The effect of planting date, hybrid, row spacing, and starter fertilizer on corn growth and development

by

Philip Sheridan Ramsel

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Program of Study Committee:
Dale E. Farnham, Major Professor
Antonio P. Mallarino
William D. Batchelor
Matt Liebman

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Graduate College
Iowa State University

This is to certify that the Master's thesis of

Philip Sheridan Ramsel

has met the thesis requirements of Iowa State University

Signatures have been redacted for privacy

TABLE OF CONTENTS

INTRODUCTION

General Overview

Corn (*Zea mays L.*) is a major world commodity. United States (U.S.) plantings to corn totaled 31,335,213 hectares in 1999 (USDA/NASS, 2000). Since 1960, U.S. corn plantings have totaled between a low of 24,364,908 hectares in 1983 and a high of 34,231,549 hectares in 1976 (USDA/NAAS, 2000). During this same time period, average corn yield per hectare has increased from 3.4 Mg ha^{-1} in 1960 to 8.7 Mg ha^{-1} in 1994 (USDA/NAAS, 2000). This is a yield increase of approximately 2 ½ fold over this time period. Total world production in 1999 was approximately 605.22 million metric tons with U.S. production at 239.72 million metric tons (approximately 40% of world production) (USDA/ERS, 2000).

Corn production in the U.S. is most common in the Corn Belt states of the Midwest. Production in 1999 by the top 10 corn producing states (Iowa, Illinois, Nebraska, Minnesota, Indiana, Kansas, Wisconsin, Ohio, South Dakota, and Michigan, respectively) accounted for 84.6% of the U.S. corn production (USDA/NASS, 2000). Production in 2000 by the top ten corn producing states (Iowa, Illinois, Nebraska, Minnesota, Indiana, Ohio, South Dakota, Kansas, Missouri, and Wisconsin, respectively) accounted for 83.1% of the U.S. corn production (USDA/NASS, 2000). The top three corn producing states (Iowa, Illinois, and Nebraska) account for approximately 45% of U.S. corn production and 18.5% of total world corn production (USDA/NASS, 2000 and USDA/ERS, 2000). The value of the corn crop in these three states totaled approximately $8,514,937,800 (U.S. dollars) in 1999 and $8,077,368,150 in 2000 (USDA/NASS, 2000). These figures demonstrate the relative importance of corn production in the U.S., particularly the Corn Belt region of the U.S.

Corn producers are constantly seeking improvements in production efficiency and yield. Planting date is a production factor that is limiting to corn yield. Mid-April to early May planting dates generally result in optimum corn yields throughout the Corn Belt (Benson, 1990; Mulder and Doll, 1994; Lauer, 1997; Nafziger, 1994; Swanson and Wilhelm, 1996). Research in Iowa has shown a 3% decrease in yield from mid-May planting dates compared to late April planting dates (Farnham, unpublished). June planting dates yield 20-30% less than late April planting dates (Farnham, unpublished). Decreases in yield due to delayed planting date or replant are often attributed to hastened vegetative development from increased thermal unit accumulation at the later planting dates (Farnham, unpublished). Hastened vegetative development causes less dry matter accumulation in the corn canopy (Swanson and Wilhelm, 1996; Cantarero et al., 1999). Decreases in dry matter accumulation are attributed to decreases in intercepted photosynthetically active radiation (Kiniry et al., 1989; Sivakumar and Virmani, 1984). Decreased dry matter accumulation causes increases in kernel abortion and decreases in kernel weight during the grain filling period due to reduced assimilate availability (Cirilo and Andrade, 1996; Otegui et al., 1995). When these factors are combined, significant yield losses are observed causing substantial economic losses to corn producers throughout the Corn Belt.

Row spacing is a production factor that receives attention from corn producers. Improvements in farm equipment have made it possible to produce corn in a variety of row spacings. Early research often compared decreases in row width from 100 cm (Alessi et. al., 1974; Aubertin et al., 1961; Brown et al., 1970; Lutz et al., 1971; Nunez et al., 1969). Most of these early studies concluded inconsistent or no response to decreases in row spacing (Alessi et. al., 1974; Brown et al., 1970; Nunez et al., 1969). The few that did find conclusive increases, however, provided sufficient evidence for the industry to move towards strategies of narrower row spacing in hope of improving yield (Nunez et al., 1969). Current studies often investigate the benefits of 38-cm to 50-cm row spacing over 76-cm row spacing and benefits of twin row spacing over single rows. Most recent studies have found decreases in row spacing from 76-cm produce small and inconsistent increases in grain yield (Polito et al., 1991; Westgate et al., 1996; Farnham, 1998). Some current studies, however, have found consistent increases to narrow row spacing and more equidistant plant spacing (Cardwell, 1982; Bullock et. al., 1988; Porter et al. 1997). Photosynthetic active radiation (PAR) interception was reported to be more efficient in 35-cm row spacing compared to 100-cm row spacing but no difference when comparing 35-cm row spacing to 66-cm row spacing when measurements were made at 6 leaf, 9 leaf, and at silking in a study by Flenet et al. (1996). Ottman and Welch (1989) found that solar radiation interception was similar between 38-cm and 76-cm row spacing but different than 152-cm twin row spacing. Aubertin and Peters (1961) found more radiation interception in 51-cm rows than in 102-cm rows.

Starter fertilizer has been shown to increase early growth of corn. Early season dry matter accumulation is often increased dramatically between the 3 leaf and 8 leaf stages of development (Gordon et al., 1997; Buah et al., 1999; Mallarino et al., 1999). Bundy and Andraski (1999) found a larger percentage of positive economic yield responses to starter fertilizer in years where air temperature was below 30 year averages in Wisconsin. Scharf (1999) reported significant yield increases due to starter fertilizer application in Missouri. Buah et al. (1999) found significant yield response to starter fertilizer 8 out of 9 site-years in Iowa.

The purpose of this research was to study the planting date, hybrid, row spacing, and starter fertilizer effects on corn growth, development, and yield. Potentially, benefits are provided by row spacing and starter fertilizer at the early stages of development that will increase carbon assimilation and enable the crop to increase grain yield at late planting dates. This experiment was conducted with modern equipment and hybrids and involved thirty-six different treatment combinations. Three planting dates, three high performing hybrids of differing maturity, two commonly used row spacings, and a common starter fertilizer blend were used as the variables in this research. The results will be used to help evaluate production strategies involving planting date, row spacings, hybrids, and starter fertilizer.

Thesis Organization

This thesis is organized in the following manner. It begins with a literature review. The literature review is followed by the materials and methods for each year and location. The results and discussions are presented next followed by the conclusions. After the conclusions, a chapter will discuss data analysis using a crop model. The thesis then concludes with literature cited and acknowledgements.

LITERATURE REVIEW

Planting Date Effects on Corn Growth, Development, Yield, and Yield Components

Optimum planting date in the central Corn Belt region of the U.S. ranges from mid-April to early May (Benson, 1990; Lauer, 1997; Mulder and Doll, 1994; Nafziger, 1994; Swanson and Wilhelm, 1996). In Wisconsin, Lauer et al. (1999) suggested later optimum planting dates ranging from 1- to 7 May in southern Wisconsin to 8- to 14 May in northern Wisconsin. Longer season hybrids tend to yield more than shorter season hybrids in Wisconsin for early planting dates, however, the yield decline, as planting date is delayed occurs at a greater rate for longer season hybrids compared with shorter season hybrids. Lauer et al. (1999) also noted that grain yield decreases and grain moisture increases as planting date is delayed. Recent research in Iowa has shown that delays in planting from late April to mid-May cause approximately 3% yield loss (Farnham, unpublished). Delays in planting beyond June 1 cause 20-30% yield loss when compared to late April planting (Farnham, unpublished).

Several studies have examined the effects of planting date on grain yield and yield components of corn. Otegui et al. (1995) looked at planting date effects on crop development, biomass production, grain yield, yield components, and intercepted photosynthetic active radiation (IPAR). Otegui et al. (1995) showed that as planting date was delayed, days after emergence (DAE) to silking and physiological maturity decreased. Variation in DAE to silking was greater than days after silking to physiological maturity (Otegui et al., 1995). Days after silking to physiological maturity was measured at 56 to 68 days depending on hybrid (Otegui et al., 1995). Otegui et al. (1995) found that the reduction in DAE to silking reduced the cumulative IPAR at silking and reduced seasonal IPAR. Linear models were obtained showing correlations between cumulative IPAR and shoot dry weight at physiological maturity ($y = -253 + 3.39X$; $r^2 = 0.64$; $n = 32$) and shoot dry weight at silking ($y = -262 + 4.14X$; $r^2 = 0.81$; $n = 32$). Differences between the two models indicated lower radiation use efficiency during grain fill (Otegui et al., 1995). Further, Otegui et al. (1995) showed that shoot dry weight at silking accounted for more than one-half of the variance of grain number and grain yield showing that dry matter accumulation to silking can be a good indicator of yield given that environment after silking is not limiting to grain fill.

In further study, Otegui and Melón (1997) found that planting date did not alter sink size. This agrees with results by Cirilo and Andrade (1994) suggesting that kernel abortion is a dominant factor determining final kernel number when comparing planting dates.

Swanson and Wilhelm (1996) showed that kernels ear^{-1} and kernels plant^{-1} showed a quadratic response to planting date. Cirilo and Andrade (1994) also found decreases in kernels ear^{-1} and ears plant^{-1} with delays in planting. The decreases in kernels ear^{-1} were determined by decreases in crop growth rate after silking (Cirilo and Andrade, 1994). Swanson and Wilhelm (1996) found that kernel weight showed a quadratic response in one of the years but the response was not significant in the other year (Swanson and Wilhelm, 1996). Cirilo and Andrade (1996) also observed lower effective grain filling rates and lower final kernel weight in later planting dates.

Row Spacing Effects on Corn Growth, Development, Yield and Yield Components

Much interest has been given to possible benefits gained through redistributing corn plants through row spacing in an attempt to gain equidistant plant spacing. Early research in

Iowa suggested increases in yield as row spacing was decreased from 102-cm to 76- or 51-cm (Hillson, 1966; Thompson, 1967). Recent research in Iowa has shown little or no response by corn to narrow (less than 76-cm) row spacing (Benson, 1994; Benson, 1995a; Benson, 1995b; Benson, 1996a; Benson 1996b). Research by Farnham (2001) in Iowa, showed a hybrid interaction with both 38- and 76-cm row spacing, however, returns to row spacing were not significant when averaged over the entire study. Polito and Voss (1991) showed a response to 51-cm row spacing over 76-cm row spacing at one location in Iowa.

Research of publicly pooled data shows a 3.2% increase in yield by corn planted in narrow rows with the largest increases coming from the northern Corn Belt (Hallman and Lowenberg-DeBoer, 1999). Hallman and Lowenberg-DeBoer (1999) concluded that the northeast area of their study was the only area that would provide economic returns to narrow row spacing. Published literature from the northern Corn Belt shows mixed results. In Minnesota, Porter et al. (1997) reported a 7% increase in yield by corn planted in 51- and 25-cm rows compared to 76-cm rows. Cardwell (1982), in a summary of historical data, summarized that decreasing row widths contributed to a 4% increase in yield in Minnesota. Others have not found a yield advantage, however, to narrow row corn production in Minnesota (Johnson et al., 1998; Westgate et al., 1997). In Michigan, Dysinger and Kells (1997) found significant yield increases from 76- and 56-cm compared to 38-cm row spacing in one plot out of fifteen. Two plots out of fifteen showed significant increases in yield due to 56-cm row spacing compared to 76-cm row spacing. In Wisconsin, Rankin (1997) reported a positive increase in grain yield from planting in narrow row spacing (38- or 51-cm compared to 76-cm) at each of seven locations with a 3.4% increase across all locations. Alessi and Power (1974) reported no significant difference between 50- and 100-cm row spacings in North Dakota. In Ontario, Scheifele and Jay (1996) reported increased yields from 51-cm row spacing compared to 76-cm row spacing in eleven trials over six years.

In southern corn producing areas, literature indicates yield increases from narrow rows also tend to be mixed. In Illinois, Nafziger (1999) preliminarily showed a slight response to row spacing with one hybrid and a 251 kg ha^{-1} increase from narrow row spacing when averaged over all years and treatments. Ottman and Welch (1989) reported no advantage to planting in 38-cm row spacing compared to 76-cm in Illinois. Nielson (1988) reported a 2.7% increase in yields in Indiana from corn planted in 38-cm rows compared to 76-cm rows. A significant ($P \leq 0.01$) hybrid response to narrow rows was reported in the Indiana study. Bullock et al. (1988) reported increases to yield from corn planted in equidistant plant spacing compared to conventional plant spacing in Indiana. Hoff and Mederski (1960) evaluated plant spacing in 106-cm rows to equidistant spacing at five different populations in Ohio with equidistant spacing increasing yield 345 kg ha^{-1}. Rzewnicki (1997) reported no significant ($P > 0.05$) differences at nine out of ten locations in Ohio and no significant difference ($P > 0.05$) when averaged over all ten locations. Brown et al. (1970) found a significant ($P \leq 0.01$) increase in yield from corn planted in 51-cm rows compared to 102-cm in Georgia. Lutz et al. (1971) found mixed increases in yield from narrow row spacing when comparing 40-, 60-, 80- and 100-cm row spacings in Virginia. In North Carolina, Nunez and Kamprath (1969) reported similar yields between 53- and 106-cm row spacing except for one location in one year under drought conditions where 53-cm row spacing yield significantly more than 106-cm row spacing. Teasdale (1995) showed significant ($P \leq 0.05$) increases to yield from corn planted in 38-cm row spacing to 76-cm row spacing under complete weed control in Maryland, however, the 38-cm row spacing plots had twice the plant population of the 76-cm row spacing. Teasdale (1995) also showed significant ($P \leq 0.05$) increases to yield from the 38-cm row spacing (with twice the plant population) compared to 76-cm row spacing under no weed control. In this case, the 38-cm row spacing (with twice the plant population) also significantly decreased weed pressure compared to the 76-cm row spacing (Teasdale, 1995). Barbieri et al. (2000) reported significant ($P \leq 0.01$) and marginally significant ($P \leq 0.10$) yield increases from 35-cm row spacing over 70-cm row spacing, respectively, in each of 2 years in Argentina.

Barbieri et al. (2000) showed significant interactions between row spacing and kernels m^{-2} at the 0.05 level of probability in 1995-1996 and marginal significance at the 0.10 level of probability in 1996-1997. No significant differences were found in 1995-1996 for kernel weight but significant differences at the 0.10 level of probability were found in 1996-1997 for kernel weight. Barbieri et al. (2000) showed relationships between intercepted photosynthetic active radiation at flowering (IPARf) and kernels m^{-2}. Barbieri et al. (2000) concluded that yield responses to narrow row spacing decreased in comparison to conventional row spacing as crop radiation interception in conventional row spacing increased relative to narrow row spacing.

Bullock et al. (1988), in growth analysis of corn grown at equidistant (EPS) and conventional plant spacing (CPS), reported that corn grown at EPS had higher ($P \leq 0.05$) leaf area index (LAI) at most testing times than corn grown at CPS. Net assimilation rate (NAR) was largely insignificant ($P > 0.05$) at each testing time (Bullock et al., 1988). Crop growth rate (CGR) defined as the product of LAI and NAR was significantly higher ($P \leq 0.05$) under EPS until the later part of the growing season (Bullock et al., 1988). Relative growth rate, defined as the product of leaf area ratio and NAR, was insignificant ($P > 0.05$) throughout the growing season.

The concept of canopy development as it relates to leaf area index (LAI), intercepted photosynthetic radiation (IPAR), subsequent biomass production, and grain yield receives much interest in comparing row spacing or equidistant plant spacing. Early research by Nunez and Kamprath (1969) reported that yield was related to LAI up to a LAI of 3.5 $m^2 m^{-2}$. Similar findings suggested that grain yields were related up to a LAI of 3.3 $m^2 m^{-2}$ (Eik and Hanway, 1966). These findings are similar to other research that indicates that dry matter accumulation in corn increases linearly up to a LAI 3.5 $m^2 m^{-2}$ (Williams et al., 1968; Christy and Williamson, 1985). Further study has shown that dry matter production is more closely related to radiation use efficiency (RUE) than simply radiation interception (Daughtry et al., 1983; Christy et al., 1986; Tollenaar and Bruulsema, 1988; Westgate, 1997). Major et al. (1991) and Westgate (1997) suggested that RUE was largely related to genotype. Westgate (1997) found that narrow row spacing had no impact on IPAR and suggested that the rigid pattern of opposite and alternate leaf display in corn probably inhibits increasing IPAR by narrowing row spacing. Potentially, the combination of maize morphology and efficient C_4 photosynthesis reduce the ability to enhance yields by altering row spacing.

Starter Fertilizer Effects on Corn Growth, Development, Yield and Yield Components

Starter fertilizer is defined as "the placement of small quantities of nutrients in a concentrated zone in close proximity to the point of seed placement at the time of planting" (Penas and Hergert, 1990). Starter fertilizer usually consists of a nutrient blend containing nitrogen/phosphorus or nitrogen/phosphorus/potassium (Penas and Hergert, 1990). Most state fertilizer recommendations in the Corn Belt are based on soil test reports. For phosphorus and potassium, Iowa State University recommendations for Iowa are based on soil test levels of each respective nutrient (Voss et al., 1999). Relative levels for phosphorus and potassium are based on expected subsoil phosphorus and potassium levels from soil type and the soil test of the top 15- to 18-cm (Voss et al., 1999). Recommendations of P_2O_5 and K_2O are then based on maintaining soil test levels in the optimal range for crop production (Voss et al., 1999). Research is currently in progress in Iowa to determine if differences between farming practices may influence recommendations of phosphorus and potassium fertilizer (Voss et al., 1999). Other universities in Corn Belt states have suggested similar recommendations for phosphorus and potassium with part of the decision based on maintenance of critical levels and/or expected response to additional fertilizer (Hoeft and Peck, 2000; Rehm et al., 2000; Hergert and Shapiro, 1995; Brouder, 1996). Some universities are suggesting the use of starter fertilizer under specific conditions or for benefits that the starter may provide. Purdue University in Indiana suggests the use of starter fertilizer before 1 April in the southern half of Indiana and before 1 May in the northern half of Indiana when soil temperature may be cold (Brouder, 1996). Brouder (1996) also suggests use of starter fertilizer with reduced tillage or no-till systems. Rehm et al. (2000) suggest the use of starter fertilizer in Minnesota due to the potential of cool and wet soils during the spring. Penas and Hergert (1990) suggest the use of starter fertilizer in Nebraska in an attempt to increase early growth and crop uniformity in order to begin cultivation earlier and possibly hasten maturity.

Research in Iowa by Buah et al. (1999) reported that starter fertilizer is likely to benefit no-till corn production in the northern regions of the Corn Belt regardless of hybrid.

Buah et al. (1999) showed significantly increased yields from starter placed 5 cm to the side and 5 cm below the seed at seven out of nine site years. Buah et al. (1999) also reported significant increase in dry matter when measured at V6 for six of the twelve hybrids tested. Mallarino et al. (1999) reported heavier plant weights at V5 to V6 for planter-applied phosphorus fertilizer over deep band and broadcast-applied phosphorus in Iowa. Mallarino et al. (1999) also showed a decrease in growth due to potassium fertilizer at two sites out of four, potentially due to the salt effect of potassium fertilizer. Grain yields from the same experiment, showed no significant difference between placement methods (Bordoli and Mallarino, 1998). Phosphorus fertilization did increase yields significantly ($P \leq 0.05$) in soils testing very low or low for phosphorus at Iowa research center sites (Bordoli and Mallarino, 1998). One year, short term trials on Iowa farmers' fields found phosphorus responses at three out of eleven sites. Responses were also mainly attributed to low soil phosphorus, however, no response occurred on five out of eight fields where soil phosphorus was very low to low (Bordoli and Mallarino, 1998). Potassium fertilization increased yields at four Iowa research center sites out of fifteen and placement was significantly different at one site with the deep band placement yielding more than planter applied and broadcast (Bordoli and Mallarino, 1998). Potassium fertilization increased yields at three Iowa farmer's fields out of eleven (Bordoli and Mallarino, 1998). Responses to potassium occurred at both Iowa research center sites and Iowa farmers' fields in cases where soil test values for potassium were optimal to very high (Bordoli and Mallarino, 1998).

Farber and Fixen (1986) reported that starter fertilizer, placed 5 cm below and 5 cm to the side, at a late planting date in a wet year in South Dakota produced higher yields than broadcast, knife, or strip applications in moldboard plow, till planted ridged, and no-till systems. Gordon et al. (1997) reported a hybrid yield response and decrease in thermal units needed to reach midsilk in starter fertilizer-treated plots for three of five hybrids tested in Kansas. This disagrees with Buah et al. (1999) where consistent responses to starter fertilizer were recorded in all hybrids tested. Gordon et al. (1997) also reported an increase in early growth regardless of hybrid for the starter treated plots. Scharf (1999) reported that starter fertilizer significantly increased yields in all six experiments in Missouri. The starter with nitrogen only increased yield more than the nitrogen plus phosphorus starters with the exception of two sites where phosphorus was low. Increased early season growth and earlier tasseling were also observed in the starter treated plots. Engelstad and Doll (1961) attempted to correlate phosphorus application with rainfall and temperature variables in Kentucky over a 12-year study. Rainfall and temperature were highly correlated so rainfall was used as the climatic variable. They reported that phosphorus response was independent of the effect of rainfall on corn yield, concluding that the rates of phosphorus that would maximize returns at each level of rainfall were relatively small.

MATERIALS AND METHODS

This experiment was conducted during the 1999 and 2000 growing seasons at the Iowa State University Sorenson Farm located southwest of Ames, Iowa and at the Iowa State University North Central Research and Demonstration Farm located south of Kanawha, Iowa. The experimental design for both locations was a randomized complete block with a split-split-split plot design and three replications of each treatment. Treatments included three planting dates, three hybrids, two row spacings, and two fertility regimes. Whole plot treatment was planting date and split plot treatments were hybrid, row spacing, and fertility regime.

Ames 1999 and 2000

The soil type at the Ames-Sorenson farm is a Clarion-Nicollet-Webster soil complex. Soil tests from both years are listed in Table 1. The previous crop in both years was soybean [*Glycine max* (L.) Merr], which was harvested for grain. Minimal tillage was used with a field cultivator being used for spring seedbed preparation. No fall or primary tillage was used.

Three planting dates were compared with the target planting dates being 15 April, 15 May, and 10 June. Actual planting dates in 1999 were 3 May, 10 May, and 17 June. Planting dates in 2000 were 11 April, 11 May, and 9 June. Two row spacings, 38- and 76-cm, were compared. A White 6100 series planter with a 6900 series splitter attachment was used to plant all plots.

Pioneer® Brand 35N05 (Relative Maturity (RM) 105 day), 34R07 (RM 110 day), and 33A14 (RM 113 day) were used under all treatments. These hybrids were selected based on

Table 1. Soil test by block at Kanawha, IA and Ames, IA.

Location	Year	Block	mg kg $^{-1}$ (Bray P1)	pH	Buffer pH	%OM	mg kg^{-1} K	mg kg^{-1} N
Kanawha	1999	1	24	5.95	6.6	4.5	149	6
Kanawha	1999	2	28	5.8	6.5	4.8	167	13
Kanawha	1999	3	38	6	6.5	5.9	170	16
Ames	1999	1	14	6.2	6.7	4	136	24
Ames	1999	2	22	6.15	6.55	4.5	150	23
Ames	1999	3	17	5.9	6.55	3.9	134	27
Kanawha	2000	1	36	6.15	6.65	5.1	141	
Kanawha	2000	2	21	5.85	6.6	5.1	91	
Kanawha	2000	3	26	6.1	6.65	4.9	113	
Ames	2000	1	11	5.4	6.35	3.5	120	
Ames	2000	2	11	5.5	6.45	3.1	118	
Ames	2000	3	18	5.75	6.5	4.2	134	

differing relative maturity, historic performance, and being commonly used hybrids in the this geographic region. All experimental plots were 12.2 meters (m) in length and 4.6 m wide. The 38-cm row spacing plots consisted of 11 rows and the 76-cm rows consisted of 6 rows.

In the fall of 1998, 67 kg P ha^{-1} and 100 kg K ha^{-1} were applied. Urea (46-0-0) was applied in the spring at a rate of 142 kg N ha^{-1} in both years. Two fertility regimes were evaluated. Fertility regimes consisted of 59 kg ha^{-1} of 6-24-6 liquid starter fertilizer placed in furrow at planting and no starter. All plots were over-planted and thinned to a final plant population of 73 482 plants ha^{-1}.

A preplant application of isoxaflutole [0.05 kg of active ingredient (ai) ha^{-1}], acetochlor (2.17 kg ai ha^{-1}), and atrazine (1.46 kg ai ha^{-1}) was applied each year. In 2000, a postemergence application of nicosulfuron (0.035 kg ai ha $^{-1}$) was applied to the 11 April and 11 May planting dates and preplant to the 9 June planting date to control escaped foxtail. Permethrin (0.22 kg ai ha^{-1}) was applied postemerge in 2000 to the 11 May planting date to control black cutworm (*Agrotis ipsilon* (Lepidoptera: Noctuidae)). Supplemental hand weeding was done when needed.

Yield rows were the center 2 rows for 76-cm plots and the center 4 rows for 38-cm plots in 1999. The center 3 rows and center 6 rows were used in 2000 for the 38- and 76-cm plots, respectively. Ten plants were arbitrarily selected from the first row outside of the yield row in the 76-cm plots and in the second row outside of the yield rows in the 38-cm rows for monitoring of crop development. Flowering dates were observed for tassel and silk. Growing degree days (GDD_{50}) to midsilk (defined as the date when 50% of the plants had silk visible) were calculated using 10° C as the base low and 30° C as the base high (Cross and Zuber, 1972). Daily high and low temperature were obtained from the weather station at the Sorenson farm.

Leaf area index is defined as the leaf area (m^2) divided by the ground area (m^2). In 1999, LAI was estimated using a LI-COR LAI-2000 (LI-COR, Inc., Lincoln, NE) at V5 for all planting dates. The fifth ring (horizon) was not removed from this data and the transmittance was not set to one for below canopy readings that were greater than above canopy readings (Wilhelm, 2000; LI-COR, 1992). In 2000, leaf area index was estimated at intervals from V2 through R2. Data was transformed by removing the fifth ring and setting all transmittance to one (Wilhelm, 2000 and LI-COR, 1992). Wilhelm (2000) found that removing the fifth ring improves the accuracy of this device. Leaf area index was transformed using LOG(LAI). Leaf area duration represents the opportunity for canopy carbon assimilation within a specified time period (Watson, 1949). Leaf area duration was calculated using the Gompertz equation to estimate LAI at each growing degree unit. Leaf area duration was then calculated using a graphical approach to arrive at the integral quantity (Hunt, 1982):

$$LAD = \int_{x}^{1} LAI \, d(GDU) \qquad \text{Equation (1),}$$

where LAD = leaf area duration; LAI = leaf area index; and d = derivative.

Intercepted photosynthetic radiation was measured using a LI-COR LI-191SA Line Quantum Sensor (LI-COR, Inc., Lincoln, NE). Measurements above the canopy and at ground level were taken. Fraction of intercepted photosynthetic radiation was calculated by subtracting below canopy measurements from above canopy measurements and dividing the result by the above canopy measurement. Fraction intercepted photosynthetic radiation was transformed using the square root (Fraction intercepted photosynthetic radiation).

Ear samples were collected from each of the ten arbitrarily selected plants that were used to record development. Ear measurements recorded were weight per ear, total ear length, effective ear length (defined as length of ear with harvestable kernels), ear length to end of kernels (defined as effective ear length plus any aborted kernels), kernel number ear^{-1}, ear diameter, cob diameter, cob weight, and weight per 100 kernels. Weight per 100 kernels was transformed to weight per kernel. All weights were measured on a fresh weight basis. Kernel weights were adjusted to a 0 mg kg^{-1} basis. Ear measurements that will be discussed in this paper are kernel number ear^{-1} and weight per kernel. All plots were mechanically harvested using a 76-cm corn head. Plots were gleaned for any dropped ears in both 38- and 76-cm rows.

Kanawha 1999 and 2000

The soil type at the Northern Research and Demonstration Farm is a Clarion-Nicollet-Webster soil complex. Soil tests are listed in Table 1. The previous crop was soybean which was harvested for grain. Minimal tillage was used with a field cultivator being used for spring seedbed preparation. No fall or primary tillage was used.

Three planting dates were compared with the target planting dates being 15 April, 15 May, and 10 June. Actual planting dates in 1999 were 21 April, 25 May, and 14 June. Planting dates in 2000 were 15 April, 15 May, and 8 June. Row spacings were 38- and 76-cm. The same hybrids, plot size, row spacings, starter fertility regimes, plant population and planter that were used at the Ames site were also used at the Kanawha site. The same treatment evaluations used at the Ames site were also used at the Kanawha site.

In the fall of 1998, 176 kg P ha^{-1}, 134 K kg ha^{-1}, and 71 kg N ha^{-1} were applied. Anhydrous ammonia (82-0-0) was applied in the fall of 1998 at a rate of 229 kg N ha^{-1}. In the fall of 1999, 324 kg N ha^{-1}, 117 kg P ha^{-1}, and 125 kg K ha^{-1} were applied. In 1999, the 21 April and 25 May planting dates received a preemergence application of dimethenamid (1.19 kg ai $ha^{-1)}$ and cyanazine (2.24 kg ai ha^{-1}). The 14 June 1999 planting date received a preplant application of dimethenamid (1.19 kg ai ha^{-1}) and cyanazine (2.24 kg ai ha^{-1}). The 25 May and 14 June 1999 planting dates received a postemergence application of nicosulfuron (0.035 kg ai ha $^{-1}$). In 2000, the 15 April and 15 May planting dates received a preemergence application of dimethenamid (1.19 kg ai $ha^{-1)}$ and cyanazine (2.24 kg ai ha^{-1}). The 8 June 2000 planting date received a preplant application of dimethenamid (1.19 kg ai ha^{-1}) and cyanazine (2.24 kg ai ha^{-1}). Supplemental hand weeding was done when needed.

Similar methods were used at the Kanawha site for recording plant development, measuring leaf area index, LAD, intercepted photosynthetic radiation, and ear samples as were used at the Ames site. Leaf area index was only taken on two dates for the third planting date in 2000 so LAD was not calculated. Yield rows at the Kanawha site were the center 3 rows and center 6 rows of the 38- and 76-cm plots respectively in 1999 and 2000. A 76-cm corn head was used and each plot was gleaned for dropped ears.

Statistical Analysis

Analysis was done on individual year/location and combined year/location data for yield, grain moisture, flowering dates, weight $kernel^{-1}$ and kernel number ear^{-1} using SAS general linear model (GLM) procedures. Location, planting date, hybrid, row spacing, and fertility regime were considered fixed effects. For individual year/location analysis, blocks were considered random effects and planting date, hybrid, row spacing and fertility regime were fixed effects. Fixed effects were tested by their interactions with random effects. Pair-wise comparison of treatment effects were generated using least significant difference. Comparisons of treatment interactions were generated using the PDIFF option of the Least Square Means statement of PROC GLM. Leaf area index, LAD, and intercepted fraction of photosynthetic active radiation were analyzed by individual location/planting date for year 2000. Leaf area duration was analyzed using SAS GLM procedures. Leaf area index and intercepted fraction of photosynthetic active radiation were analyzed using SAS mixed model procedures with block as the random variable and growing degree units as the repeated variable. Years and blocks were considered random effects for all combined year/location analysis. Pair-wise comparisons and comparisons of interactive effects were generated using the PDIFF option of the Least Square Means statement of PROC MIXED.

RESULTS AND DISCUSSION

AMES 1999 AND 2000

Summary of season growing conditions

The month of April 1999 was the wettest in Iowa in 127 years (Iowa Agricultural Statistics, Table 2). A very mild winter led into a very wet spring. There was very little fieldwork done in April due to rain. A dry period occurred in early May allowing planting to begin. Heavy rains resumed in mid-May causing further delays in planting. Planting resumed again in late May to mid-June with some producers changing their intended corn plantings to soybeans. Early June was uncharacteristically cold. Late June and July had regular rainfalls that seemed to be timely for crop utilization. Late August, September, and October were much drier than normal. Dry conditions seemed to hasten grain drying allowing harvest to finish earlier than normal.

The 2000 growing season was very dry (Table 2). Very little precipitation fell from the fall of 1999 through the 2000 growing season. Fieldwork occurred at a very rapid pace allowing some farmers to have their corn planted by mid- to late April. Increased rainfall occurred during May and June, however, rainfall was still below the 50-year average. July, August, and September were increasingly dry with rainfall drastically below the 50-year average. Harvest occurred at a rapid pace with dry conditions hastening grain drying. Average monthly high and low temperatures from 1999 and 2000 are in Table 3.

Table 2. Average precipitation per month.

Year	Apr	May	Jun	Jul	Aug	Sep	Oct
				Month			
1999	188 mm	132 mm	170 mm	142 mm	142 mm	58 mm	8 mm
2000	23	81	89	64	25	23	18
50-year average:	89	110	130	102	106	81	61

Table 3. Average Temperature at Ames, IA.

	Apr	May	Jun	Jul	Aug	Sep	Oct
					Month		
1999 Ave. Low	4°C	11°C	16°C	19°C	16°C	9°C	3°C
1999 Ave. High	15	21	26	31	26	23	18
2000 Ave. Low	3	11	14	17	17	11	4
2000 Ave. High	17	24	26	27	28	26	17
50-year Ave. Low:	3	10	15	17	16	11	5
50-year Ave. High:	16	23	27	29	28	24	18

Main effects of year and planting date on corn yield

Average yield between years was significantly different ($P < 0.01$). Yields in 2000 were 19.5 % lower than in 1999 (Fig. 1). Individual grain yield treatment means are summarized in Table 4.

In 1999, yield was similar ($P > 0.05$) between the 3 May (Date 1) and 10 May (Date 2) planting dates (Fig. 2). Yield was significantly different ($P < 0.01$) between the 17 June (Date 3) and the 3 May and 10 May planting dates. Inclement weather delayed the 15 April target planting date until 3 May in 1999. The 7 day delay in planting between the first planting date and second planting date was not enough to produce a significant yield difference with the 10 May planting date yielding only 1.5% less than the 3 May planting date. Delaying planting from 3 May to 17 June produced a 47.8% loss in yield and delaying planting from 10 May to 17 June produced a 46.9% loss.

Table 4. Individual corn grain yield treatment means in Mg ha^{-1} at Ames, IA.

Date 1			Year		Date 2			Year		Date 3			Year	
Row Spacing	Fertilizer	Hybrid	1999	2000	Row Spacing	Fertilizer	Hybrid	1999	2000	Row Spacing	Fertilizer	Hybrid	1999	2000
38-cm	0	33A14	14.1	11.7	38-cm	0	33A14	13.6	9.2	38-cm	0	33A14	7.1	7.0
		34R07	13.1	10.8			34R07	13.5	9.8			34R07	7.1	6.8
		35N05	12.5	10.1			35N05	12.6	8.7			35N05	7.4	7.1
76-cm	0	33A14	13.9	11.9	76-cm	0	33A14	12.8	9.8	76-cm	0	33A14	5.8	7.0
		34R07	13.0	11.5			34R07	13.5	9.5			34R07	6.7	6.9
		35N05	12.8	9.9			35N05	12.5	8.7			35N05	6.6	6.8
38-cm	NPK	33A14	13.8	12.0	38-cm	NPK	33A14	13.8	9.5	38-cm	NPK	33A14	7.5	7.4
		34R07	13.8	11.2			34R07	13.5	9.4			34R07	8.0	7.4
		35N05	13.2	10.4			35N05	12.7	8.2			35N05	8.1	6.5
76-cm	NPK	33A14	13.9	12.0	76-cm	NPK	33A14	14.0	9.9	76-cm	NPK	33A14	6.1	7.6
		34R07	14.1	11.2			34R07	13.9	9.7			34R07	5.5	6.8
		35N05	13.0	10.4			35N05	12.7	8.6			35N05	8.1	6.4

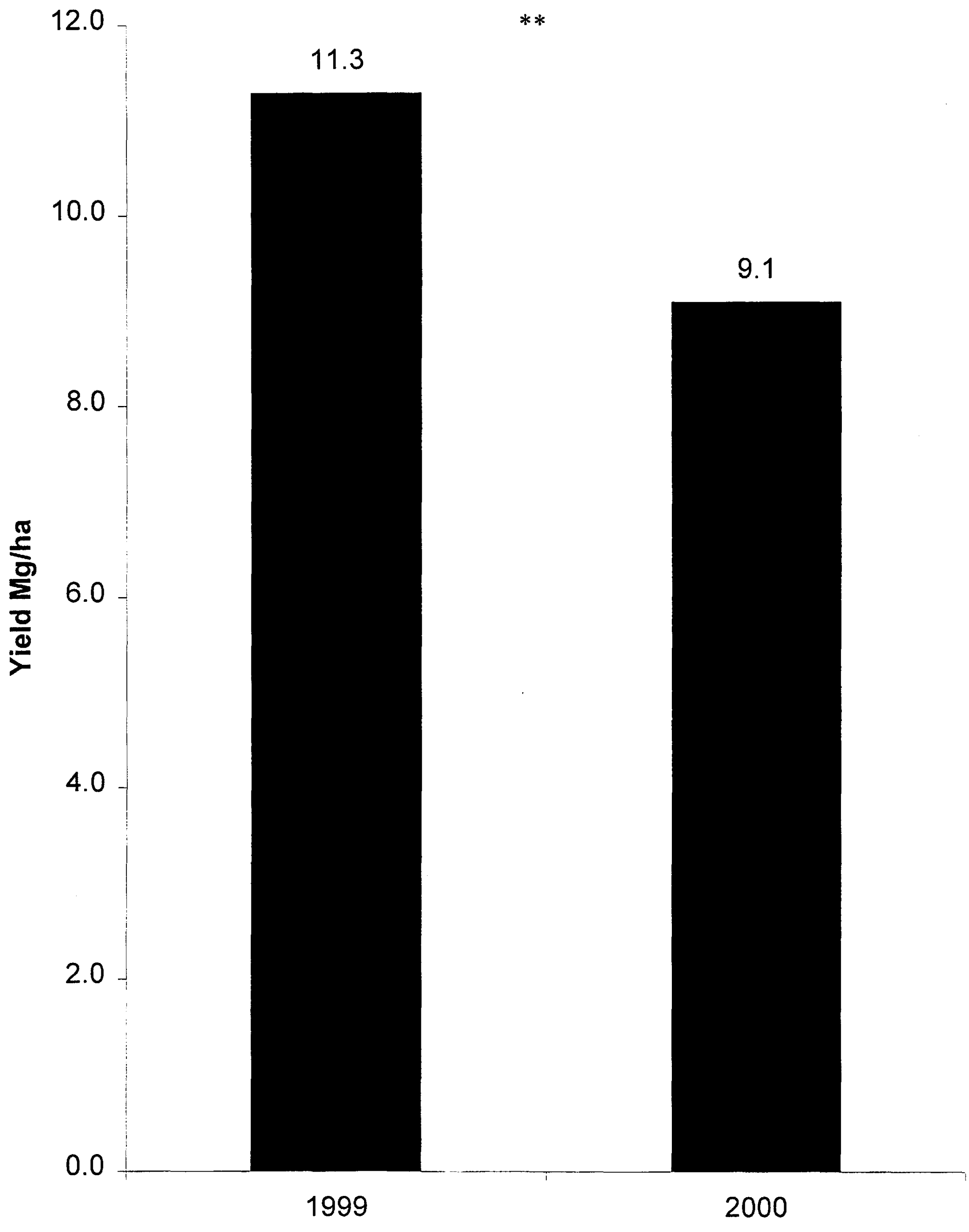


Fig. 1. Corn grain yield at Ames, IA, 1999-2000.

** = significant main effect (P < 0.01).

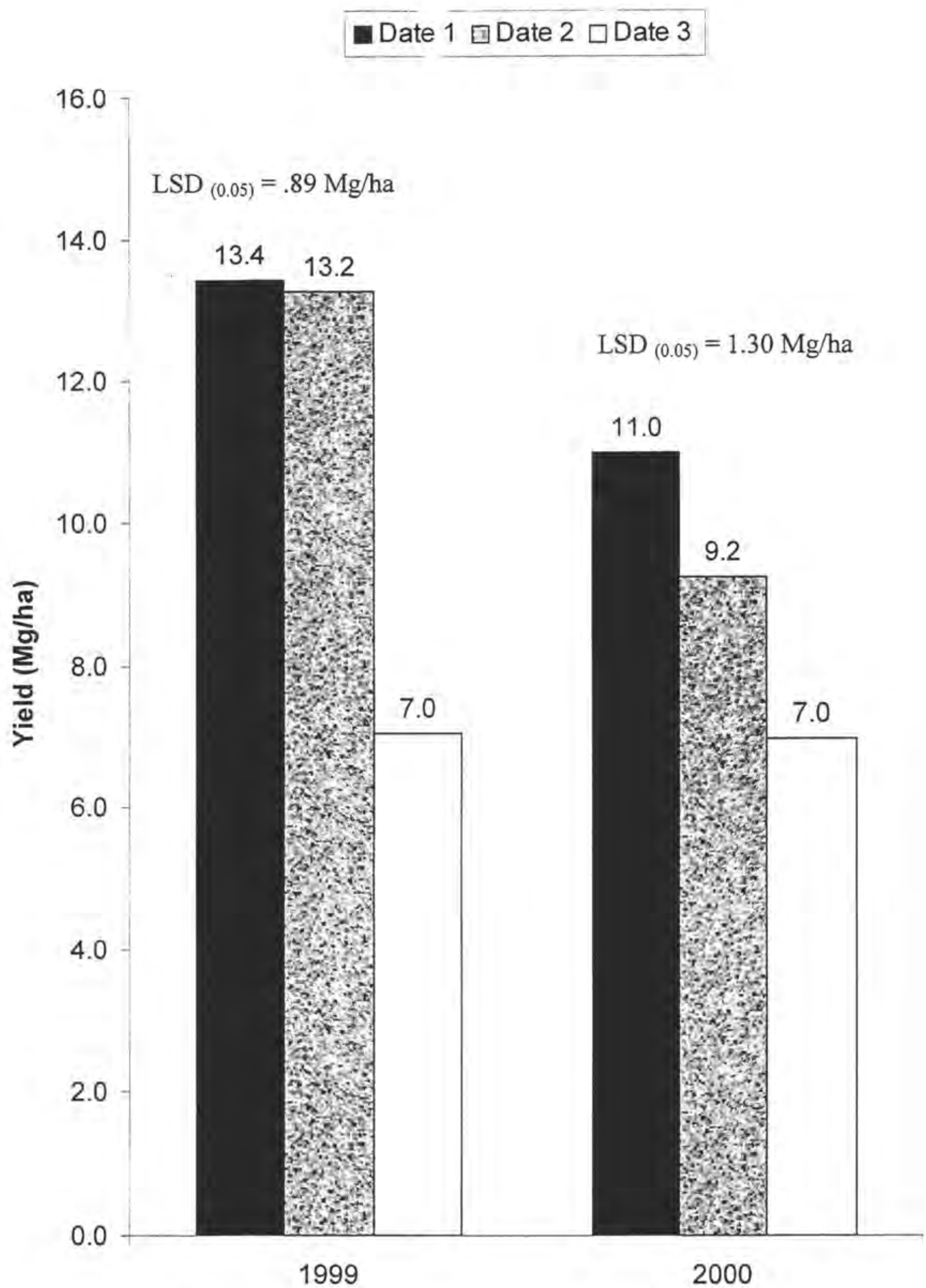


Fig. 2. Main effect of planting date on corn grain yield at Ames, IA.

In 2000, optimal planting weather allowed planting near the target planting dates. Each planting date produced statistically different ($P < 0.01$) results with the 11 April (Date 1) planting date yielding more than the 11 May (Date 2) and 9 June (Date 3) planting dates and the 11 May planting date yielded more than the 9 June planting date (Fig. 2). The 11 April planting date yielded 16.3% more than the 11 May planting date and 36.3% more than the 9 June planting date. The 11 May planting date yielded 23.9% more than the 9 June planting date.

The results from this study show effects of planting date on corn yield similar to what has been shown in other planting date studies (Lauer, 1997; Mulder and Doll, 1994, Nafziger, 1994, Swanson and Wilhelm, 1996). Decreases in yield reached a higher magnitude than what has recently been shown in Iowa by Farnham (2000, unpublished). Decreases of 16.3% between the mid-April and mid-May planting date suggest that yield decreases can be much higher when planting date is delayed during this period. Delays in planting until June also produced higher yield losses compared to what has recently been measured in Iowa. Decreases up to 47.8 % were measured in this study compared to recent yield losses in the range of 20-30% when comparing late April planting dates to June planting dates. Planting date interactions with other treatments did occur in this study, which will be addressed later.

Main effects of hybrid on corn yield

No significant differences ($P > 0.05$) were found between hybrids in 1999 (Fig. 3). Each hybrid was significantly different ($P < 0.01$) in 2000 (Fig. 3). A 5.2% increase in yield was found for 33A14 over 34R07 and a 12.4% increase was found for 33A14 over 35N05.

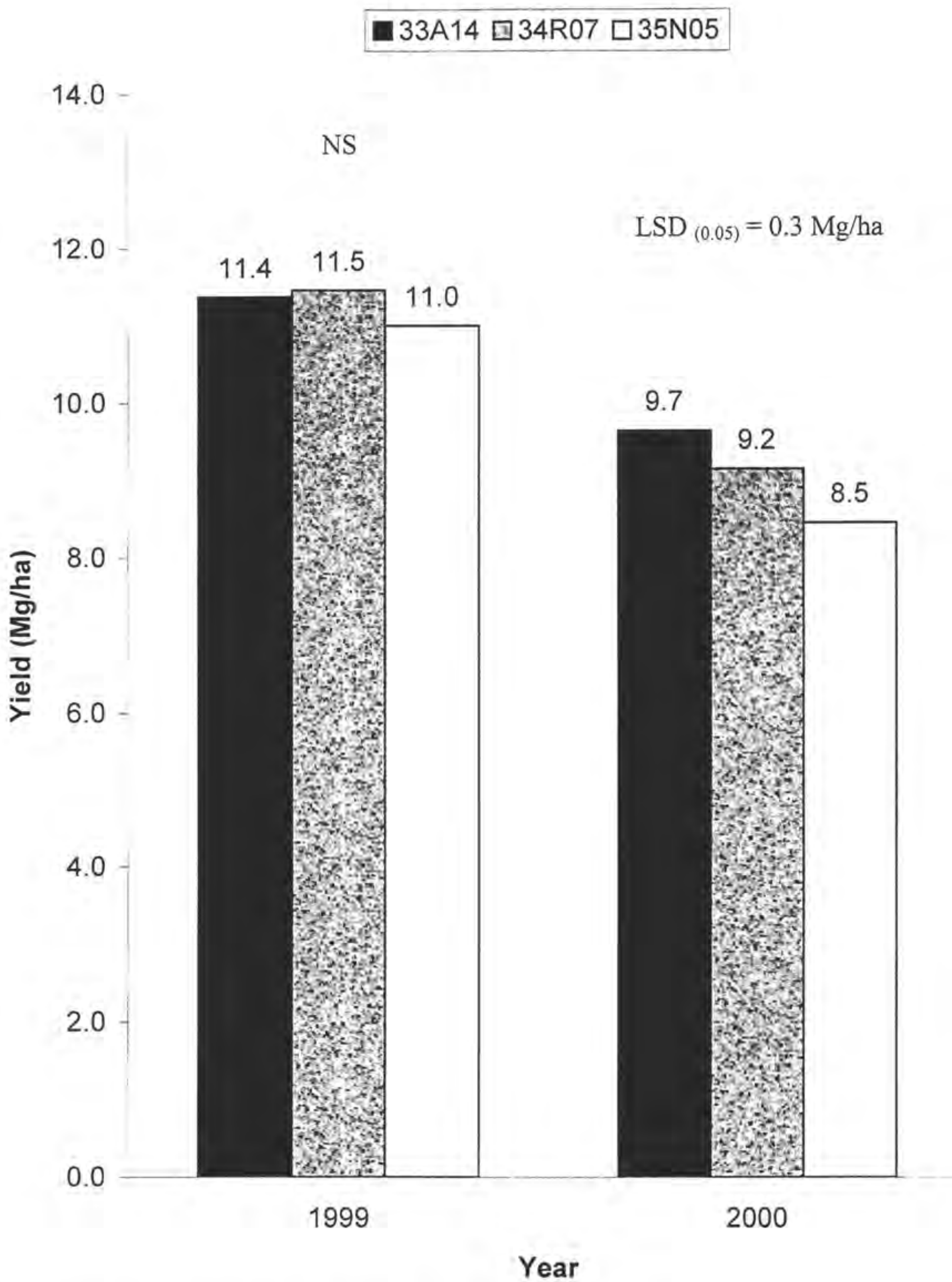


Fig. 3. Main effect of hybrid on corn grain yield at Ames, IA.

NS = no significant main effect ($P > 0.05$).

An 8.2% increase in yield was found for 34R07 over 35N05. Hybrid interactions with other treatments did occur in this study, and will be addressed later.

Main effects of row spacing on corn yield

Yield between 38- and 76-cm row spacing was not significant ($P > 0.05$) in both years of this study (Fig. 4). The results of this study at this location agree with Benson (1995) and Farnham (2001) who have not found a significant or consistent yield advantage from planting corn in narrow row spacings less than 76-cm in Iowa. Others have also found no significant or consistent yield increase from narrowing row spacing in corn (Johnson et al, 1998; Westgate et al., 1997; Dysinger and Kells, 1997; Alessi and Power, 1974; Ottman and Welch, 1989; Rzewnicki, 1997; Lutz et al., 1970; Bitzer and Herbeck, 1997). Row spacing interactions with other treatments did occur in this study, which will be addressed later.

Main effects of starter fertilizer on corn yield

In 1999, yields for starter fertilizer were significantly higher ($P < 0.05$) than yields without starter fertilizer (Fig. 5). Starter fertilizer treatment yielded 4.3% more than plots without starter fertilizer. In 2000, no difference ($P > 0.05$) occurred between fertility regimes (Fig. 5).

Weather in 1999 was much wetter and cooler during the early part of the growing season than 2000 (Tables 2 and 3). Brouder (1996) and Rehm et al. (2000) suggest use of starter fertilizer, which may increase early growth and grain yield, when soil conditions tend to be cooler and wetter at planting. Buah et al. (1999) reported that starter fertilizer is likely to benefit no-till corn production regardless of hybrid. No-till corn production is likely to have cooler soils during planting than conventional systems especially with earlier planting

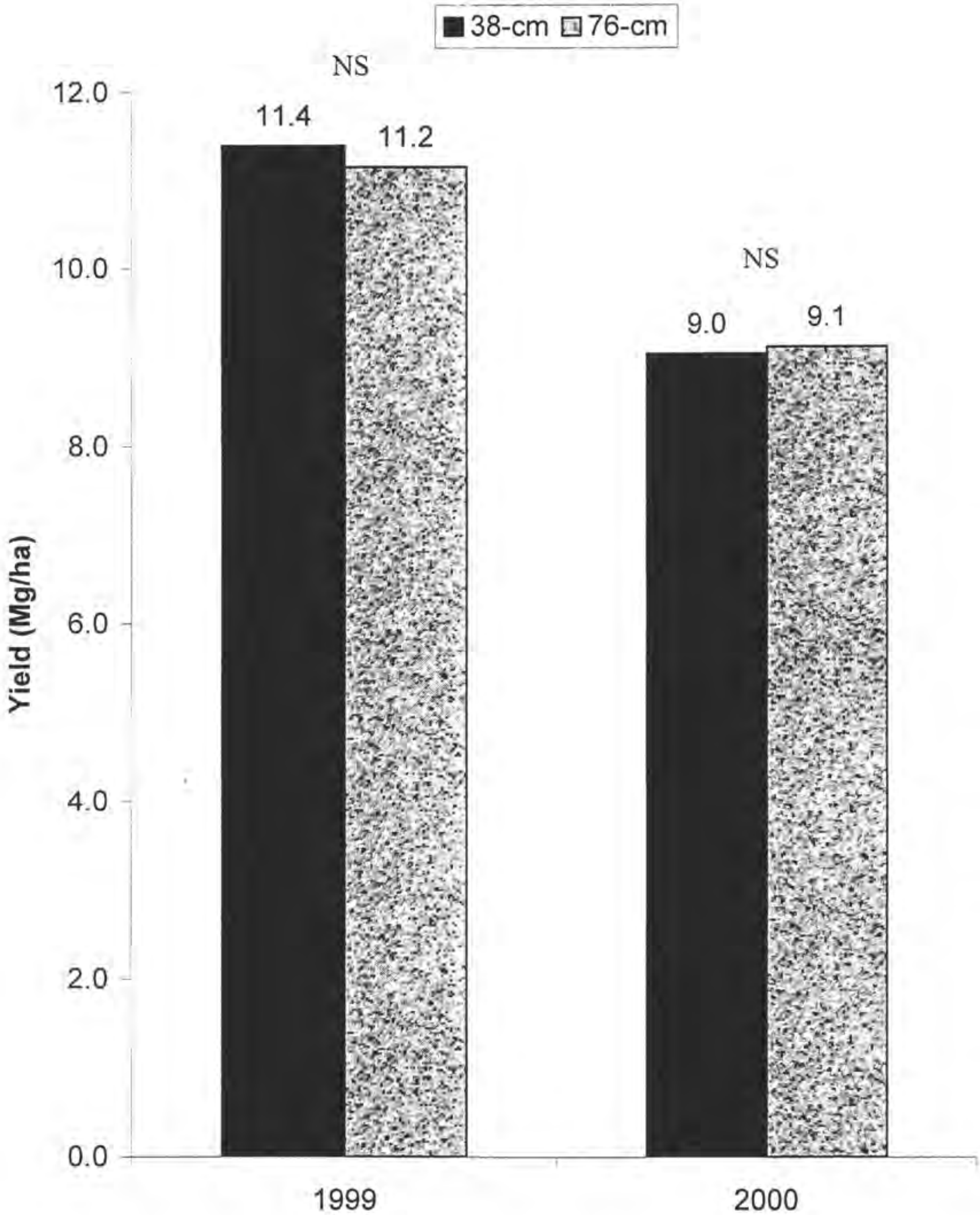


Fig. 4. Main effect of row spacing on corn grain yield at Ames, IA.

