destroy the late-emerging plants, in order to increase food production. This could increase NUE in cereals to near 50% and above the current world estimates of NUE in cereals that hover near 33% (Raun and Johnson, 1999). Moreover, while advances in agriculture technologies and intensive management strategies have contributed to improved crop performance, tackling problems related to seed emergence and uneven crop stand remains a difficult hurdle. This study addresses this issue by hypothesizing 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.

OBJECTIVE

- To determine the effect of delayed emergence on corn grain yields with and without fertilizer N

MATERIALS AND METHODS

Site description

Two experiments were established in 2007, 2008, 2009 and 2010 at the Lake Carl Blackwell (LCB) irrigated research station, located in north central Oklahoma, 14 km west of Stillwater. The average annual air temperature is 15^0 C and a mean annual rainfall of 932 mm (Stillwater, Oklahoma Mesonnet). Most of the precipitation occurs in the spring and early summer. Many different soil profiles are represented at varying degrees of slope, with Pulaski Fine Sandy Loam (coarse-loamy, mixed, superactive, nonacid, thermic Udic Ustifluvent) and Port Silt Loam (Fine-silty, mixed, superactive, thermic Cumulic Haplustolls) being common (USDA / NRCS soil taxonomy).

Experiment and management

The experiment employed a randomized complete block design (RCBD) with 14 treatments and 3 replications (Table1). Soils samples (0-15 cm) from each site were collected and characterized before application of treatments. In 2007, 2008 and 2009 Dekalb (DKC 66-23) Bt corn hybrid was planted at a seedling rate of 73,779 seeds ha^{-1}. The row spacing was 76.2 cm and the distance between individual plants was 17.8 cm In 2010 Dekalb (DKC 61-35) Bt corn was planted at 81,000 seeds ha^{-1}. Border rows were planted with a 4-row John Deere Maxemerge-2, vacuum planter, while the center row was planted by hand.

To achieve equal inter-row spacing and 5.08 cm planting depth, a planting device was made from 3.81 cm^2 square metal tubing. Bolts positioned 0.95 cm deep were placed every 17.8 cm apart along the tube. This was then used to create a fixed depression in the soil and ensuring specific planting points for each of the seeds. Fifteen seeds were planted in each row, which were further divided into five, 3-plant subgroups. The subgroups containing three plants had two seeds planted on the same day and a delayed seed planted in the middle of the other two. The delayed seed was planted 4, 7 and 10 days after the neighboring 2 seeds (to simulate various delayed emergence scenarios) according to the treatment structure.

A preplant fertilizer application of 67kg N ha^{-1} was made for all treatments excluding the 0-N control, using a streamer nozzle and urea ammonia nitrate (UAN, 28-0-0). At V8 corn growth stage a side dress UAN application was made at 0, 45, 67 and 90 kg ha^{-1} N (Table 2).

At maturity, subgroups within each row were tagged in sets of three, hand harvested, and each plant bagged separately. After hand harvesting, each bag was individually weighed to obtain the wet weight, oven dried at 66^0C then weighed again to obtain dry weight (15% moisture) and grain yields determined.

Data management and analysis

Data was statistically analyzed using GLM in SAS version 9.1 (SAS Institute, 2003) to determine treatment effects. Means were separated using Fishers protected LSD and non-orthogonal, single-degree-of-freedom contrasts were performed.

RESULTS AND DISCUSSION

In 2007 although yield data was obtained, extreme rainfall amounts above the annual averages were recorded. Large portions of this rainfall were received at planting which lead to less than optimum plant emergence and homogeneity among treatments. In 2008 and 2009 both experiments encountered significant damage due to feral hogs and excess rainfall, respectively and no reasonable data were collected. The experiment was repeated in 2010 and no damage due feral hogs was encountered. Thus, only results obtained from experiments in 2007 and 2010 are discussed.