NS = no significant main effect ($P > 0.05$).

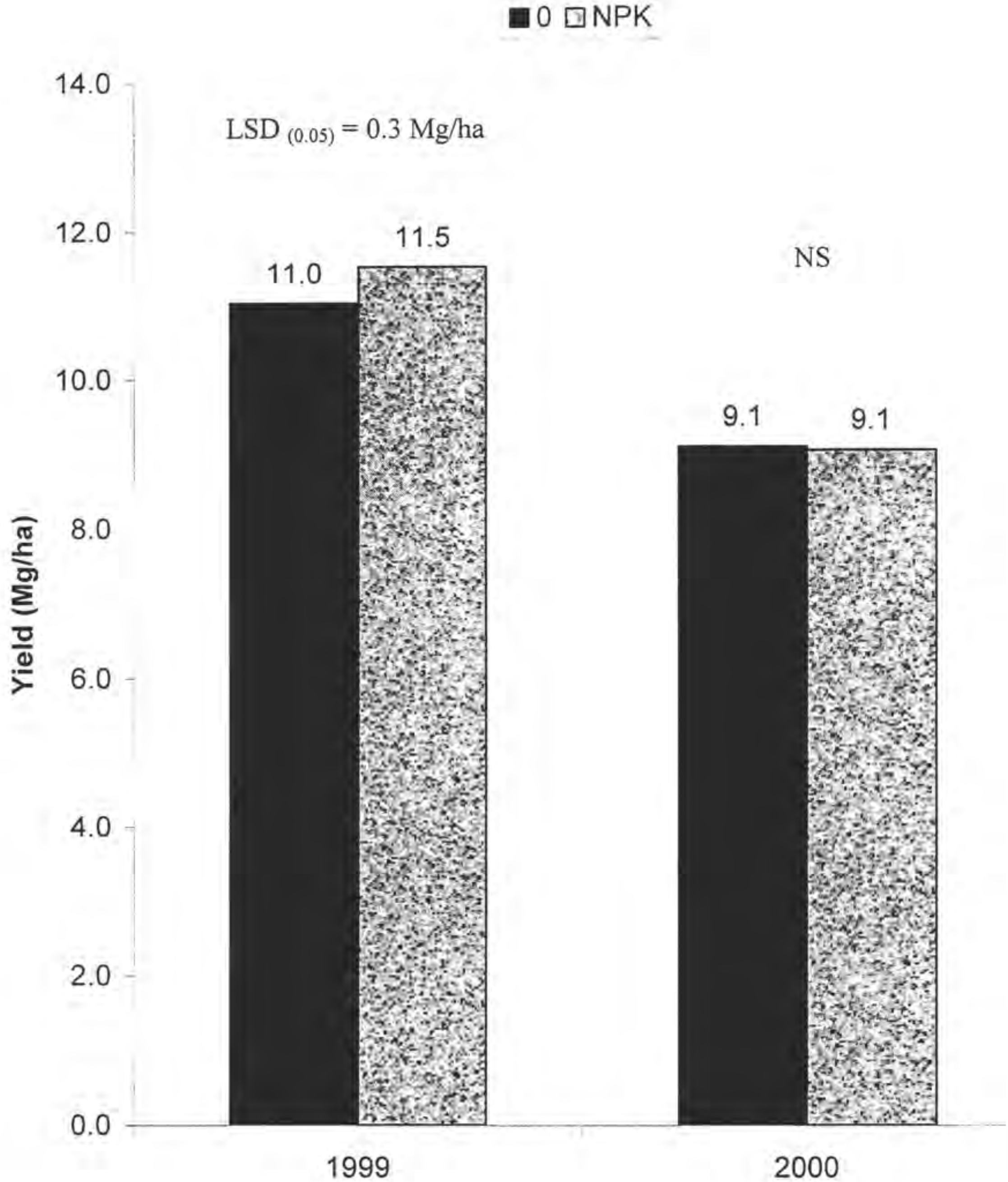


Fig. 5. Main effect of starter fertilizer on corn grain yield at Ames, IA.

NS = no significant main effect ($P > 0.05$).

dates. Based on Iowa State University fertilizer recommendations and soil samples collected near Ames, a good chance for response to starter fertilizer existed (Table 1; Voss et al., 1999). On account of no response in 2000, a warm and dry spring, versus a response in 1999, a much cooler and wetter spring, it is possible that the response to starter fertilizer was due more to weather factors than soil test results in these situations.

Interactive effects of planting date and hybrid on corn yield

Significant ($P < 0.01$) interactions occurred in 1999 between hybrid and planting date (Fig. 6). In 1999, 33A14 yielded significantly ($P < 0.01$) more than 35N05 and 34R07 yielded significantly ($P < 0.05$) more than 35N05 for the 3 May planting date (Date 1). No significant difference ($P > 0.05$) in yield occurred between 33A14 and 34R07 for the 3 May planting date. Hybrid 33A14 yielded 7.2% more than 35N05 and 34R07 yielded 4.4% more than 35N05 for the 3 May planting date. No significant differences ($P > 0.05$) occurred between 33A14 and 34R07 for the 10 May 1999 planting date (Date 2). Significant differences ($P < 0.01$) occurred between 33A14 and 34R07 contrasted with 35N05 for the 10 May planting date. Hybrid 33A14 and 34R07 yielded 6.7 and 7.4% more than 35N05, respectively. Hybrid 34R07 yielded similarly ($P > 0.05$) to 33A14 and 35N05 for the 17 June planting date (Date 3). Significant differences ($P < 0.01$) occurred between 33A14 and 35N05 for the 17 June planting date. 35N05 yielded 12% more than 33A14 for the 17 June planting date.

Significant interactions ($P < 0.01$) also occurred between hybrid and planting date in 2000 (Fig. 6). Significant differences ($P < 0.01$) occurred between each hybrid for the 11 April planting date (Date 1). Hybrid 33A14 yielded 8.4 and 15.1% more than 34R07 and

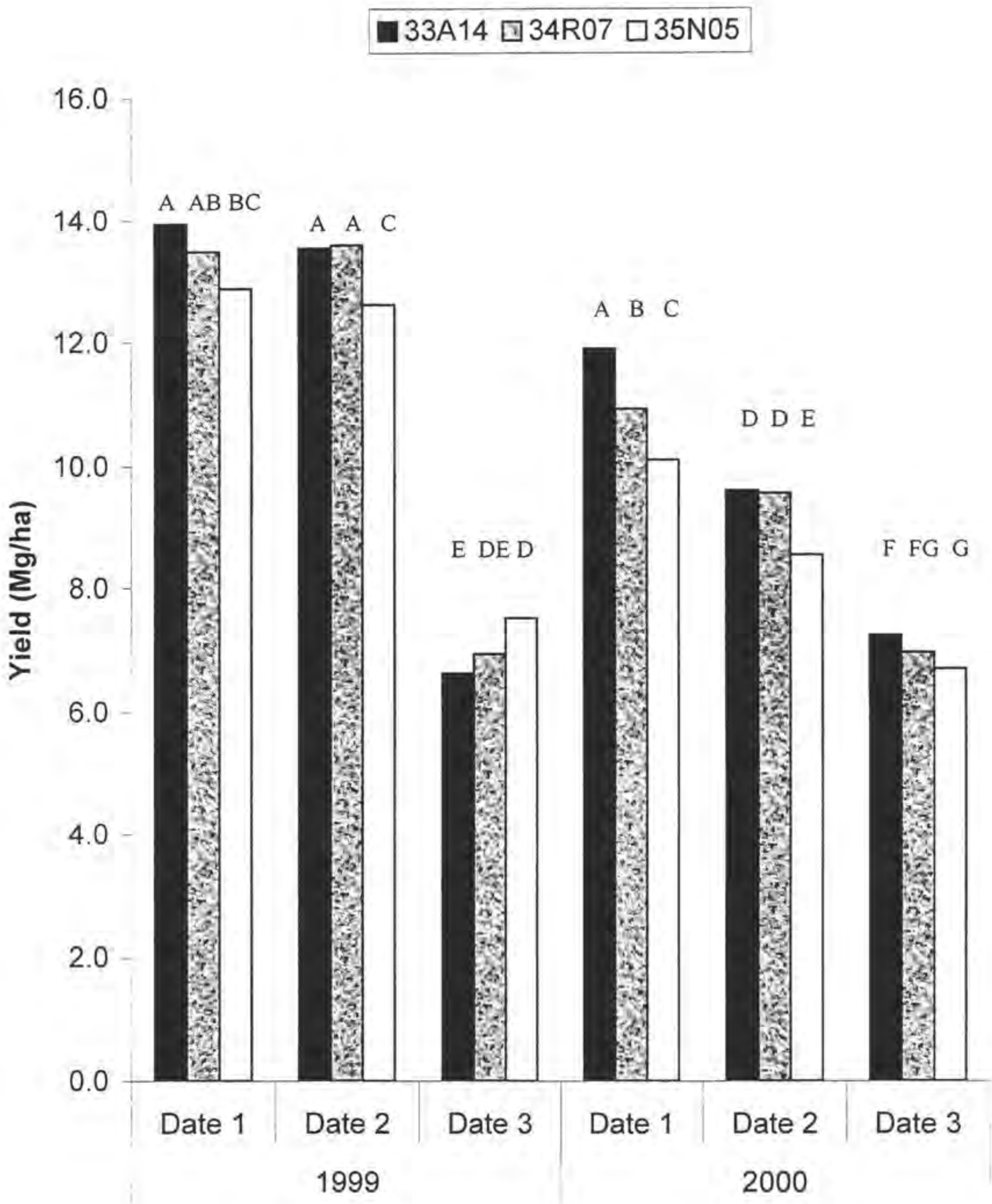


Fig. 6. Interactive effects of planting date and hybrid on corn grain yield at Ames, IA.

Year 1999 yields with same letter are statistically similar (P > 0.05).

Year 2000 yields with same letter are statistically similar (P > 0.05).

35N05, respectively, and 34R07 yielded 7.3% more than 35N05. Hybrid 33A14 yielded similarly ($P > 0.05$) to 34R07 for the 11 May planting date (Date 2). Hybrid 33A14 and 34R07 yielded significantly more ($P < 0.01$) than 35N05. Hybrid 33A14 and 34R07 each yielded 11.5%more than 35N05. Similar yields ($P > 0.05$) occurred contrasting 34R07 with 33A14 and 35N05 for the 9 June planting date (Date 3). Significant differences ($P < 0.05$) occurred between 33A14 and 35N05 for Date 3, where 33A14 yielded 6.9% more than 35N05. In both years, 33A14 yielded significantly more ($P < 0.05$) than 35N05 at the early and mid- planting dates (Fig. 6). Hybrid 33A14 is a 113-day RM hybrid compared with 35N05 which is a 105-day RM hybrid. Results from this experiment, indicate that planting 33A14, a longer season hybrid, from April through mid-May is likely to produce more grain yield than 35N05, a shorter season hybrid. Planting dates delayed until June are likely to produce variable results depending on conditions through the growing season such as stress conditions during early growth and development and time of frost in the fall.

Interactive effects of planting date and row spacing on corn yield

A significant interaction ($P < 0.01$) between planting date and row spacing occurred in 1999 (Fig. 7). The planting date by row spacing interaction was not significant ($P > 0.05$) for corn yield at the 3 May (Date 1) or 10 May (Date 2) planting date. Contrast of the 17 June planting date produced a significant date by row spacing interaction ($P < 0.01$) with yields for 38-cm row spacing yielding 13.3% more than 76-cm row spacing. Planting date and row spacing was not significant ($P = 0.06$) in 2000 (Fig. 7).

Studies have indicated that row spacing may help compensate for performance losses due to limiting circumstances such as planting date or fertility deficiencies (Barbieri et al.,

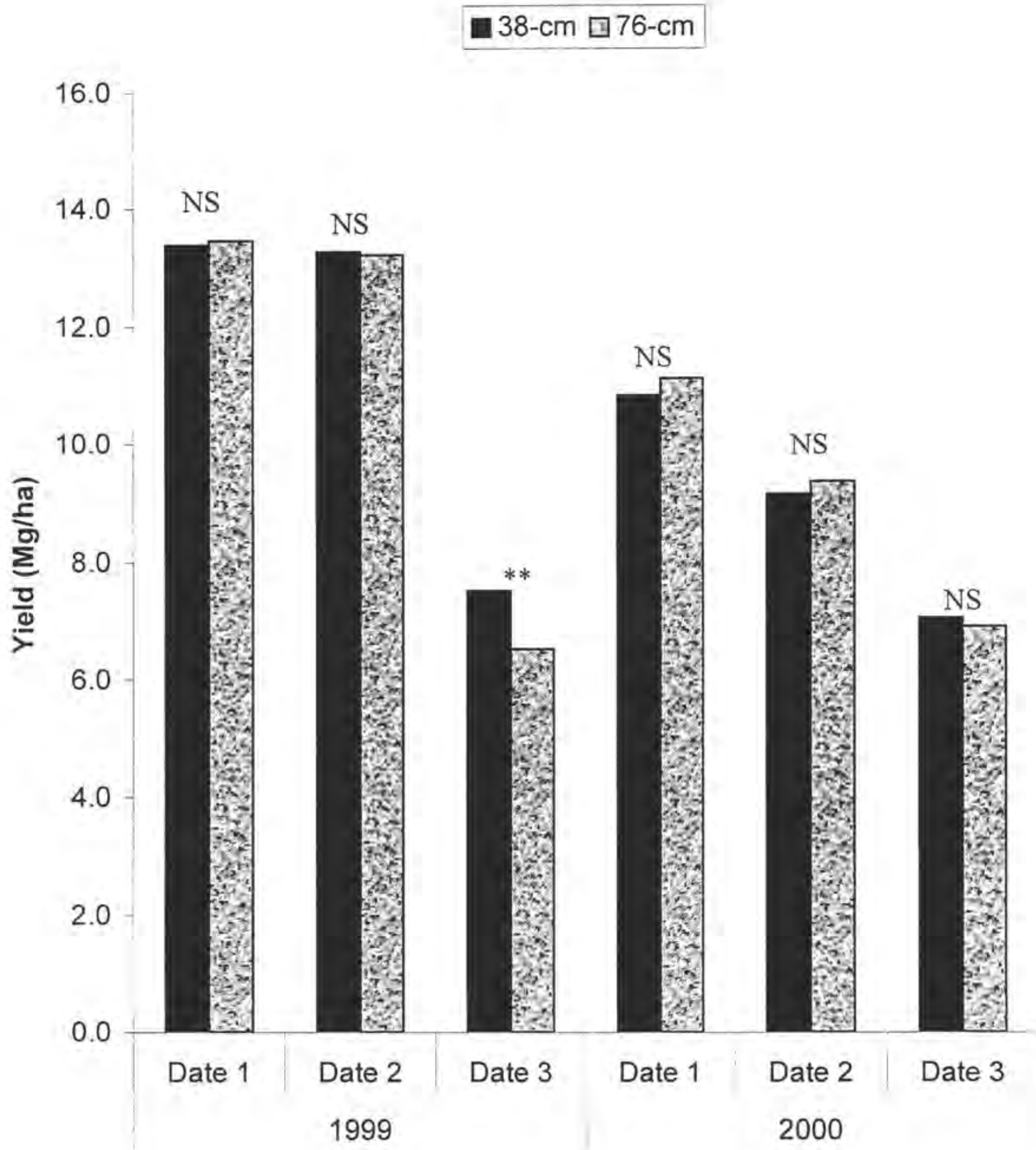


Fig. 7. Interactive effects of planting date and row spacing on corn grain yield at Ames, IA.

** = significant planting date and row spacing interactive effect ($P < 0.01$).

NS = no significant planting date and row spacing interactive effect ($P > 0.05$).

2000; Roth et al., 1999). Results from this study show that row spacing less than 76-cm may help to offset yield loss associated with delayed planting until mid-June. Growth and development at later planting dates is hastened creating lower shoot dry weights at silking (Otegui et al., 1995). Potentially, improved early canopy development helps in resource capture allowing plants to fix more carbon creating heavier shoots allowing improved effective grain fill for the 38-cm rows under situations where early growth is hastened.

Interactive effects of planting date and starter fertilizer on corn yield

Interaction between planting date and starter fertilizer was not significant ($P > 0.05$) in both 1999 and 2000. Yields between fertility regimes were similar ($P > 0.05$) at each of the three planting dates in 1999 (Fig. 8). Lack of interaction between use of starter fertilizer and planting date but an interaction between year and starter fertilizer suggests that conditions in 1999, a cold and wet spring were more conducive to starter fertilizer success than in 2000, a hot and dry spring. This agrees with Rehm et al. (2000); Brouder (1996); and Buah et al. (1999) who suggested that the potential for benefits from starter fertilizer increase under cold and wet soil conditions.

Interactive effects of hybrid and starter fertilizer on corn yield

Interaction between hybrid and starter fertilizer was significant ($P < 0.05$) in both 1999 and 2000. In 1999, 33A14 and 35N05 responded significantly ($P < 0.05$) to starter fertilizer (Fig. 9). Hybrid 34R07 did not respond significantly to starter fertilizer in 1999. In 2000, only 33A14 responded significantly ($P < 0.05$) to starter fertilizer. Gordon et al. (1997) also reported an interaction between starter fertilizer and hybrid on final grain yield.

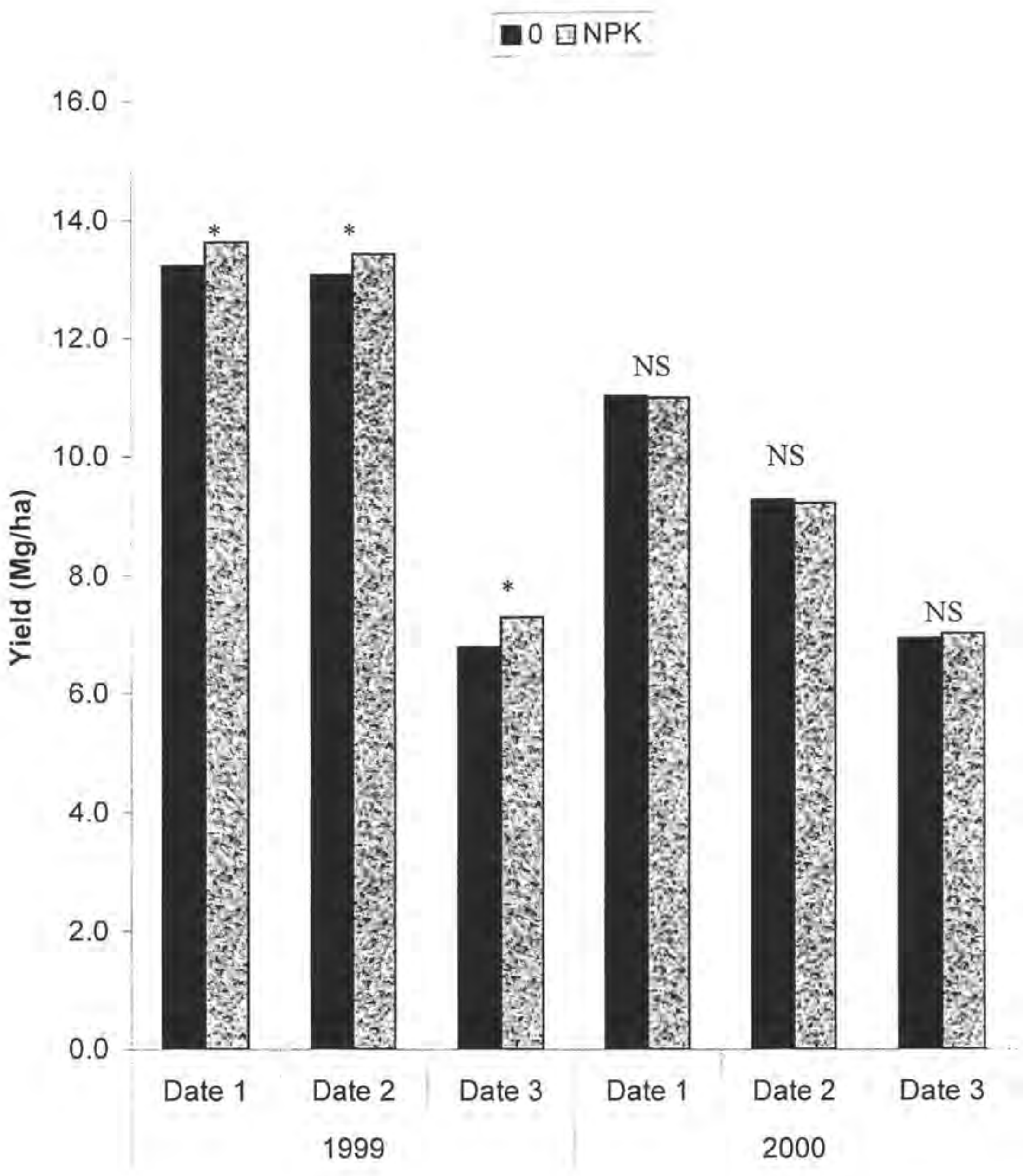


Fig. 8. Interactive effects of planting date and starter fertilizer on corn grain yield at Ames, IA.

* = significant difference between fertility regimes within year and planting date (P < 0.05).

NS = no significant difference between fertility regimes within year and planting date (P > 0.05).

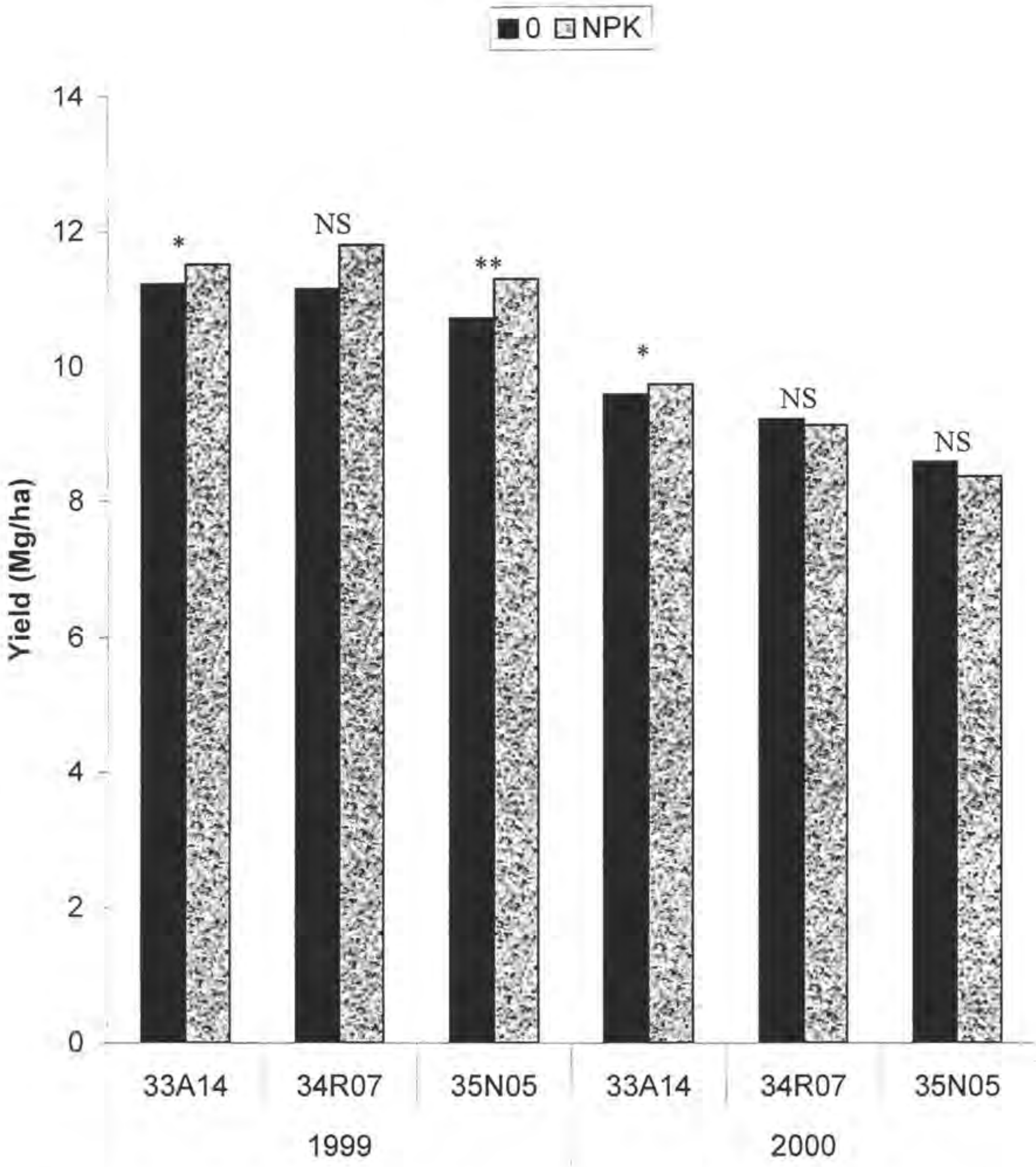


Figure 9. Interactive effects of hybrid and starter fertilizer on corn grain yield at Ames, IA.

* = significant difference between fertility regime within year and hybrid ($P < 0.05$).

** = significant difference between fertility regime within year and hybrid ($P < 0.01$).

NS = no significant difference between fertility regime within year and hybrid ($P > 0.05$).

Main effects of planting date, hybrid, row spacing, and starter fertilizer on grain moisture

Significant difference ($P < 0.01$) occurred among planting dates for grain moisture at harvest in both years (Fig. 10). In both years, the third planting date produced grain with significantly more moisture at harvest than the first and second planting date. No significant difference ($P > 0.05$) in grain moisture at harvest occurred between the first and second planting dates in either year. Interactions between planting date and other treatments will be addressed later.

Significant difference ($P < 0.01$) occurred among hybrids for grain moisture at harvest in both years. In 1999, a significant difference did not occur ($P > 0.05$) between 34R07 and 33A14. Hybrid 35N05 had significantly less moisture ($P < 0.01$) than both 33A14 and 34R07 in 1999. In 2000, each hybrid had significantly ($P < 0.01$) different grain moisture at harvest. Hybrid 33A14 had significantly more grain moisture than 34R07 and 35N05, and 34R07 had significantly more grain moisture than 35N05 (Fig. 11). A significant interaction between planting date and hybrid occurred in 2000 which will be addressed later.

Row spacing effect on grain moisture was not significant ($P > 0.05$) in either year of the study. A significant ($P < 0.01$) interaction between planting date and row spacing did occur in 2000 and will be addressed later.

Starter fertilizer effect on grain moisture was significant ($P < 0.01$) in 2000 but not in 1999. A significant ($P < 0.01$) interaction between planting date and starter fertilizer occurred in 2000 and will be addressed later.

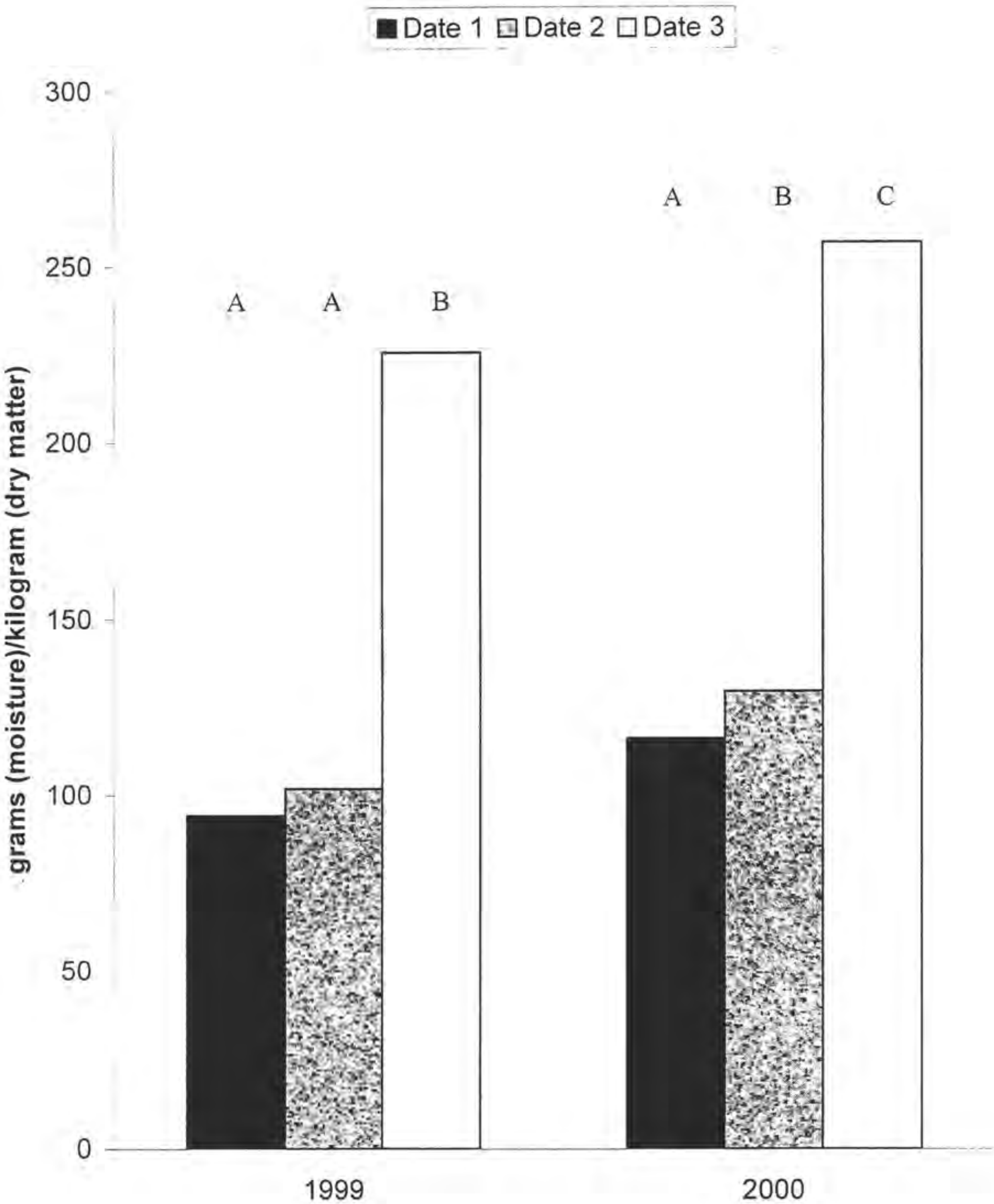


Fig. 10. Main effect of planting date on corn grain moisture at Ames, IA, 1999-2000. Means within years with the same letters are not significantly different ($P > 0.05$).

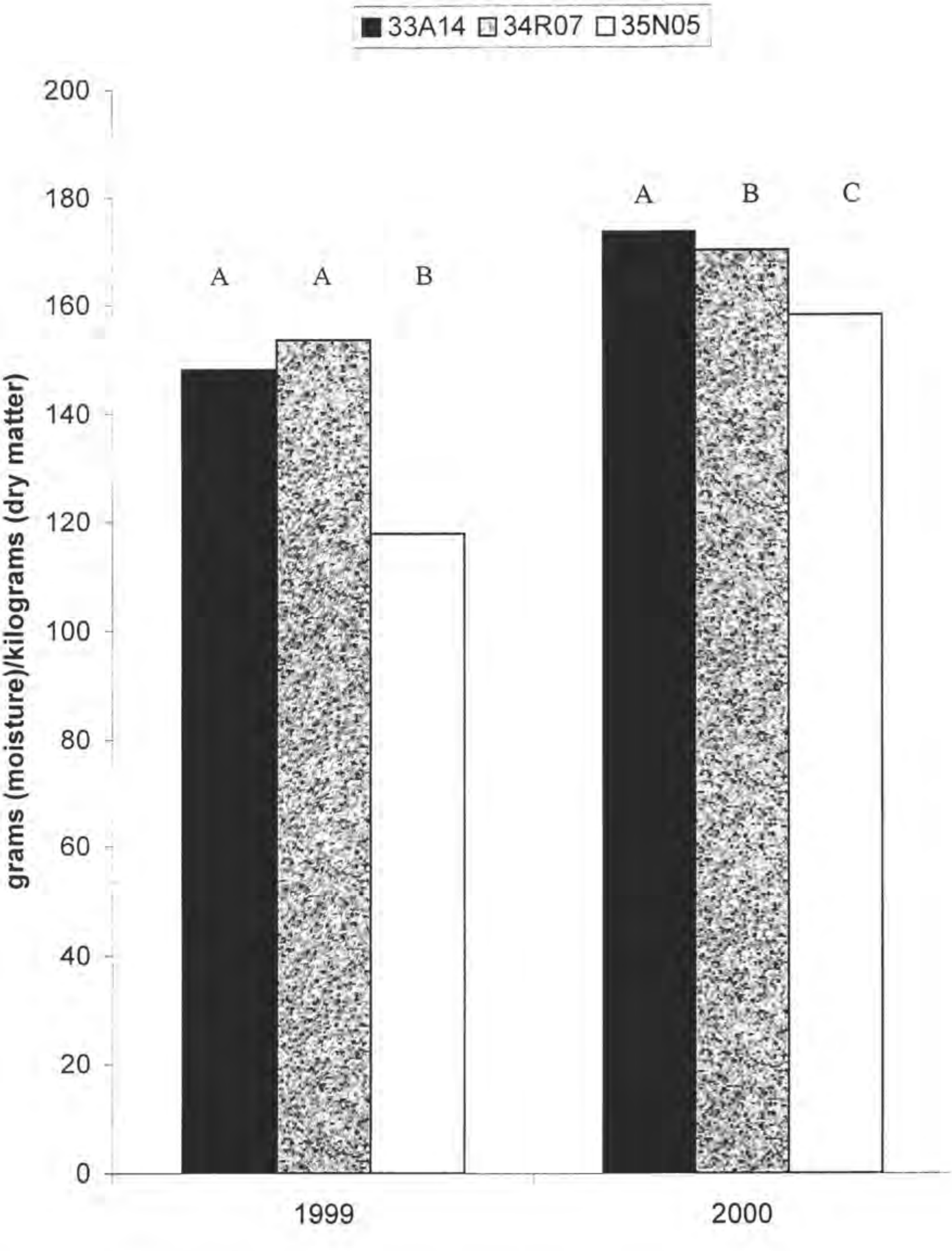


Figure 11. Main effect of hybrid on corn grain moisture, Ames, IA 1999-2000.

Means within years with the same letter are not significantly different (P > 0.05).

Interactive effects of planting date and hybrid on grain moisture

A significant interactive effect between planting date and hybrid occurred in 2000 ($P < 0.01$) but did not occur in 1999 ($P > 0.05$). In 2000, all hybrids had similar grain moisture at harvest for the 11 April 2000 planting date (Fig. 12). Significant difference ($P < 0.01$) occurred between 35N05 compared with 34R07 and 33A14 for the 11 May 2000 planting date. Hybrids 33A14 and 34R07 had similar grain moisture for the 11 May 2000 planting date. Each hybrid had significantly different grain moisture for the 9 June 2000 planting date. Hybrid 33A14 had significantly more grain moisture than 34R07 and 35N05, and 34R07 had significantly more grain moisture than 35N05.

Grain moisture measurements in this study are similar to what is typically observed in Iowa between hybrids of different relative maturities (Farnham, unpublished). Lauer et al. (1999) also observed increased differences in grain moisture between short and long season hybrids as planting date was delayed. In this study, an interactive effect on grain moisture between hybrid and planting date occurred in 2000 but not in 1999. As planting date was delayed in 2000, the grain moisture differences between the hybrids increased in magnitude. Hybrid decisions based on planting date should take into account the hybrid's potential yield at the particular planting date as well as the potential grain moisture at harvest. Yield differences between each hybrid decreased as planting date was delayed but differences in grain moisture increased as planting date was delayed so a shift from planting 33A14 or 34R07 to 35N05 should occur as planting date is delayed into late May or early June.

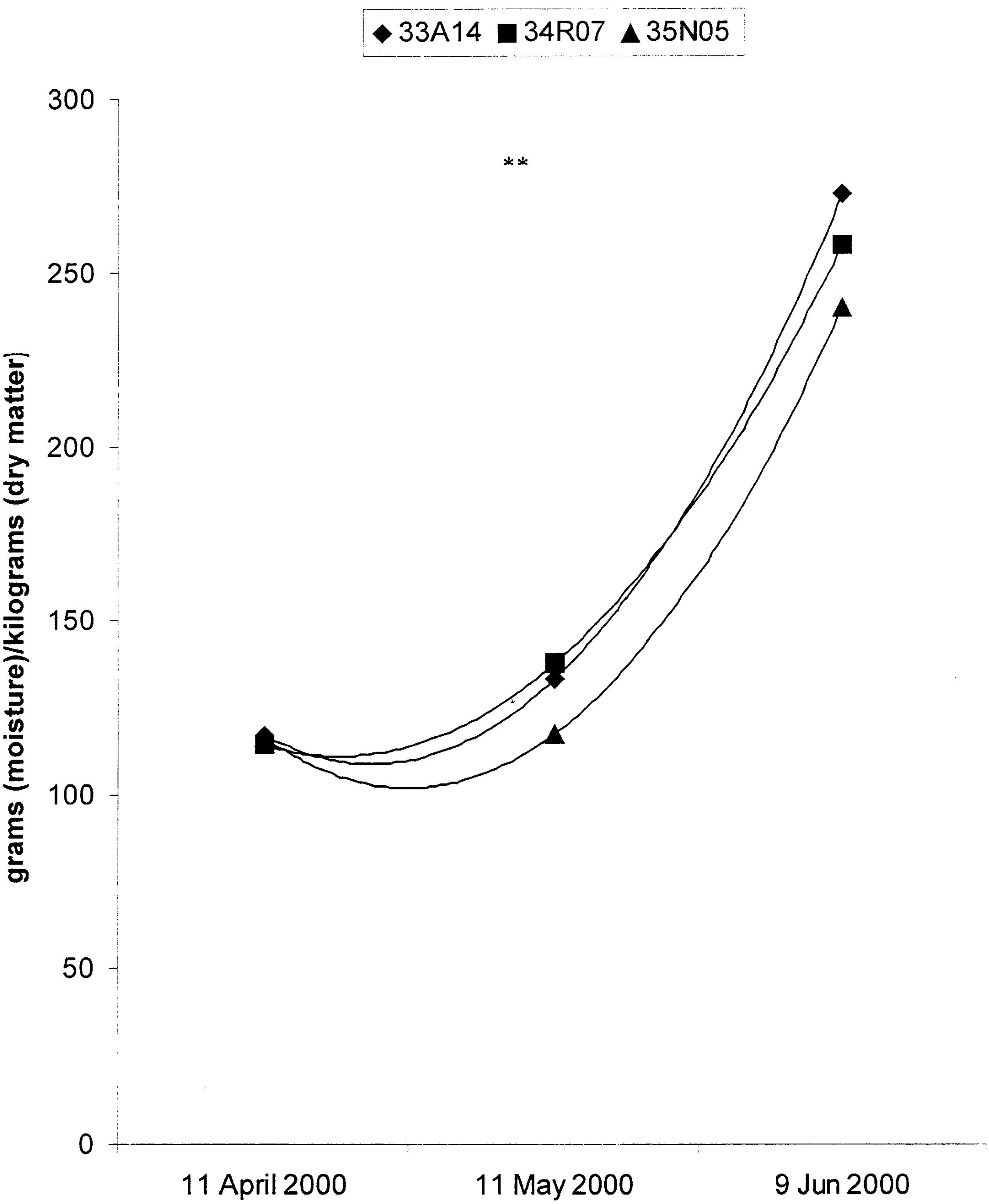


Fig. 12. Interactive effect between planting date and hybrid at Ames, IA, 2000.

** = significant interactive effect ($P < 0.01$).

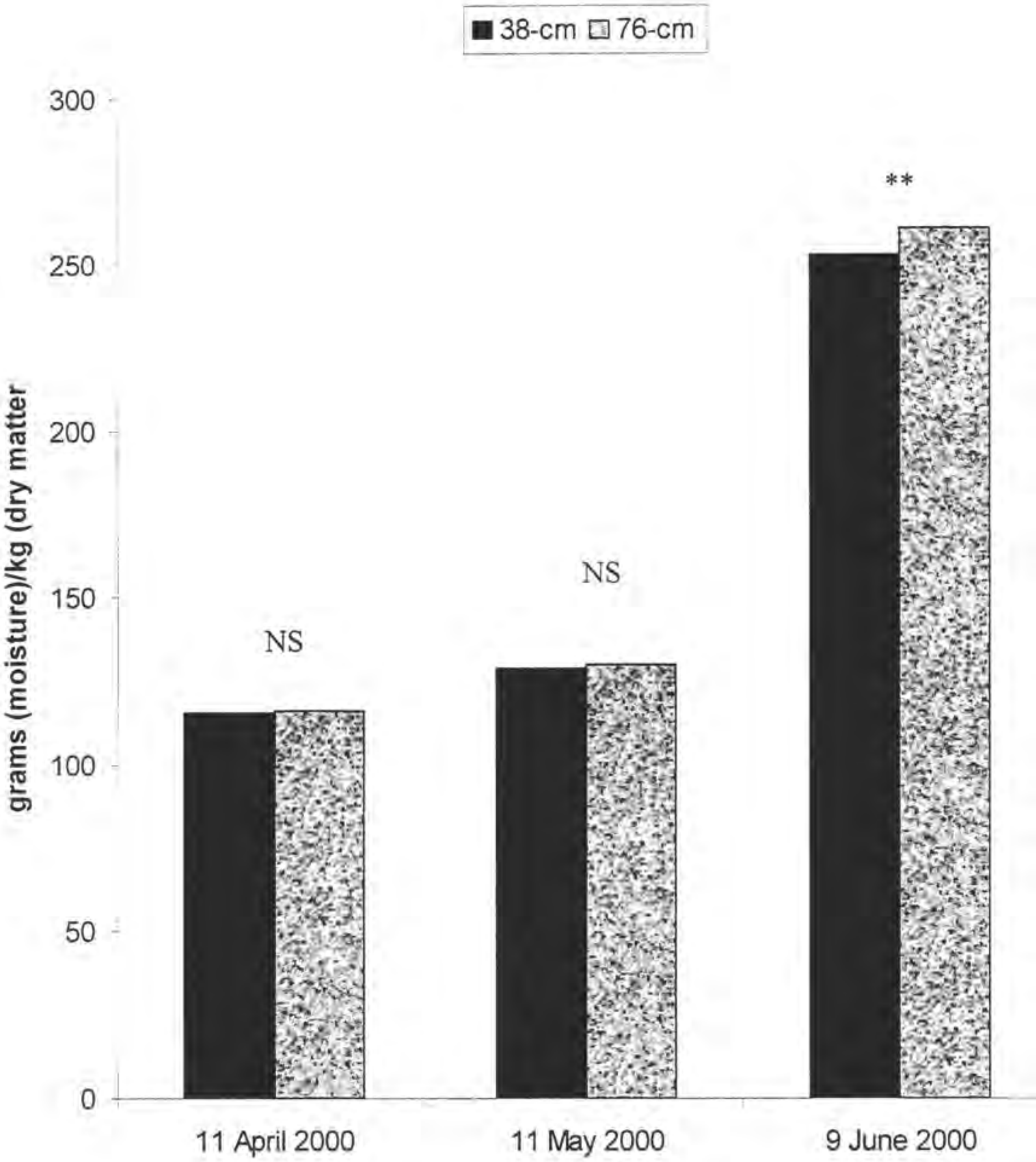


Fig. 13. Interactive effect between planting date and row spacing on corn grain moisture, Ames, IA.

NS = no significant differences between treatments within planting date.

** = significant difference between treatments within planting date ($P < 0.01$).

Interactive effects of planting date and row spacing on corn grain moisture

A significant interactive effect between planting date and row spacing occurred in 2000 ($P < 0.01$) but did not occur in 1999 ($P > 0.05$). In 2000, grain moisture was similar ($P > 0.05$) between each row spacing for the 11 April and 11 May planting dates (Fig. 13). Significant difference ($P < 0.01$) occurred between row spacing for the 9 June planting date with lower grain moisture for the 38-cm compared with the 76-cm (Fig. 13). Farnham (2001) observed similar differences between 38- and 76-cm row spacing for grain moisture.

Interactive effects of planting date and starter fertilizer on corn grain moisture

A significant interactive effect between planting date and starter fertilizer on corn grain moisture occurred in 2000 ($P < 0.01$) but did not occur in 1999 ($P > 0.05$) (Fig. 14). No significant difference ($P > 0.05$) occurred for grain moisture between fertility regimes from the 11 April or 11 May 2000 planting dates. Significant difference ($P < 0.01$) occurred between fertility regimes for grain moisture from the 9 June 2000 planting date (Fig. 14).

Interactive effect of planting date, hybrid and starter fertilizer on corn grain moisture

A significant interactive effect between planting date, hybrid, and starter fertilizer on grain moisture occurred in 1999 ($P < 0.01$) but did not occur in 2000 ($P > 0.05$). Grain moisture for 33A14 was not significantly different ($P > 0.05$) between fertility regimes for the 3 May and 10 May 1999 planting dates (Fig. 15). Grain moisture for 33A14 was significantly different ($P < 0.05$) between fertility regimes for the 17 June 1999 planting date with starter fertilizer treated plots having higher grain moisture than plots with no starter fertilizer. Grain moisture for 34R07 was significantly different between fertility regimes for the 3 May 1999 planting date ($P < 0.01$) and the 17 June planting date ($P < 0.05$) with starter

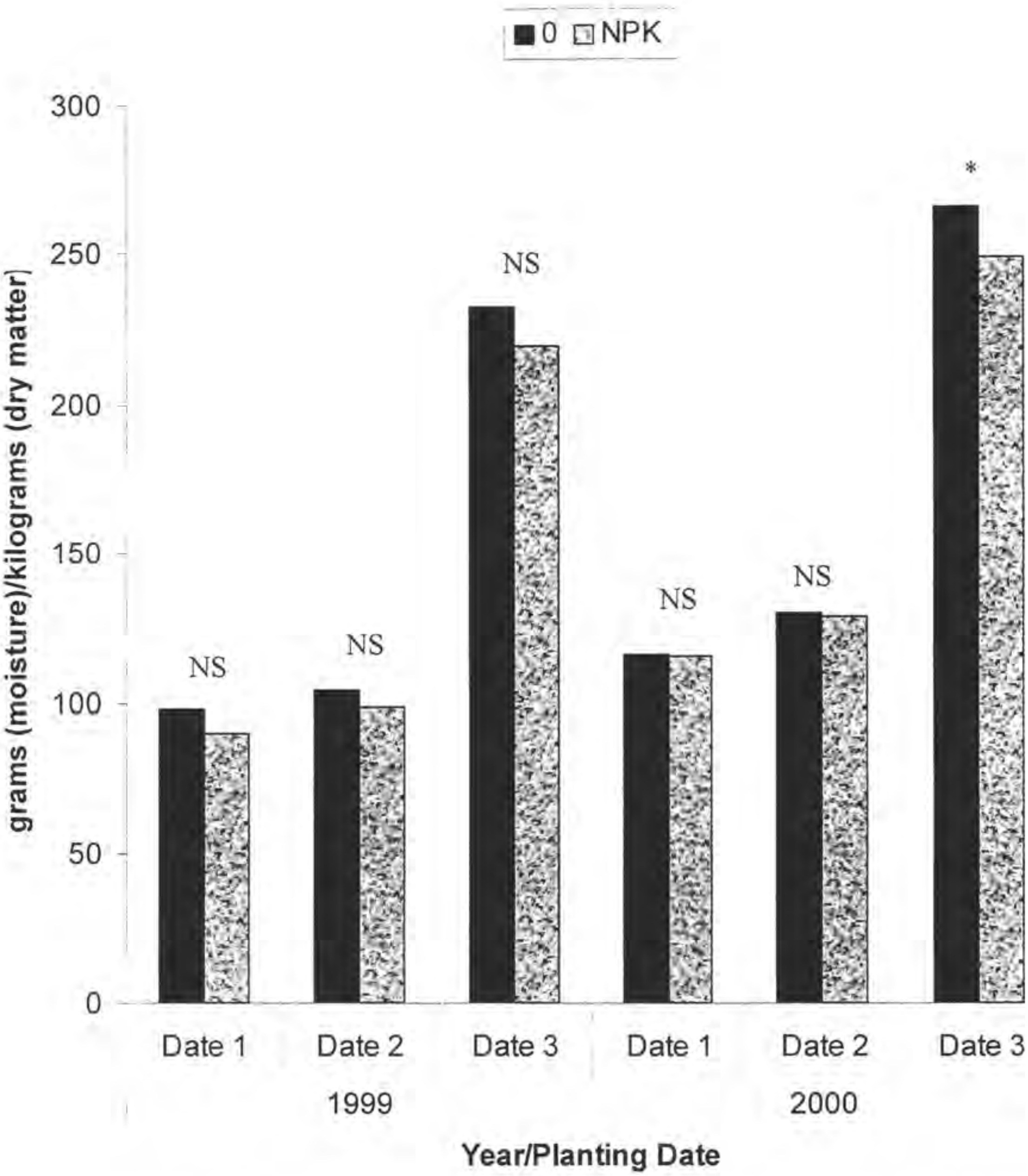


Figure 14. Interactive effect of planting date and starter fertilizer on corn grain moisture at Ames, IA.

* = significant effect of starter fertilizer on corn grain moisture within year and planting date.

NS = no significant effect of starter fertilizer on corn grain moisture within year and planting date.

fertilizer treated plots having less grain moisture than plots not treated with starter fertilizer (Fig. 15). No difference ($P > 0.05$) between fertility regimes for 34R07 occurred for the 10 May 1999 planting date. Grain moisture was not significantly different ($P > 0.05$) for 35N05 between fertility regimes for the 3 May and 10 May 1999 planting dates (Fig. 15). Grain moisture was significantly different ($P < 0.01$) for 35N05 between fertility regimes for the 17 June 1999 planting date with starter fertilizer treated plots having significantly less moisture than the plots with no starter fertilizer. These results indicate that starter fertilizer may hasten development to allow more rapid or earlier grain moisture loss before harvest, particularly for the later planting dates with 35N05 and 34R07 responding with lower grain moisture.

Seasonal pattern of leaf area index expressed as a function of growing degree units and the main effects of hybrid, row spacing, and starter fertilizer on leaf area index

Increases in leaf area index as a function of growing degree units occurred through the growing season with the maximum leaf area index reached near R1 (Figs. 16, 17 and 18).

No significant differences ($P > 0.05$) for leaf area index occurred between hybrids for each planting date in 2000. Interactive effects between hybrid, row spacing, and treatment did occur for the 11 April 2000 planting date and will be addressed later.

Significant difference did not occur ($P > 0.05$) between starter fertilizer treated plots and no starter treated plots when averaged over all sampling times and other treatments for the 11 April 2000 and 11 May 2000 planting dates (Figs. 19 and 20, respectively). Significant difference did occur ($P < 0.05$) for the 9 June 2000 planting date with starter fertilizer having a higher leaf area index than the no starter treated plots (Fig. 21). Significant changes in leaf area index as a function of growing degree units for the 9 June 2000 planting date did occur between fertility regimes and will be addressed later.

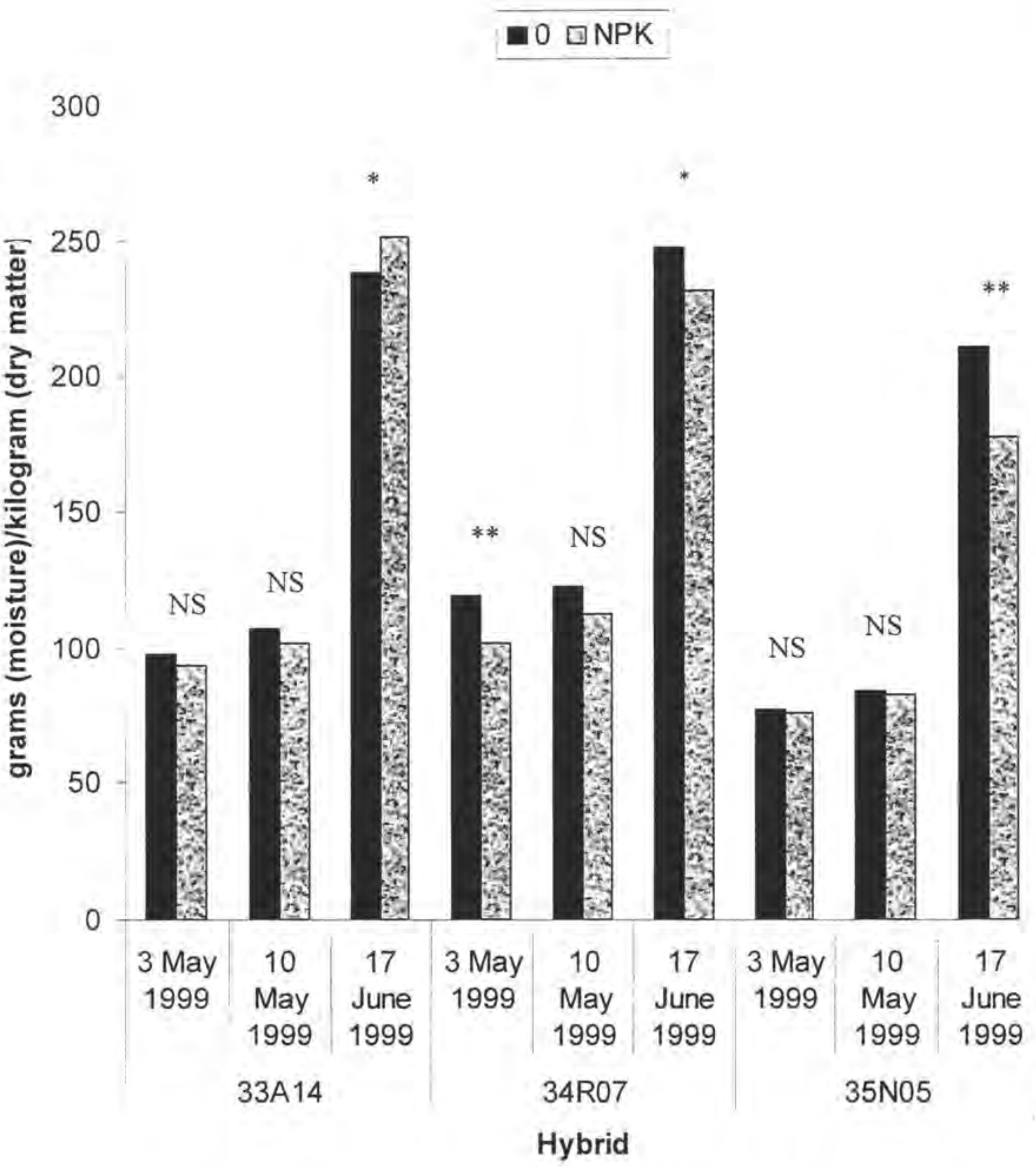


Fig. 15. Interactive effects between planting date, hybrid, and starter fertilizer on corn grain moisture, Ames, IA, 1999.

NS = no significant effect of starter fertilizer within planting date and hybrid ($P > 0.05$).

* = significant effect of starter fertilizer within planting date and hybrid ($P < 0.05$).
** = significant effect of starter fertilizer within planting date and hybrid ($P < 0.01$).

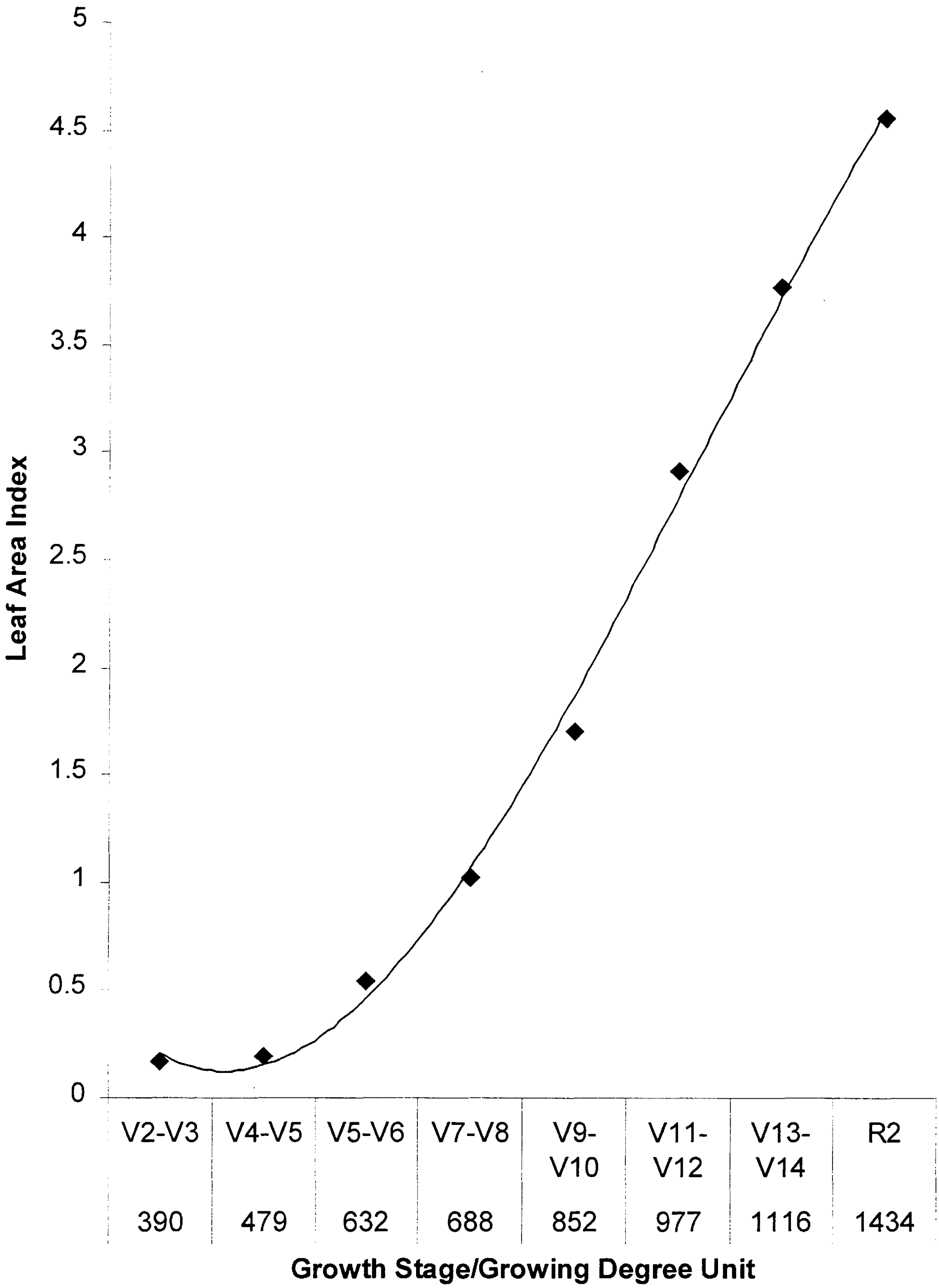


Fig. 16. Seasonal pattern of leaf area index expressed as a function of growing degree units from sowing for the 11 April 2000 planting date at Ames, IA.

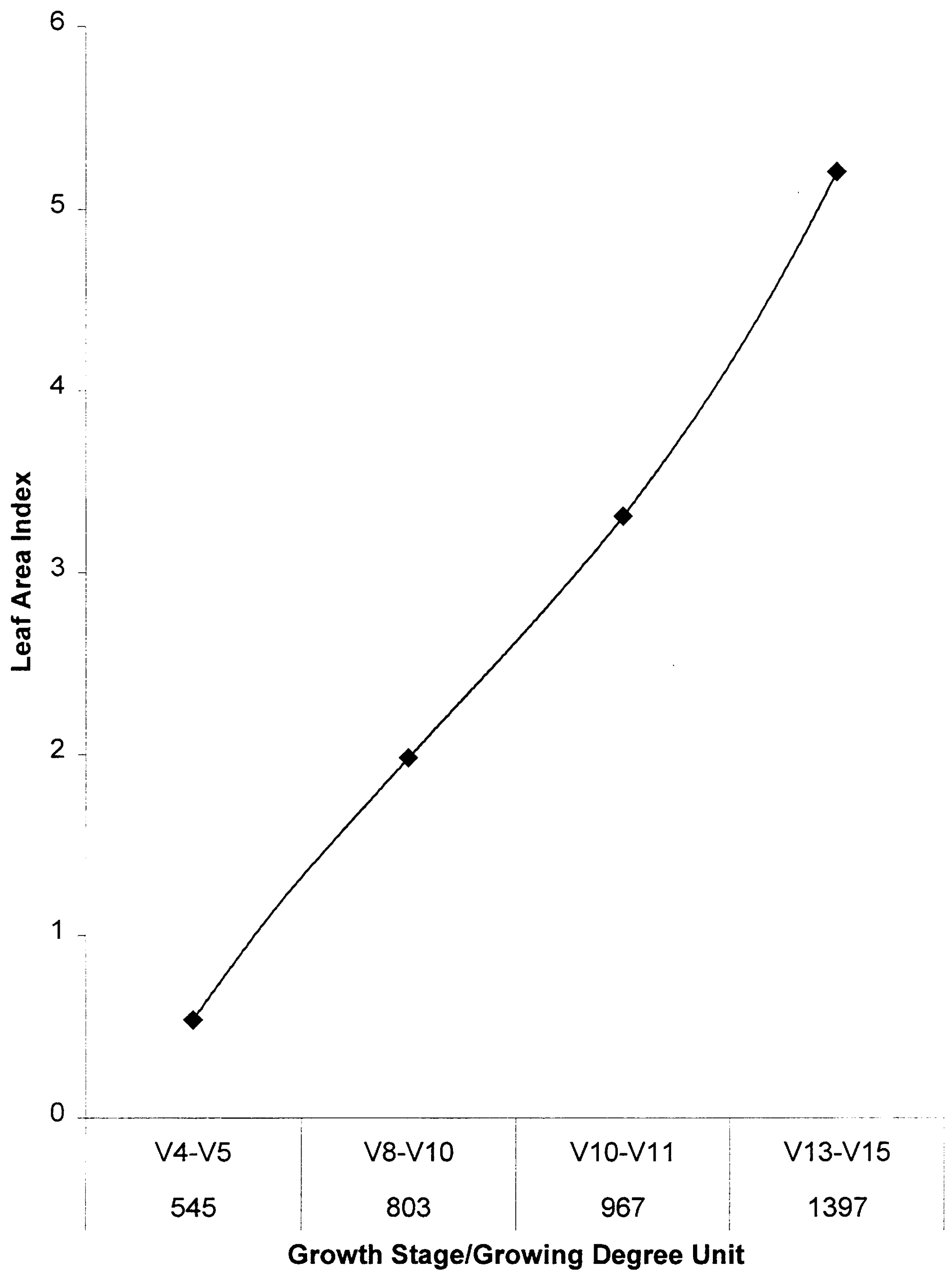


Fig. 17. Seasonal pattern of leaf area index expressed as a function of growing degree units from sowing for the 11 May 2000 planting date at Ames, IA.

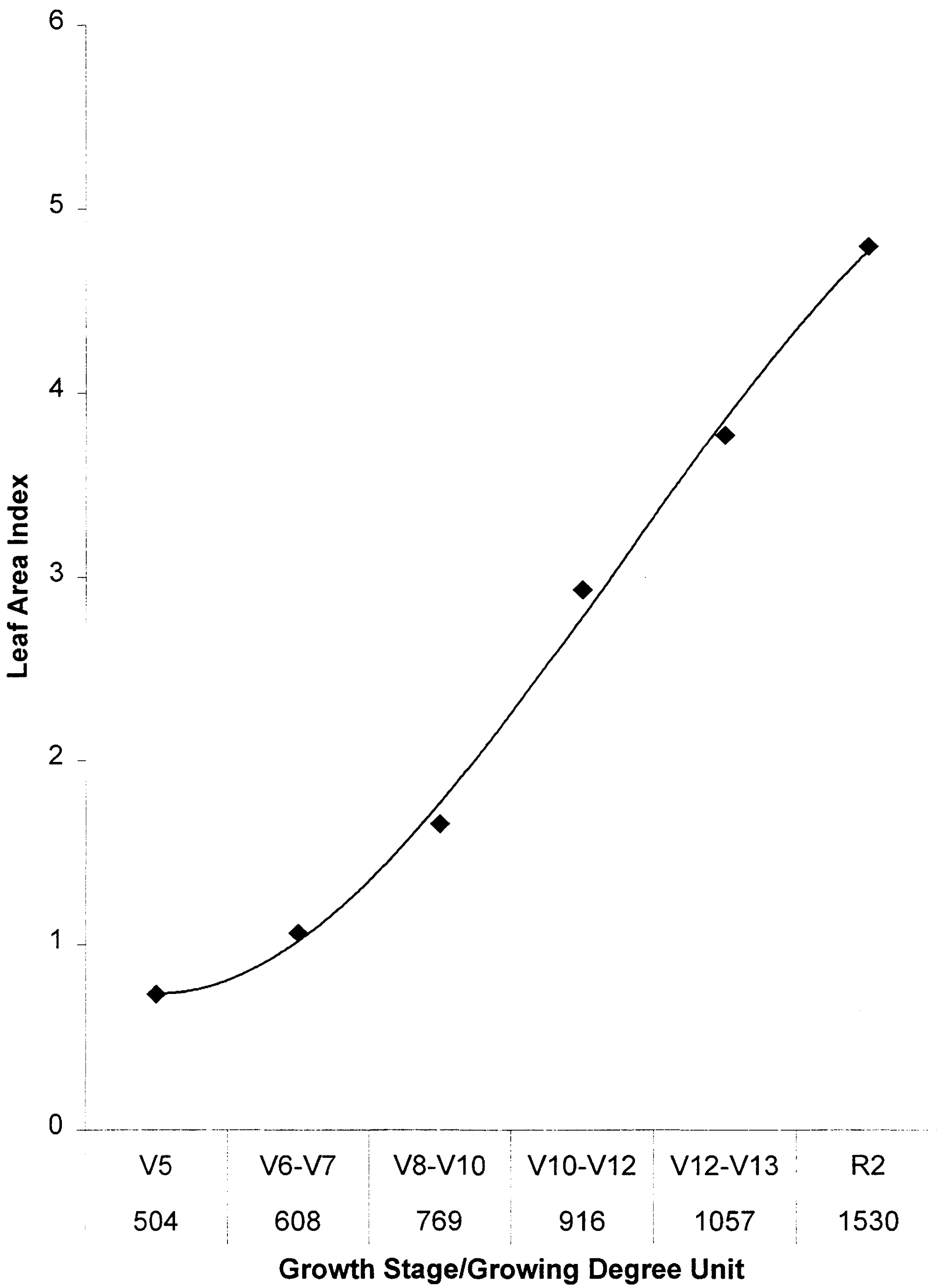


Fig. 18. Seasonal pattern of leaf area index expressed as a function of growing degree units from sowing for the 9 June 2000 planting date at Ames, IA.

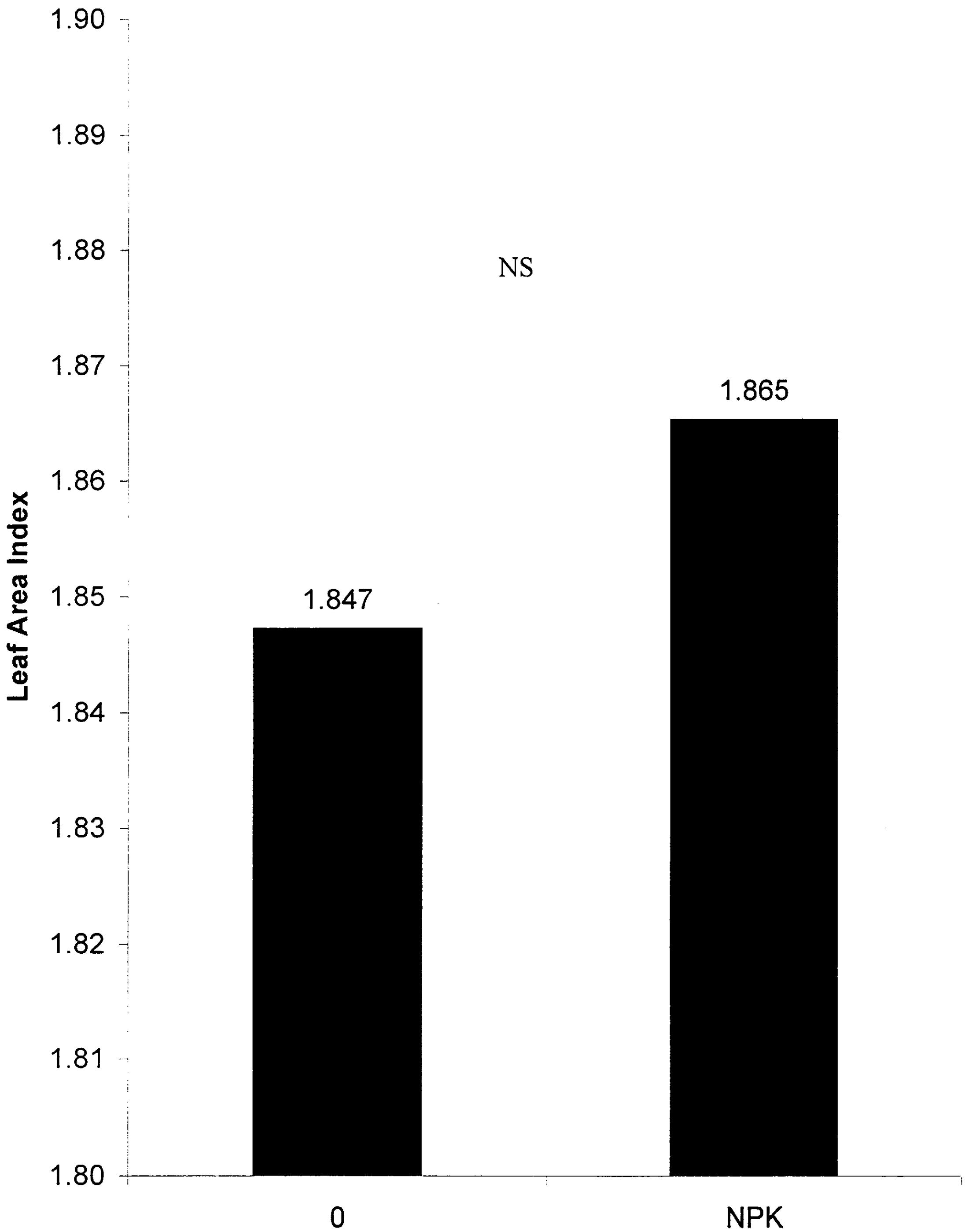


Fig. 19. Main effect of starter fertilizer on leaf area index for the 11 April 2000 planting date at Ames, IA.

NS=no significant main effect ($P > 0.05$)

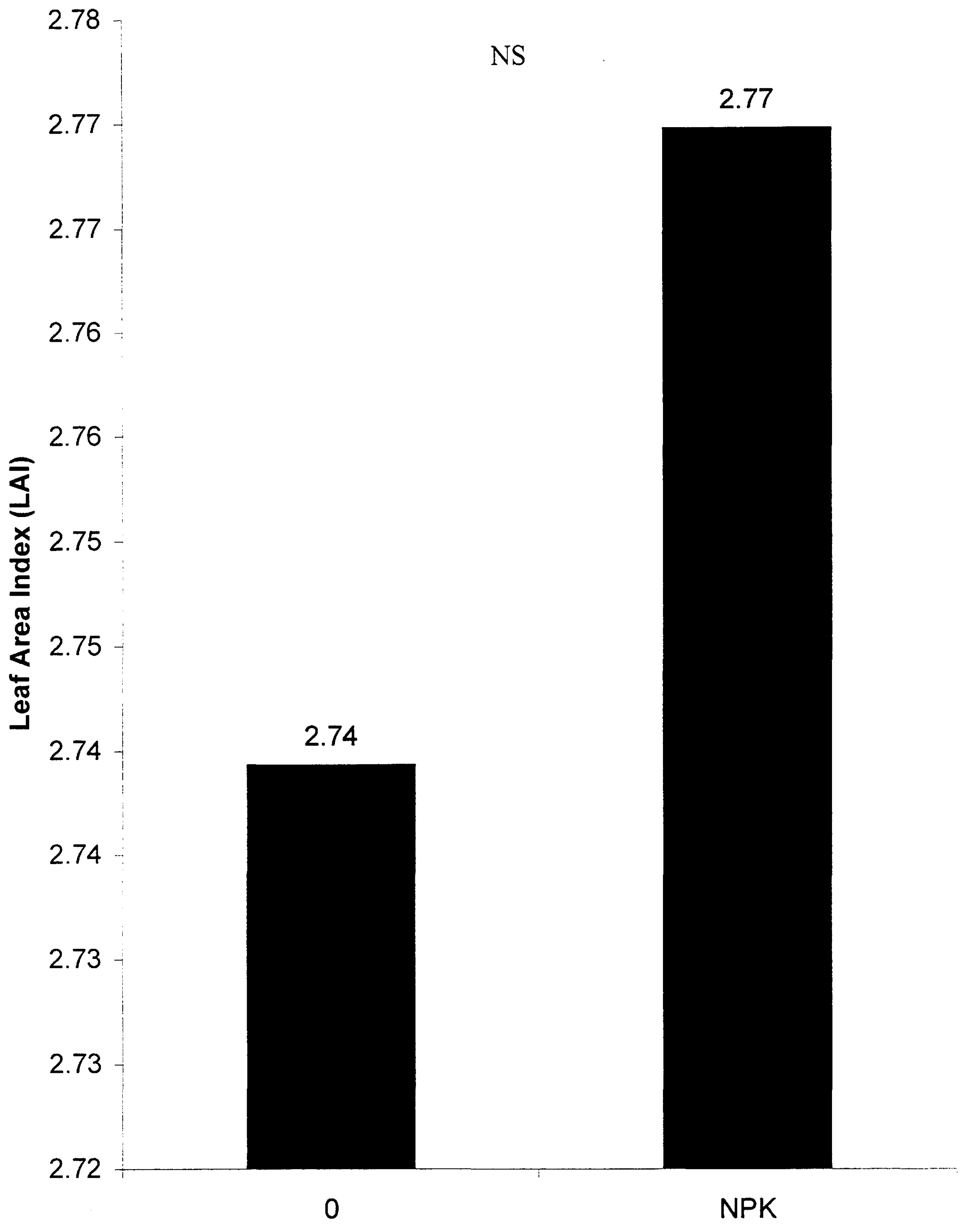


Fig. 20. Main effect of starter fertilizer on leaf area index for the 11 May 2000 planting date at Ames, IA.

NS=no significant main effect (P > 0.05).

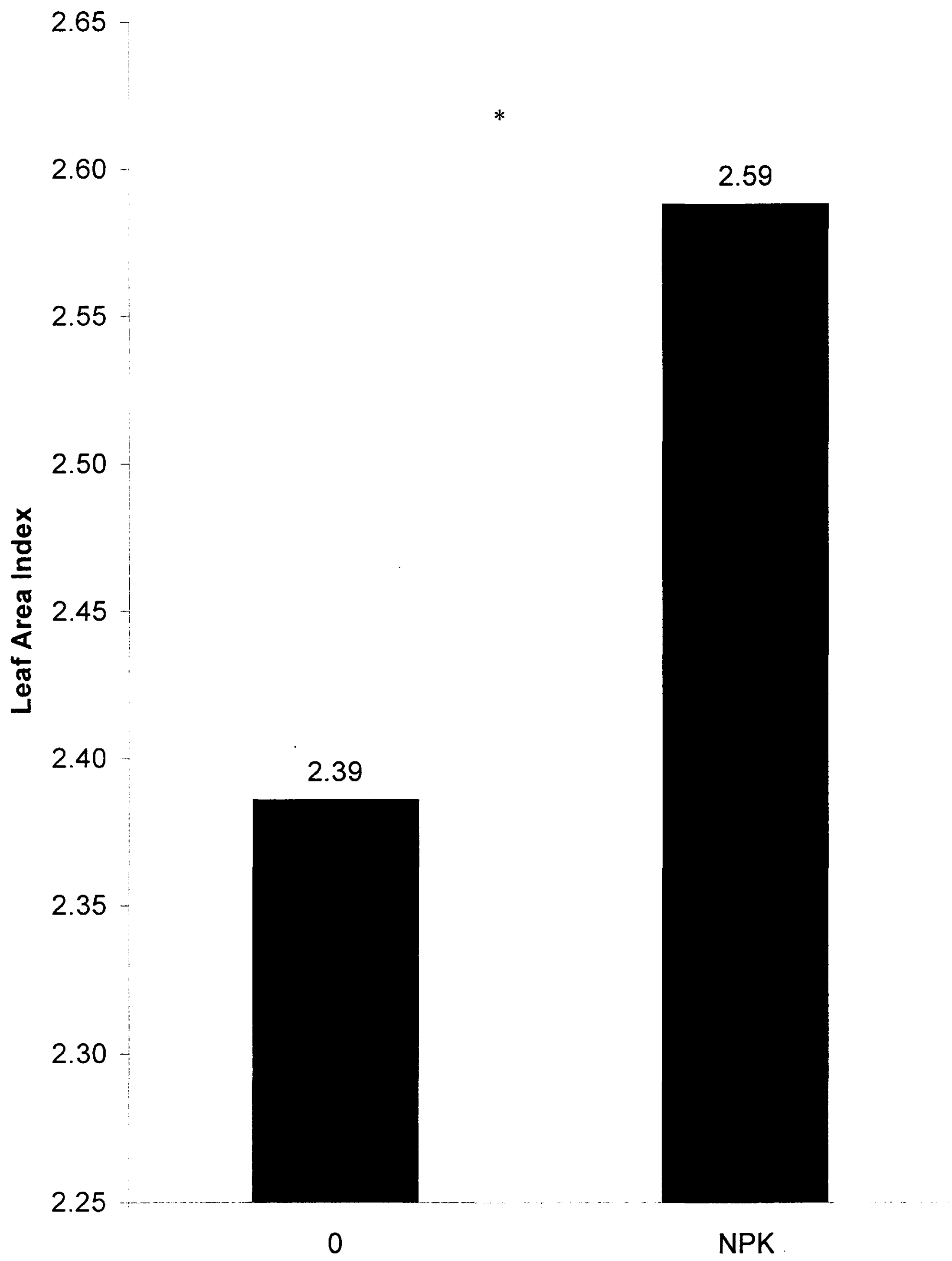


Fig. 21. Main effect of starter fertilizer on leaf area index for the 9 June 2000 planting date at Ames, IA.

* = significant main effect ($P < 0.05$).

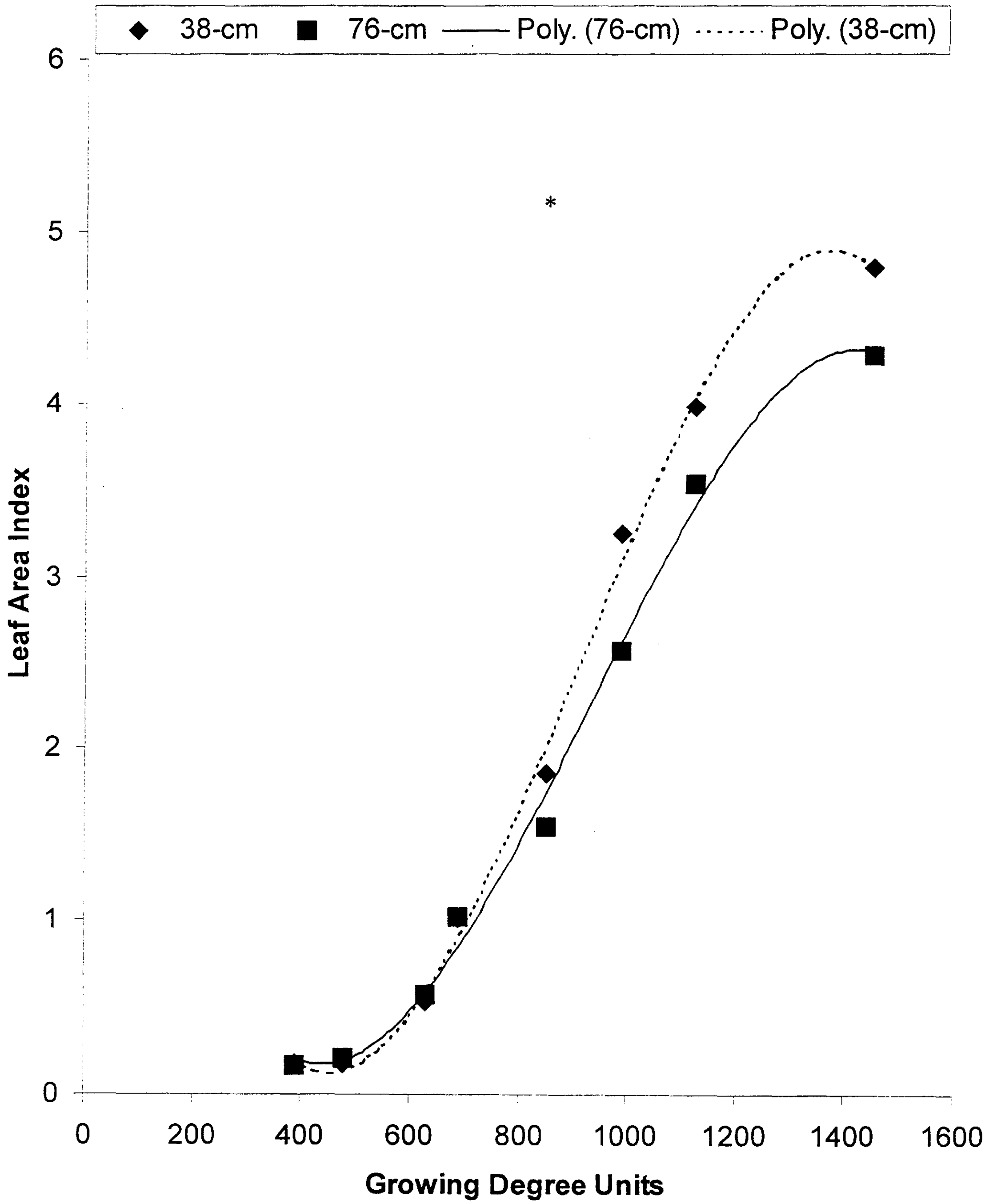


Fig. 22. Effect of row spacing on seasonal pattern of leaf area index expressed as a function of growing degree units from sowing for the 11 April 2000 planting date at Ames, IA.

* = significant effect ($P < 0.05$).

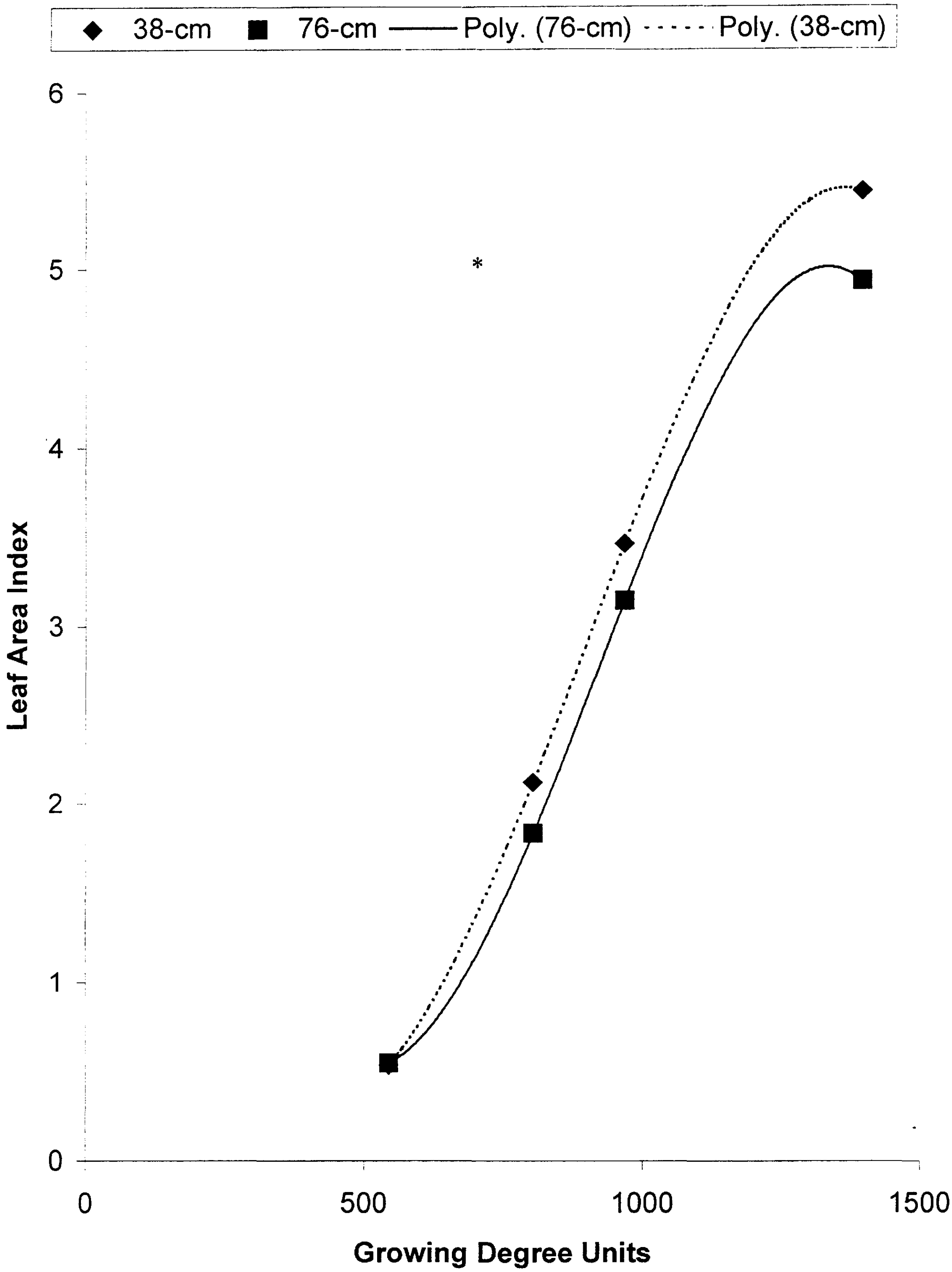


Fig. 23. Effect of row spacing on seasonal pattern of leaf area index expressed as a function of growing degree units from sowing for the 11 May 2000 planting date at Ames, IA.

* = significant effect (P = 0.05)

Effect of row spacing on leaf area index as a function of growing degree units

Significant ($P < 0.05$) changes in leaf area index as a function of growing degree units occurred between 38- and 76-cm row spacing for the 11 April 2000 and 11 May 2000 planting dates (Figs. 22 and 23, respectively). Significant changes did not occur between 38- and 76-cm row spacing for the 9 June 2000 planting date for leaf area index as a function of growing degree units (Fig. 24). Potential benefits of faster accumulation of leaf area index between row spacing treatments include improved crop competitiveness with weed species and potentially water management benefits such as lessened water erosion risks and lessened evaporation from increased ground cover. Teasdale (1995) showed that 38-cm row spacing at a 2X plant population was more competitive with weed species than 76-cm row spacing at a 1X plant population. While this study did not measure the effect of row spacing on weed presence and survival, increasing differences in magnitude of leaf area index at approximately V8 indicate that 38-cm row spacing may be more competitive at a critical time where certain weed species become competitive. Increasing leaf area index at this time may improve the crop competitiveness with weed species, lessening the harmful effects associated with weed survival. Differences in leaf area index between treatments did not seem to influence grain yield in this study.

Interactive effects of growing degree units and starter fertilizer on leaf area index

Significant interaction between growing degree units and starter fertilizer on leaf area index did not occur for the 11 April 2000 and 11 May 2000 planting dates ($P > 0.05$). A significant interaction ($P < 0.01$) did occur between growing degree units and starter fertilizer for the 9 June 2000 planting date (Fig. 25). Significant differences

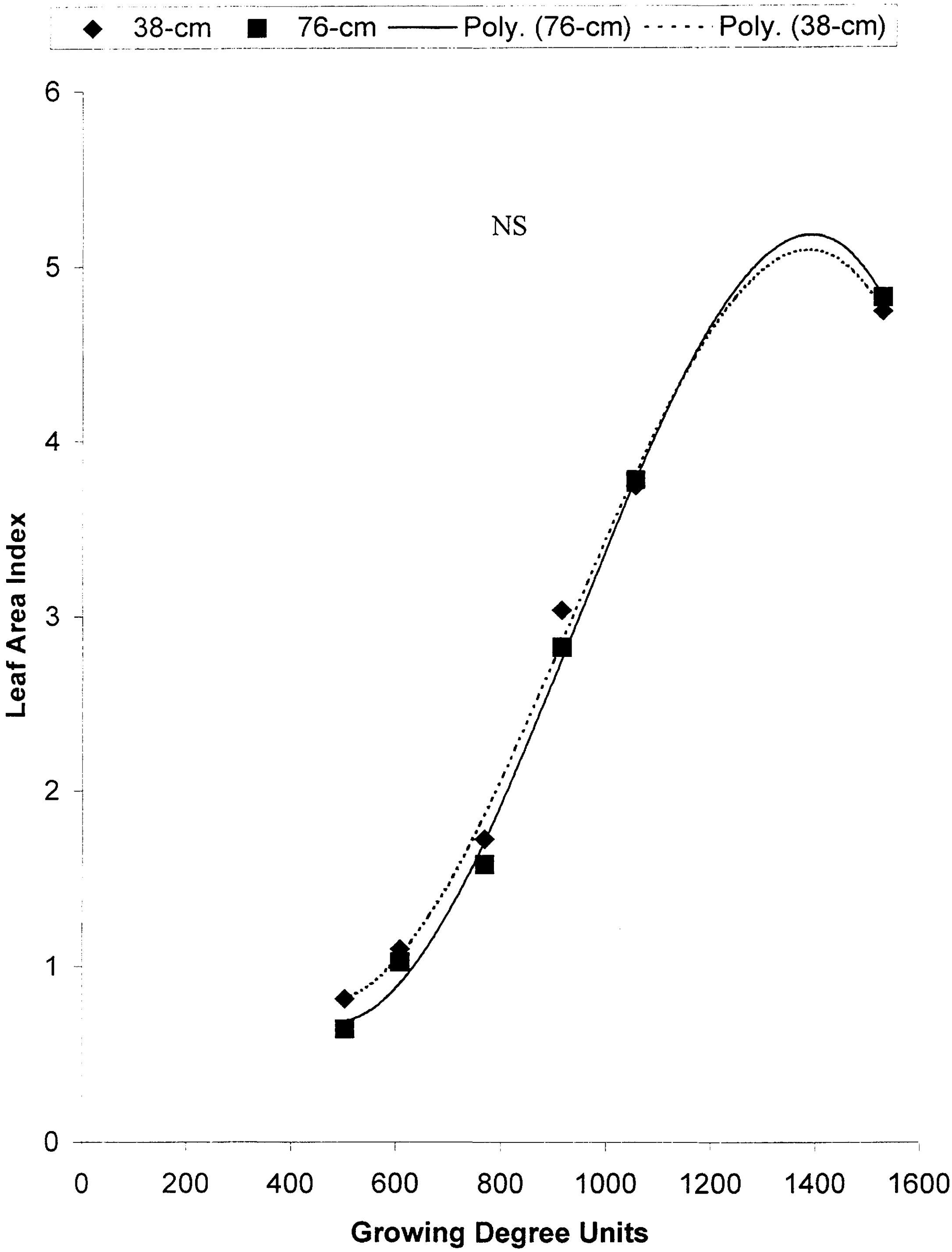


Figure 24. Effect of row spacing on the seasonal pattern of leaf area index expressed as a function of growing degree units from sowing for the 9 June 2000 planting date at Ames, IA.

NS = effect is not significant (P > 0.05).

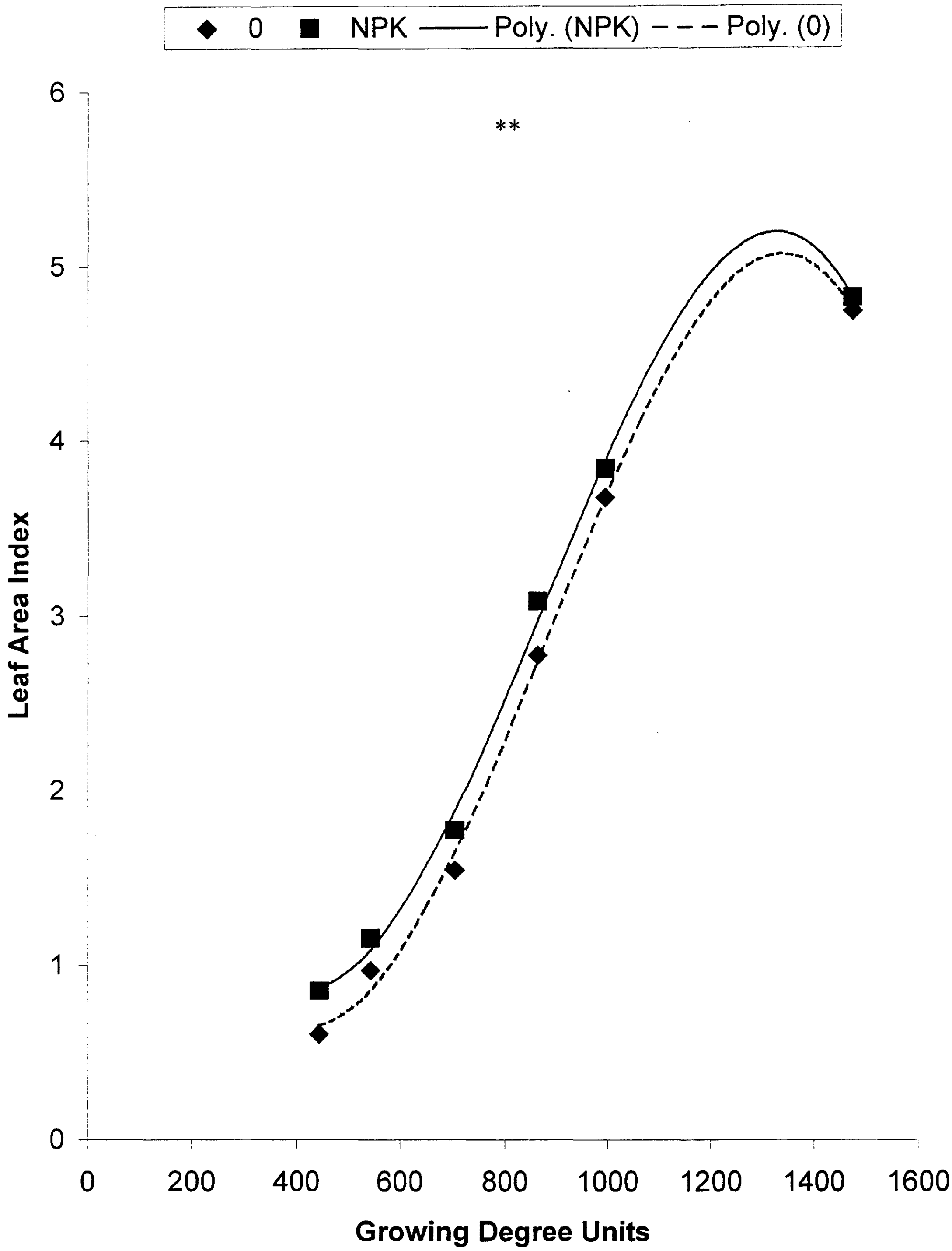


Fig. 25. Effect of starter fertilizer on the seasonal pattern of leaf area index expressed as a function of growing degree units from sowing for the 9 June 2000 planting date at Ames, IA.

* *= significant effect ($P < 0.01$).

occurred between fertility regimes for the 9 June 2000 planting until approximately 1000 growing degree units. After 1000 growing degree units, differences between fertility regimes were not significant. Many researchers have attributed use of starter fertilizer or phosphorus application to increased early season growth or improved uniformity (Penas and Hergert, 1990; Gordon et al., 1997; Buah et al., 1999; Mallarino et al., 1999; Scharf, 1999). Leaf area index was not improved by starter fertilizer for the 11 April 2000 and 11 May 2000 planting dates suggesting that potential increases in plant size from starter fertilizer are not consistently observed.

Pattern of intercepted fraction of photosynthetic active radiation and the main effect of hybrid, row spacing, and starter fertilizer on intercepted fraction of photosynthetic active radiation

Increases ($P < 0.05$) in the pattern of intercepted fraction of photosynthetic active radiation as a function of growing degree units occurred between sampling times. Intercepted fraction of photosynthetic active radiation is summarized in Table 5.

Significant differences ($P < 0.01$) in intercepted fraction of photosynthetic active radiation occurred between hybrids for the 11 April 2000 and 9 June 2000 planting dates. No significant difference ($P > 0.05$) occurred between hybrids for the 11 May 2000 planting date. Fraction of intercepted photosynthetic active radiation was greater for 34R07 than 33A14 and 35N05 for the 11 April 2000 planting date. Fraction of intercepted photosynthetic active radiation was similar between 33A14 and 35N05 for the 9 June 2000 planting date. Fraction for 34R07 was significantly greater ($P < 0.01$) than 33A14 and 35N05 for the 9 June 2000 planting date. Fractions for each hybrid, averaged across sampling time, row spacing, and starter fertilizer are summarized in Table 6.

Significant differences (P < 0.01) in fraction of intercepted photosynthetic active radiation occurred between row spacing for the 11 April 2000 and 11 May 2000 planting dates. No significant difference (P > 0.05) occurred for the 9 June 2000 planting date. Fractions of intercepted photosynthetic active radiation were significantly higher (P < 0.01) in 38-cm row spacing compared with 76-cm row spacing for the 11 April 2000 and 11 May 2000 planting dates. Fractions for row spacing, averaged across sampling time, hybrid, and starter fertilizer, are summarized in Table 7.

Table 5. Pattern of intercepted fraction of photosynthetic active radiation (Fraction) expressed as a function of growing degree units at Ames, IA.

Planting Date	GDU	Fraction
11-Apr-2000	1034.45	0.7718913
	1123.55	0.8533456
	1623.40	0.9407271
11-May-2000	735.15	0.5984485
	802.75	0.6884278
	994.15	0.8038711
9-Jun-2000	607.85	0.3399836
	1650.40	0.9436719

Table 6. Main effect of hybrid on intercepted fraction of photosynthetic active radiation at Ames, IA.

Planting Date	Hybrid	Fraction	t-Grouping
11-Apr-2000	33A14	0.85490	B
	34R07	0.87675	A
	35N05	0.83432	B
11-May-2000	33A14	0.68261	A
	34R07	0.69675	A
	35N05	0.71139	A
9-Jun-2000	33A14	0.62611	B
	34R07	0.67071	A
	35N05	0.62866	B

Table 7. Main effect of row spacing on intercepted fraction of photosynthetic active radiation at Ames, IA.

Planting Date	Row Spacing	Fraction	t-Grouping
11-Apr-2000	38 cm	0.87326	A
	76 cm	0.83739	B
11-May-2000	38 cm	0.72340	A
	76 cm	0.67043	B
9-Jun-2000	38 cm	0.64857	A
	76 cm	0.63508	A

Significant differences (P < 0.05) in fraction of intercepted photosynthetic active radiation occurred between fertility regimes for the 11 April 2000 planting date. No significant differences between fertility regimes occurred for the 15 May 2000 or 9 June 2000 planting dates. Fractions for starter fertilizer treated plots were significantly less (P < 0.01) than no-starter treated plots for the 11 April 2000 planting date. Fractions for fertility regime, averaged across sampling time, hybrid, and row spacing, are summarized in Table 8.

Table 8. Main effect of starter fertilizer on intercepted fraction of photosynthetic active radiation at Ames, IA.

Planting Date	Starter Fertilizer	Fraction	t-Grouping
11-Apr-2000	0	0.86717	A
	NPK	0.84347	B
11-May-2000	0	0.69073	A
	NPK	0.70310	A
9-Jun-2000	0	0.63480	A
	NPK	0.64885	A

Effect of hybrid on intercepted fraction of photosynthetic active radiation expressed as a function of growing degree units

Significant differences (P < 0.05) among hybrids effect on intercepted fraction of photosynthetic active radiation expressed as a function of growing degree units from planting occurred for the 11 April and 9 June 2000 planting dates. Hybrid did not significantly (P > 0.05) affect intercepted fraction of photosynthetic active radiation expressed as a function of growing degree units for the 11 May 2000 planting date. For the 11 April 2000 planting date, 34R07 intercepted a higher (P < 0.01) fraction of photosynthetic active radiation at 1034 growing degree units than 33A14 and 35N05 (Fig. 26). Hybrids 33A14 and 35N05 intercepted similar (P > 0.05) fractions of photosynthetic active radiation at 1034 growing degree units. Significant differences between 35N05 compared with 33A14 (P < 0.05) and 34R07 (P < 0.01) existed for intercepted fraction of photosynthetic active radiation at 1123 growing degree units. No difference (P > 0.05) occurred between 33A14 and 34R07 for intercepted fraction of photosynthetic active radiation at 1123 growing degree units. No significant differences (P > 0.05) existed among hybrids at 1623 growing degree units.

Significant differences (P < 0.01) occurred between 34R07 compared with 33A14 and 35N05 at 607 growing degree units for the 9 June 2000 planting date (Fig. 27). A significant difference did not occur between hybrids at 1650 growing degree units.

Differential light interception occurred between hybrids during vegetative growth for the 11 May and 9 June planting dates. It is important to consider that there was no difference or advantage among hybrids for intercepted fraction of photosynthetic active radiation during the flowering and grain fill periods for any of the planting dates. Because no differences were found among hybrids at this time, it is difficult to correlate any yield differences among hybrids to light interception.

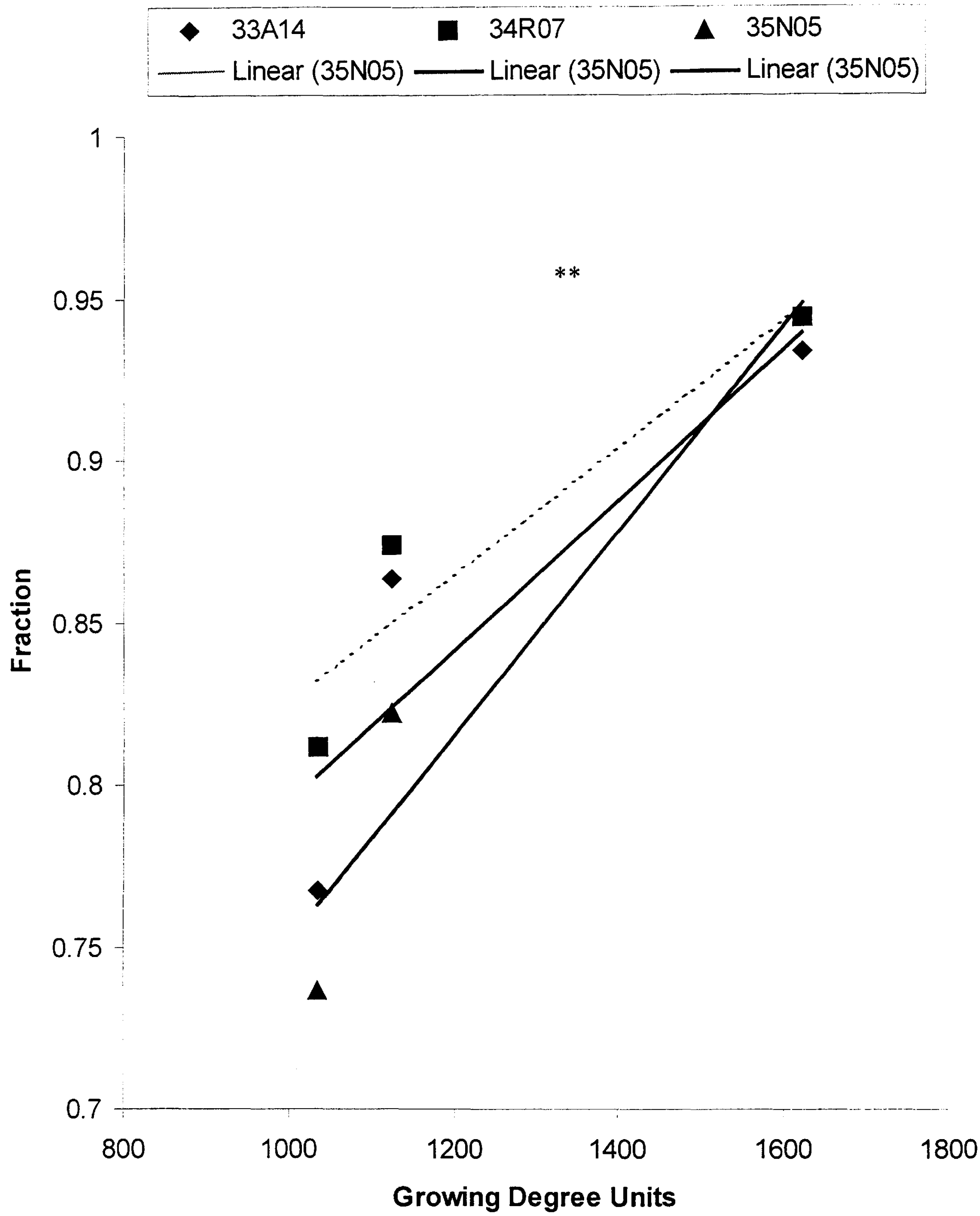


Fig. 26. Effect of hybrid on the pattern intercepted fraction of photosynthetic active radiation expressed as a function of growing degree units from planting for the 11 April 2000 planting date at Ames, IA.