Yield Decrease

The grain yield of the delayed plant was calculated by determining the difference in yield between the delayed plant (#2) and the average of the earlier planted neighboring plants (#1 and #3). The yield of the center plant compared to the average of the neighbors, significantly ($p<0.05$) decreased with each delay in planting for 2007 LCB 2 and 2010 LCB 2 cropping seasons (Table 2). In 2007 LCB 1 and 2010 LCB 1, the decrease was not significant, but still, with each day delay, yield losses were recorded (Fig.1). Apart from LCB 1 in 2007 which had a yield decrease of 27 kg ha^{-1} for each day delay in planting, the rest of the locations and seasons, the yield depression of the delayed plant was slightly lower (Fig.1). For 2010 LCB 1, 2010 LCB 2, and 2007 LCB 2, for each day delay in planting, the delayed plant was depressed in yield by 20 kg ha^{-1}, 12 kg ha^{-1} and 8 kg ha^{-1} respectively.

Overall, these findings indicated that, with the exception of 2007 LCB 1, delaying planting by more than 7 days resulted to a decrease in yield of the delayed plant. This could be attributed to the inability of the delayed plant to compete for sunlight, nutrients and moisture with the earlier established plants; hence reduction in yield. Efficient N and moisture use by the plant and the ability to capture solar radiation for photosynthetic process is crucial for growth and yield production.

Application of sidedress N application to the delayed plants, led to a general decline in grain yield, with the exception of 2010 LCB 1 (Fig 2). This could have been due to poor response to sidedress N by the delayed plant which resulted from an underdeveloped root system. Early planted plants have more established root systems than the late planted; hence their efficiency to take up nutrients and moisture is high (Weiner, 1990). For all the sites and cropping seasons, interaction between number of days delayed after planting and nitrogen application was not significant ($P<0.05$). This suggests that application of the sidedress N fertilizer regardless of the rate applied, did not improve the growth and development of the delayed plant.

Mean Grain yield

Delayed Planting

Depending on the cropping season and the location, mean corn grain yield, was affected differently with each delay in planting. The results for 2007 and 2010 cropping seasons at LCB 1 and 2 are presented in Table 2 and Fig. 3. In 2007 at LCB 1, mean corn grain yield recorded was the lowest compared to other locations and cropping seasons. The yield ranged from 4464 kg ha^{-1} to 7630 kg ha^{-1} when planting was delayed by 10 and 7 days respectively (Table 2). For this particular site and cropping season, grain yield increased by 94 kg ha^{-1} with each delay in planting (Fig 3), contrary with past findings (Nafziger *et al*., 1991), that delayed planting leads to a decrease in yields.

The highest grain yield was recorded in 2007 LCB 2, which ranged from 12559 to 14525 kg ha^{-1} (Table 2). Each day delay in planting resulted in a 337 kg ha^{-1} yield decline (Fig. 3). In the 2010 cropping season at LCB 1 and 2, each day delay in planting, contributed to a 224 kg ha^{-1} and 22 kg ha^{-1} mean corn yield decrease, respectively. In general, regardless of the cropping season and site, delayed planting for up to 7 days, did not contribute to a sizeable yield reduction. However, delaying for 10 days led to a modest decline in yields; an indication that, delaying planting for this period of time did not have a substantial negative impact on the overall grain yield and that would not necessitate replanting. This finding is in agreement with what (Nafziger *et al*., 1991) determined that, <2 weeks delay in planting only contributed to 6 to 7 % grain yield reduction, irrespective of the percentage of the plants delayed. Their study concluded that, while earlier planted plants (#1 and #3) will not make up for the yield loss of the delayed plants, replanting will not increase yield potential unless more than half of the plants were delayed by three or more weeks. However, in a separate study by Liu *et al*., 2004 it was established that, plants neighboring delayed plants can partially offset yield losses of the delayed plants, and plants located near the gaps in the row are able to compensate for the gaps; hence reducing the negative impact delayed planting will have on the mean grain yield. These findings assist in explaining the results obtained in this study.

Nitrogen Response

The results for corn response to sidedress nitrogen (N) application in 2007 and 2010 cropping seasons, at LCB 1 and 2 are presented in Table 2 and Fig. 4. Generally the results varied with location, implying that corn responded differently to fertilizer N application. This could be due to field variability that exists at low resolutions (Solie *et al*., 1996).