** = significant effect (P < 0.01).

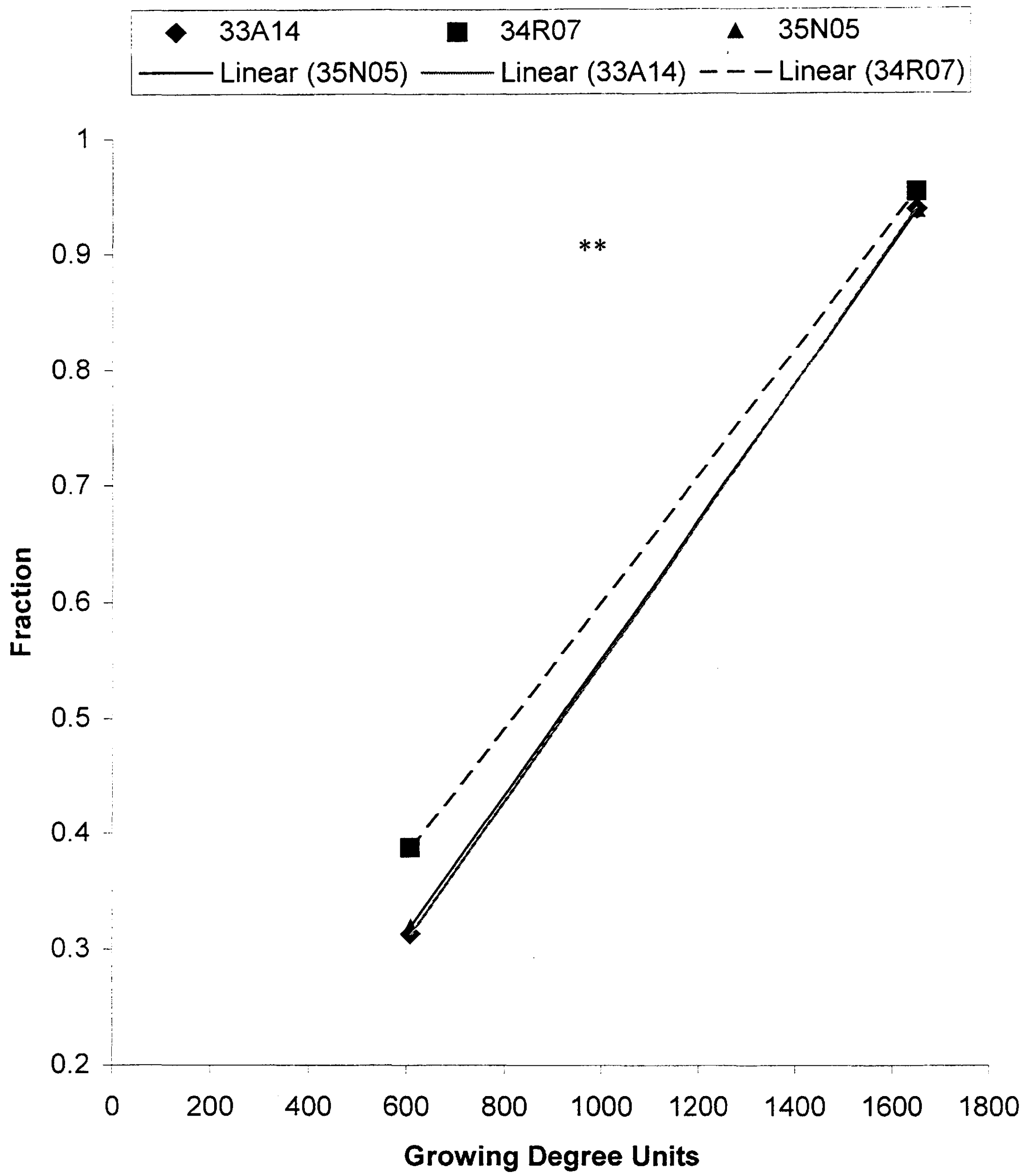


Fig. 27. Effect of hybrid on intercepted fraction of photosynthetic active radiation expressed as a function of growing degree units from planting for the 9 June 2000 planting date at Ames, IA.

** = significant effect ($P < 0.01$).

Effect of row spacing on intercepted fraction of photosynthetic active radiation expressed as a function of growing degree units from silking

Significant differences ($P < 0.01$) occurred between 38- and 76-cm row spacings at 1034 growing degree units for the 11 April 2000 planting date (Figure 28). No significant difference ($P < 0.05$) occurred when contrasting measurements between 38- and 76-cm row spacing from at 1123 or 1623 growing degree units which were closer to full canopy cover.

Significant differences ($P < 0.01$) occurred between 38- and 76-cm row spacing for intercepted fraction of photosynthetic active radiation for the 11 May 2000 planting date with 38-cm row spacing intercepting a higher fraction than 76-cm row spacing (Figure 29). No significant differences ($P > 0.05$) occurred at either of the sampling dates between 38- and 76-cm row spacings for the 9 June 2000 planting date (Figure 30).

With exception of the second planting date, differences in light interception between row spacings tend to decrease as canopy development progresses. Essentially no difference existed during the period where vegetative growth reached its peak. These findings are similar to conclusions offered by Westgate (1997) where the rigid canopy structure found in maize makes improving light interception through row spacing difficult. This may be a partial reason for the small and inconsistent yield increases attributed to row spacing less than 76-cm. The size and structure of the maize canopy improves light interception for the wider rows during flowering and grain fill which offsets any advantages that may be gained due to narrower rows. Additionally, the maize canopy does not branch or tiller at high plant density to the extent of crops that respond on a more consistent basis than maize, further lending to the concept of a rigid canopy structure (Farnham, personal conversation; Westgate, 1997). When tillering does occur in maize, often it is at a low plant population

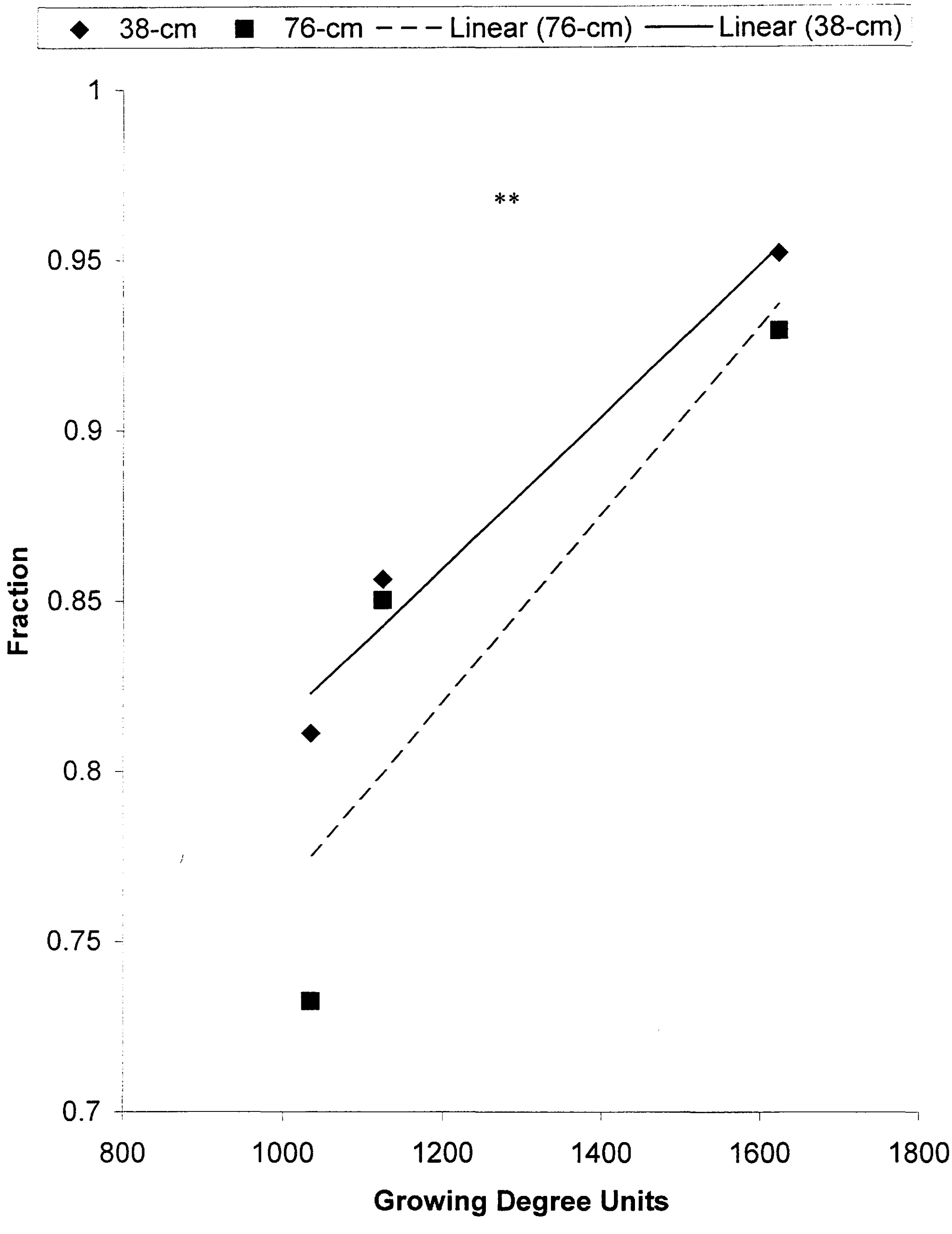


Fig. 28. Effect of row spacing on intercepted fraction of photosynthetic active radiation expressed as a function of growing degree units from planting for the 11 April 2000 planting date at Ames, IA.

** = significant effect ($P < 0.01$).

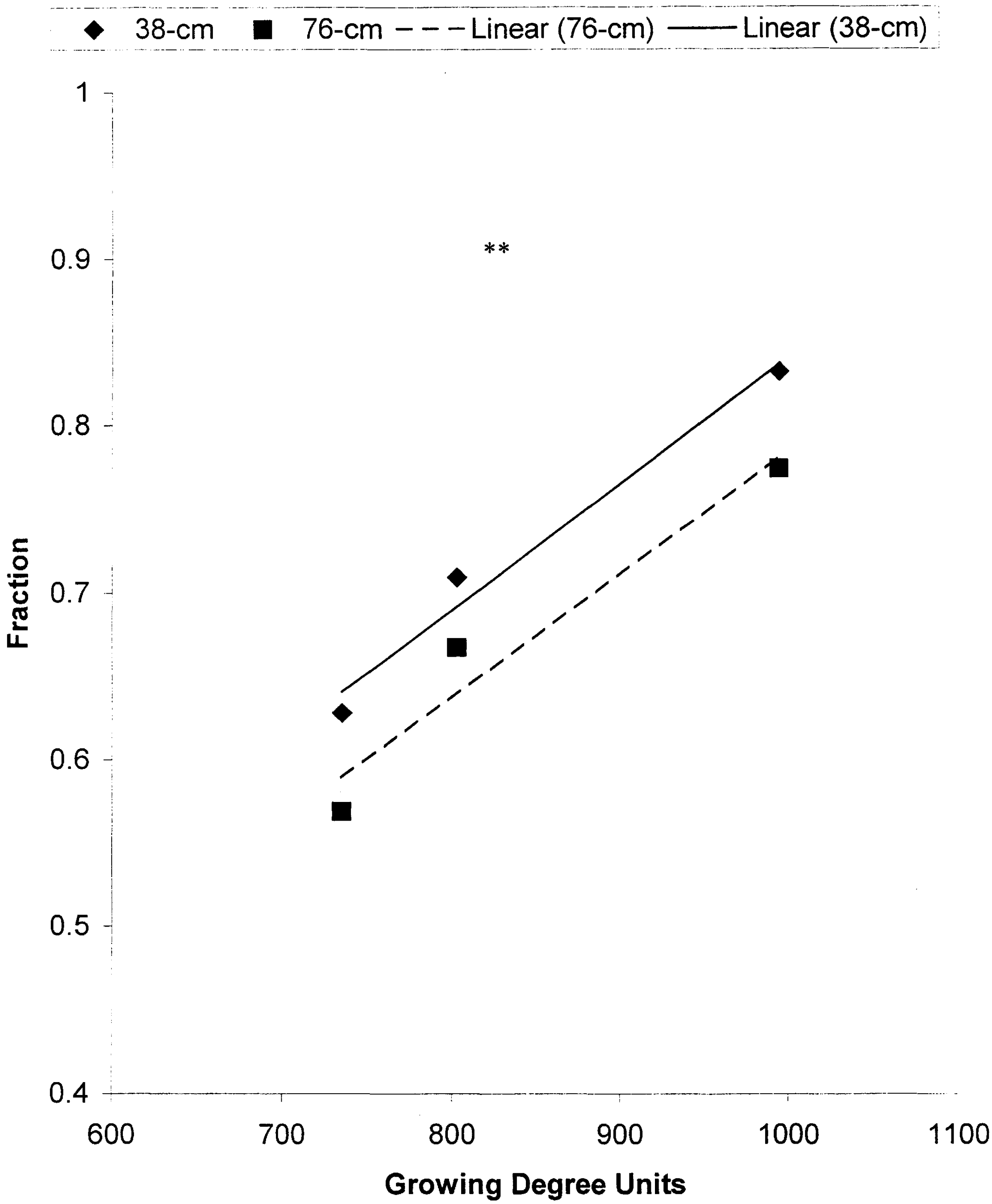


Fig. 29. Effect of row spacing on intercepted fraction of photosynthetic active radiation expressed as a function of growing degree units from planting for the 11 May 2000 planting date at Ames, IA.

** = significant effect (P < 0.01).

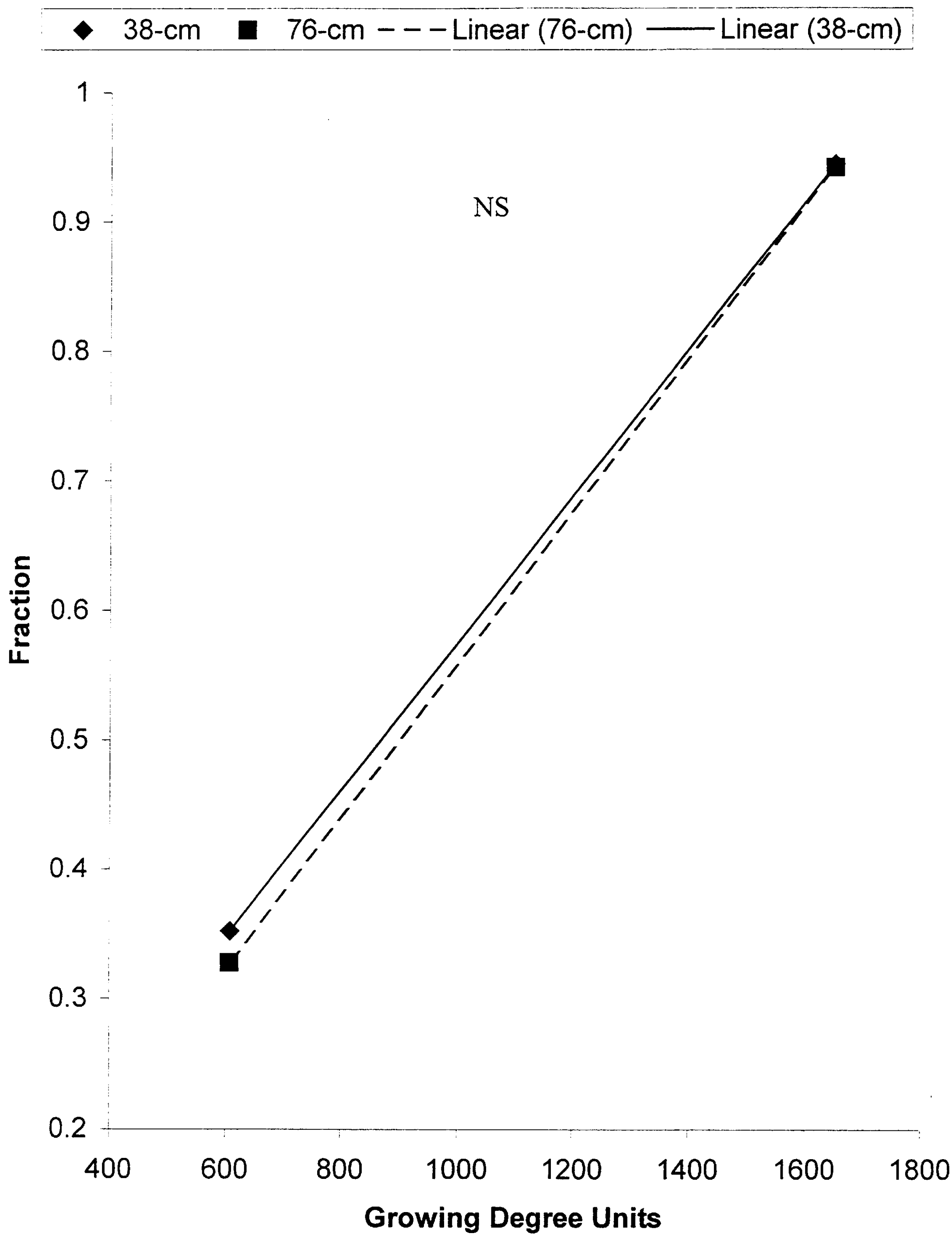


Fig. 30. Effect of row spacing on intercepted fraction of photosynthetic active radiation expressed as a function of growing degree units from planting for the 9 June 2000 planting date at Ames, IA.

NS = no significant difference ($P > 0.05$)

that does not produce as yields as high as optimum densities or if tillering does occur, the tiller does not produce grain at a high plant density (Farnham, personal conversation). Several have also suggested that increased dry matter accumulation is more closely related to radiation use efficiency than to radiation interception (Daughtry et al., 1983; Christy et al., 1986, Tollenaar and Bruulsema, 1988; Westgate, 1997). This suggests that yield increases due to light are largely related to other factors such as physiology or genotype, which was suggested by Westgate (1997).

Main effect of planting date on days to mid-silk and growing degree units from sowing to mid-silk

Significant effects ($P < 0.01$) occurred in 1999 and 2000 on days to mid-silk between each planting date (Fig. 31). As planting date was delayed, the days to mid-silk decreased in all cases. Several studies have linked changes in maize development, up to the flowering period, to photoperiod and temperature variables (Yan and Wallace, 1998; Birch et al., 1998; Ellis et al., 1992; Bonhomme et al., 1994; Ellis et al., 1992). Hastened development due to delayed planting from this study was also likely due to seasonal differences related to photoperiod and temperature as planting date was delayed.

Significant difference ($P < 0.05$) for growing degree units to mid-silk occurred between the 17 June1999 planting date (Date 3) compared to the 3 May 1999 planting date (Date 1) and the 10 May 1999 planting date (Date 2) (Fig. 32). No significant difference ($P > 0.05$) occurred between the 3 May 1999 and 10 May 1999 planting dates.

Significant difference ($P < 0.05$) for growing degree units to mid-silk occurred between the 11 April 2000 planting date (Date 1) compared to the 11 May 2000 (Date 2) and the 9 June 2000 (Date 3) planting dates. No significant difference ($P > 0.05$) occurred between the 11 May 2000 and 9 June 2000 planting dates (Fig. 32). Similar to the effect of planting date on days to mid-

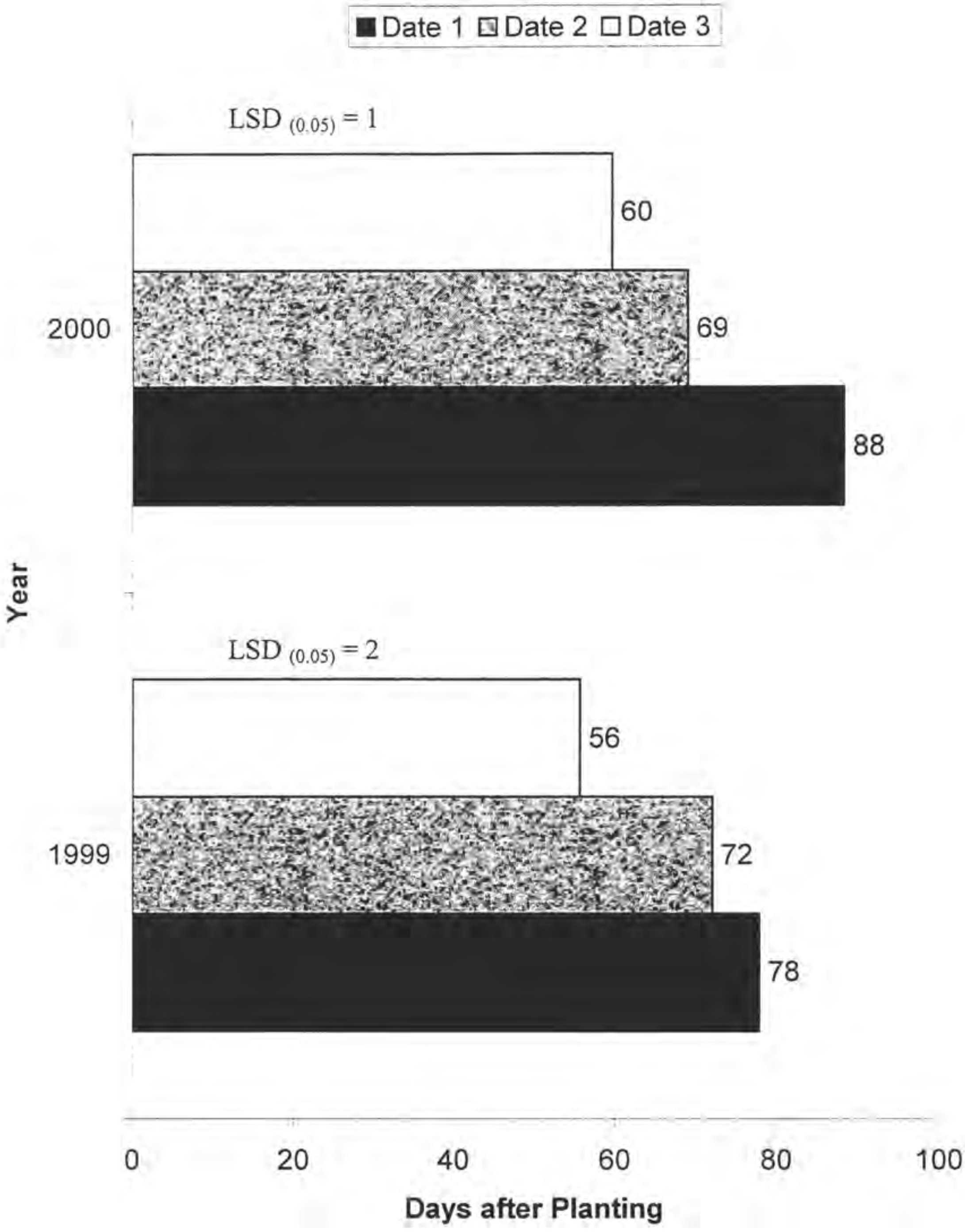


Fig. 31. Main effect of planting date on days to mid-silk at Ames, IA.

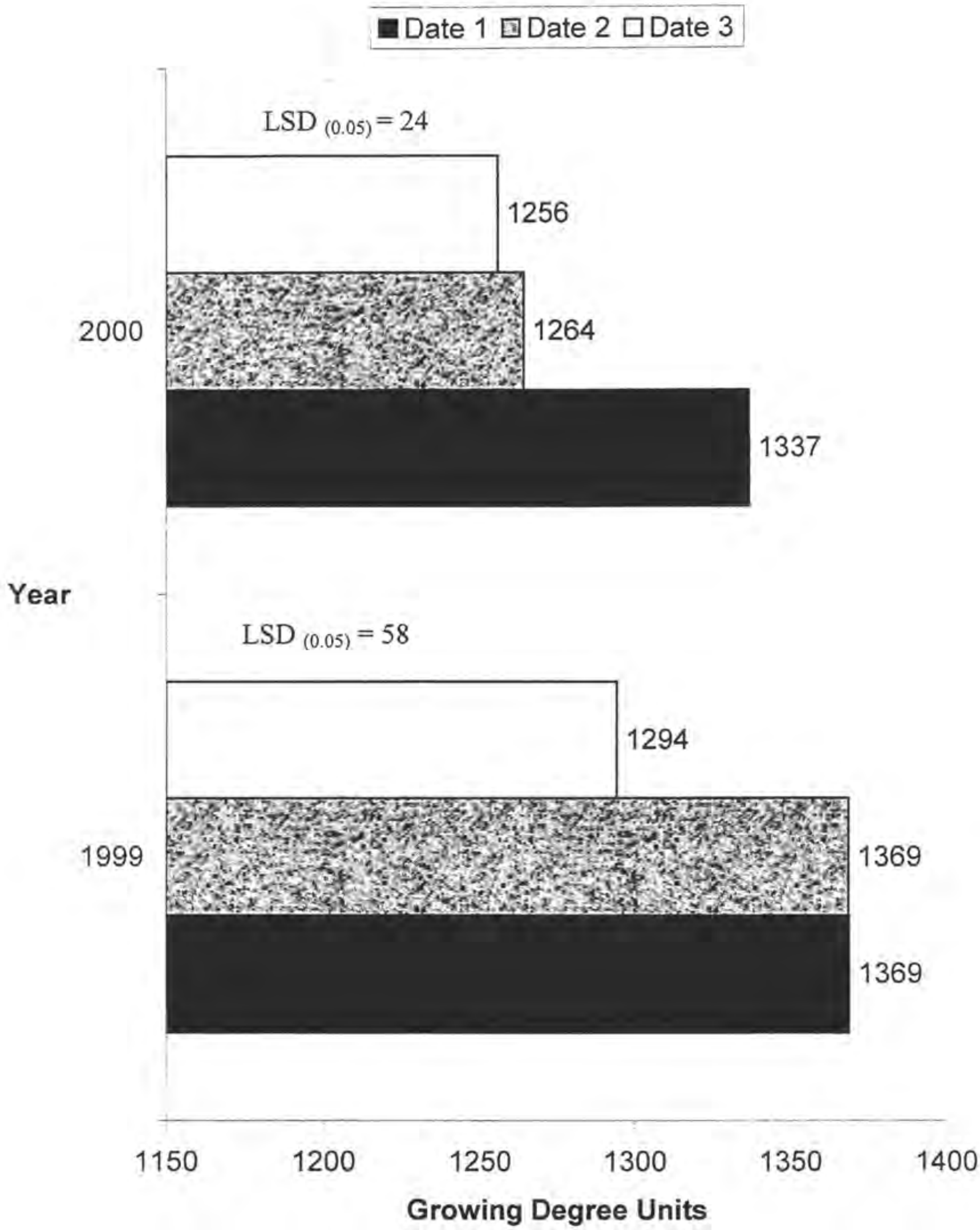


Fig. 32. Main effect of planting date on growing degree units to mid-silk at Ames, IA.

silk, decreases in the number growing degree units to mid-silk as planting date is delayed can be attributed to plant responses to seasonal photoperiod and temperature differences.

Main effect of hybrid on growing degree units and days after planting to mid-silk

Significant difference ($P < 0.05$) for growing degree units to mid-silk occurred between 34R07 compared to 33A14 and 35N05 in 1999 with 34R07 reaching mid-silk later than 33A14 and 35N05 (Fig. 33). No significant difference occurred between 33A14 and 35N05. In 1999, the average silking date for 34R07 was one day later, with one day averaging around 20 growing degree units, than 35N05 and 33A14. No significant difference ($P > 0.05$) between hybrids for growing degree units or days after planting to mid-silk occurred in 2000 (Fig. 33).

Main effect of row spacing on growing degree units and days after planting to mid-silk

Significant difference ($P < 0.05$) for growing degree units and days after planting to mid-silk occurred between 38-cm row spacing and 76-cm row spacing in 1999 with 38-cm row spacing reaching mid-silk before 76-cm row spacing (Fig. 34). No significant difference ($P > 0.05$) occurred in 2000 between row spacings (Fig. 34). Differences between years were possibly due to a cold wet spring in 1999 versus a warm and dry spring in 2000. Potentially, improved early canopy development from the narrower row spacing improved energy capture, which hastened plant development during a cold and wet spring where slower growth and development would occur resulting in earlier flowering for the 38-cm rows spacing.

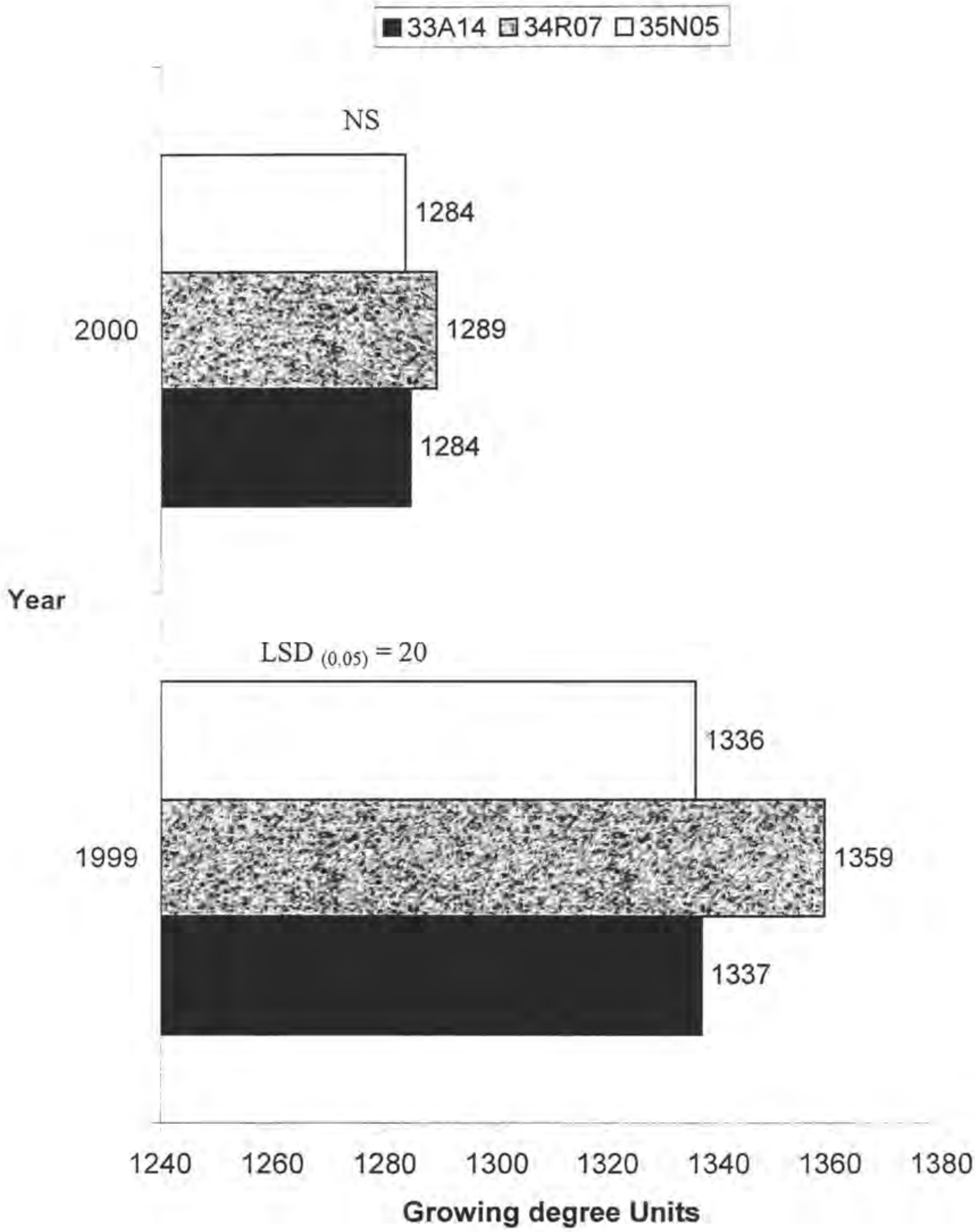


Fig. 33. Main effect of hybrid on growing degree units to mid-silk at Ames, IA.

NS = no significant difference ($P > 0.05$).

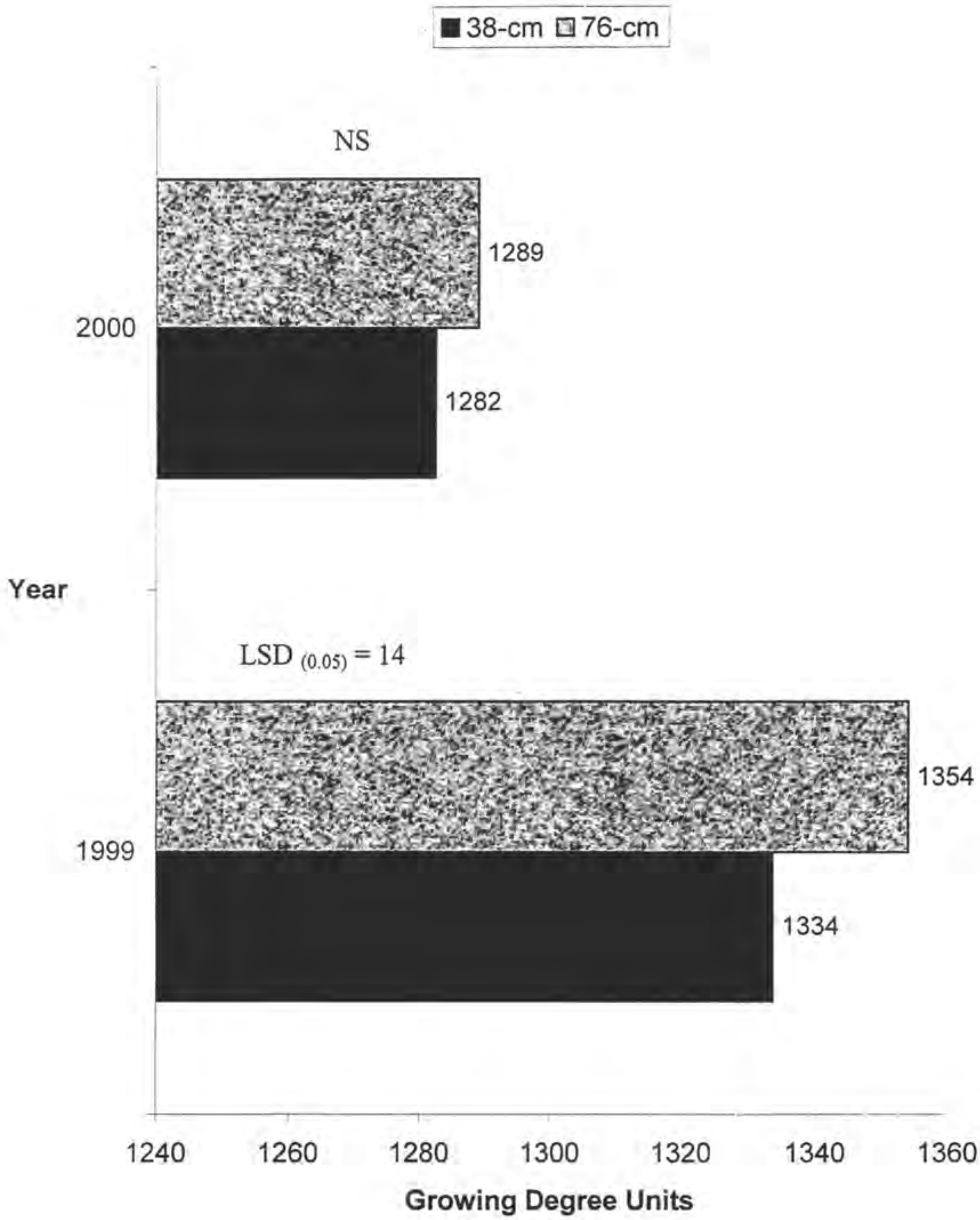


Fig. 34. Main effect of row spacing on growing degree units to mid-silk at Ames, IA. NS = no significant difference ($P > 0.05$).

Main effect of starter fertilizer on growing degree units and days after planting to mid-silk

Significant difference (P < 0.01) occurred between fertility regimes for growing degree units and days after planting to mid-silk in 1999 with starter fertilizer treated plots reaching mid-silk with fewer growing degree units and days than plots with no starter fertilizer (Fig. 35). Significant difference (P < 0.01) also occurred between fertility regimes for growing degree units and days after planting to mid-silk in 2000 with starter fertilizer treated plots reaching mid-silk with fewer growing degree units and days after planting than plots with no starter fertilizer. Gordon et al. (1997) reported a similar decrease in growing degree units needed to reach mid-silk in starter fertilizer treated plots and Scharf (1999) reported earlier tasseling in starter fertilizer treated plots. Interactions between planting date and starter fertilizer occurred in 1999 and 2000 and an interaction between row spacing and starter fertilizer occurred in 1999 will be addressed later.

Interactive effect of planting date and starter fertilizer on growing degree units to mid-silk

Significant difference (P < 0.01) occurred between no starter fertilizer treatment and starter fertilizer treatment for growing degree units to mid-silk at the 3 May 1999 planting date (Fig. 36). Growing degree units to mid-silk for the 10 May 1999 planting date were not significant (P > 0.05) when comparing no starter treatments with starter fertilizer treatments (Fig. 36). Significant difference (P < 0.01) occurred between no starter fertilizer treatment and starter fertilizer treatment for growing degree units to mid-silk at the 17 June 1999 planting date (Fig. 36).

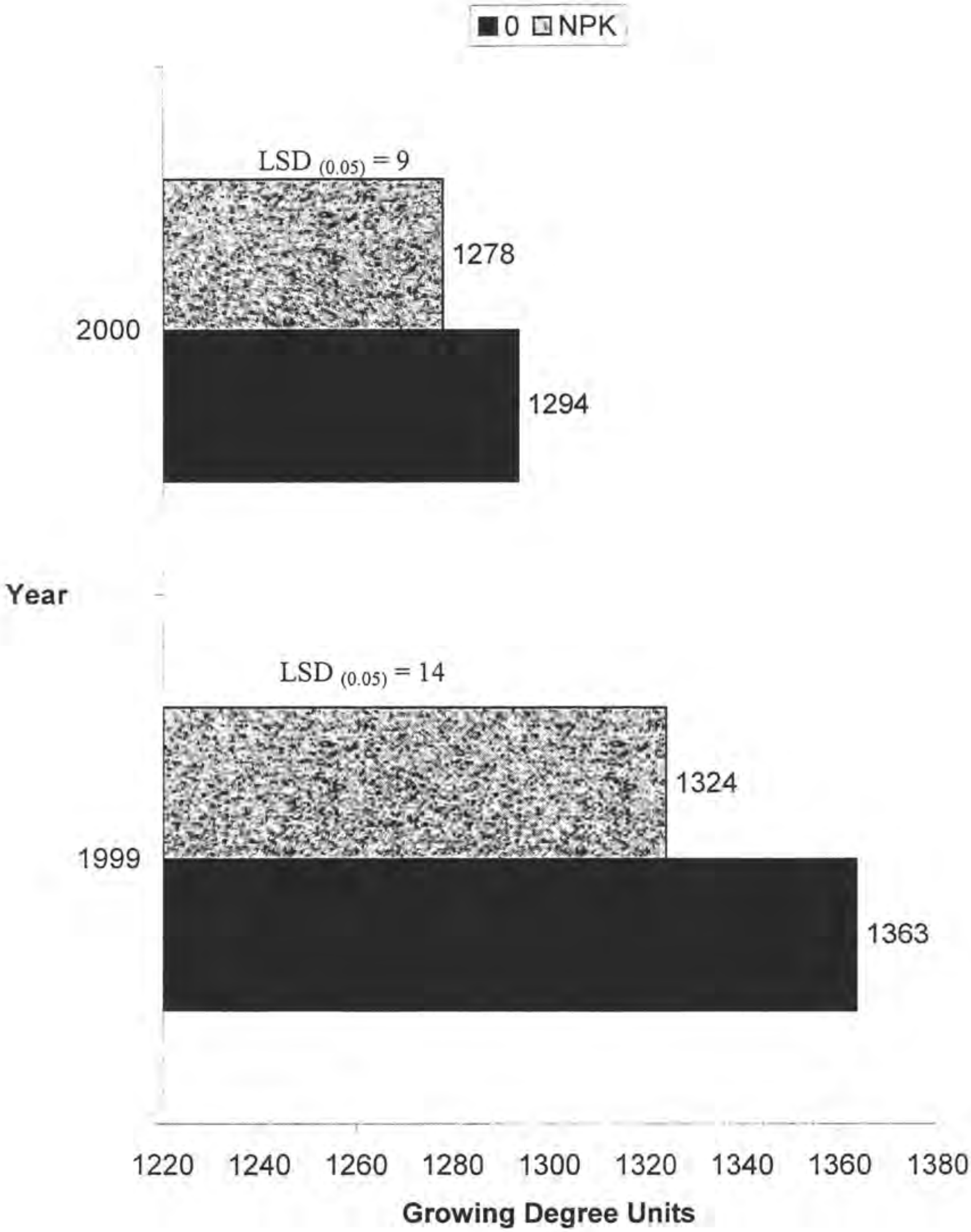


Fig. 35. Main effect of starter fertilizer on growing degree units to mid-silk at Ames, IA.

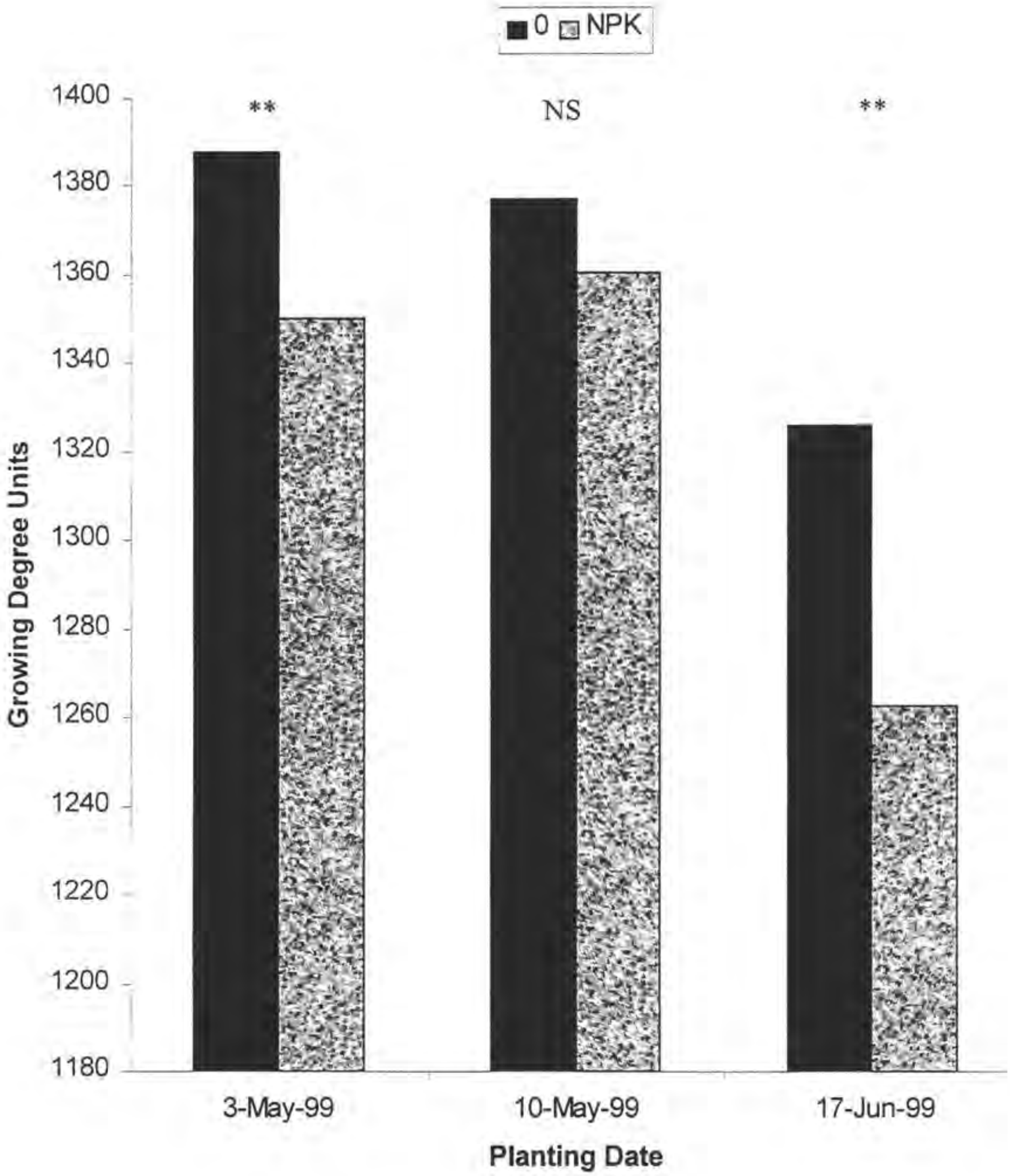


Fig. 36. Interactive effect of planting date and starter fertilizer on growing degree units to mid-silk at Ames, IA.

** = significant effect within planting date (P < 0.01).

NS = no significance within planting date (P > 0.05).

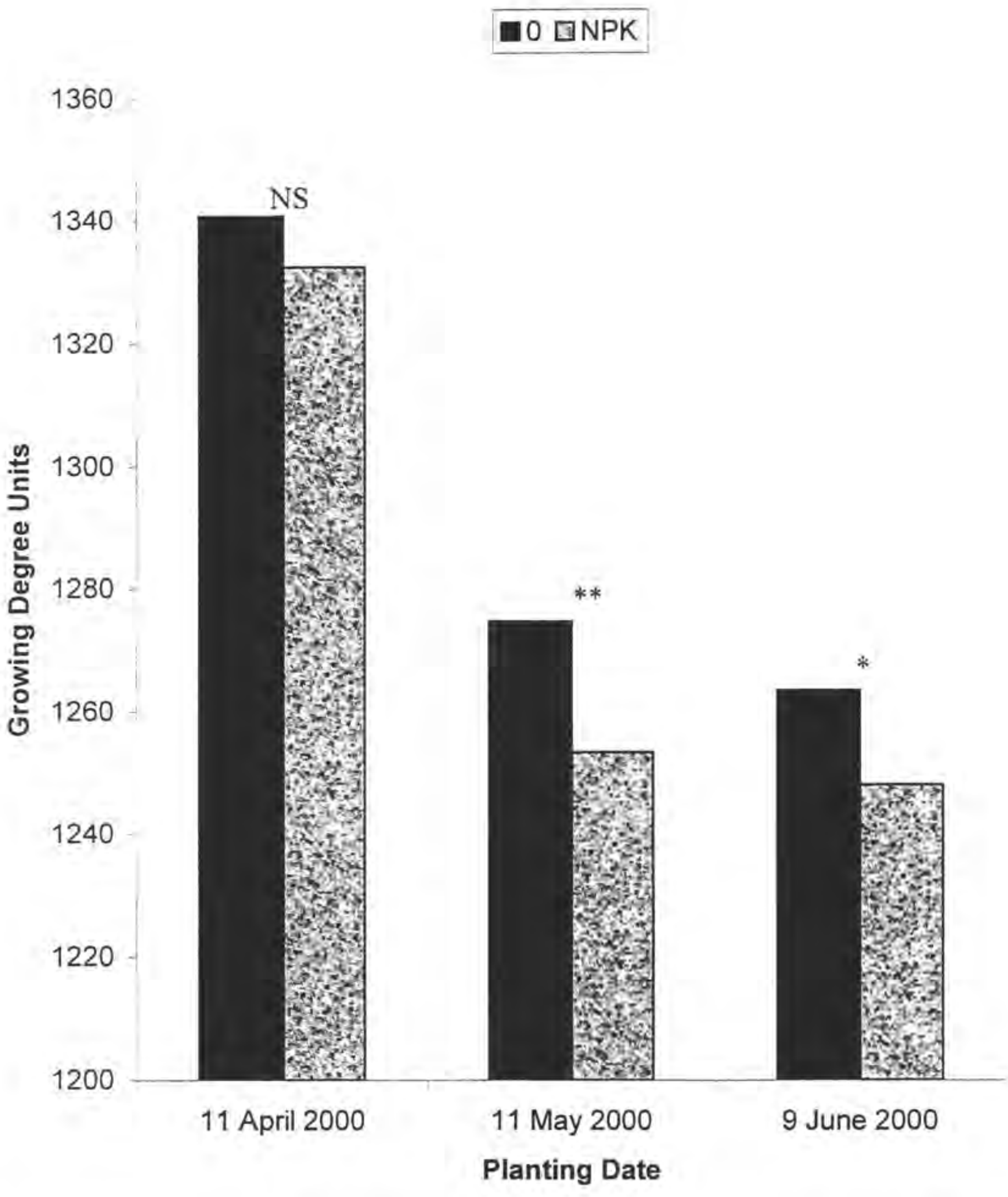


Fig. 37. Interactive effect of planting date and starter fertilizer on growing degree units to mid-silk, Ames, IA.

* = significant difference between means within planting date ($P < 0.05$).

** = significant difference between means within planting date ($P < 0.01$).

NS = no significant difference ($P > 0.05$).

A significant interaction ($P > 0.01$) between planting date and starter fertilizer for growing degree units to mid-silk also occurred in 2000 (Fig. 37). No difference ($P > 0.05$) occurred between fertility regimes for the 11 April 2000 planting date. Significant difference between fertility regimes occurred for the 11 May 2000 ($P < 0.01$) and 9 June 2000 ($P < 0.05$) planting dates with starter fertilizer treated plots reaching mid-silk with fewer growing degree units than no starter treated plots.

Interactive effect of row spacing and starter fertilizer on growing degree units to mid-silk

Significant difference ($P < 0.05$) occurred between each fertility regime/row spacing combination for growing degree units to mid-silk in 1999 (Fig. 38). Differences in magnitude existed between row spacing when contrasting starter fertilizers effect on growing degree units to mid-silk. Starter fertilizer produced a larger decrease in growing degree units to mid-silk in 38-cm rows compared with no starter fertilizer than comparing 76-cm treatments. Significant difference did not occur ($P > 0.05$) between 38- and 76-cm row spacing with no starter fertilizer while significant difference ($P < 0.01$) did occur between 38- and 76-cm row spacing with starter fertilizer. A significant interaction did not exist ($P > 0.05$) between row spacing and starter fertilizer on growing degree units to mid-silk in 2000.

Main effect of planting date on rows of kernels per ear, kernels per row, and total kernels per ear

Significant differences did not occur ($P > 0.05$) between planting dates for rows of kernels per ear in 1999 (Fig. 39). Significant differences ($P < 0.05$) did occur between planting dates for kernels per row in 1999 (Fig. 40). The 3 May 1999 and 10 May 1999 planting dates produced similar kernels per row and both dates produced significantly more

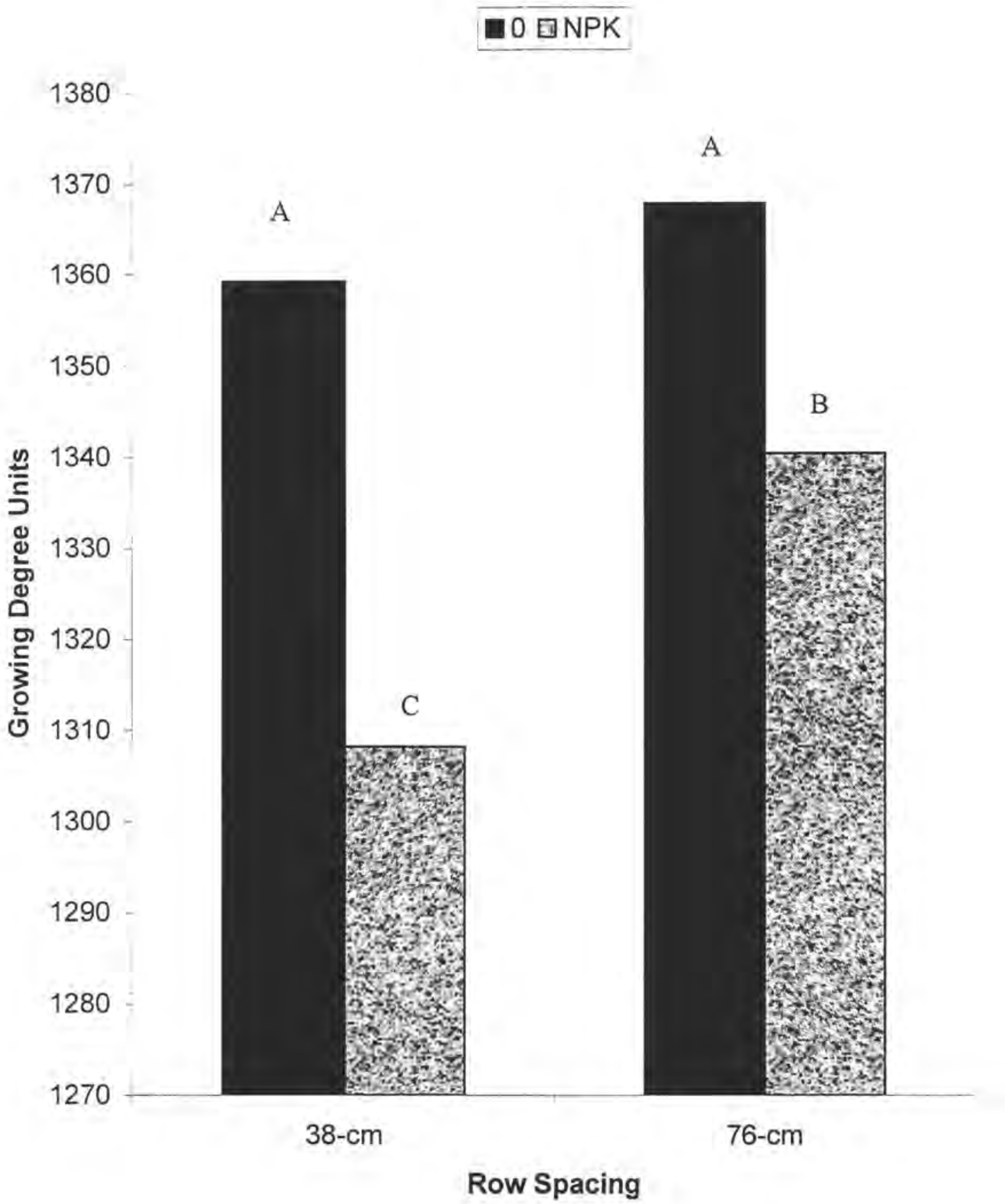


Fig. 38. Interactive effect of starter fertilizer and row spacing on growing degree units to mid-silk at Ames, IA.

Means with the same letter are not significantly different (P > 0.05).

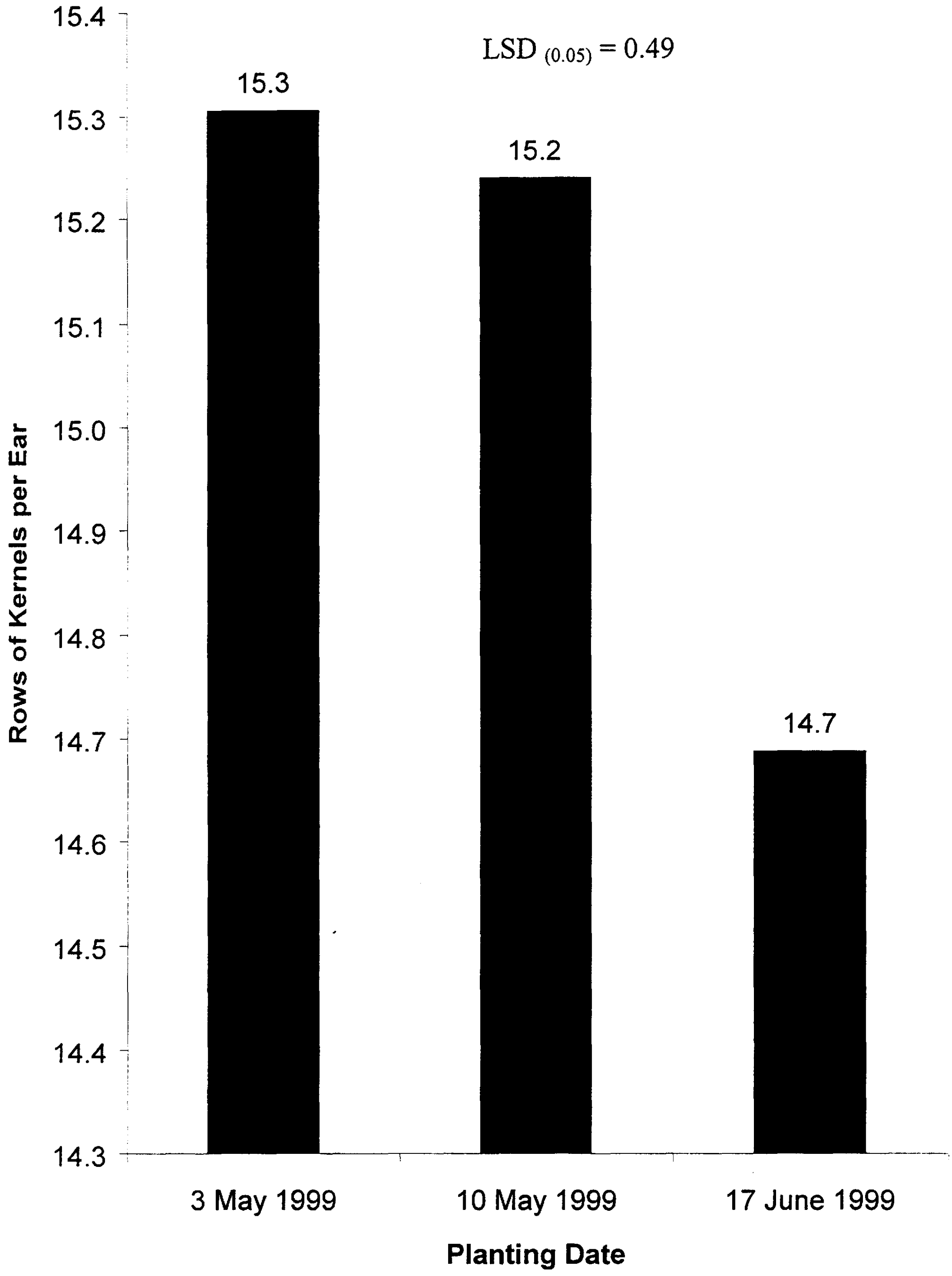


Fig. 39. Main effect of planting date on rows of kernels ear^{-1} at Ames, IA.

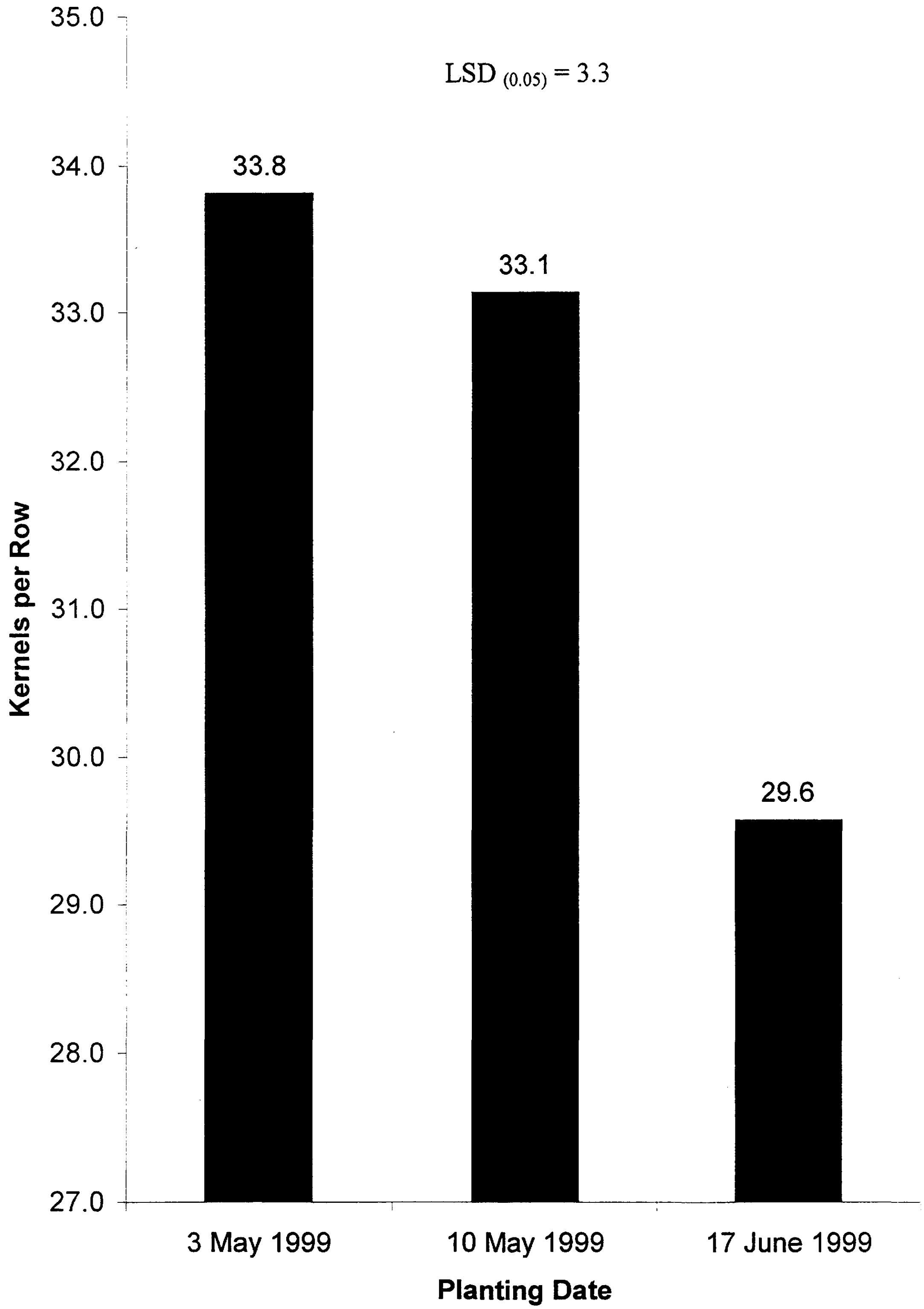


Fig. 40. Main effect of planting date on number of kernels row^{-1} at Ames, IA.

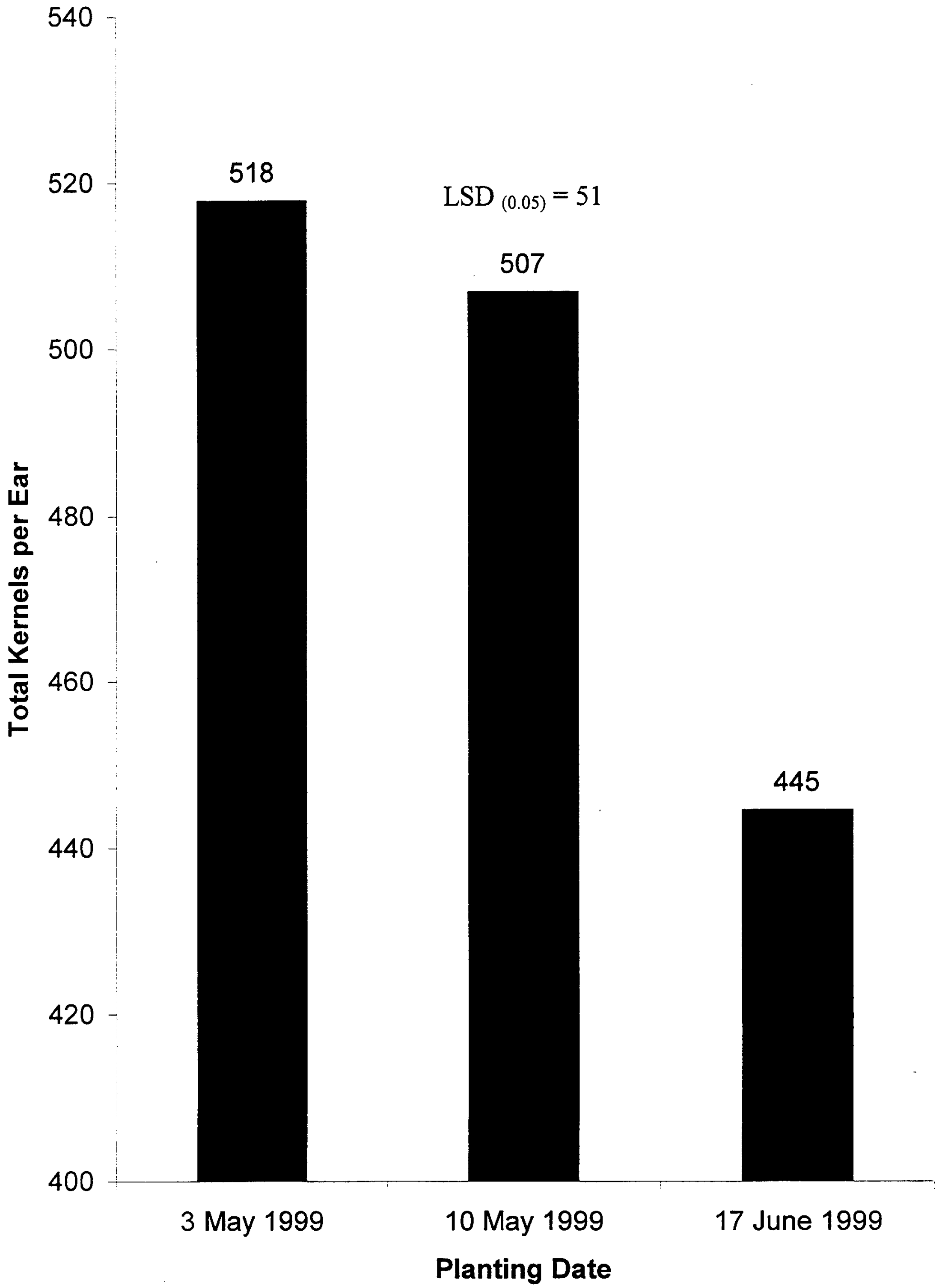


Fig. 41. Main effect of planting date on total kernels ear^{-1} at Ames, IA.

kernels per row than the 17 June 1999 planting date. Significant differences existed ($P < 0.05$) between planting dates for total kernels per ear in 1999 (Fig. 41). Total kernels ear^{-1} was significantly less for the 17 June 1999 planting date compared with the 3 May and 10 May 1999 planting dates. Significant difference did not exist ($P > 0.05$) for total kernels ear^{-1} for the 3 May 1999 planting date compared with the 10 May 1999 planting date.

Significant differences ($P < 0.05$) occurred between the 11 April 2000 planting date compared with the 11 May 2000 and 9 June 2000 planting dates for rows of kernels per ear. The 11 April 2000 planting date produced significantly more rows of kernels per ear than the 11 May 2000 and 11 June 2000 planting dates (Fig. 42). The 11 May 2000 and 9 June 2000 produced similar ($P > 0.05$) rows of kernels per ear. Significant differences occurred between each planting date in 2000 for number of kernels per row (Fig. 43). The 11 April 2000 planting date produced significantly more ($P < 0.05$) kernels per row than the 11 May 2000 and 9 June 2000 planting dates. Significant differences ($P < 0.05$) occurred between each planting date in 2000 for total kernels per ear (Fig. 44). The 11 April 2000 planting date produced significantly more kernels per ear than the 11 May 2000 and 9 June 2000 planting dates and the 11 May 2000 planting date produced significantly more kernels per ear than the 9 June 2000 planting date.

Delays in planting for 1999 and 2000 resulted in decreases in number of kernels per ear. Results of previous studies have shown that sink size is not altered by planting date causing kernel abortion to be the dominant factor in determining final kernel number (Otegui and Melón, 1997; Cirilo and Andrade, 1994). Swanson and Wilhelm (1996) showed

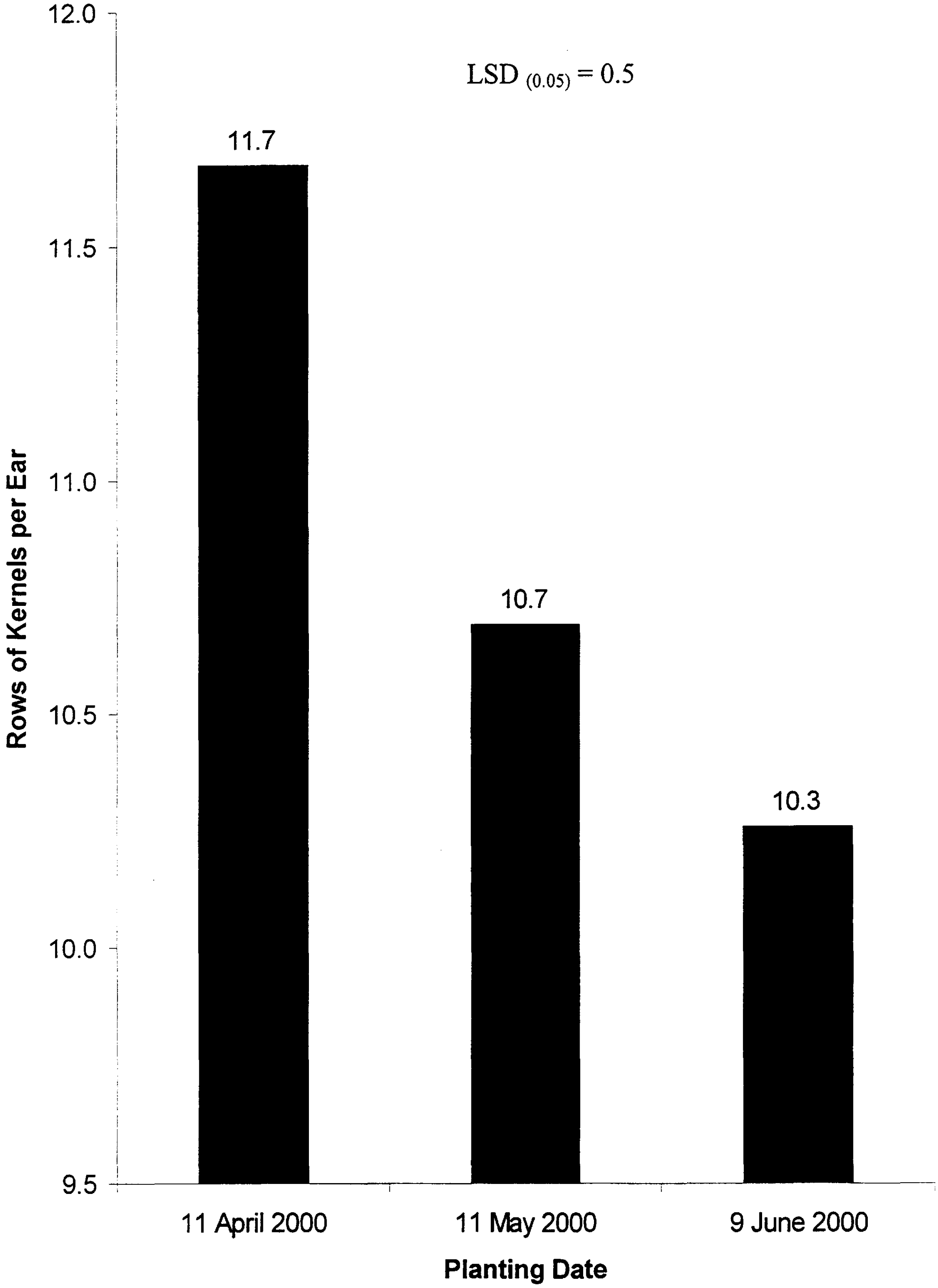


Fig. 42. Main effect of planting date on rows of kernels ear^{-1} at Ames, IA.

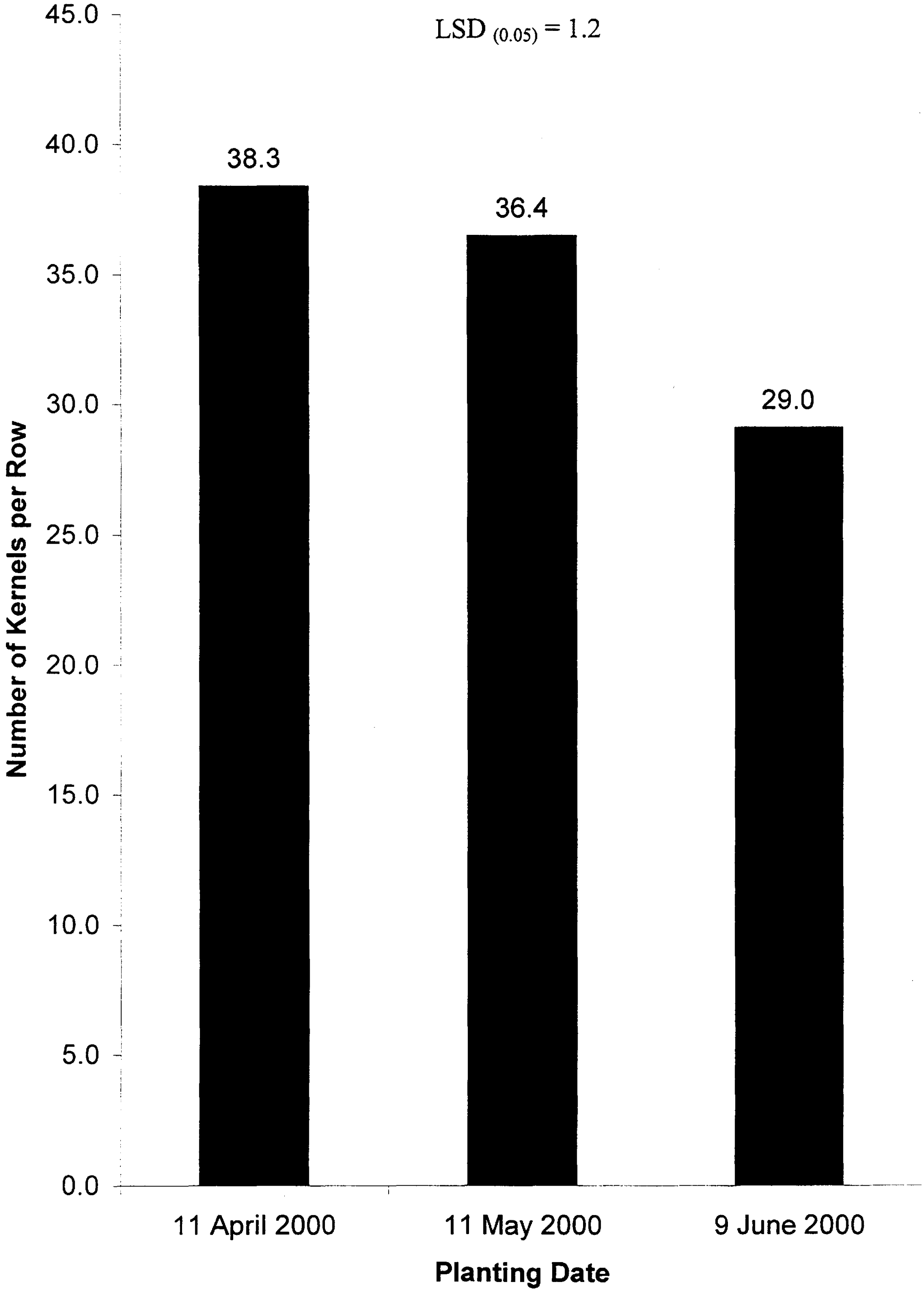


Fig. 43. Main effect of planting date on number of kernels row^{-1} at Ames, IA.

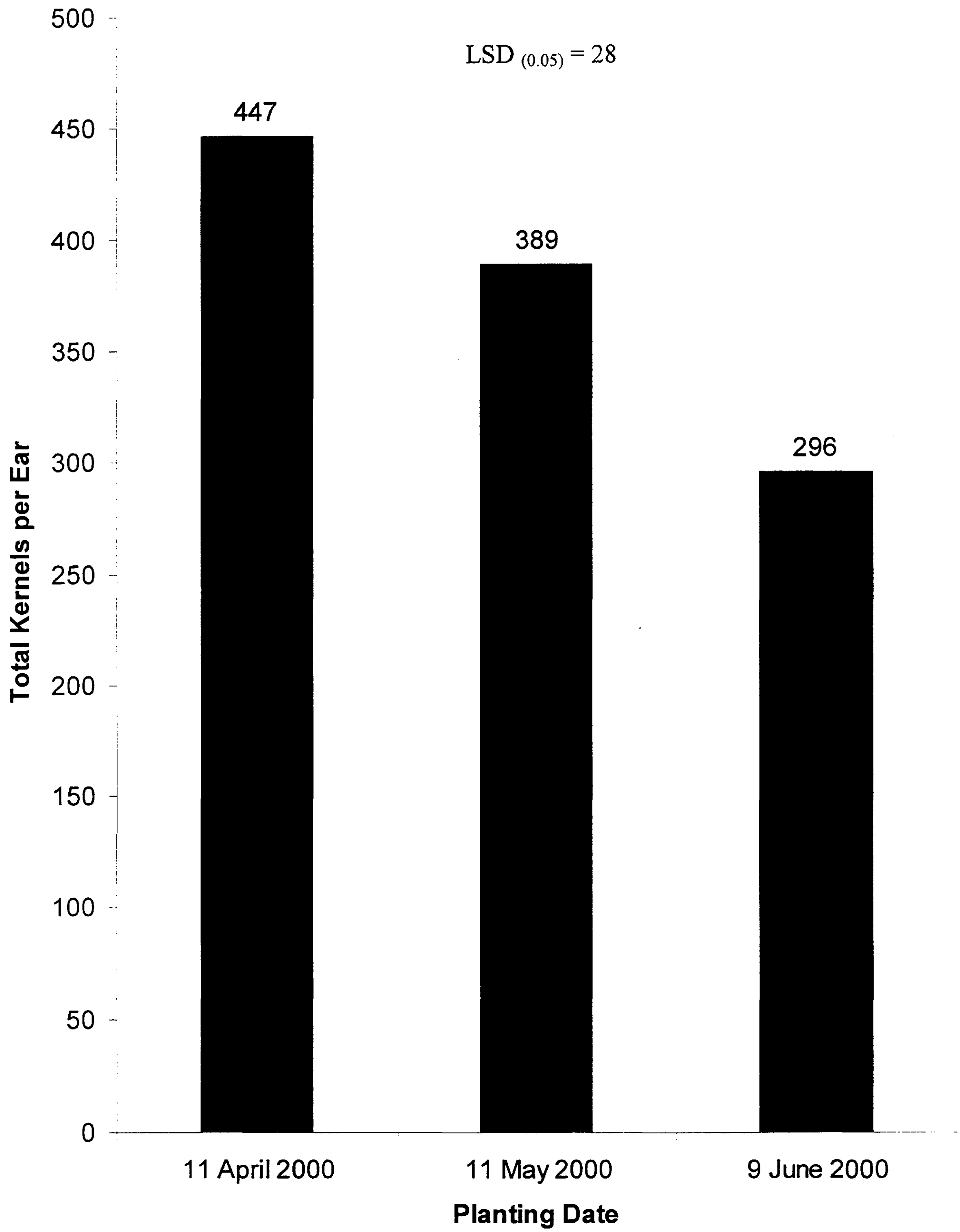


Fig. 44. Main effect of planting date on total kernels ear^{-1} at Ames, IA.

decreases in kernels ear^{-1} and kernels plant^{-1} which is similar to observations from this study from both years.

Main effect of planting date on weight per kernel

No significant differences ($P > 0.05$) occurred between the 3 May 1999 and 10 May 1999 planting dates for weight per kernel. The 17 June 1999 produced a significantly lower kernel weight ($P < 0.05$) than the 3 May 1999 and 10 May 1999 planting dates (Fig. 45). The 11 April 2000 planting date produced significantly higher ($P < 0.05$) kernel weights compared with the 11 May 2000 and 9 June 2000 planting dates (Fig. 46). There was no significant difference ($P > 0.05$) between the 11 May 2000 and 9 June 2000 planting dates for kernel weight.

Total kernel number did not correlate strongly ($R^2 = 0.04$) to grain yield in 1999 (Fig. 47). In 1999, a strong positive correlation ($R^2 = 0.72$) occurred between kernel weight and yield (Fig. 48). The differences in kernel weight between planting dates is similar to what was found by Cirilo and Andrade (1996) in which delays in planting produced lower effective grain filling rates and thus lower final kernel weight.

In 2000, correlation was found between both total kernels ear^{-1} and kernel weight to grain yield (Figs. 49 and 50). The difference between years was likely due to difference in rainfall during the growing season. Rainfall for 2000 was much lower than normal where 1999 was wet with rainfall occurring at times important for crop development. In previous studies, it has been shown that delays in planting date do not alter the sink size of the ear indicating that potential kernel number ear^{-1} is not effected by delays in planting (Otegui and Melón, 1997). Decreases in kernel number ear^{-1} due to delays in planting are due to kernel

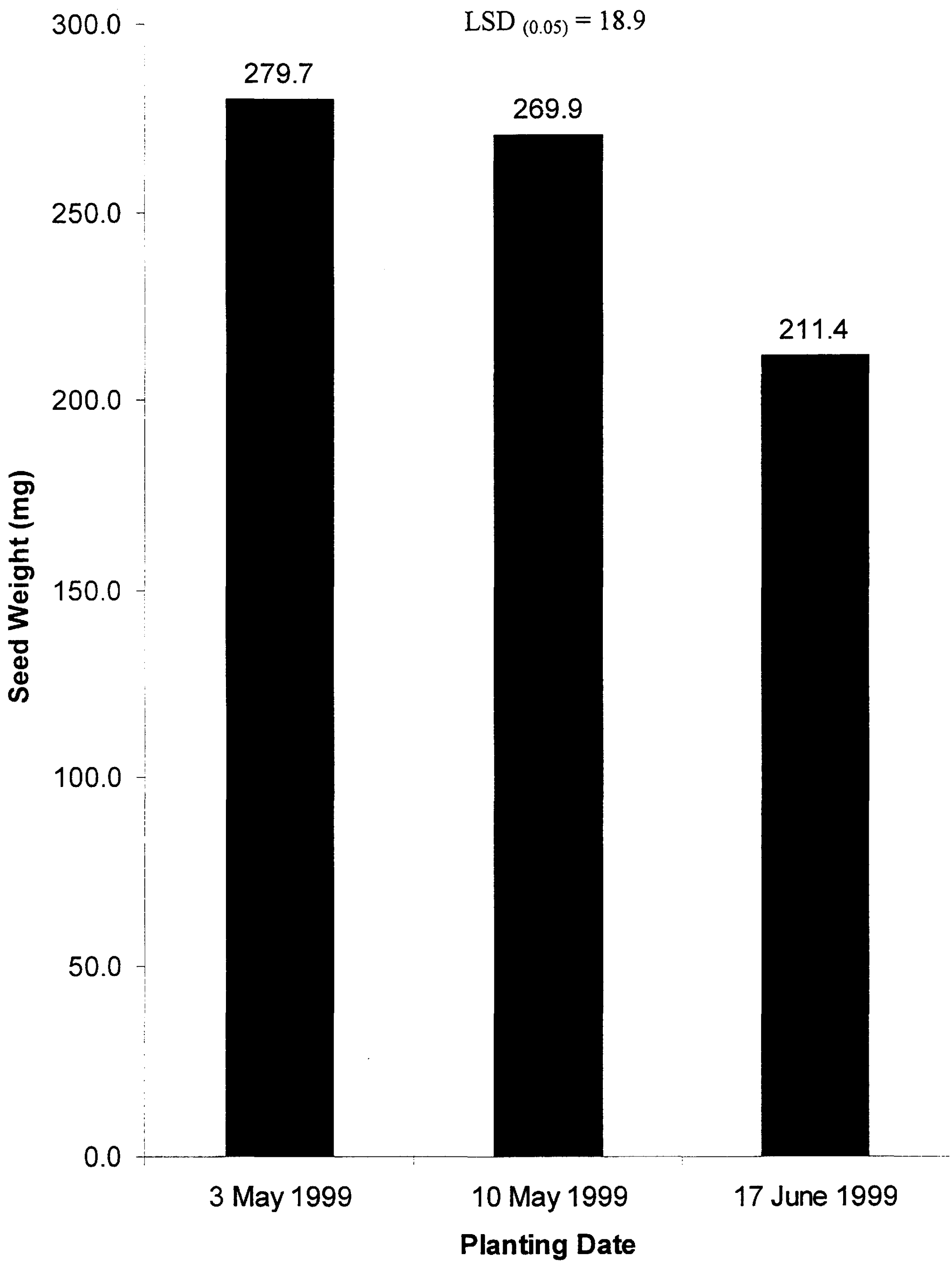


Fig. 45. Effect of planting date on weight kernel^{-1} at Ames, IA.

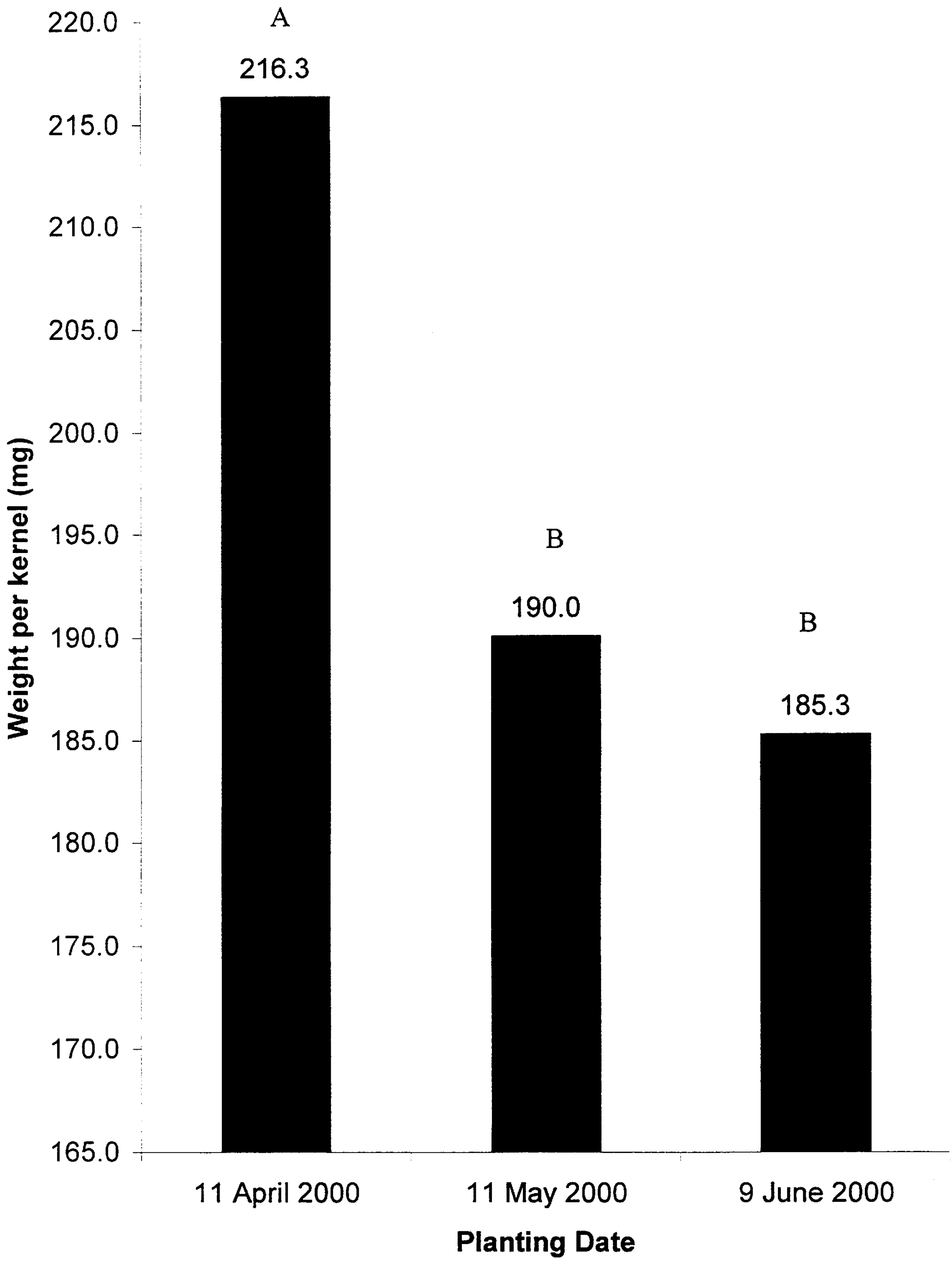


Fig. 46. Effect of planting date on weight kernel^{-1} at Ames, IA.

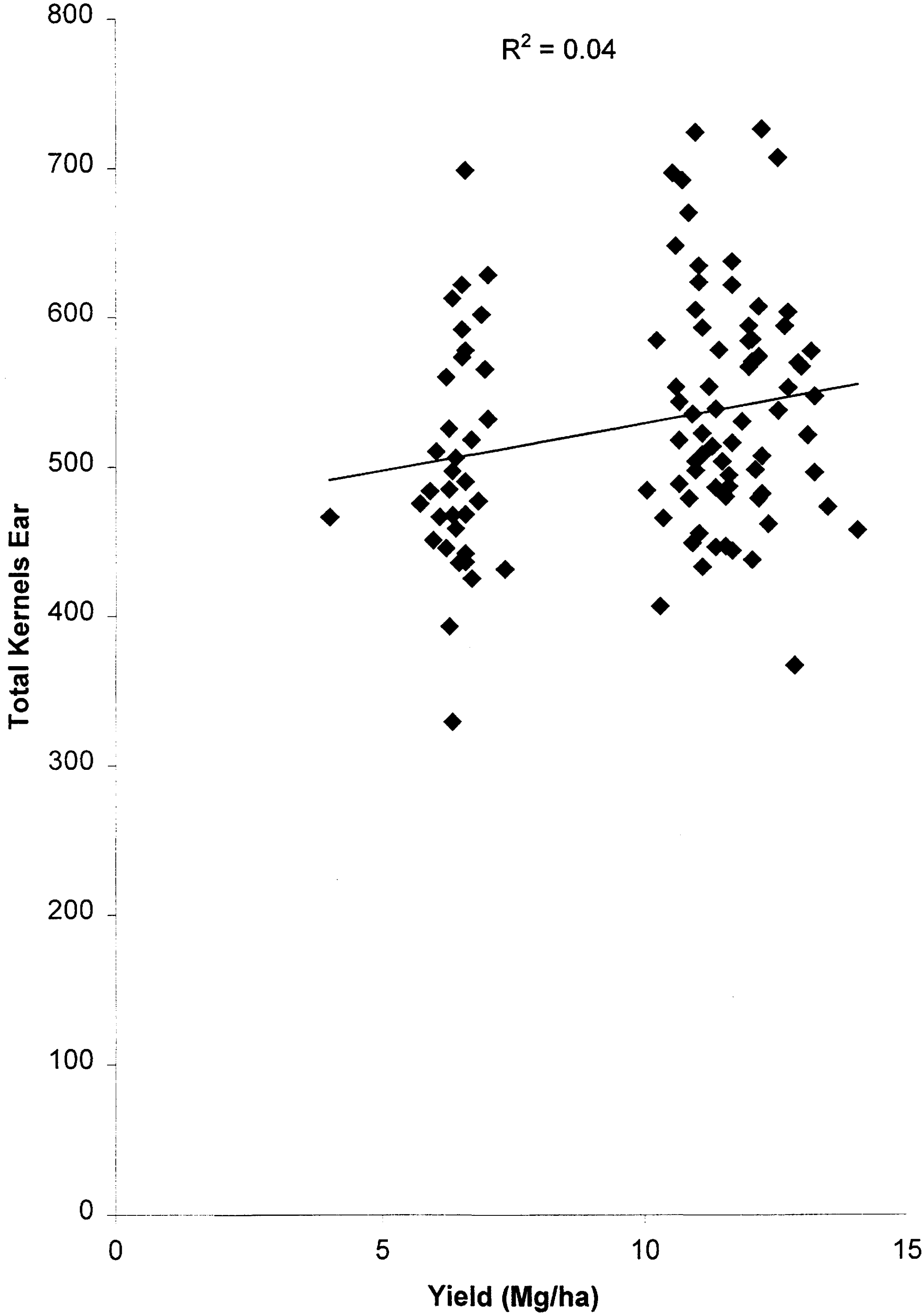


Fig. 47. Correlation between total kernels ear^{-1} and grain yield at Ames, IA, 1999.

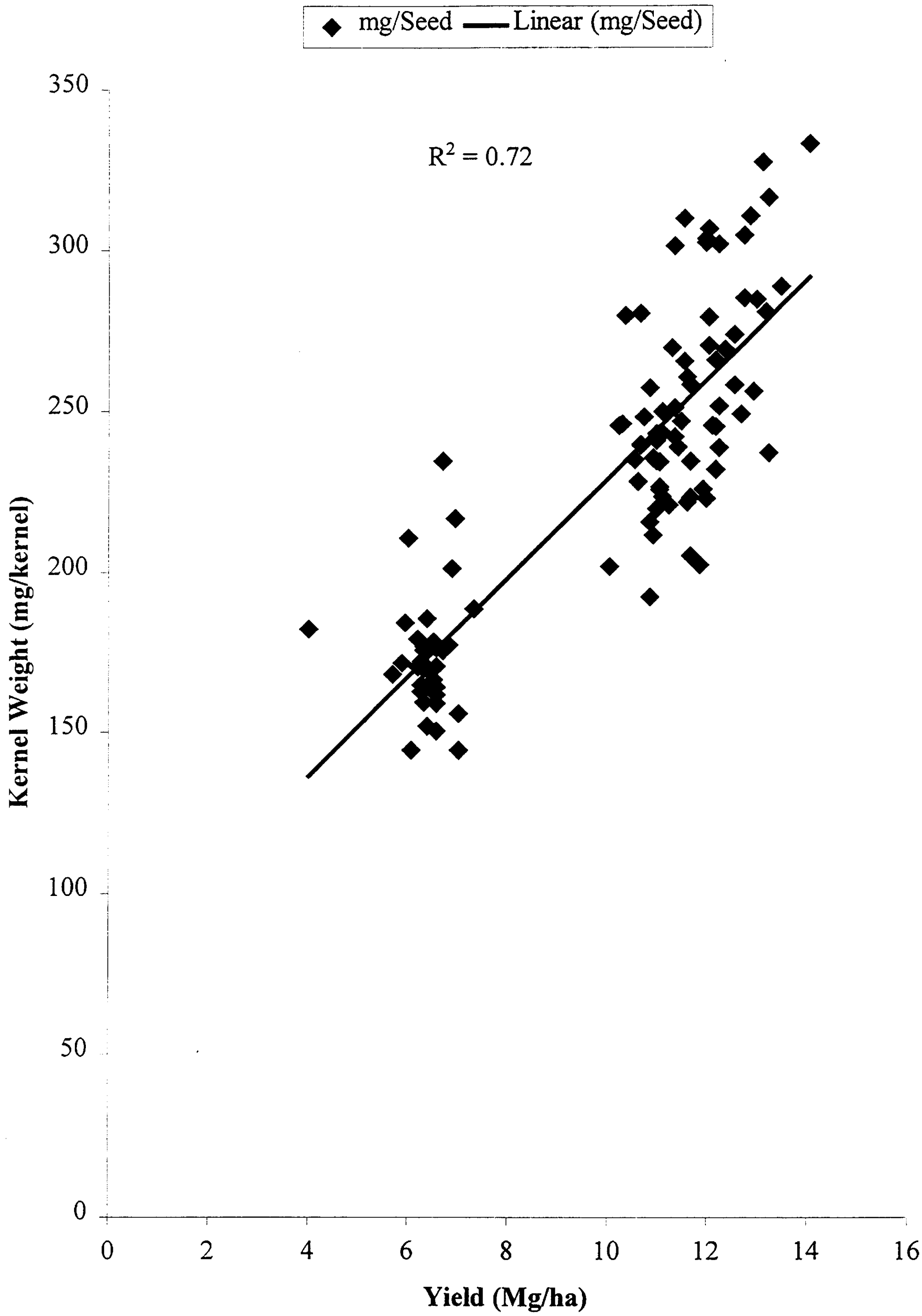


Fig. 48. Correlation between kernel weight and grain yield at Ames, IA, 1999.

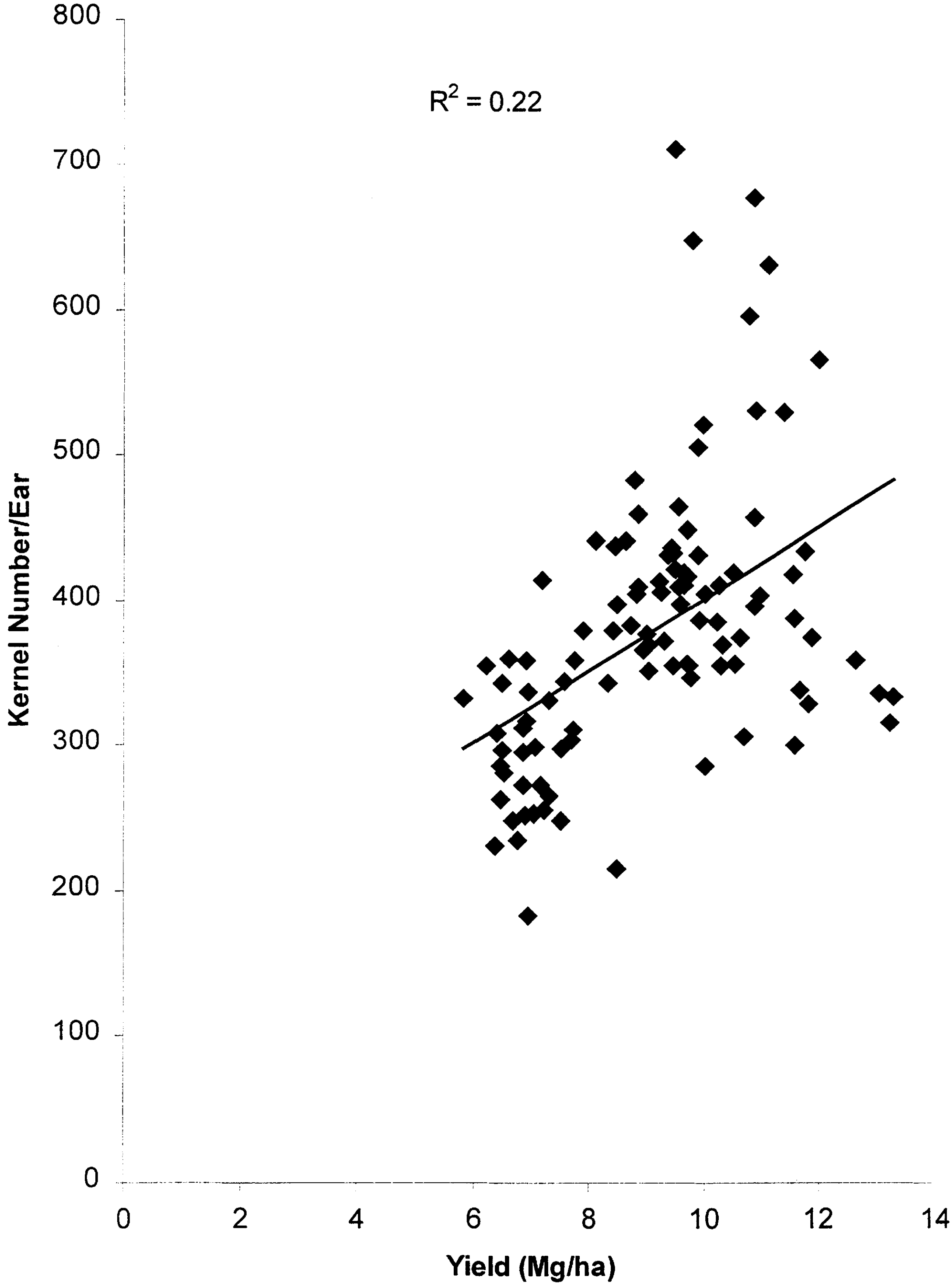


Fig. 49. Correlation between kernel number ear^{-1} and final grain yield, Ames, IA, 2000.

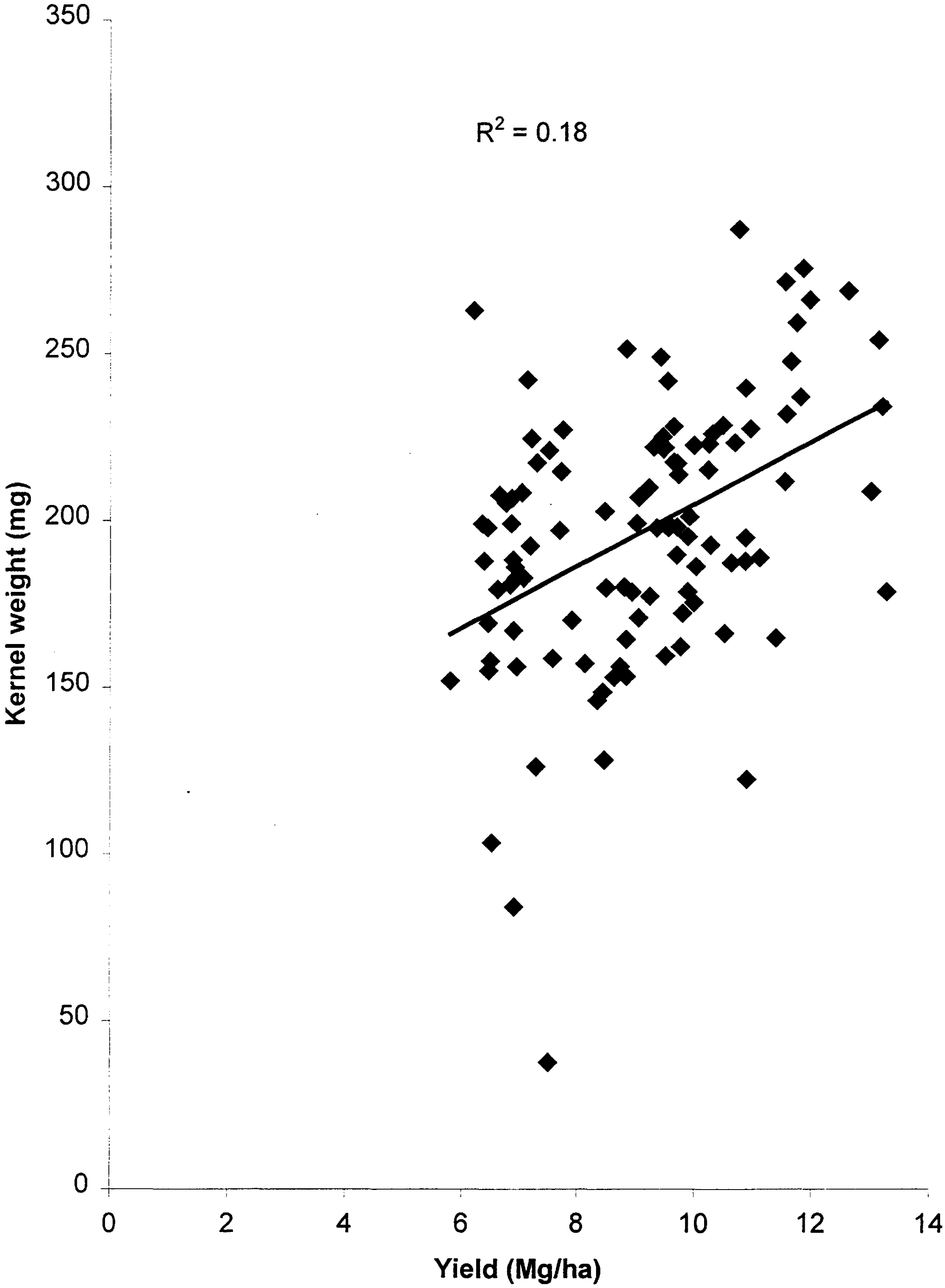


Fig. 50. Correlation between kernel weight and final grain yield, Ames, IA, 2000.

abortion (Cirilo and Andrade, 1994). Due to large differences in rainfall between the two years, kernel abortion was probably the factor causing stronger correlation between total kernels ear^{-1} and grain yield for 2000, where in 1999, rainfall was not as limiting, kernel abortion was not as apparent.

Main effect of hybrid on rows of kernels per ear, kernels per row, and total kernels per ear

Significant differences ($P < 0.05$) between hybrids for number of kernel rows ear^{-1} occurred in 1999. Hybrid 35N05 had significantly ($P < 0.05$) more kernel rows ear^{-1} than 34R07 and 33A14 (Fig. 51). Hybrid 34R07 had significantly ($P < 0.05$) more kernel rows ear^{-1} than 33A14. Kernels per row were not significantly different ($P > 0.05$) between hybrids in 1999. Significant differences ($P < 0.05$) occurred between 35N05 compared with 34R07 and 33A14 for total kernels per ear in 1999 (Fig. 52). The increased number of kernels per ear for 35N05 is not representative of its yielding capability in that it yielded less than 33A14 and 34R07 in 1999.