In 2007 at LCB 1, corn yield increased with N rate (40 kg N ha^{-1}). Grain yields however declined when the N rate was increased to 80 kg N ha^{-1} (Fig 4). During the cropping season, at LCB 2, for each increase in sidedress N applied , mean grain yield increased by 608 kg ha^{-1} . Mean grain yields as earlier recorded at LCB1 dropped as well for LCB 2 to 13,633 kg ha^{-1}, at the 80 kg N ha^{-1} rate, and to 14327 kg ha^{-1} when 40 kg N ha^{-1} was applied (Table 2).

For 2010, LCB 1, mean corn yields were generally low. However, the highest response to sidedress N was recorded, with each increase in N rate applied, contributing to a 998 kg ha^{-1} mean corn yield increase. Nonetheless, with 80 kg ha^{-1}, a slight drop in yield was recorded (Fig. 4). At LCB 2, a negative response to applied N was recorded as mean grain yields decreased by 174 kg ha^{-1} with each increase in N side dress applied (Fig. 4).

These findings, with exception of 2010 LCB 2, indicated that, mean grain yield increased with 40 kg N ha^{-1} sidedress application and dropped when the rate was increased to 80 kg N ha^{-1}. This suggests that over cropping seasons and locations, 40 kg N ha^{-1} appeared to have been an optimum rate and beyond which mean grain yields declined. Nitrogen fertilization increases corn yield when N supply by soil is low (Wienhold *et al*., 1995; Sexton *et al*., 1996). Therefore, an excess application of N fertilizer, beyond maximums will not lead to further increases. Instead, nitrate N is accumulated below the root zone which can cause toxicity especially with in adequate soil moisture (Ludwick *et al*., 1976). Excess N in the soil is also susceptible to loss by other mechanisms such as plant loss as ammonia (NH_3), denitrification, surface runoff, leaching and volatilization (Raun and Johnson, 1999); thereby reducing NUE.

CONCLUSIONS

The yield of the delayed plant (#2) consistently decreased with each day delay in planting. For 2007 LCB 1,2007 LCB 2, 2010 LCB 1 and 2010 LCB 2, yields decreased by 27, 8, 20 and 12 kg ha^{-1} for each planting day delay, respectively. Generally, the delayed plants did not respond to sidedress N application, although a slight decrease in yield was noted with each additional N rate. The overall grain yield was not significantly reduced by delayed planting to warrant replanting. However, across seasons and locations, mean grain yield almost always resulted in a yield decrease when planting was delayed by 10 days. This demonstrated the ability of the earlier established plants to partially compensate for the decreased grain yield as a result of delayed planting. Therefore replanting plants delayed by 10 days may not be necessary since grain yield potential will not be increased. However, over all locations and years, the mean grain yield decrease of the delayed plant versus neighboring plants for each day delay was 122 kg/ha. Sidedress application contributed to an increase in yield by, 609 and 998 kg ha^{-1} for 2007 LCB 1 and 2010 LCB1 respectively. The 40 kg N ha^{-1} N rate seemed to have been an optimum rate across seasons and sites, and beyond this yield generally declined.

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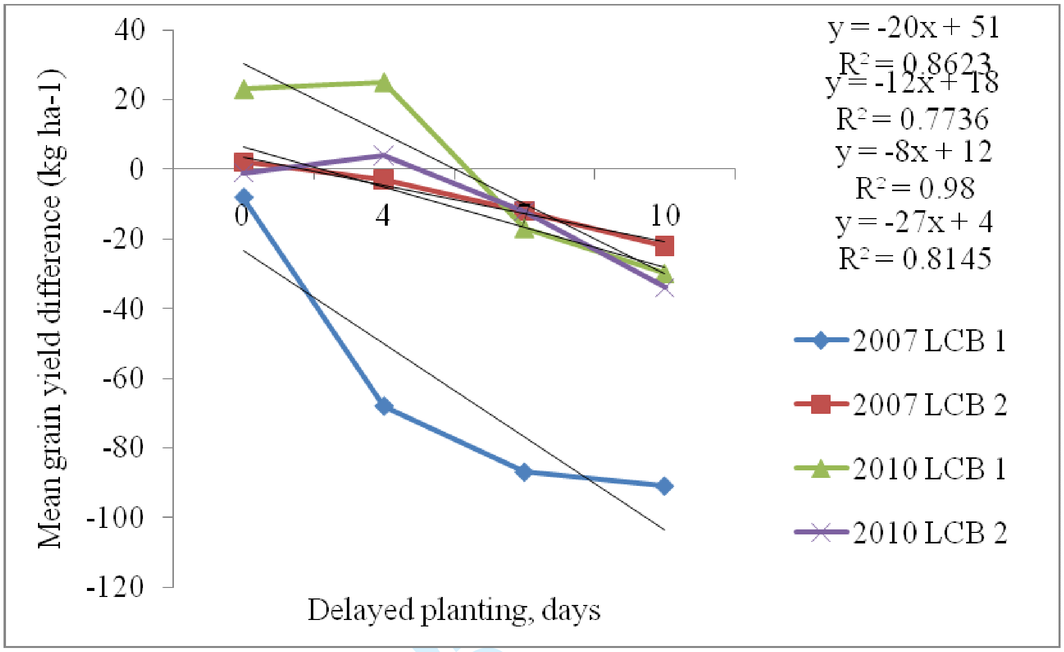