Significant differences ($P < 0.05$) occurred between 33A14 compared with 34R07 and 35N05 in 2000 for number of rows of kernels per ear in 2000. Hybrid 35N05 and 34R07 had significantly more rows of kernels per ear than 33A14 (Fig. 53). Significant differences ($P < 0.05$) occurred between 35N05 compared with 34R07 and 33A14 for number of kernels row^{-1} in 2000. Hybrid 35N05 had significantly more kernels row^{-1} than 34R07 and 33A14 (Fig. 54). Hybrid 34R07 and 33A14 were statistically similar ($P > 0.05$) for kernels row^{-1}. Significant differences ($P < 0.05$) occurred between 35N05 compared with 34R07 and 33A14 for total kernels ear^{-1} with 35N05 producing significantly more kernels ear^{-1} than the other hybrids in 2000 (Fig. 55). No significant differences occurred between

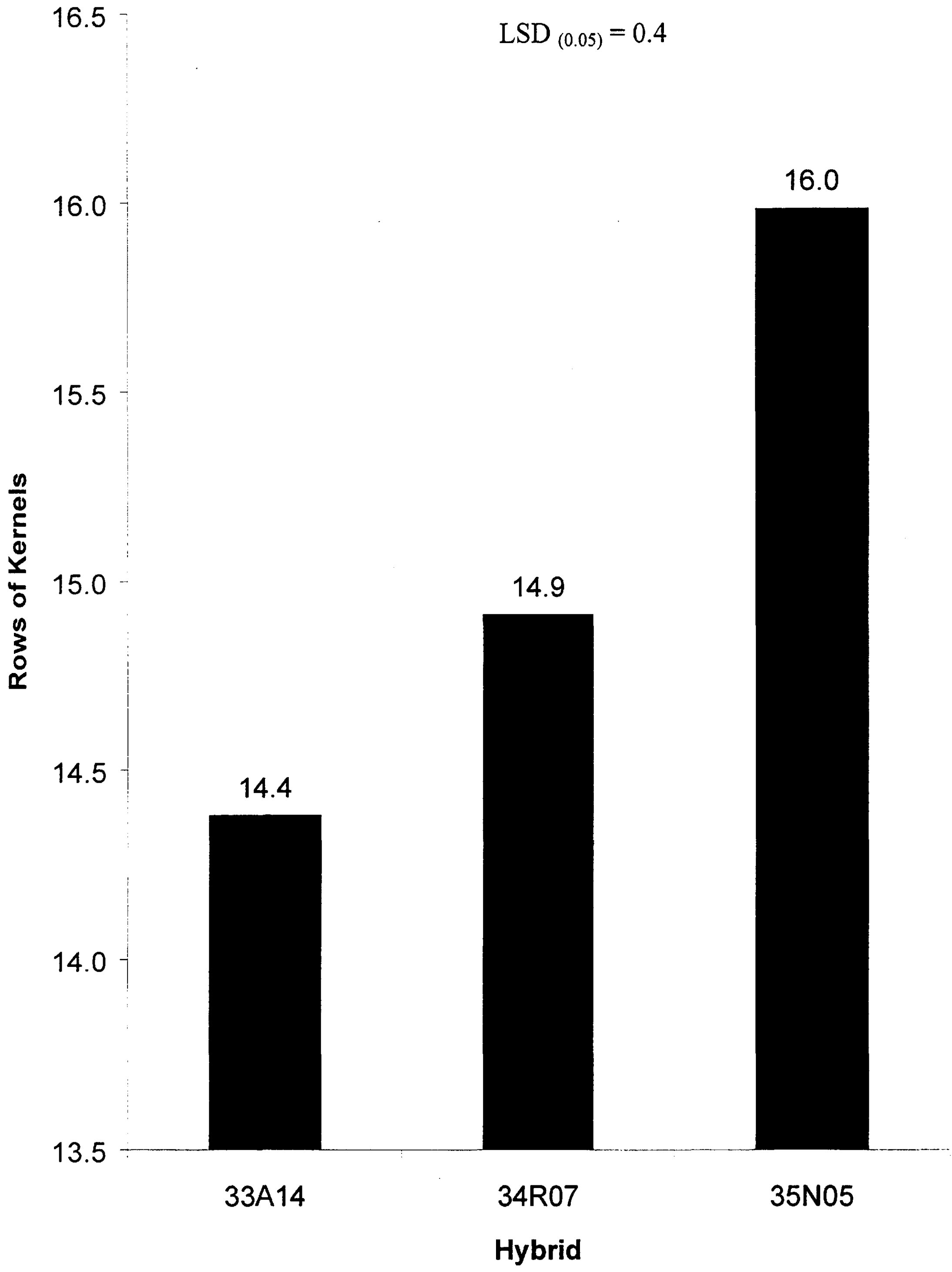


Fig. 51. Effect of hybrid on rows of kernels ear^{-1} at Ames, IA in 1999.

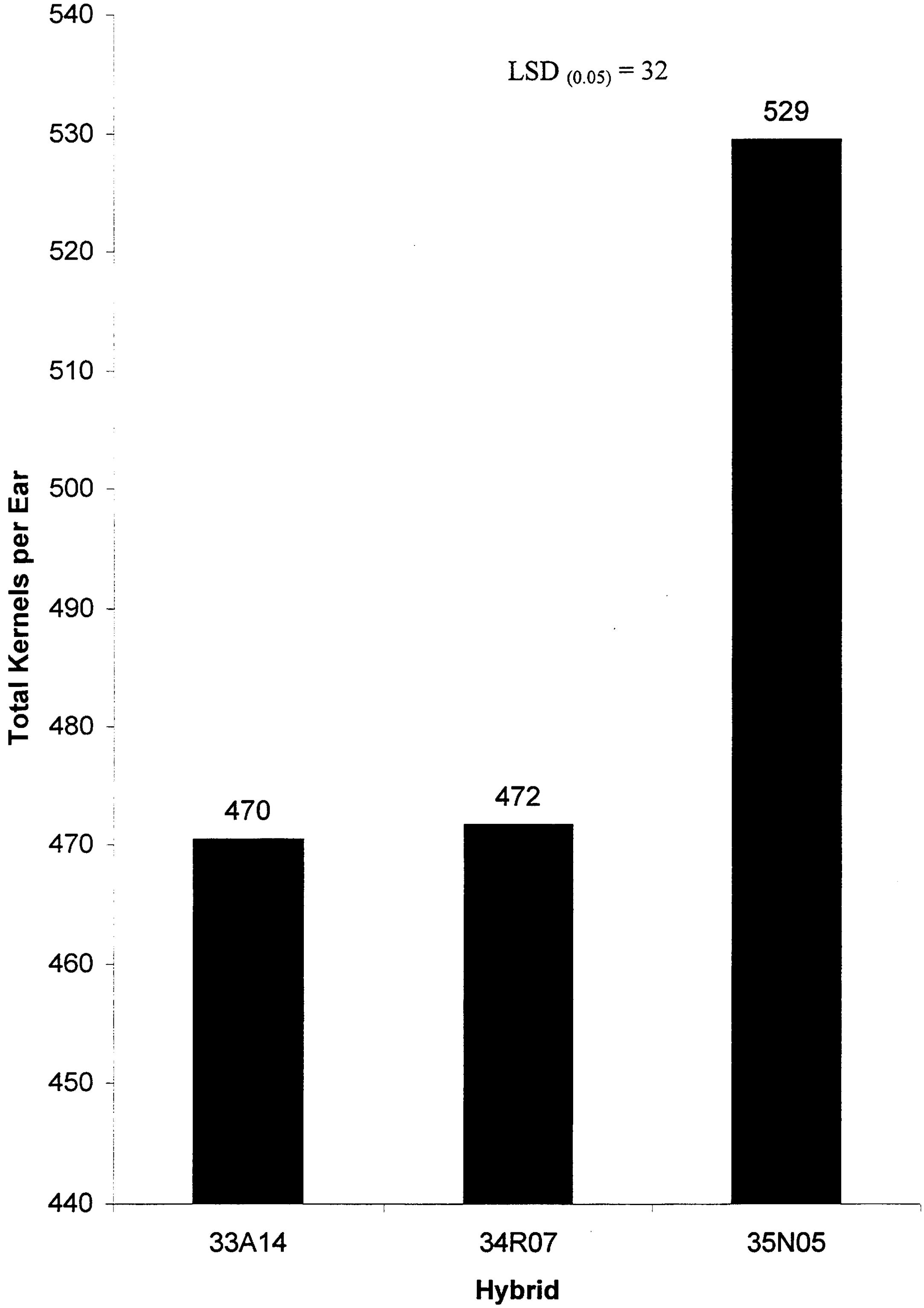


Fig. 52. Effect of hybrid on total kernels ear^{-1} at Ames, IA in 1999.

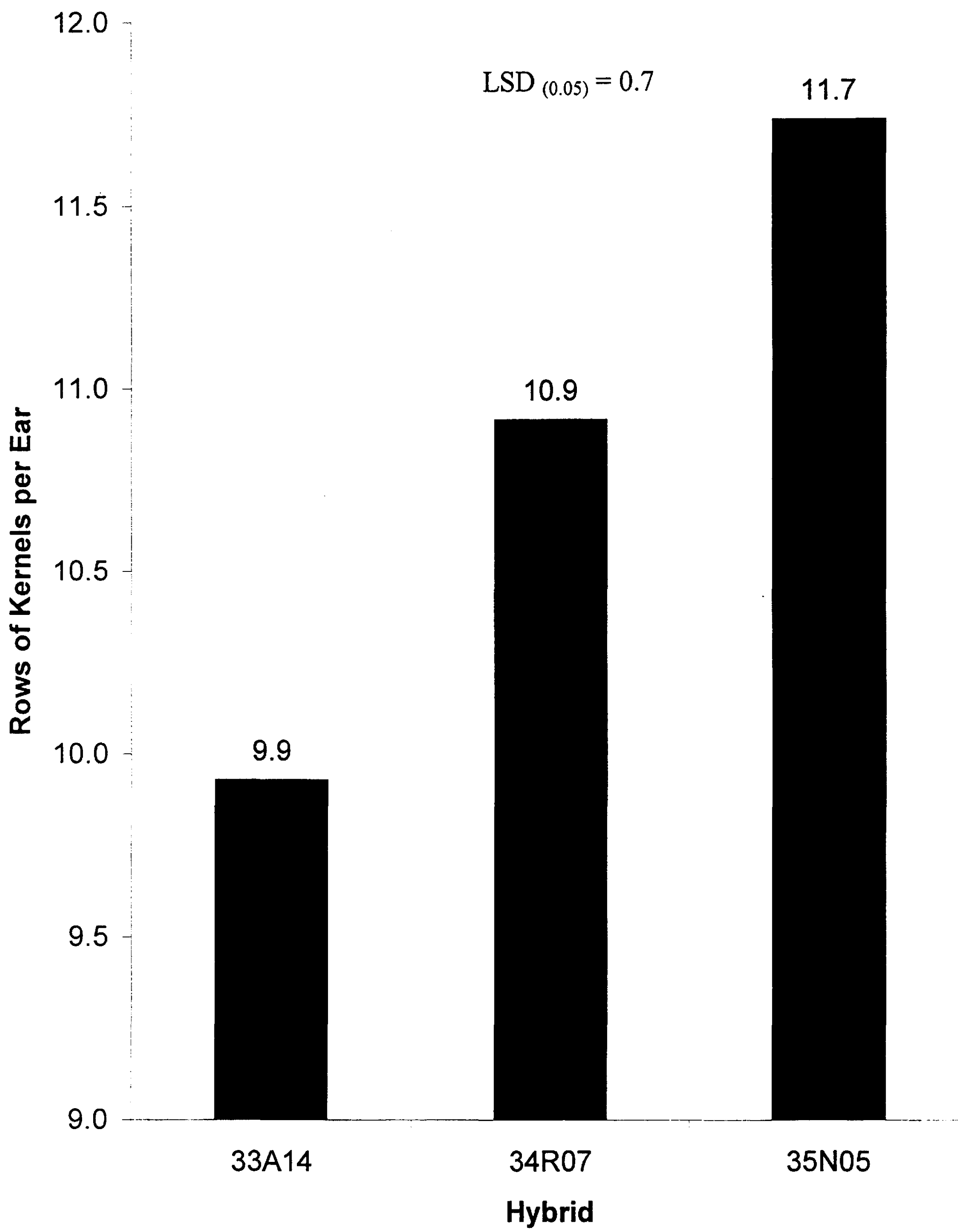


Fig. 53. Effect of hybrid on rows of kernels ear^{-1} at Ames, IA in 2000.

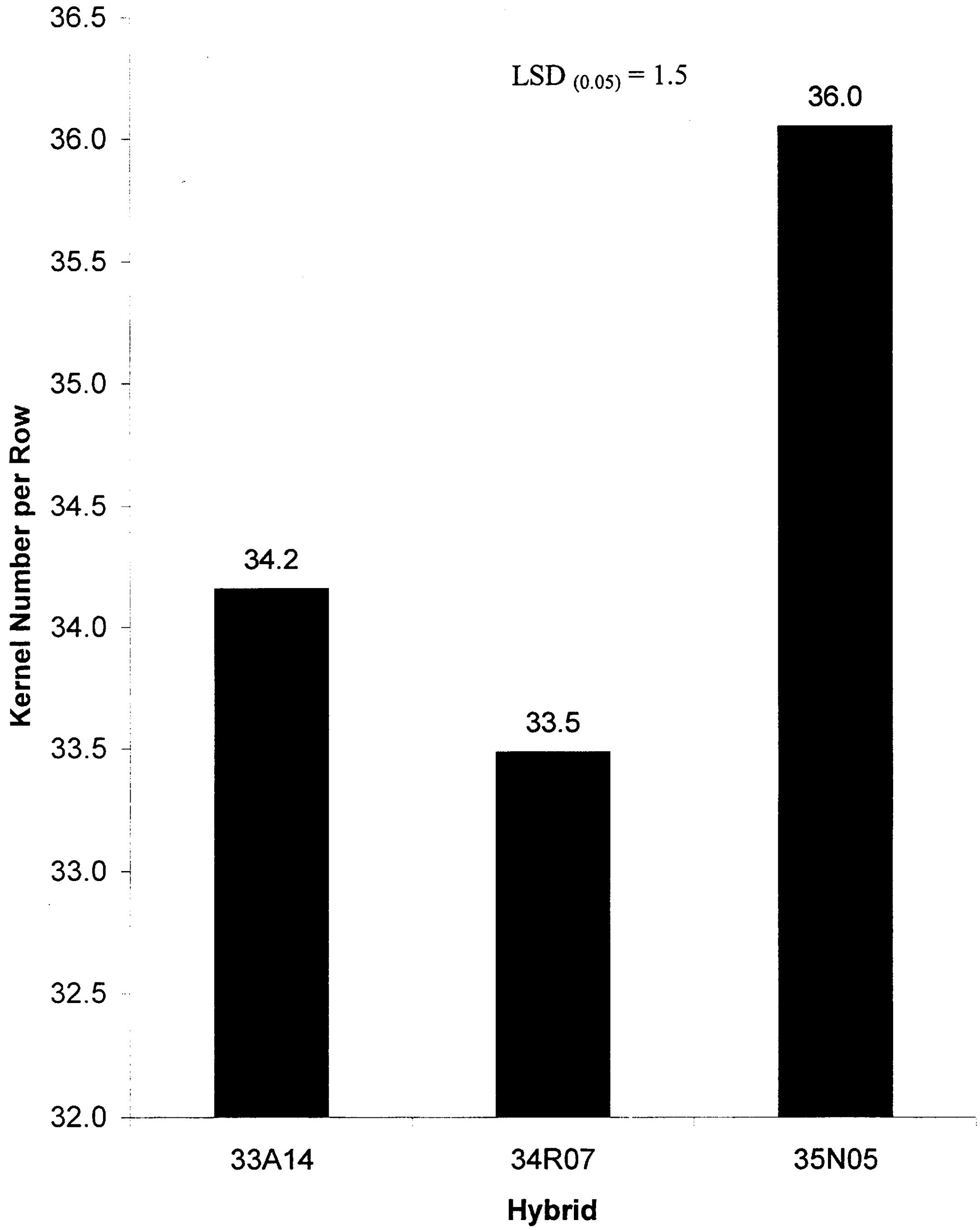


Fig. 54. Effect of hybrid on kernels row^{-1} at Ames, IA in 2000.

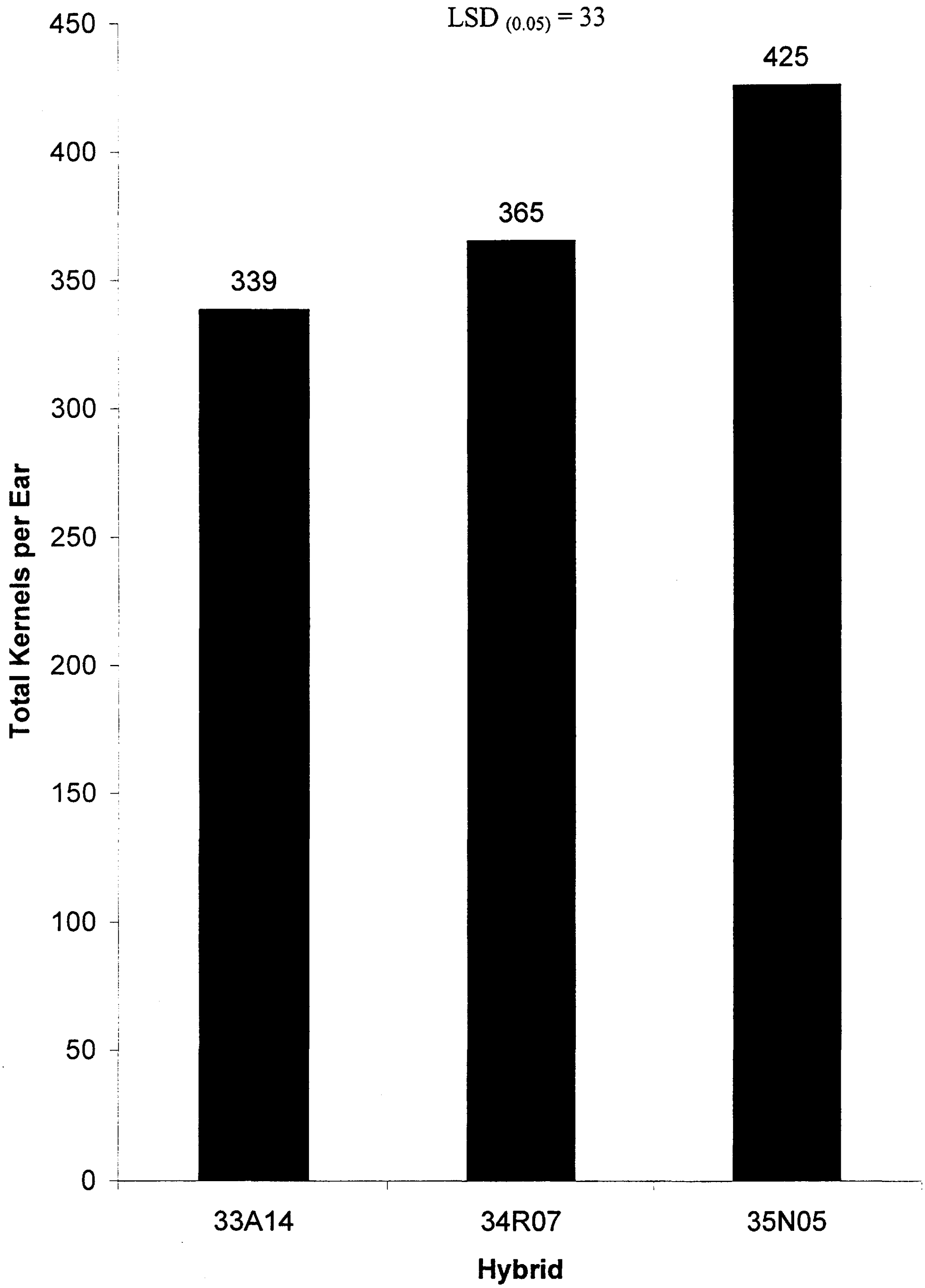


Fig. 55. Effect of hybrid on total kernels ear^{-1} at Ames, IA, 2000.

34R07 and 33A14. Hybrid 35N05 did not yield significantly more than 33A14 or 34R07 in 2000, however, 35N05 produced significantly more kernels ear^{-1}. Yield differences between these hybrids are thus more dependent on kernel weight than kernels ear^{-1} and will be addressed later.

Main effect of hybrid on weight per kernel

Significant difference ($P < 0.05$) occurred between 35N05 compared with 34R07 and 33A14 for weight per kernel in 1999. Hybrid 35N05 produced significantly ($P < 0.05$) lighter kernels than 34R07 and 33A14 (Fig. 56). No differences existed ($P > 0.05$) between 34R07 and 33A14 in 1999. Significant difference ($P < 0.05$) occurred between 33A14 compared with 34R07 and 35N05 for weight $kernel^{-1}$ in 2000. Hybrid 33A14 produced significantly higher kernel weight than 34R07 and 35N05 (Fig. 57). No difference ($P > 0.05$) occurred between 34R07 and 35N05 for kernel weight in 2000.

Differences in yield were more dependent on kernel weight than kernel number. Hybrid 35N05 produced more kernels ear^{-1} than 33A14 in 1999 and more kernels ear^{-1} than 33A14 and 34R07 in 2000 (Figs. 52 and 55). Regardless of kernel number ear^{-1}, 35N05 yielded less than the other two hybrids in each year due to lower kernel weights than the other two hybrids (Figs. 4, 56 and 57). Differences between hybrids were thus more dependent on grain weight than kernels ear^{-1} for both years.

Interactive effect of planting date and hybrid on weight per kernel

A significant ($P < 0.05$) interactive effect occurred between planting date and hybrid for weight per kernel in 1999. For the 3 May 1999 planting date, contrasts showed no significant differences ($P > 0.05$) between 33A14 and 34R07 for weight per kernel (Fig. 58).

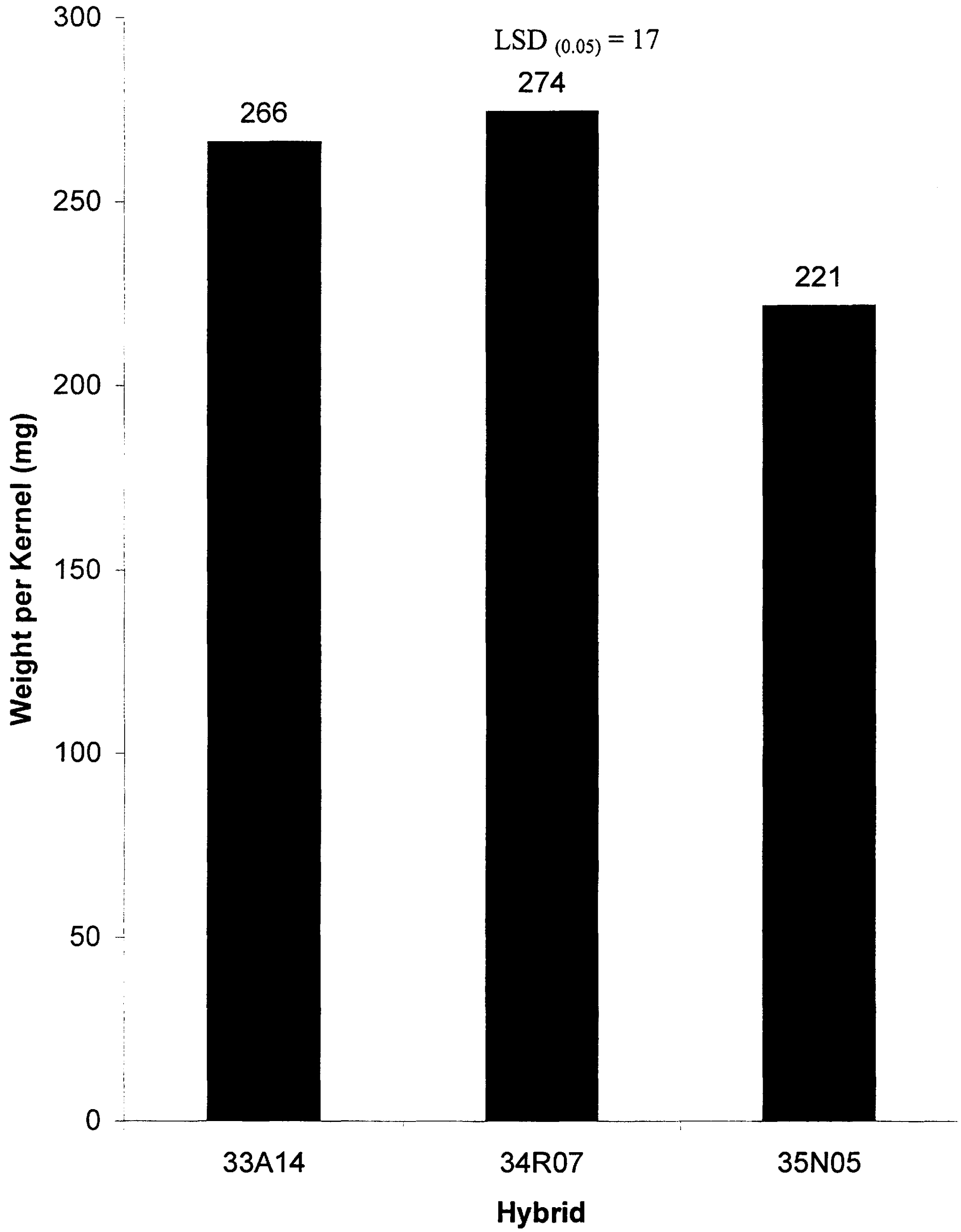


Fig. 56. Effect of hybrid on weight kernel^{-1} at Ames, IA in 1999.

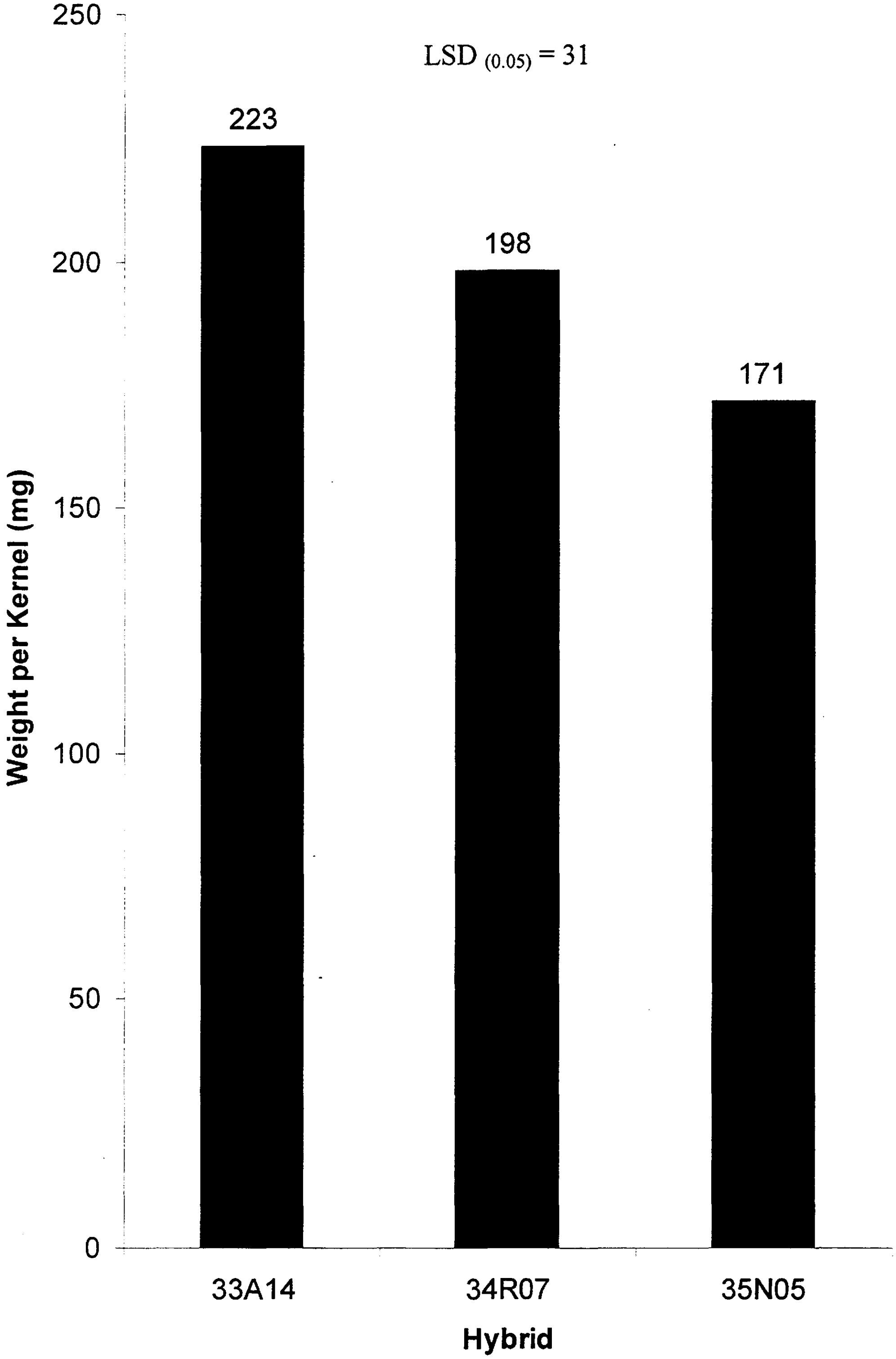


Fig. 57. Effect of hybrid on weight kernel^{-1} at Ames, IA in 2000.

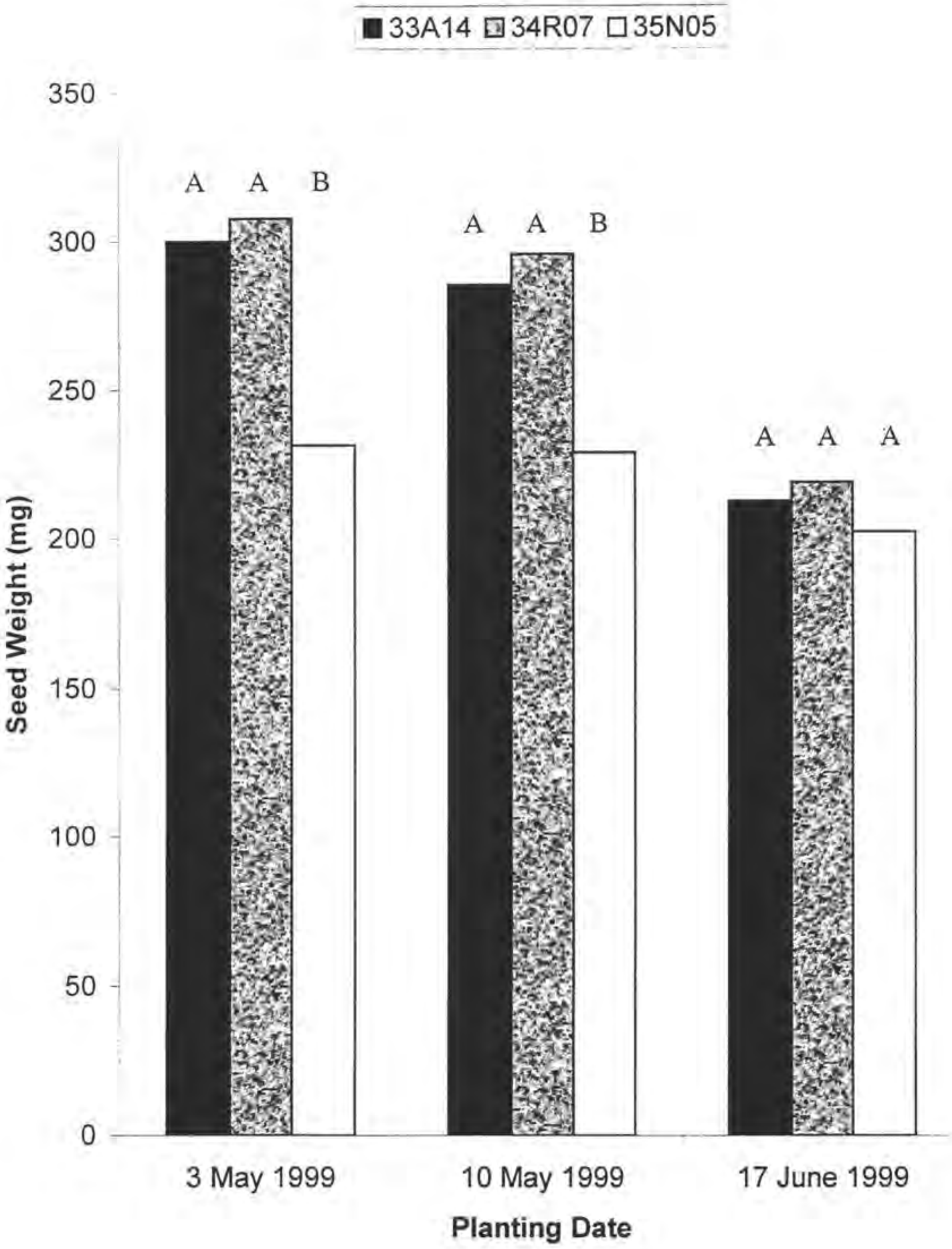


Fig. 58. Interactive effect of planting date and hybrid on weight kernel^{-1} at Ames, IA. Means within planting dates with same letter are not significantly different (P > 0.05).

Significant differences ($P < .01$) occurred for the 3 May 1999 planting date between 35N05 compared with 34R07 and 33A14. Hybrid 35N05 was significantly different ($P < 0.05$) when compared with 34R07 and 33A14 comparing weight kernel^{-1} for the 10 May 1999 planting date (Fig. 58). No differences existed ($P > 0.05$) between 33A14 and 34R07 for weight kernel^{-1} for the 10 May 1999 planting date. No differences ($P > 0.05$) between hybrids occurred for the 17 June 1999 planting date for weight kernel^{-1} demonstrating the interactive effect. Benefits in terms of yield and kernel weight favored planting 33A14 and 34R07 at the earlier planting dates (Figs. 6 and 58). No advantages existed between hybrids for the June planting date in 1999.

Significant ($P < 0.05$) interactive effects occurred in 2000 between hybrid and planting date for weight kernel^{-1}. Hybrids 34R07 and 33A14 were similar ($P > 0.05$) for the 11 April 2000 and 11 May 2000 planting dates for weight kernel^{-1} (Fig. 59). Hybrid 35N05 produced significantly ($P < 0.05$) lighter kernels compared with 34R07 and 33A14 at the 11 April 2000 and 11 May 2000 planting dates. Hybrid 33A14 produced significantly ($P < 0.05$) heavier kernel weights than 34R07 and 35N05 for the 9 June 2000 planting date. No significant differences ($P > 0.05$) for weight kernel^{-1} occurred between 34R07 and 35N05 for the 9 June 2000 planting date. Similar results were observed when comparing grain yield. Hybrid 33A14 produced heavier kernels and higher grain yield than 35N05 at each planting date (Figs. 6 and 59). Hybrid 34R07 produced statistically similar ($P > 0.05$) grain yield and kernel weight as 35N05 for the 9 June 2000 planting date.

In both years, 35N05 was relatively stable in kernel weight between planting dates while 33A14 and 34R07 showed relatively steep decreases in kernel weight as planting date was delayed. Potentially, the effective filling rate of 35N05 isn't slowed as much with delays

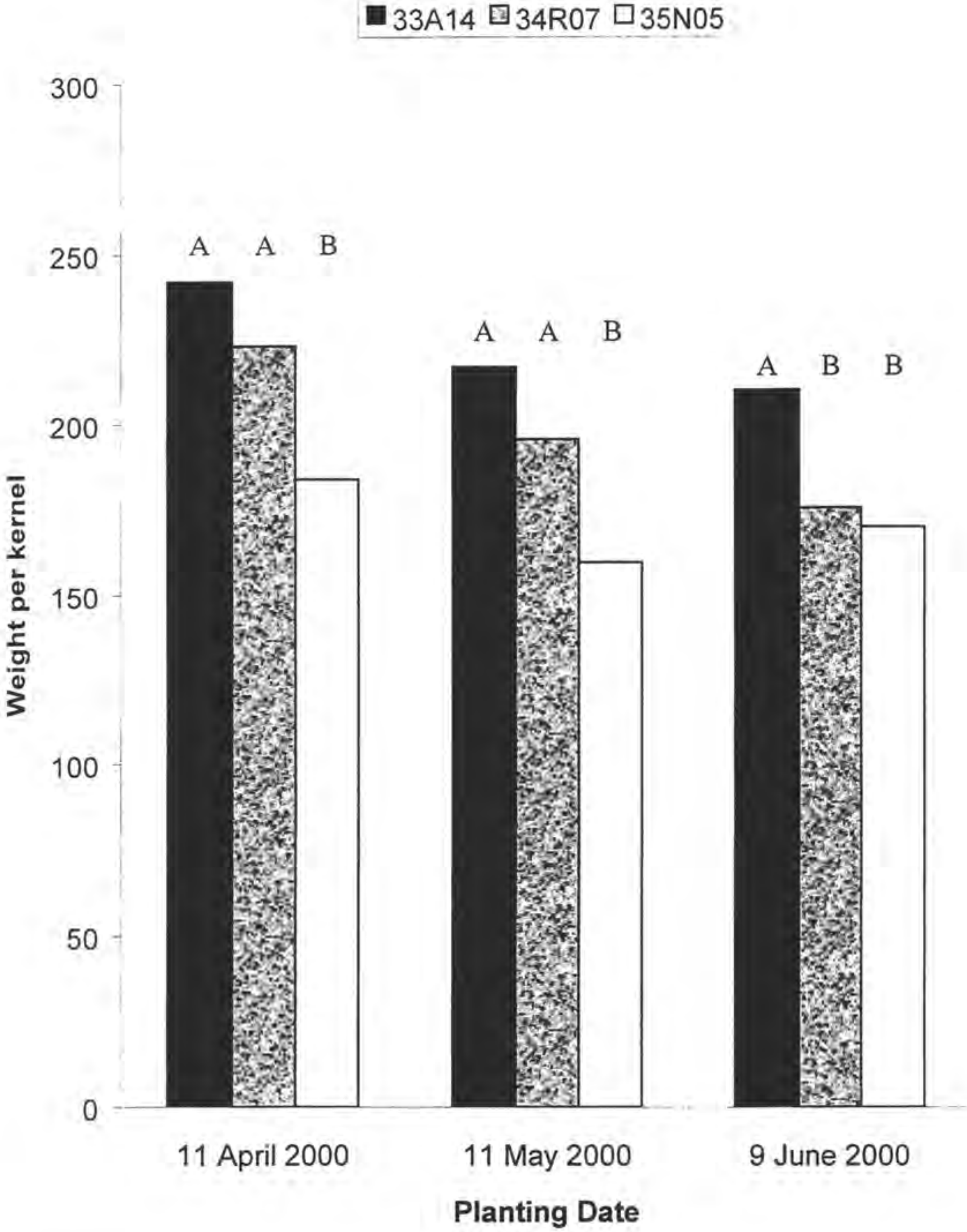


Fig. 59. Interactive effect of planting date and hybrid on weight kernel^{-1} at Ames, IA.

in planting as 34R07 and 33A14 or the kernel-filling period isn't interrupted by cool weather due to the shorter relative maturity of 35N05. Lauer et al. (1999) observed similar circumstances between maturity ranges where an increased rate of yield decline as planting date was delayed for longer season hybrids compared with shorter season hybrids in Wisconsin.

RESULTS AND DISCUSSION

KANAWHA 1999 AND 2000

Summary of season growing conditions

Weather conditions in Kanawha were similar to other areas of Iowa in 1999 with the month of April being the wettest in 127 years (Iowa Agricultural Statistics, Table 9). Rainfall limited fieldwork in early April. A small window allowed planting to begin briefly in late April. Rain continued in May allowing another planting window in late May. June and July continued with higher rainfall than normal. Beginning in August, rainfall was much lower than normal through the fall and winter months. Grain drying was more rapid than normal in the fall due to higher temperature and lower rainfall. As a result of earlier drydown, harvest was completed faster than normal.

Temperatures were higher than normal and precipitation was slightly above to slightly below average in the months from April through August in 2000. Fieldwork was completed very early in the spring due to dry field conditions. September and October were much drier than normal allowing rapid grain drying and a fast harvest. Precipitation and temperature data are summarized in Tables 9 and 10, respectively.

Table 9. Average precipitation per month at Kanawha, IA.

	Month						
Year	Apr	May	Jun	Jul	Aug	Sep	Oct
1999	193 mm	124 mm	132 mm	124 mm	30 mm	25 mm	25 mm
2000	68	105	113	107	92	45	51
Historical Average:	74	93	116	106	94	92	56

Table 10. Average Temperature at Kanawha, IA.

	Month						
	Apr	May	Jun	Jul	Aug	Sep	Oct
1999 Ave. Low:	10 °C	10 °C	15 °C	19 °C	15 °C	7 °C	2 °C
1999 Ave. High:	14	21	26	30	26	23	17
2000 Ave. Low:	2	10	13	16	16	9	3
2000 Ave. High:	16	24	26	27	27	25	16
Historical Average Low:	2	9	14	16	15	10	4
Historical Average High:	9	16	21	23	21	17	10

Year effect and planting date effect on corn grain yield

Average yield between years was significantly different ($P < 0.01$). Yields in 2000 were 8% lower than in 1999 (Fig. 60). Individual grain yield treatment means are summarized in Table 11.

Significant differences ($P < 0.01$) occurred for yield between planting dates in 1999 and 2000. Means for all treatments from each planting date in 1999 and 2000 are summarized Fig. 61. In 1999, means over all treatments for the 21 April planting date (Date 1) were 9.5% higher than means over all treatments for the 25 May 1999 planting date (Date 2) and 47% greater than means over all treatments for the 14 June planting date (Date 3). The means over all treatments for the 25 May planting date were 42% greater than the means over all treatments for the 14 June planting date. In 2000, means over all treatments for the 15 April planting date (Date 1) were 11% greater than means over all treatments for the 15 May planting date (Date 2) and 34% greater than means over all treatments for the 8 June planting date (Date 3).

Results from the Kanawha site were similar to results observed in other planting date studies (Lauer, 1997; Mulder and Doll, 1994, Nafziger, 1994, Swanson and Wilhelm, 1996).

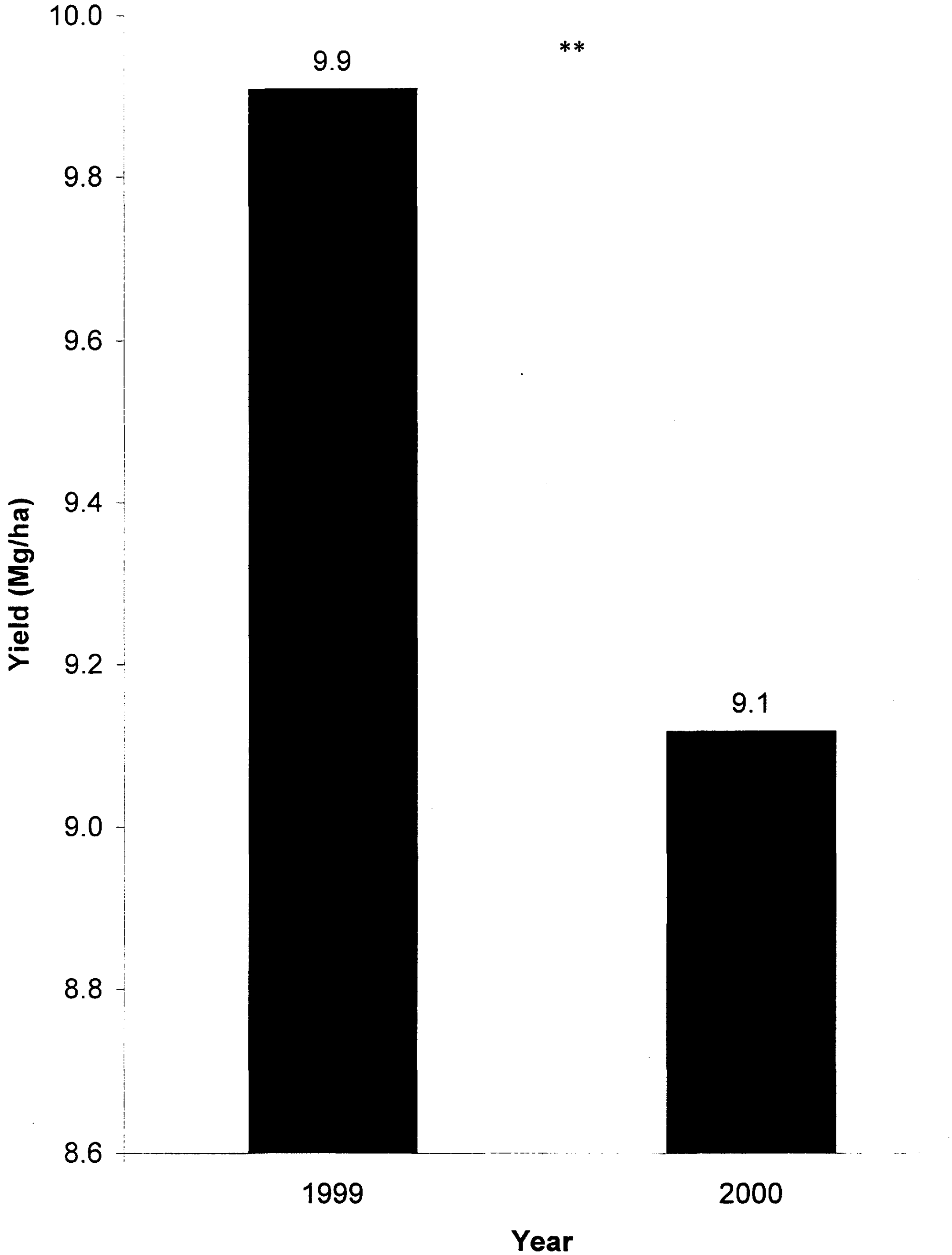


Fig. 60. Corn grain yield at Kanawha, IA, 1999-2000.

** = significant main effect (P < 0.01).

Table 11. Individual corn grain yield treatment means in Mg ha^{-1} at Kanawha, IA

Date 1			Year		Date 2			Year		Date 3			Year	
Row Spacing	Fertilizer	Hybrid	1999	2000	Row Spacing	Fertilizer	Hybrid	1999	2000	Row Spacing	Fertilizer	Hybrid	1999	2000
38-cm	0	33A14	12.1	11.1	38-cm	0	33A14	11.4	10.5	38-cm	0	33A14	6.6	7.2
		34R07	11.7	9.5			34R07	10.9	10.2			34R07	6.5	7.1
		35N05	11.5	10.0			35N05	10.5	8.7			35N05	6.9	6.2
76-cm	0	33A14	11.7	11.7	76-cm	0	33A14	11.6	10.1	76-cm	0	33A14	5.2	7.6
		34R07	12.9	10.9			34R07	11.3	9.9			34R07	6.3	7.2
		35N05	12.0	9.8			35N05	10.9	8.3			35N05	6.2	6.2
38-cm	NPK	33A14	12.4	11.6	38-cm	NPK	33A14	10.9	9.9	38-cm	NPK	33A14	6.9	8.0
		34R07	12.8	10.5			34R07	11.4	10.3			34R07	6.2	6.6
		35N05	12.3	10.4			35N05	10.8	8.5			35N05	6.5	6.2
76-cm	NPK	33A14	12.5	12.2	76-cm	NPK	33A14	11.4	9.7	76-cm	NPK	33A14	6.7	7.8
		34R07	12.7	11.1			34R07	11.0	10.1			34R07	6.3	7.5
		35N05	12.4	10.3			35N05	10.7	8.4			35N05	6.4	6.9

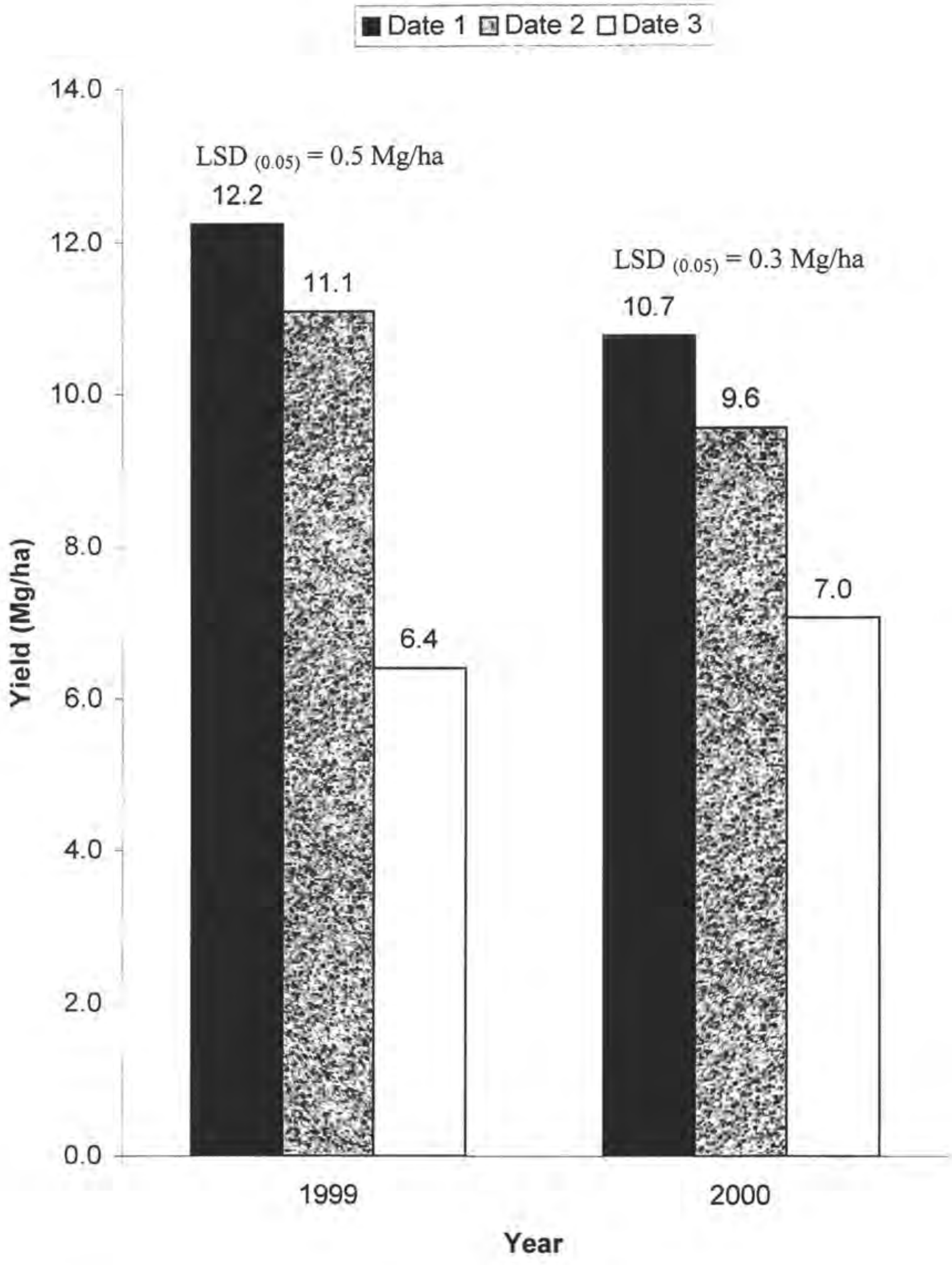


Fig. 61. Effect of planting date on corn grain yield at Kanawha, IA.

Differences between mid-late April planting dates compared with mid-late May planting dates suggested higher losses in grain potential than recent studies by Farnham (2000, unpublished). Yield losses associated with planting delays from May to June were also higher than recent studies in Iowa have indicated (Farnham, unpublished).

Main effect of hybrid on corn yield

No differences ($P > 0.05$) occurred among hybrids when comparing means across all treatments in 1999. Significant differences ($P < 0.01$) occurred among hybrids when comparing means across all treatments in 2000. Means of hybrids' effect on corn yield are summarized in Fig. 62. In 2000, no significant differences ($P > 0.05$) occurred between 33A14 and 34R07. Significant differences ($P < 0.01$) occurred between 35N05 compared with 33A14 and 34R07. Hybrid 35N05 yielded 10 and 15% less than 34R07 and 33A14, respectively.

Main effects of row spacing on corn yield

No differences ($P > 0.05$) existed between row spacing comparing means of each row spacing over all treatments in 1999 and 2000. Means for row spacing are summarized in Fig. 63. The results of this location is similar to what was observed at the Ames location and also agrees with Benson (1995) and Farnham (2001) who have not found a significant or consistent yield advantage from planting corn in narrow row spacings less than 76-cm in Iowa. Others have also found insignificant or inconsistent yield increases from narrowing row spacing in corn (Johnson et al, 1998; Westgate et al., 1997; Dysinger and Kells, 1997; Alessi and Power, 1974; Ottman and Welch, 1989; Rzewnicki, 1997; Lutz et al., 1970; Blitzer and Herbeck, 1997).