Fig 1: Influence of delayed planting by 0, 4, 7 and 10 days on the grain yield of the delayed plant compared to the earlier planted neighboring plants, at Lake Carl Blackwell (LCB), 2007 and 2010 cropping seasons.

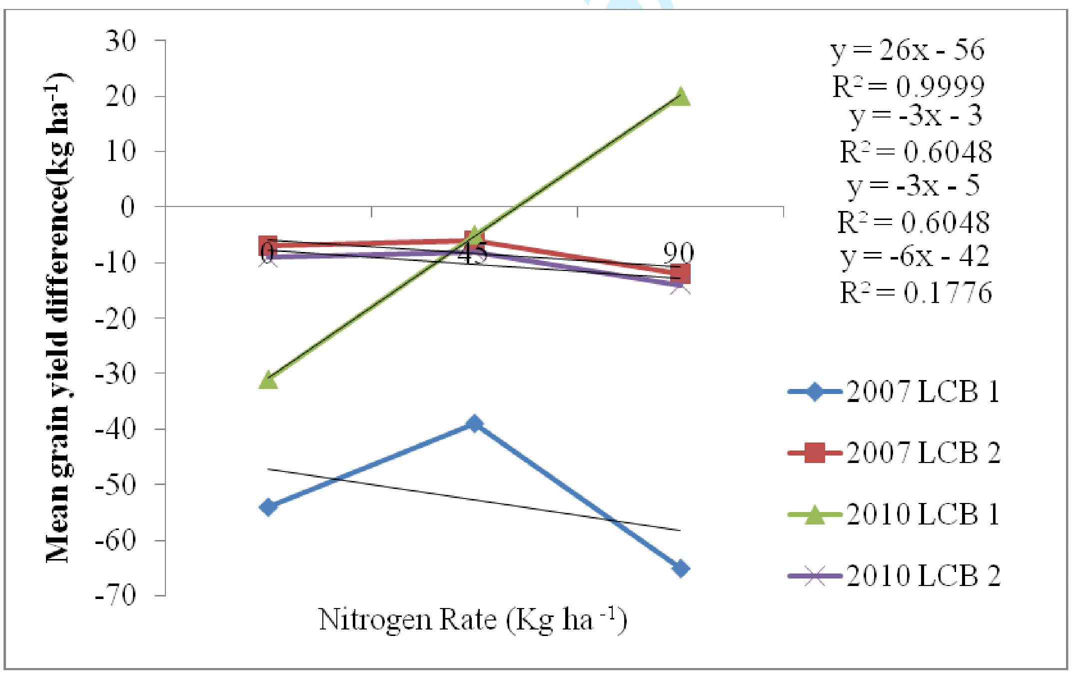

Fig 2: Influence of application of sidedress nitrogen fertilizer at 0, 45, 1nd 90 kg ha^{-1} on grain yield of the delayed plant compared to the earlier planted neighboring plants, at Lake Carl Blackwell (LCB), 2007 and 2010 cropping seasons.