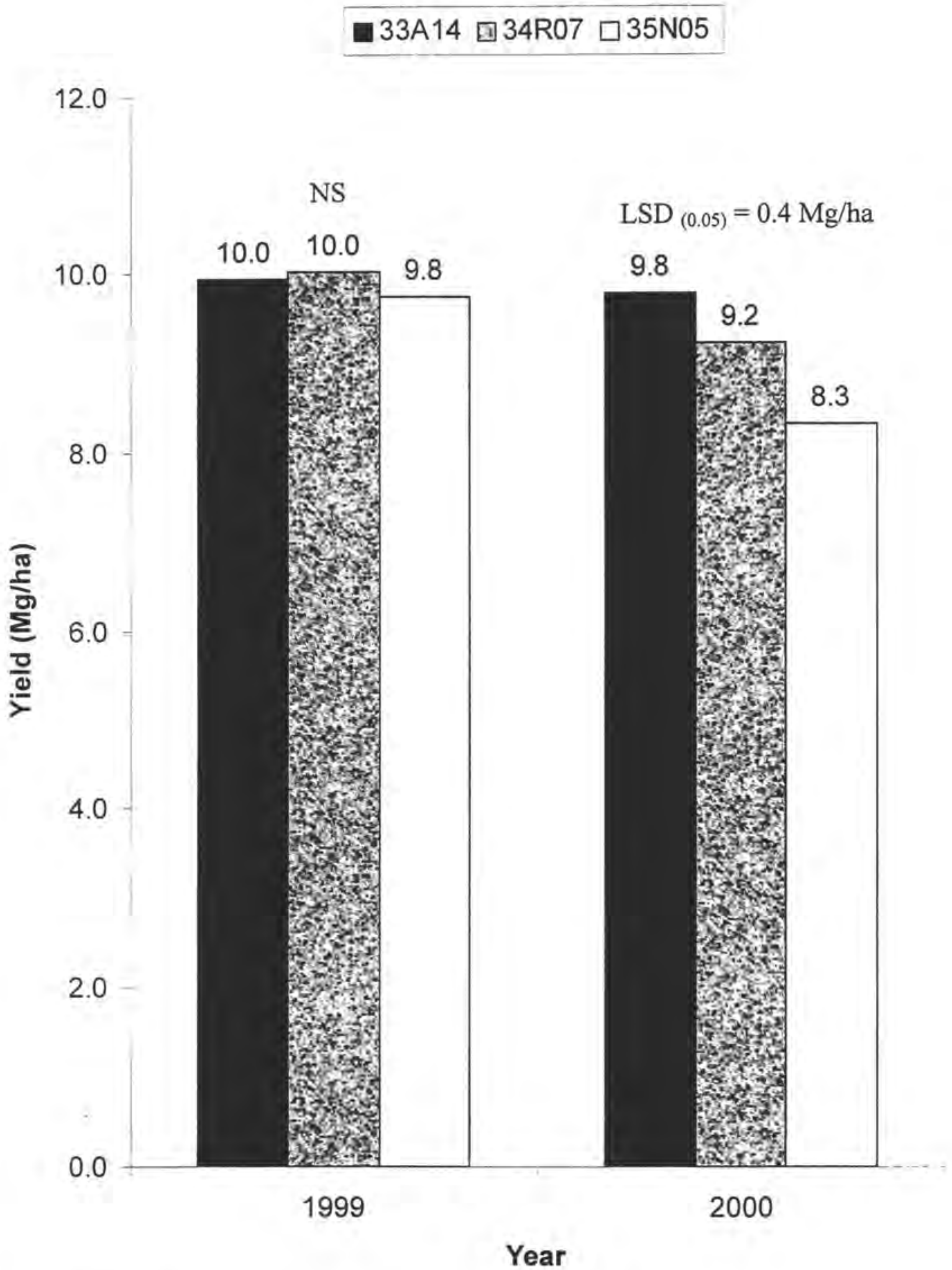


Fig. 62. Effect of hybrid on corn grain yield at Kanawha, IA.

NS= no significant main effect ($P > 0.05$).

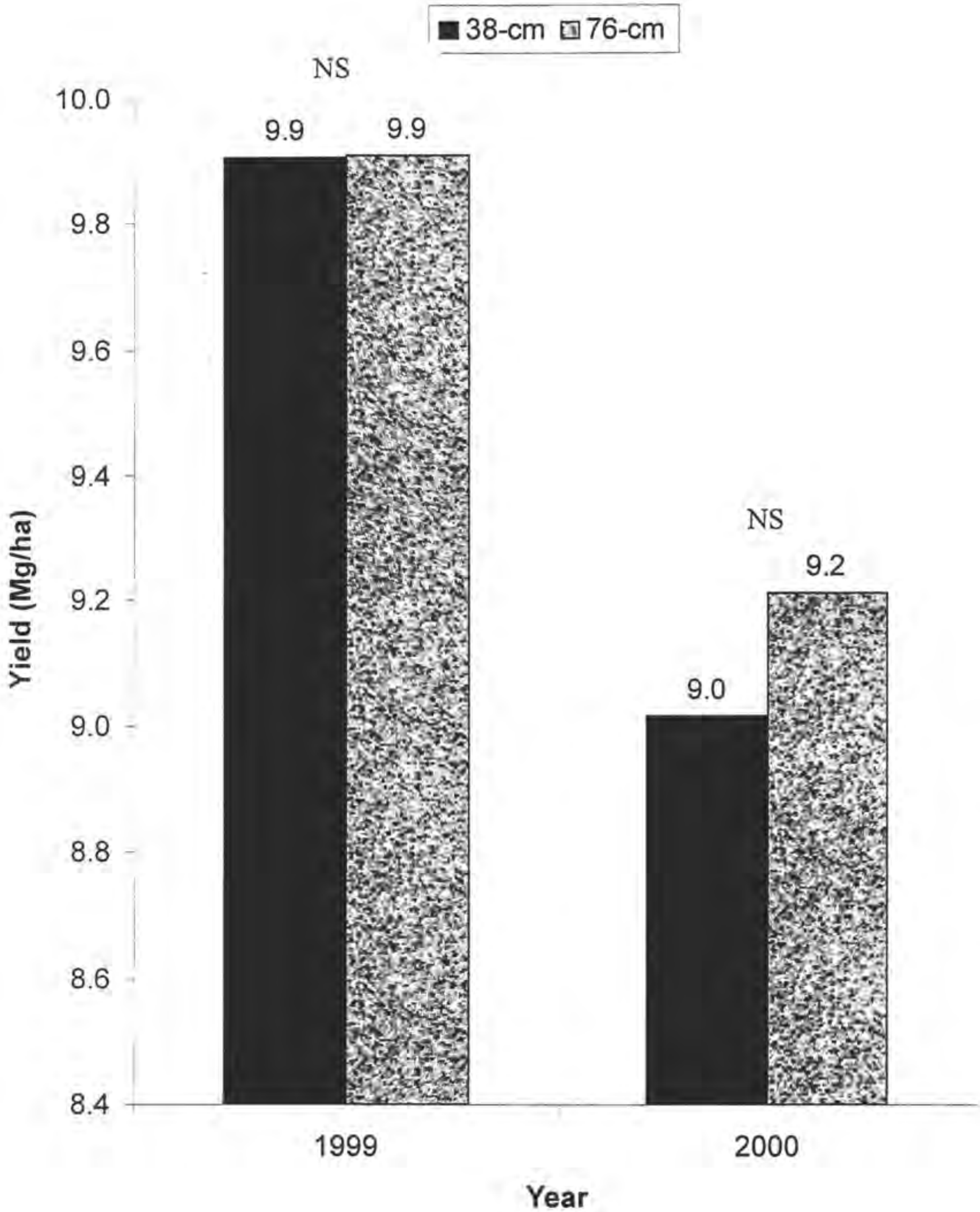


Fig. 63. Effect of row spacing on corn grain yield at Kanawha, IA.

NS = no significant main effect (P > 0.05).

Main effect of starter fertilizer on corn yield

Significant differences ($P < 0.05$) occurred between fertility regimes in 1999. Yields for starter fertilizer treated plots were significantly higher than plots with no starter fertilizer (Fig. 64). No differences ($P > 0.05$) occurred between fertility regimes in 2000.

Soil phosphorus levels in both years were in the high to very high levels (Table 1). Current Iowa State recommendations suggest that a response to additional starter fertilizer was not likely to result in a yield increase (Voss et al., 1999). Due to a response in 1999 but no response in 2000, differences in starter fertilizer response were likely due to weather differences between years. Weather during the spring of 1999 was much cooler and wetter than 2000, a much warmer and drier spring. Several authors have suggested use of starter fertilizer under conditions that result in cool and wet soils at planting (Brouder, 1996; Rehm et al., 2000; Buah et al., 1999). Possibly, the close proximity of starter fertilizer when planting in cool or wet soils improves the emerging seedlings' ability to capture nutrient resources sooner, lessening potential stress early in development.

Interactive effects of planting date and hybrid on corn grain yield

Significant interactive effects ($P < 0.05$) occurred between planting date and hybrid in 1999 and 2000 for corn grain yield (Fig. 65). In 1999, no differences ($P > 0.05$) in yield occurred between hybrids for the 21 April planting date. Significant differences ($P < 0.05$) in yield occurred between 35N05 when compared with 33A14 for the 25 May 1999 planting date (Date 2). Yield for 34R07 was similar ($P > 0.05$) when compared with 35N05 and 33A14 for the 25 May 1999 planting date. No difference ($P > 0.05$) occurred between hybrids

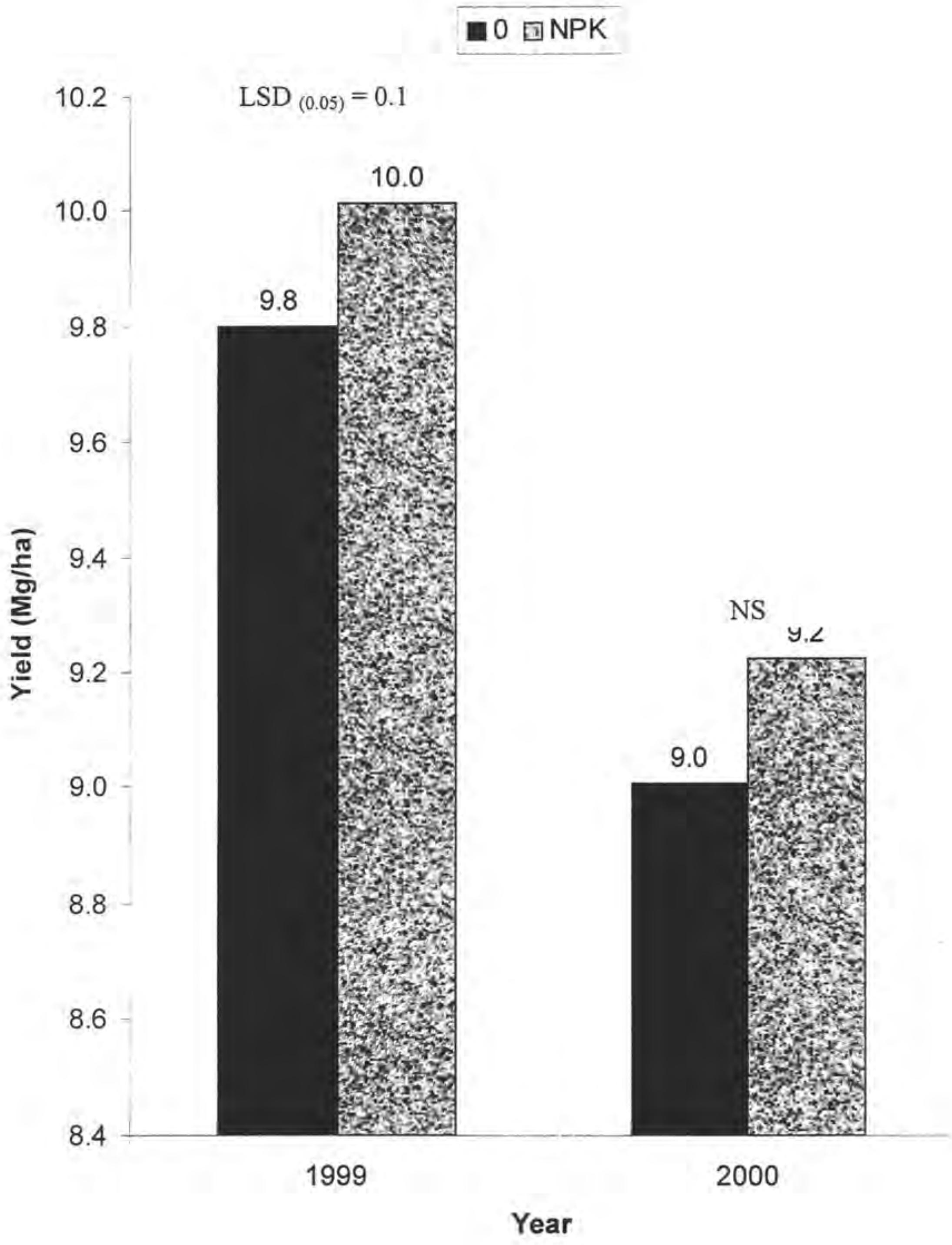


Fig. 64. Effect of starter fertilizer on corn grain yield at Kanawha, IA.

NS = no significant main effect (P > 0.05).

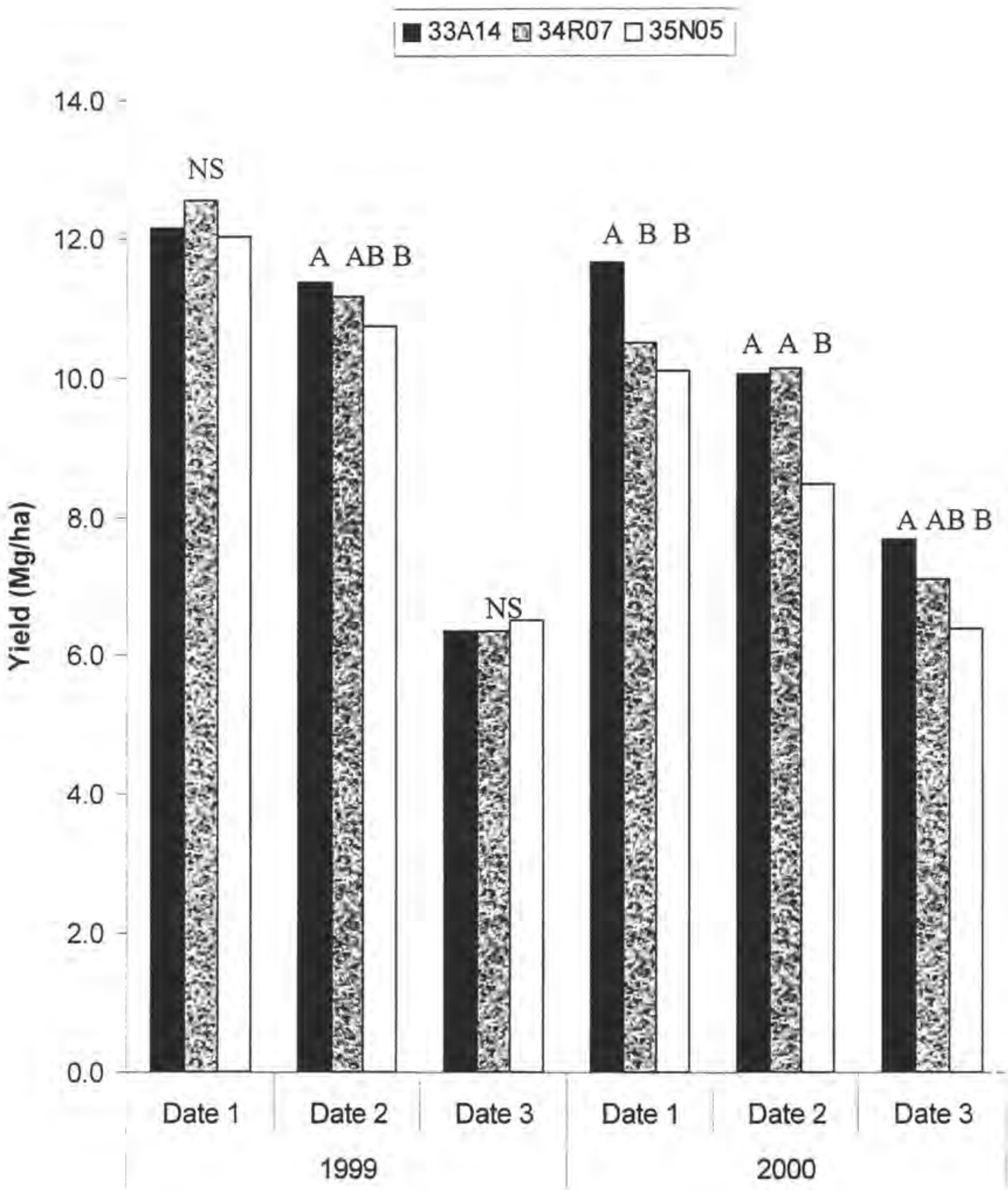


Fig. 65. Interactive effect of planting date and hybrid on corn grain yield at Kanawha, IA.

NS = no significant difference between hyrids within planting date and year.

Means within planting date and year with the same letter are not significantly different.

for the 14 June 1999 (Date 3) planting date for yield. In 2000, significant differences ($P < 0.05$) existed for yield between 33A14 compared with 34R07 and 35N05 for the 15 April planting date (Date 1). No differences in yield ($P > 0.05$) occurred between 34R07 and 35N05 for the 15 April 2000 planting date. Significant difference ($P < 0.05$) for yield occurred between 35N05 compared with 33A14 and 34R07 for the 15 May 2000 planting date (Date 1). No significant difference ($P > 0.05$) occurred between 33A14 and 34R07 for the 15 May 2000 planting date. Significant difference ($P < 0.01$) occurred between 33A14 and 35N05 for the 8 June 2000 planting date (Date 3). No difference ($P > 0.05$) occurred between 34R07 compared with 33A14 and 35N05 for the 8 June 2000 planting date.

Interactive effects of planting date and row spacing on corn yield

Significant interactive effects ($P < 0.05$) between planting date and row spacing on corn yield occurred in 1999 and in 2000 ($P < 0.05$). Significant difference did not occur ($P > 0.05$) between row spacings for the 21 April (Date 1) and 25 May 1999 (Date 2) planting dates for yield (Fig. 66). Significant difference ($P < 0.05$) between row spacing did occur for the 14 June 1999 planting date for yield with 38-cm row spacing yielding 6% more than 76-cm row spacing. In 2000, 76-cm row spacing was significantly different than 38-cm row spacing for the 15 April (Date 1) planting date.

As planting date is delayed, development is hastened in response to increased temperatures and a longer photoperiod (Yan and Wallace, 1998; Birch et al., 1998; Ellis et al., 1992; Bonhomme et al., 1994; Ellis et al., 1992). Hastened development due to delayed planting decreases resource capture, which results in decreased yields (Otegui et al., 1995).

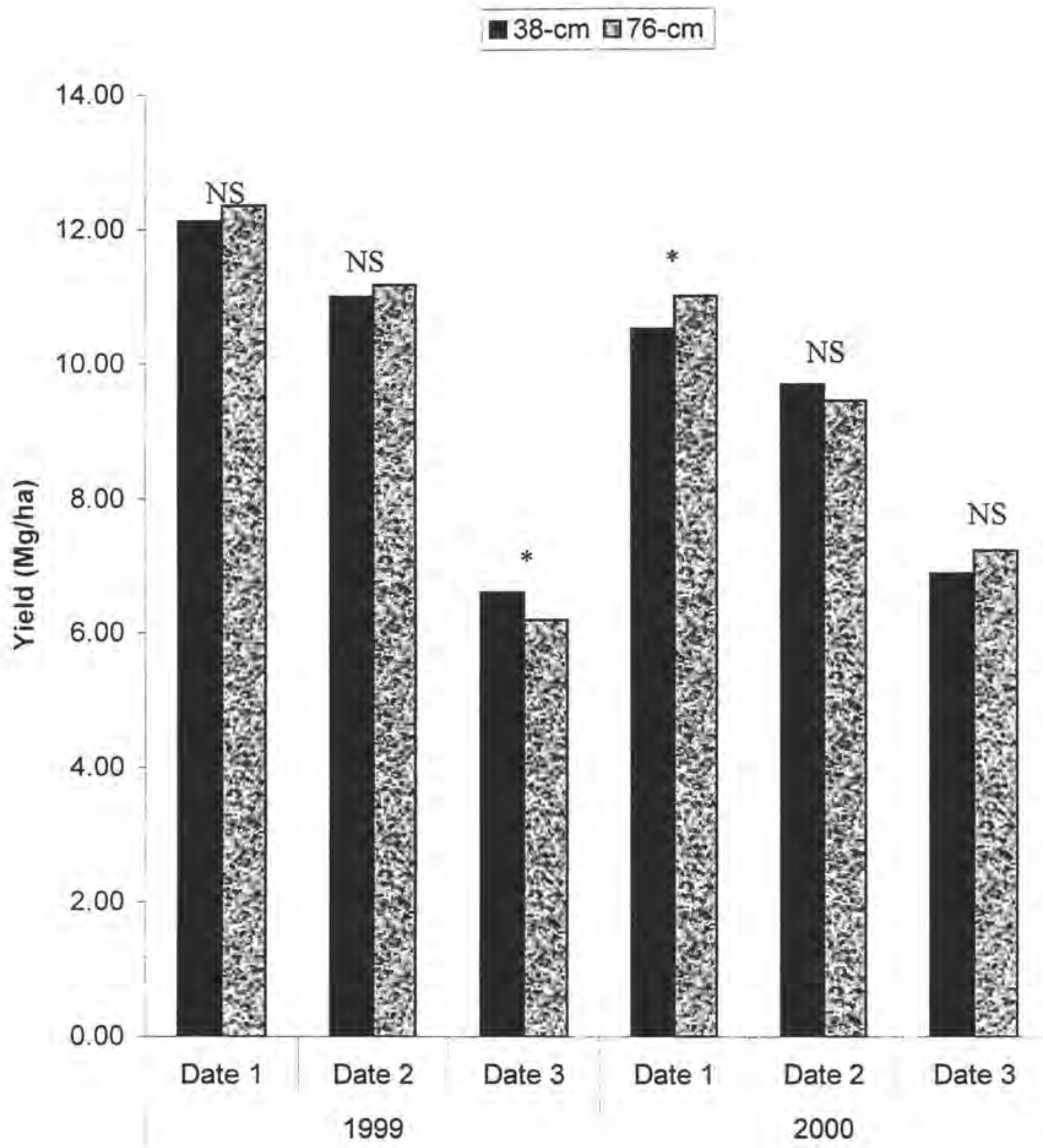


Fig. 66. Interactive effect of planting date and row spacing on corn grain yield at Kanawha, IA.

NS = no significant main effect within planting date and year.

* = significant main effect within planting date and year (P < 0.05).

Some studies have shown increased response to narrow row spacing under conditions that are limiting. Roth et al. (1999) showed increased silage yield due to narrow row spacing as planting date was delayed in Pennsylvania and Barbieri et al. (2000) showed increased response to narrow row spacing under nitrogen stress. Results from 1999, at both Ames and Kanawha, suggest that in some cases, narrow row spacing may significantly improve yield when planting dates are delayed until mid-June. Possibly, canopy development is enhanced for 38-cm rows compared with 76-cm rows improving resource capture enough to improve final grain yield for the late planting dates.

Main effect of planting date, hybrid, row spacing and starter fertilizer on grain moisture

Significant difference ($P < 0.01$) occurred between planting dates for grain moisture in 1999 and 2000 (Fig. 67). In both years, as planting date was delayed, grain moisture at harvest was greater.

Significant difference ($P < 0.01$) occurred between hybrids for grain moisture in 1999 and 2000. In 1999, grain for 33A14 was significantly wetter ($P < 0.05$) than 34R07 and 35N05 and 34R07 was significantly wetter than 35N05 (Fig. 68). In 2000, grain moisture for 33A14 was similar ($P > 0.05$) to 34R07. Hybrids 33A14 and 34R07 were significantly ($P < 0.05$) wetter than 35N05 in 2000. Row spacing and starter fertilizer did not have effects on grain moisture at Kanawha, which is different from what was observed at Ames.

Interactive effect of planting date and hybrid on grain moisture

Significant interactive effects occurred between planting date and hybrid on grain moisture in 1999 and 2000 (Fig. 69). In 1999, moisture for 34R07 was significantly greater than 33A14 and 35N05 ($P < 0.05$ and $P < 0.01$, respectively) for the 21 April planting date

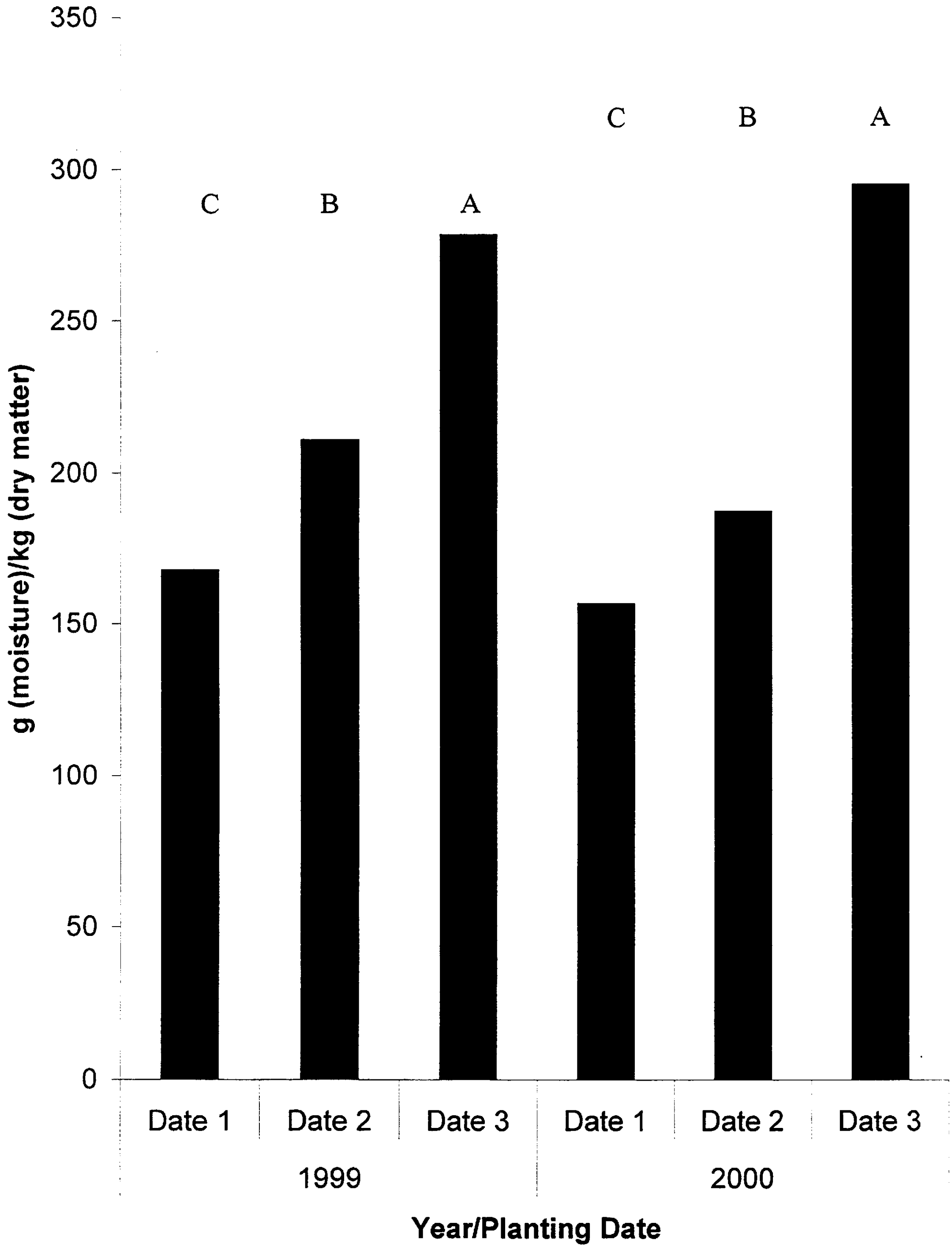


Fig. 67. Main effect of planting date on grain moisture at Kanawha, IA.

Means within years with the same letter are not significantly different ($P > 0.05$).

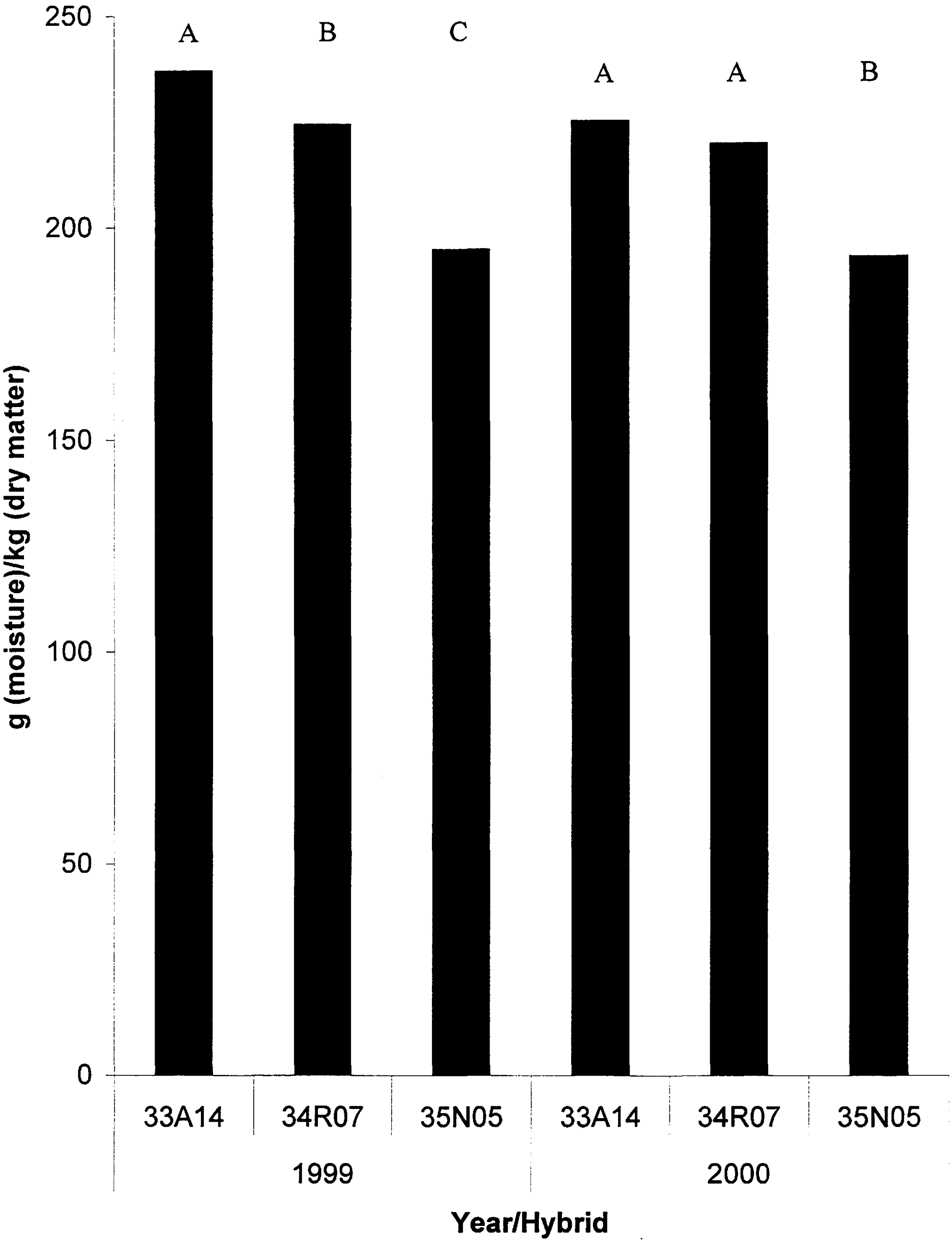


Fig. 68. Main effect of hybrid on grain moisture at Kanawha, IA.

Means within year with the same letters are not significantly different (P > 0.05).

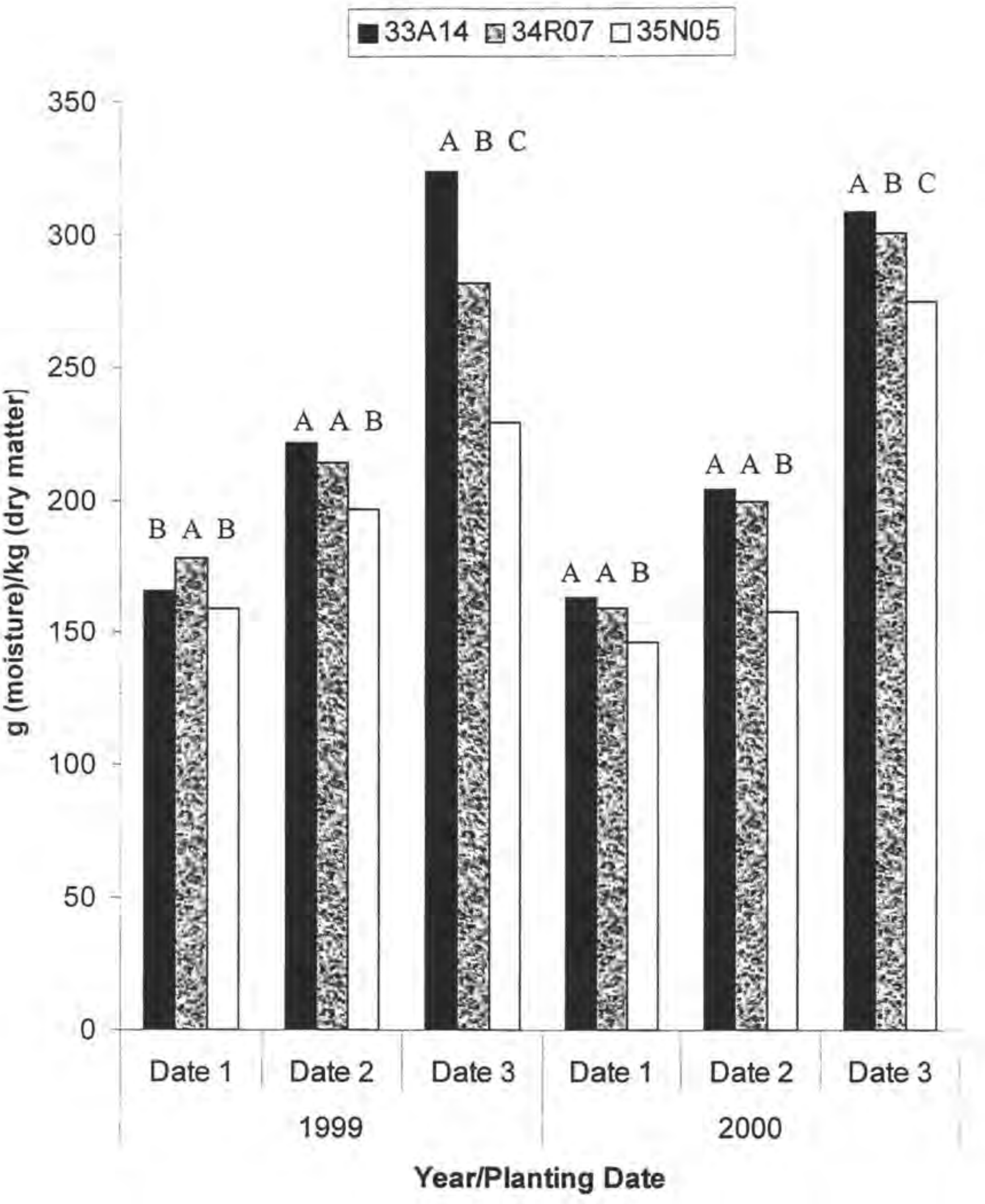


Fig. 69. Interactive effect of planting date and hybrid on grain moisture at Kanawha, IA.

Means within year and planting date with the same letter are not significantly different ($P > 0.05$).

(Date 1). No difference ($P > 0.05$) occurred between 33A14 and 35N05 for the 21 April planting date. Hybrid 35N05 had significantly ($P < 0.01$) less grain moisture than 33A14 and 34R07 for the 25 May 1999 planting date (Date 2). Hybrids 33A14 and 34R07 had similar ($P > 0.05$) grain moisture for the 25 May 1999 planting date. Hybrid 33A14 had significantly ($P < 0.01$) greater grain moisture than 34R07 and 35N05 and 34R07 had significantly ($P < 0.01$) greater grain moisture than 35N05 for the 14 June planting date (Date 3). In 2000, grain moisture for 33A14 and 34R07 was similar ($P > 0.05$) and both 33A14 and 34R07 had significantly ($P < 0.01$) more grain moisture than 35N05 for the 15 April (Date 1) and 15 May (Date 2) planting dates. Hybrid 33A14 had significantly greater grain moisture than 34R07 and 35N05 for the 8 June 2000 planting date (Date 3). Hybrid 34R07 had significantly ($P < 0.01$) higher grain moisture than 35N05 for the 14 June 1999 planting date.

Seasonal pattern of leaf area index expressed as a function of growing degree units and the main effects of hybrid, row spacing, and starter fertilizer on leaf area index

Increases in leaf area index as a function of growing degree units occurred through the growing season (Figs. 70, 71, 72). A significant ($P < 0.05$) hybrid effect on LAI occurred for the 15 April 2000 planting date (Fig. 73). Hybrid 33A14 and 34R07 had significantly higher LAI ($P < 0.05$) than 35N05. Significant difference between hybrids did not exist ($P > 0.05$) for the 15 May 2000 or the 8 June 2000 planting dates. A significant interaction between hybrid and starter fertilizer occurred for the 15 May 2000 planting date, which will be covered later.

Significant differences ($P < 0.05$) occurred between 38-cm and 76-cm row spacing for the 15 April 2000 and 15 May 2000 planting dates (Figs. 74 and 75). The 38-cm row spacing had higher mean LAI values than the 76-cm row spacing for both planting dates.

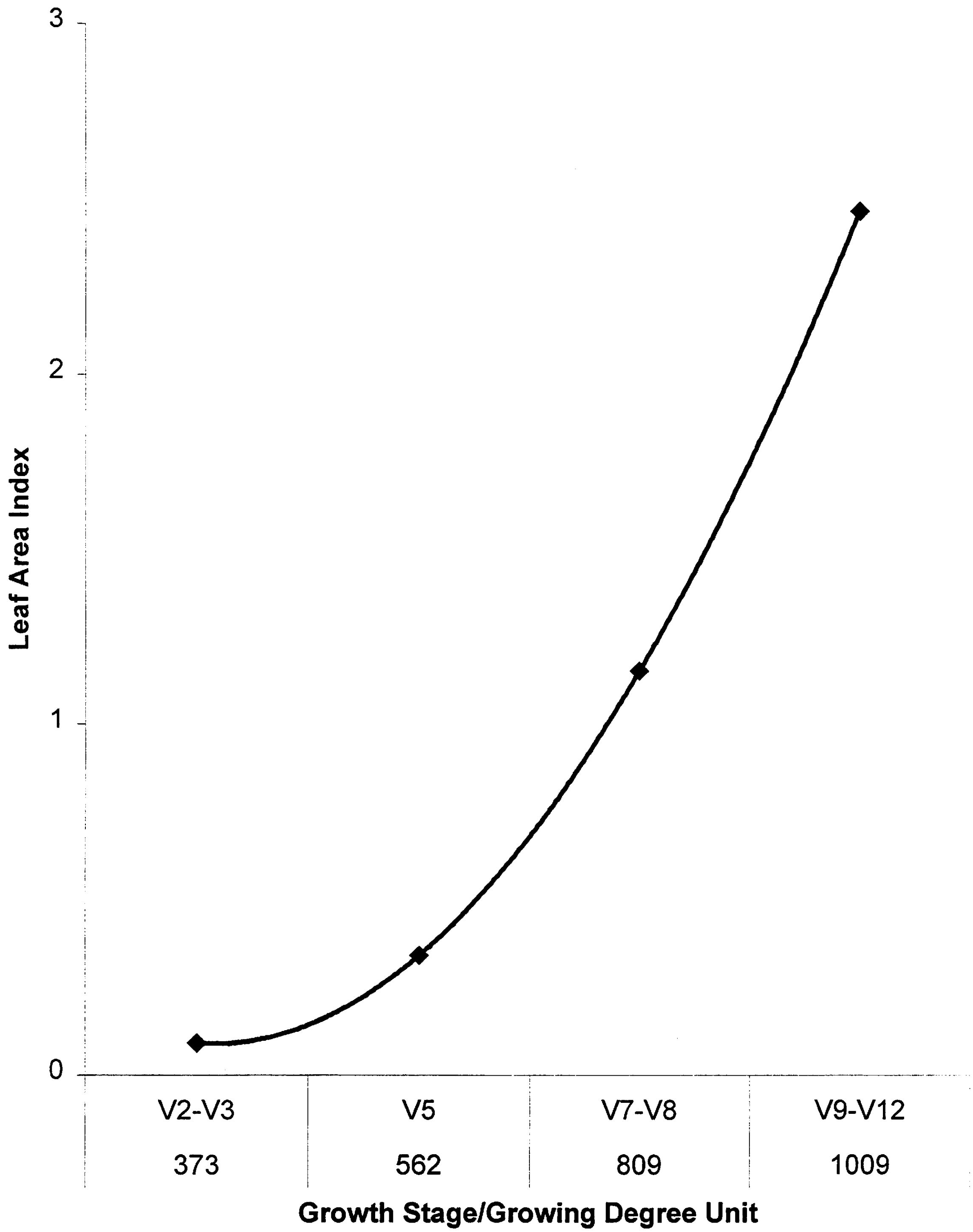


Fig. 70. Seasonal pattern of leaf area index expressed as a function of growing degree units from planting for the 15 April 2000 planting date, Kanawha, IA, 2000.

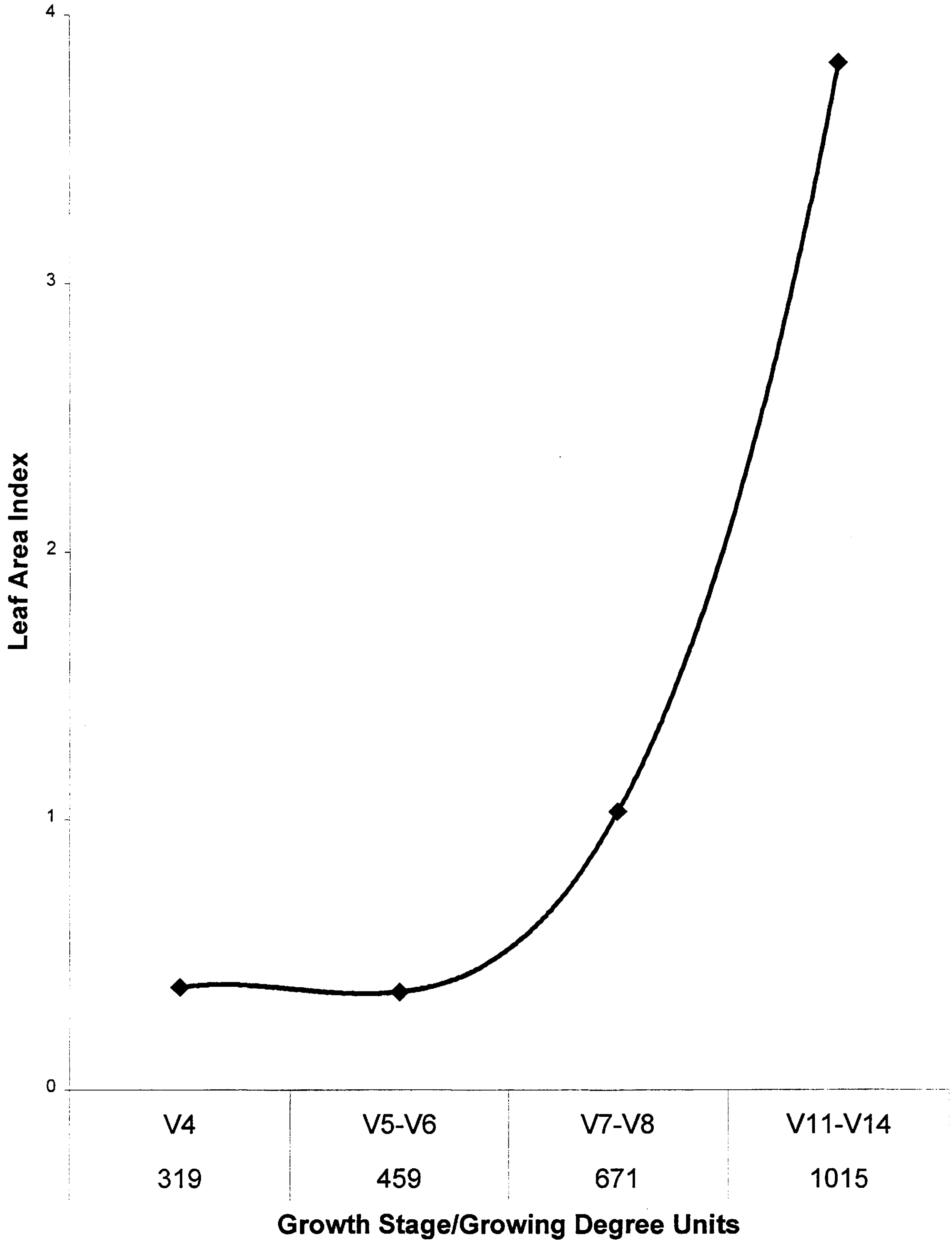


Fig. 71. Seasonal pattern of leaf area index expressed as a function of growing degree units from planting for the 15 May 2000 planting date, Kanawha, IA.

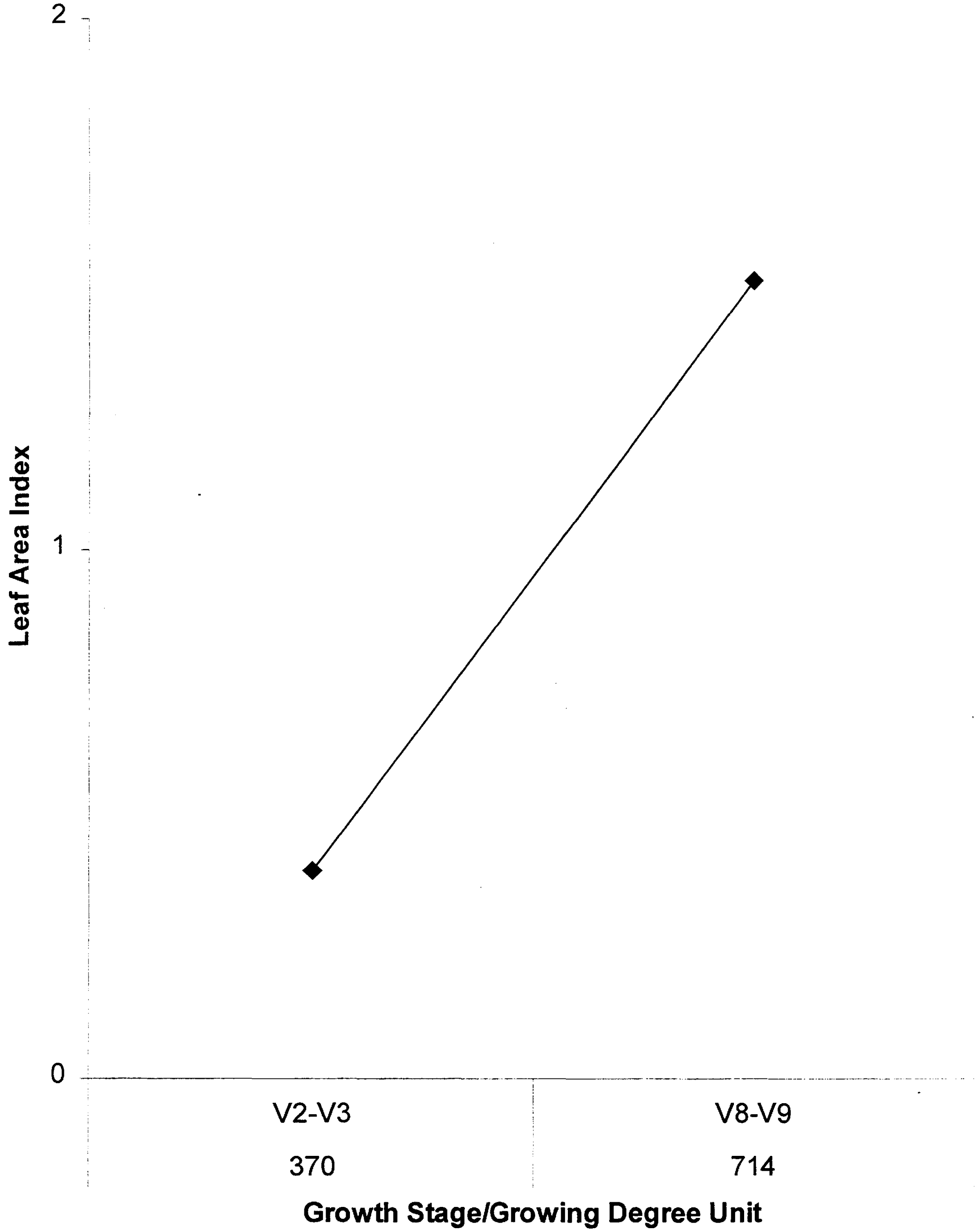


Fig. 72. Seasonal pattern of leaf area index expressed as a function of growing degree units from planting for the 8 June 2000 planting date, Kanawha, IA.

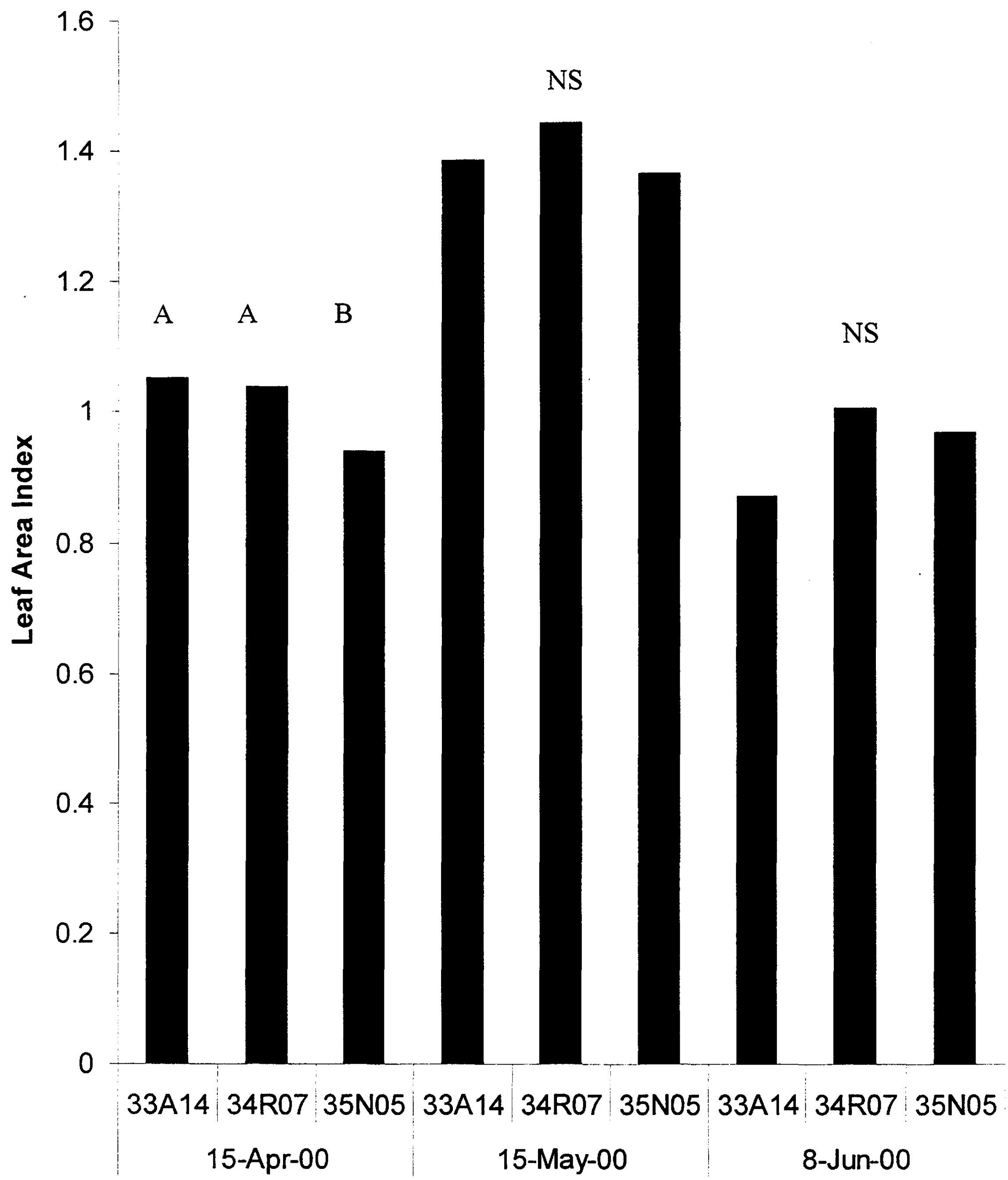


Fig. 73. Main effect of hybrid on leaf area index for the 15 April 2000 planting date, Kanawha, IA.