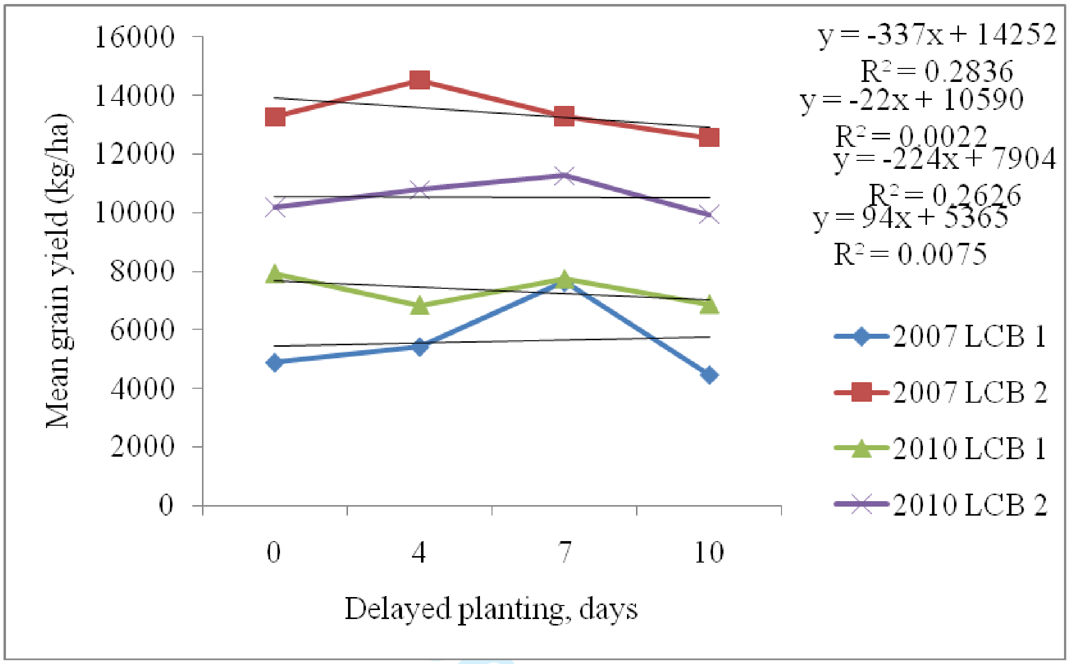

Fig 3: Effect of delaying planting corn by 0.4, 7 and 10 days on mean grain yield during 2007 and 2010 cropping seasons at Lake Carl Blackwell, sites 1 and 2.

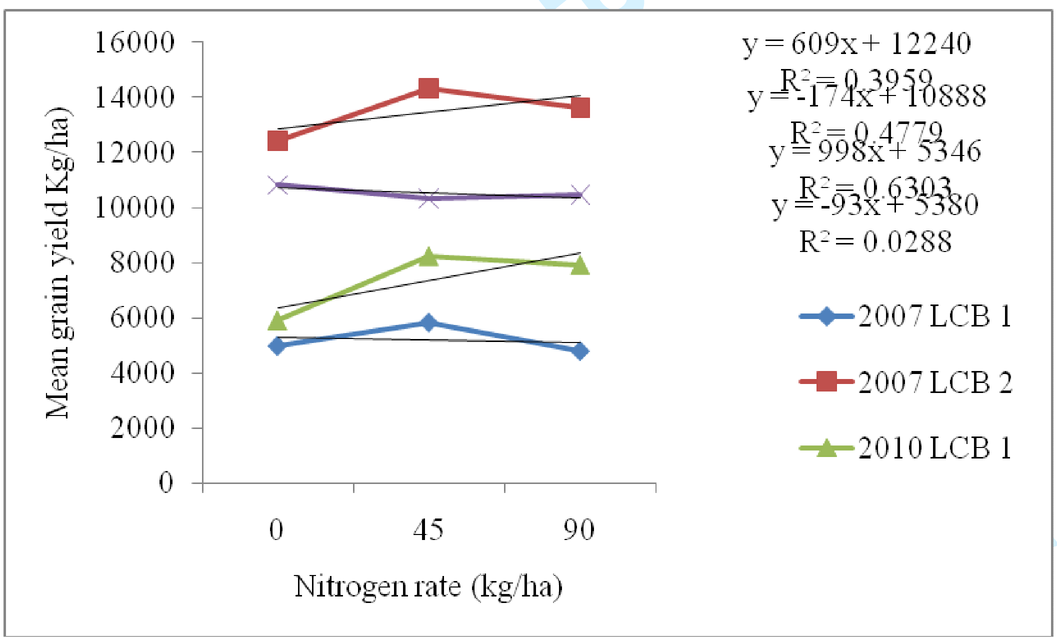

Fig 4: Effect of varrying nitrogen application on mean corn grain yield during 2007 and 2010 cropping seasons at Lake Carl Blackwell, sites 1 and 2.

Table 1: Initial surface (0-15) soil test results prior to experiment initiation at Lake Carl Blackwell (LCB), OK, 2007 and 2010

Year	Location	K (mg kg^{-1})	P (mg kg^{-1})	NH_4-N (mg kg^{-1})	NO_3-N (mg kg^{-1})	pH
2007	LCB 1	105	27	17	3.2	6.2
	LCB 2	144	45	28	4.3	5.6
2010	LCB 1	100	29	19	3.0	6.2
	LCB 2	150	40	30	4.1	5.5

pH – 1:1 soil water
K and P – Mehlich III extraction
NH4-N and NO3-N, 2M KCl extraction

Table 2: The influence of delayed planting by 0, 4, 7 and 10 days and application of sidedress nitrogen (N) fertilizer at 0, 45 and 90 kg ha^{-1}, on corn grain yield at Lake Carl Blackwell (LCB), OK, 2007 and 2010 cropping seasons.

	Mean Square			
	2007		2010	
Source	LCB 1	LCB 2	LCB 1	LCB 2
Replication	3203961	19934334	29554464	8221937
Days Delayed in Planting	4776508	4458226	2877563¶	2885505
Sidedress N rate	5639966	11521857¶	18970314**	522405
Error	2446345	3649283	1222939	3277459
	Grain yield (kg ha^{-1})			
Days Delayed in Planting (Days)				
0	4885	13268	7920	10172
4	5424	14525	6841	10774
7	7630	13283	7736	11258
10	4464	12559	6874	9938
Sidedress N rate (kg ha^{-1})				
0	4975	12415	5903	10819
40	5818	14327	8226	10330
80	4790	13633	7899	10471
SED	1277	1560	903	1810
N rate linear	ns	ns	***	ns
N rate quadratic	ns	*	***	ns
DDP§ linear	ns	ns	ns	ns
DDP quadratic	ns	ns	ns	ns

§ Days delayed after planting.

δ Not determine due to absence of data.

*, **, ¶ significant at the 0.05, 0.01, and 0.10 probability levels, respectively.

SED = standard error of the difference between two equally replicated treatment means.

Table 3: Change in grain yield of the middle delayed plant compared to the average of the earlier planted neighboring plants as affected by delayed planting of 0, 4, 7 and 10 days and application of sidedress nitrogen (N) fertilizer at 0, 45 and 90 kg ha^{-1}, at Lake Carl Blackwell (LCB), OK in 2007 and 2010 cropping seasons.

	Mean squares			
	2007		2010	
Source	LCB 1	LCB 2	LCB 1	LCB 2
Replication	1021	991	702	1194
Days Delayed in Planting	8456	851*	4098	2280*
Sidedress N rate	634	100	3413	275
Error	3145	280	3027	659
	Grain yield (kg ha^{-1})			
Delayed Planting (Days)				
0	-8	2	24	-2
4	-68	-3	26	4
7	-87	-12	-17	-12
10	-91	-22	-30	-34
Sidedress N rate (kg ha^{-1})				
0	-54	-7	-31	-9
40	-39	-6	-5	-8
80	-66	-12	20	-14
SED	46	14	45	21
N rate linear	ns	ns	ns	ns
N rate quadratic	ns	ns	ns	ns
DDP§ linear	ns	**	ns	**
DDP quadratic	ns	ns	ns	ns

§ Days delayed after planting.

[δ] Not determined due to absence of data.

*, **significant at the 0.05, and 0.01 probability levels, respectively.

SED = standard error of the difference between two equally replicated treatment means.