Means within planting dates with the same letter are not significantly different (P > 0.05).

NS = no significant difference (P > 0.05)

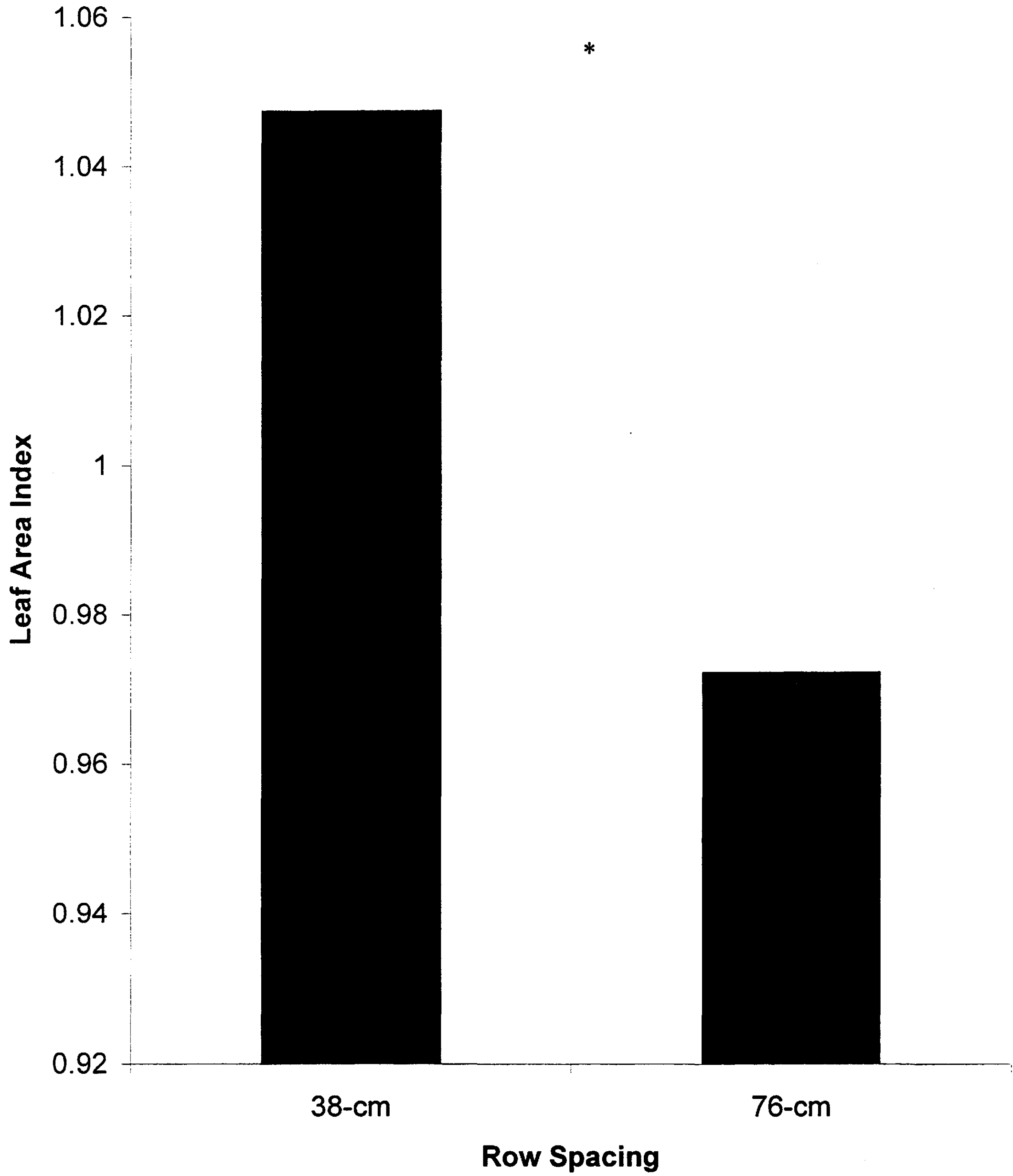


Fig. 74. Main effect of row spacing on leaf area index for the 15 April 2000 planting date, Kanawha, IA.

* = significant main effect ($P < 0.05$).

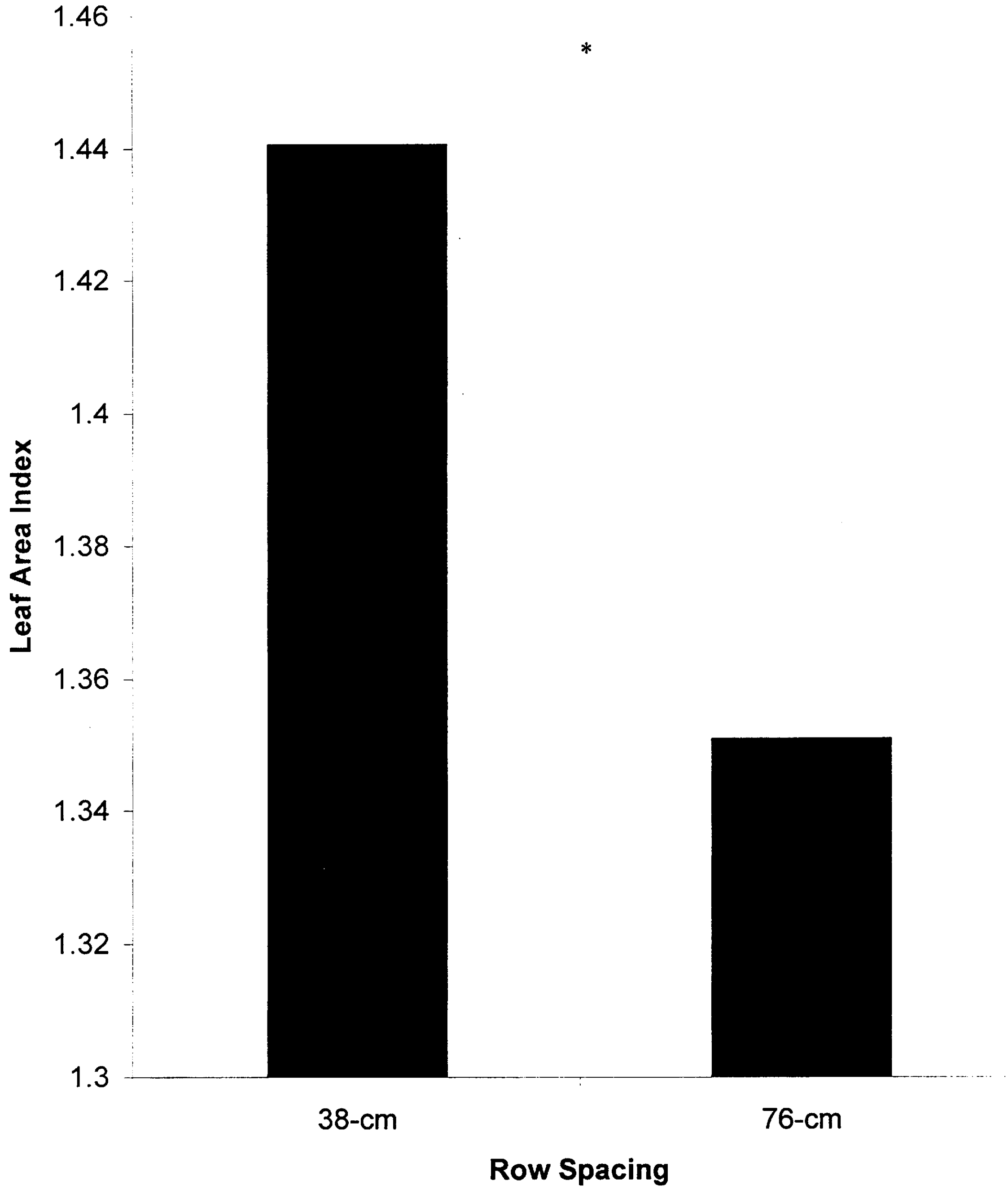


Fig. 75. Main effect of row spacing on leaf area index for the 15 May 2000 planting date at Kanawha, IA.

* = significant main effect (P < 0.05).

Significant interactions occurred between row spacing and GDU for the 15 April 2000 and 15 May 2000 planting dates. No significant difference between row spacing occurred for the 8 June 2000 planting date. The 8 June 2000 planting date had only 2 leaf area index readings taken. Potentially, more readings were needed for the 8 June 2000 planting date for separation between mean comparisons.

The findings at Kanawha were similar to Ames where the 11 April and 11 May 2000 planting dates with 38-cm row spacing accumulating higher mean leaf area index readings than the 76-cm row spacing. Row spacing seemed to significantly improve canopy development around the V5-V9 growth stage.

Significant difference ($P < 0.05$) occurred between fertility regimes for the 15 April 2000 planting date (Fig. 76). Starter fertilizer treated plots had significantly ($P < 0.05$) higher mean LAI than the no starter treated plots. No significant difference ($P > 0.05$) between fertility regimes occurred for the 15 May 2000 or 8 June 2000 planting dates. Potentially, the early planting date benefited from the application of starter fertilizer through improved canopy development. Cooler temperatures in April could have slowed development resulting in a benefit of improved canopy development from starter fertilizer. Later planting dates did not have cooler temperatures early in development resulting in less benefit in canopy development from starter fertilizer.

Interactive effects between hybrid and starter fertilizer on leaf area index

Significant ($P < 0.05$) interactive effects between hybrid and starter fertilizer on leaf area index occurred for the 15 May 2000 planting date (Fig. 77). Starter fertilizer produced a

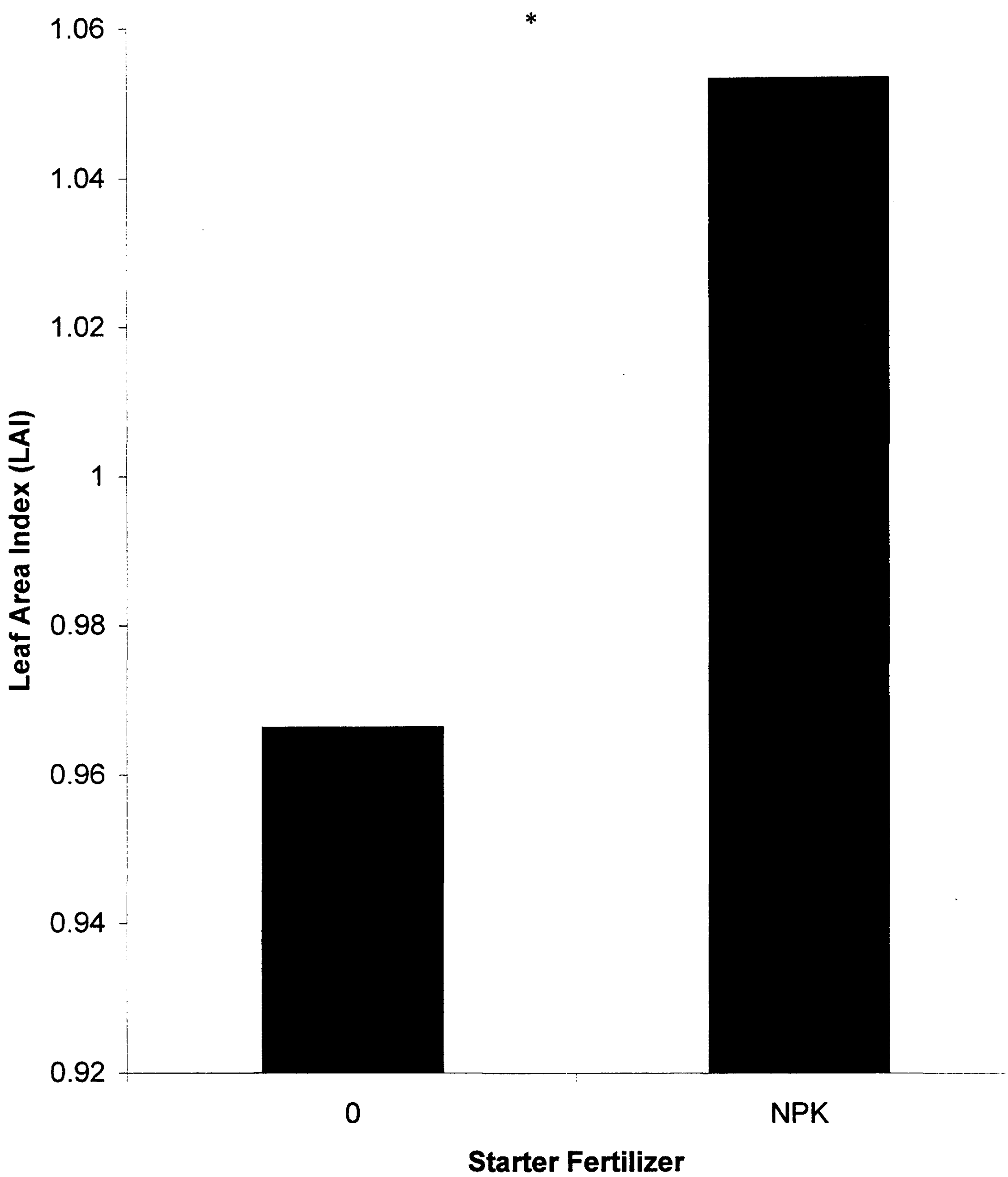


Fig. 76. Main effect of starter fertilizer on leaf area index for the 15 April 2000 planting date.

* = significant main effect ($P < 0.05$).

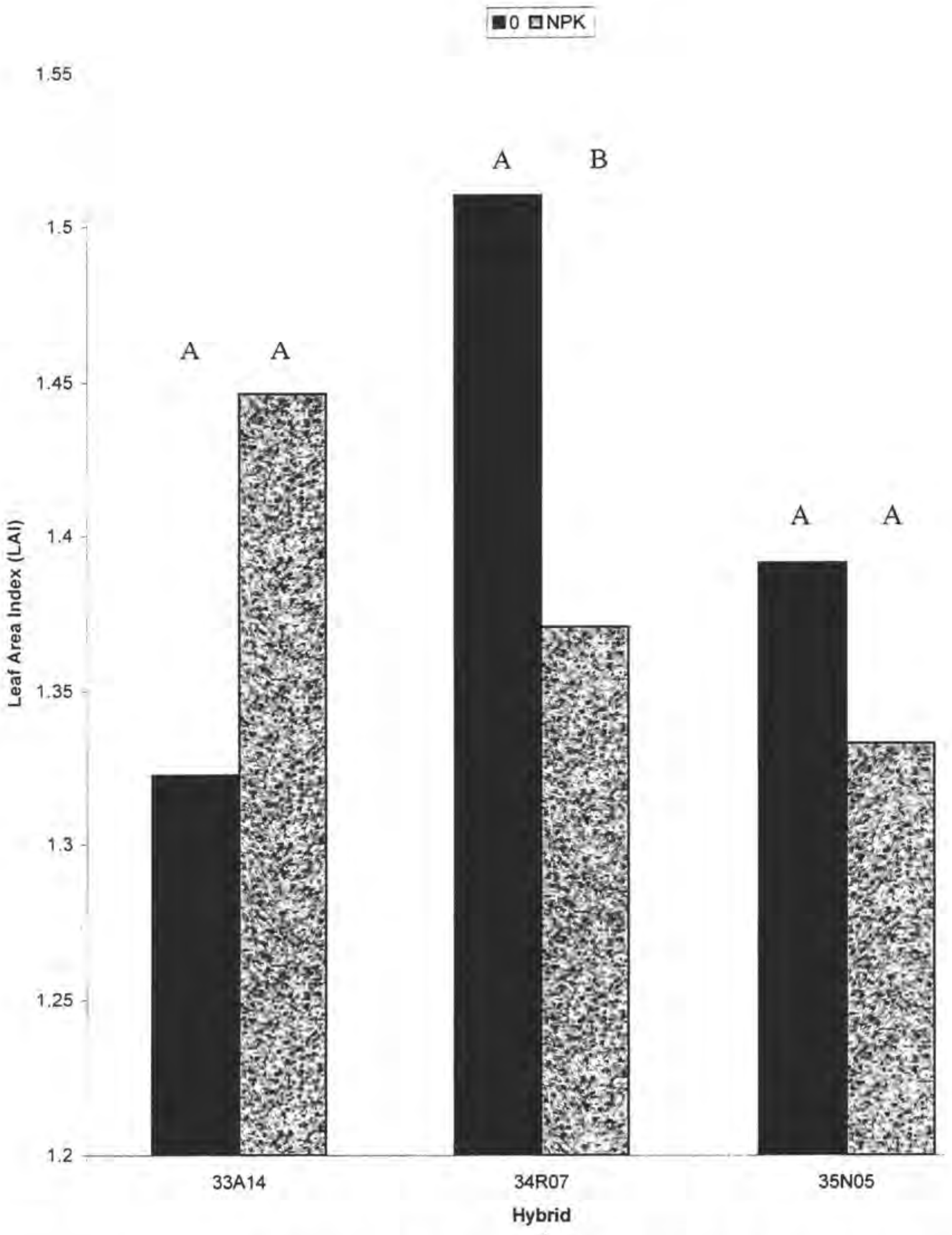


Fig. 77. Interactive effects between hybrid and starter fertilizer for the 15 May 2000 planting date at Kanawha, IA.

Starter fertilizer treatments within hybrid with the same letter are statistically similar.

lower leaf area index mean for 34R07 than the fertility regime with no starter fertilizer. Significant interactions between starter fertilizer and hybrid on leaf area index did not occur ($P > 0.05$) for 35N05 or 33A14 for the 15 May 2000 planting date. Potentially, with the dry weather, a salting effect due to starter fertilizer occurred at the 15 May 2000 planting date with 34R07. Mallarino et al. (1999) observed a salting effect, potentially due to potassium, that decreased the early growth of maize. No significant interactive effects ($P > 0.05$) occurred for the 15 April or 8 June 2000 planting dates.

Row spacing effect on the seasonal pattern of leaf area index expressed as a function of growing degree units

Row spacing effect on the seasonal pattern of leaf area index expressed as a function of growing degree units from planting was significant ($P < 0.05$) between 38- and 76-cm row spacing (Figs. 78 and 79). Significant differences ($P < 0.05$) in leaf area index between row spacing occurred between the V5 and V8 stages of development for or between approximately 500 to 800 growing degree units for both planting dates.

There was no effect, between row spacing, on seasonal pattern of leaf area index expressed as a function of growing degree units for the 8 June 2000 planting date. There were only two sampling dates for this planting date, which may not have been sufficient to detect differences in leaf area index between the two row spacings over time.

Data collected at Kanawha for leaf area index was similar to the Ames location where the rate of leaf area index accumulation was higher for 38-cm row spacing compared with 76-cm row spacing. Potential benefits of increased leaf area index for the 38-cm rows may include increased crop competitiveness with weed species, and water management benefits

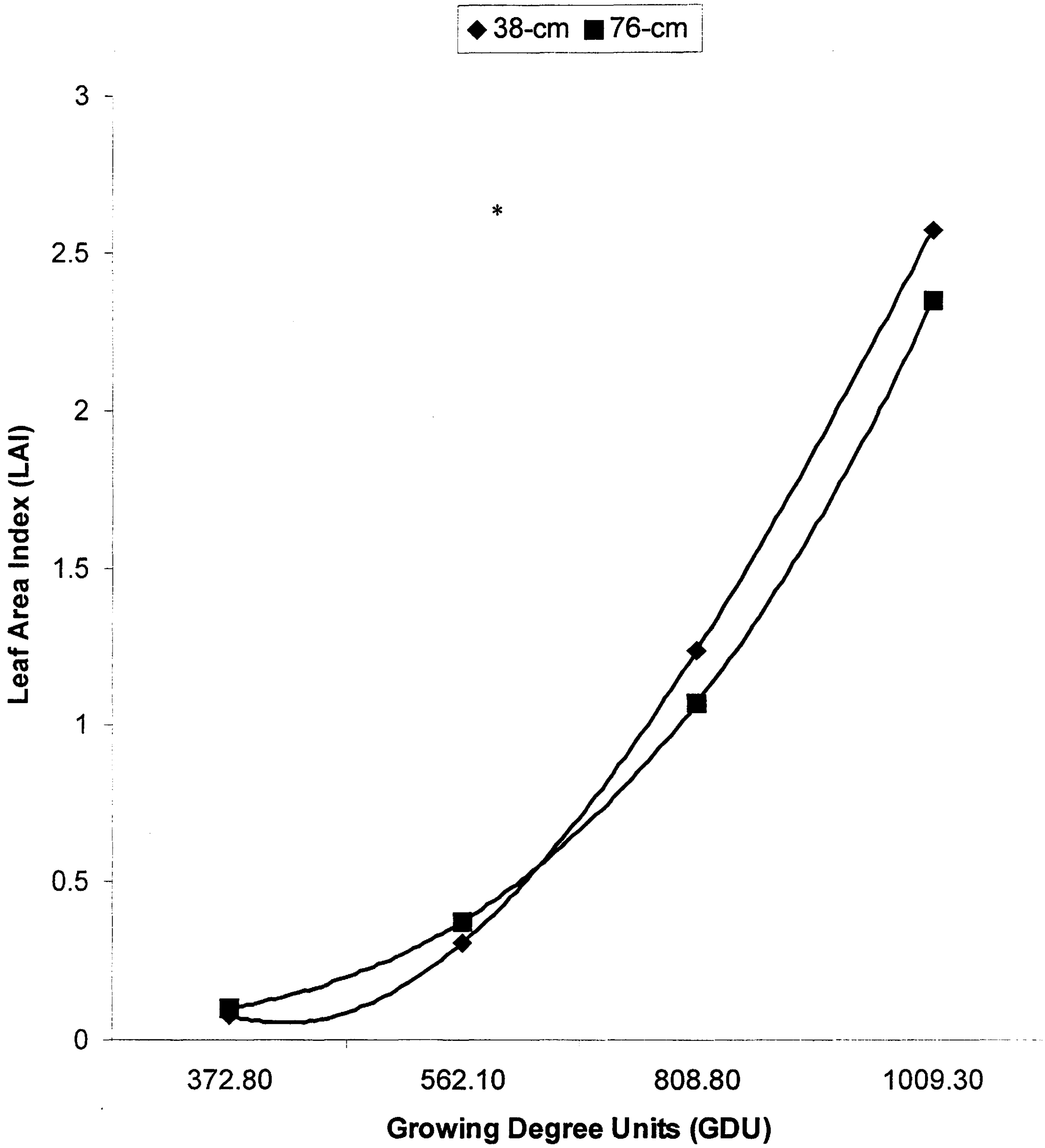


Fig. 78. Row spacing effect on the seasonal pattern of leaf area index expressed as a function of growing degree units from planting for the 15 April 2000 planting date at Kanawha, IA.

* = significant effect ($P < 0.05$).

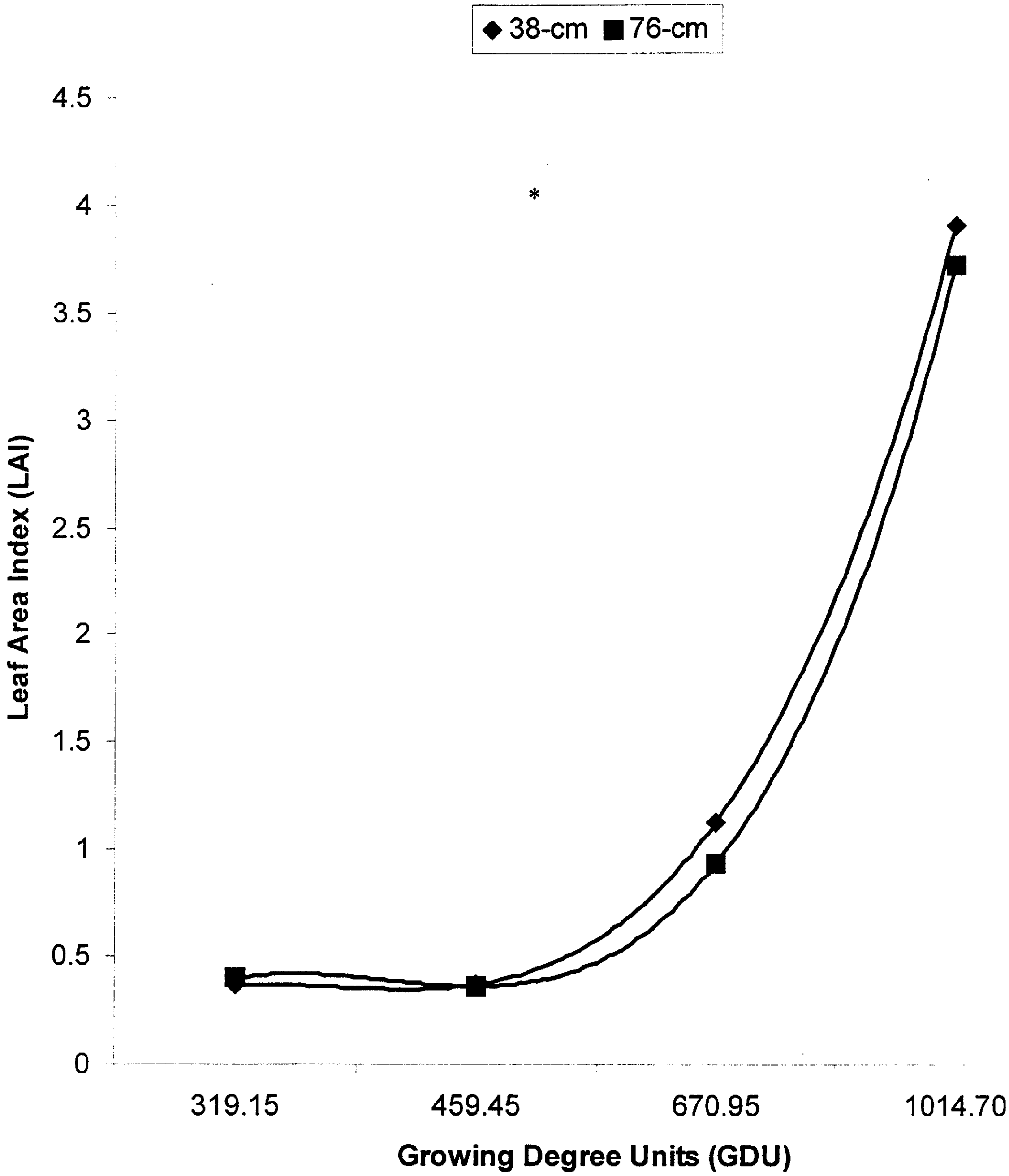


Fig. 79. Effect of row spacing on the seasonal pattern of leaf area index expressed as a function of growing degree units from planting for the 15 May 2000 planting date, Kanawha, IA.

* = significant effect ($P < 0.05$).

such as decreased erosion risks and decreased soil evaporation from increased ground cover. Teasdale (1995) showed that 38-cm row spacing is more competitive with weed species than 76-cm row spacing. This study did not observe the effect of row spacing on weed presence and survival but the measurement of canopy development shows that canopy development is more advanced between the V5 and V8 stages of growth for the 38-cm row spacing, which potentially shows a weed competition benefit for 38-cm row spacing over 76-cm row spacing.

Main effect of planting date on days and growing degree units to mid-silk

Days to mid-silk was significantly different ($P < 0.01$) as planting date was delayed in 1999 and 2000 (Fig. 80). As planting date was delayed, days to mid-silk decreased.

Significant difference ($P < 0.01$) for growing degree units to mid-silk occurred in 1999 and 2000 (Fig. 81). In 1999, the 25 May planting date required significantly more growing degree units to reach mid-silk than the 21 April and 14 June planting dates. This is different from what was observed in Ames in 1999 where growing degree units to mid-silk decreased as planting date was delayed. In 2000, growing degree units to mid-silk significantly decreased ($P < 0.01$) as planting date was delayed. This is similar to what occurred at the Ames site in both years. The decreases in days and growing degree units to mid-silk as planting date was delayed were potentially due to seasonal temperature and photoperiod differences as several have observed (Yan and Wallace, 1998; Birch et al., 1998; Ellis et al., 1992; Bonhomme et al., 1994; Ellis et al., 1992).

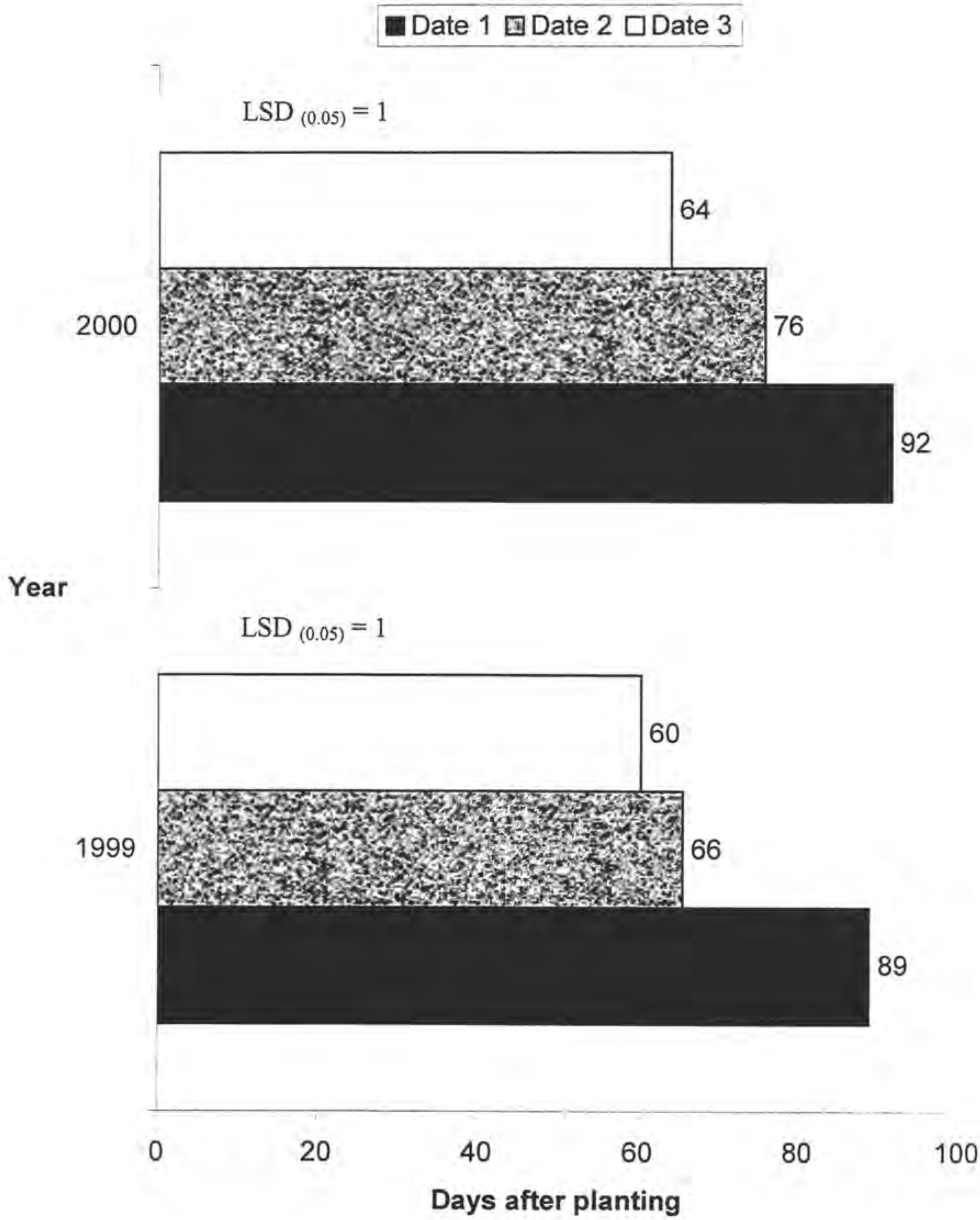


Fig. 80. Main effect of planting date on days to mid-silk, Kanawha, IA, 1999-2000.

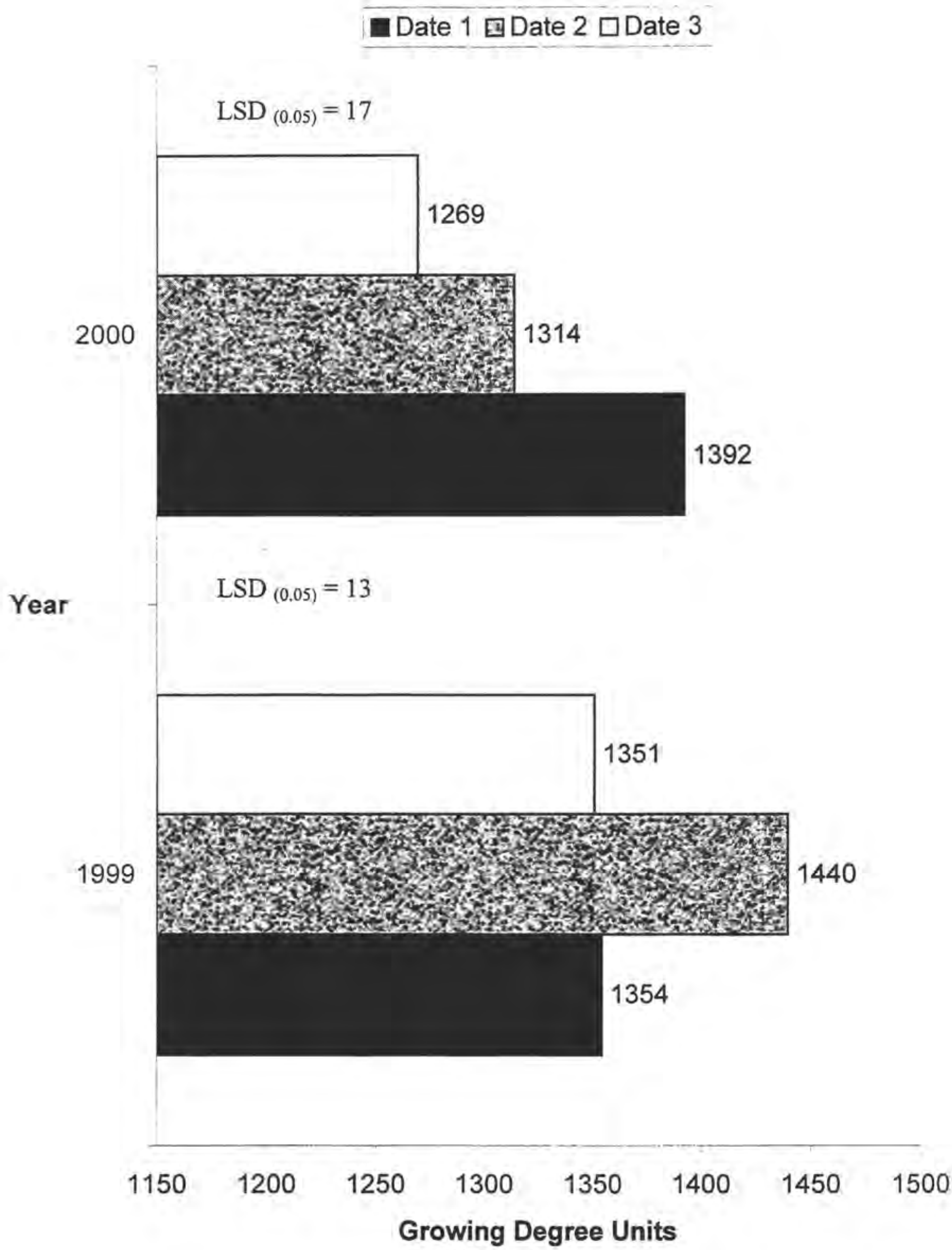


Fig. 81. Main effect of planting date on growing degree units to mid-silk, Kanawha, IA.

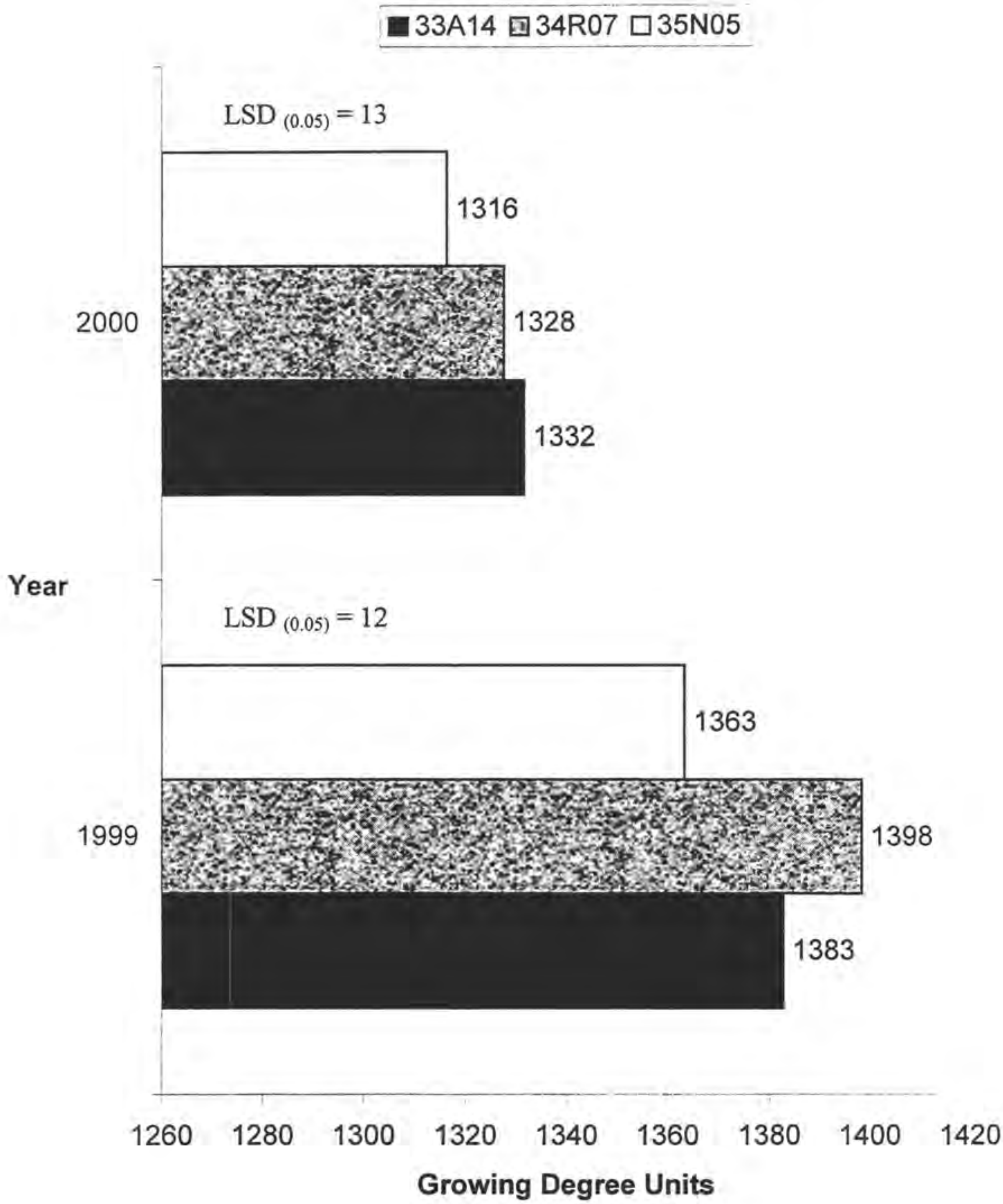


Fig. 82. Main effect of hybrid on growing degree units to mid-silk, Kanawha, IA, 1999-2000.

Main effect of hybrid on growing degree units to mid-silk

Significant difference for growing degree units to mid-silk occurred in 1999 ($P < 0.01$) and 2000 ($P < 0.05$) (Fig. 82). In 1999, 34R07 required significantly more growing degree units to reach mid-silk than 33A14 and 35N05. Hybrid 33A14 required more growing degree units to reach mid-silk than 35N05 in 1999. In 2000, 33A14 required more growing degree units to reach mid-silk than 33A14 and 35N05. Hybrid 33A14 required more growing degree units to reach mid-silk than 35N05 in 1999. In 2000, 33A14 required significantly more growing degree units to reach mid-silk than 35N05. Hybrid 34R07 required similar growing degree units to mid-silk as 33A14 and 35N05.

Main effect of row spacing on growing degree units to mid-silk

Significant difference for growing degree units to mid-silk occurred between 38- and 76-cm row spacing in 2000 ($P < 0.05$) but did not occur in 1999 ($P > 0.05$) (Fig. 83). Fewer growing degree units were required to reach mid-silk for the 38-cm row spacing in 2000 than the 76-cm row spacing. This is similar to what was observed in Ames in 1999.

Main effect of starter fertilizer on growing degree units to mid-silk

Starter fertilizer treated plots required significantly ($P < 0.01$) fewer growing degree units to reach mid-silk in both years (Fig. 84). This is similar to the effect that was observed at the Ames plot and similar to what others have observed (Bullock et al., 1993; Gordon et al., 1997; Scharf, 1999). A potential advantage to use of starter fertilizer is to hasten development so that the reproductive development period will occur during cooler temperatures or to hasten development of later planting dates allowing more days for grain fill before a killing frost.

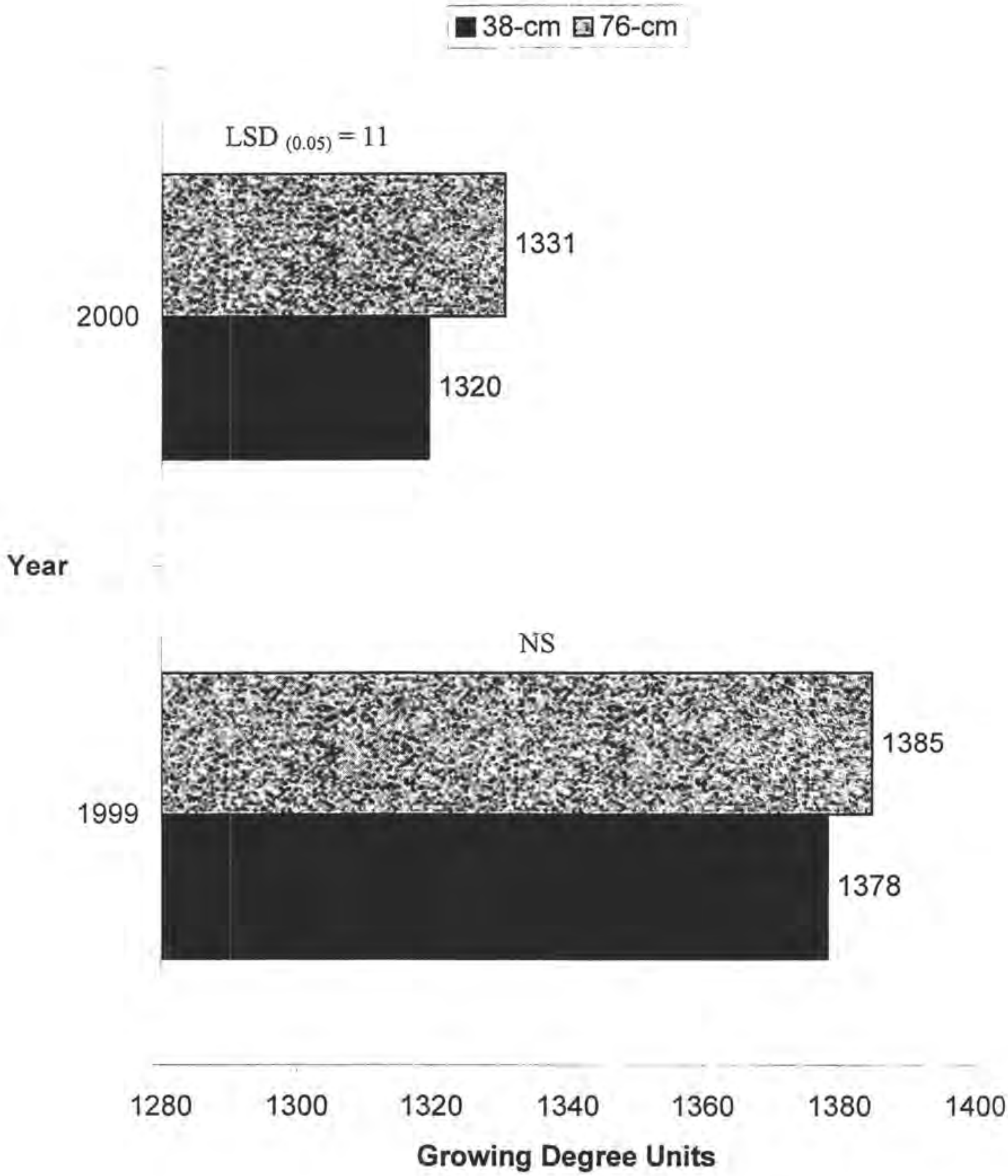


Fig. 83. Main effect of row spacing on growing degree units to mid-silk, Kanawha, IA, 1999-2000.

NS = no significant main effect ($P > 0.05$).

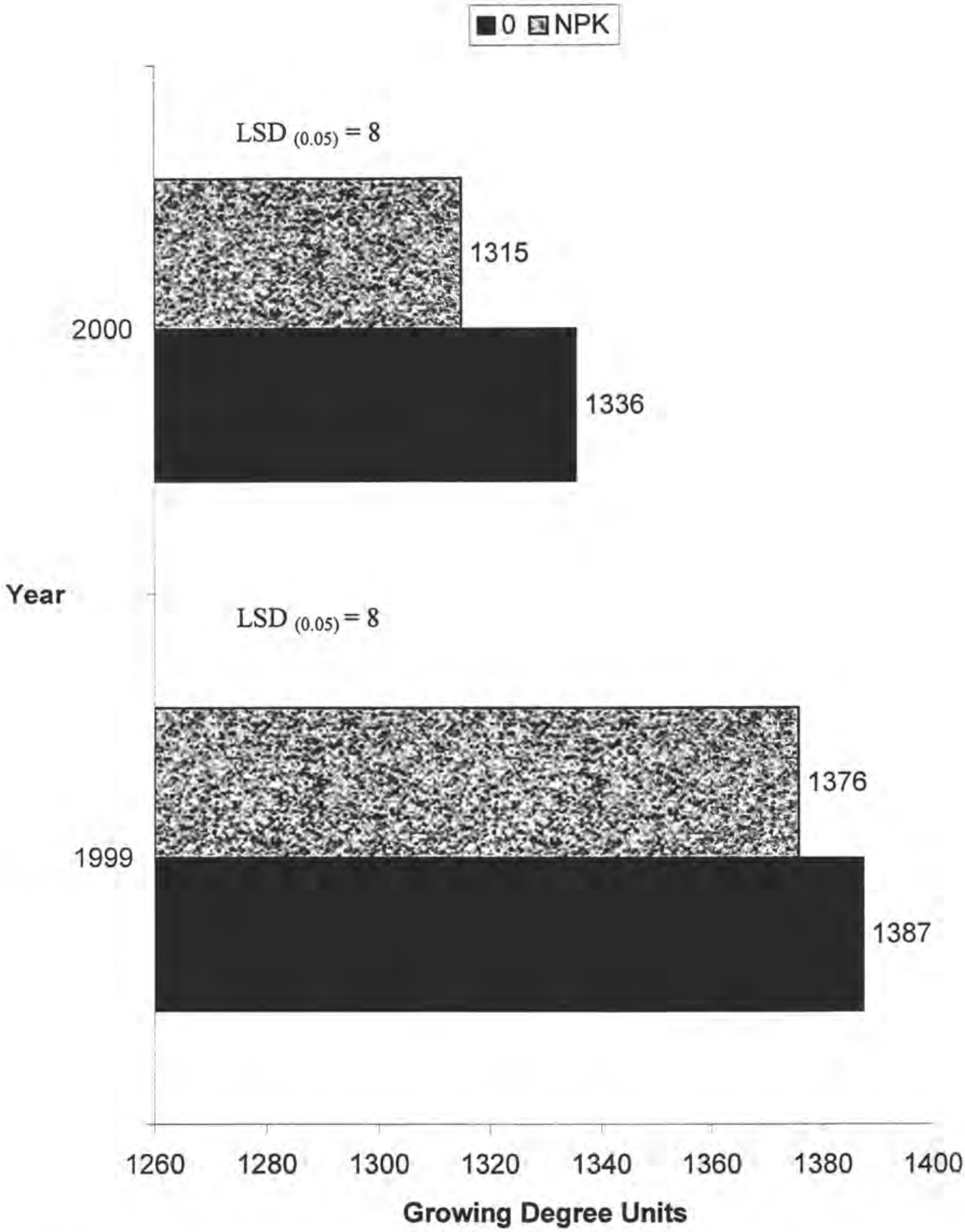


Fig. 84. Main effect of starter fertilizer on growing degree units to midsilk, Kanawha, IA, 1999-2000.

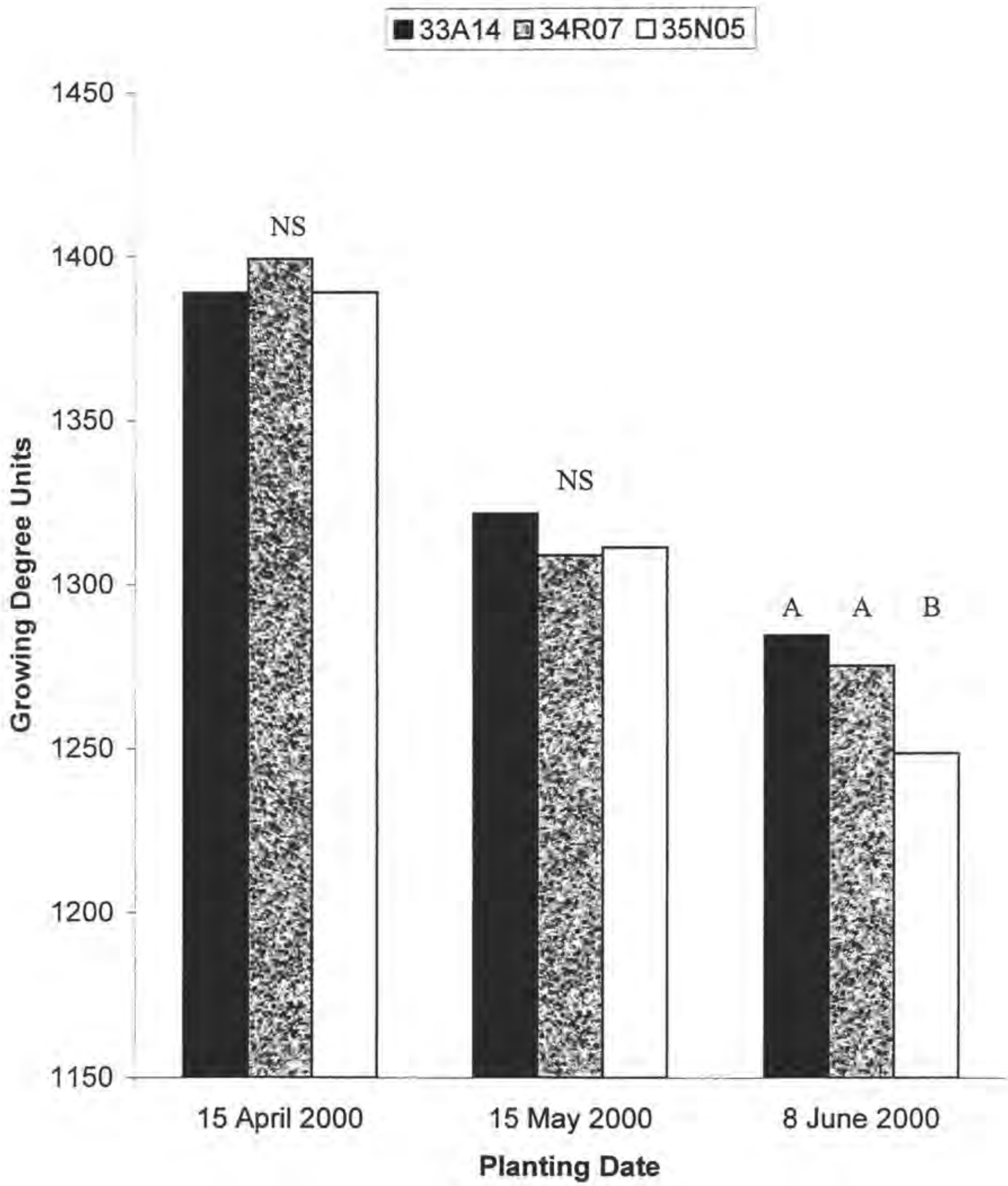


Fig. 85. Interactive effect of planting date and hybrid on growing degree units to mid-silk, Kanawha, IA.

Means within planting date with the same letter are not significantly different ($P > 0.05$).

NS = no significant main effect within planting date ($P > 0.05$).

Interactive effects of hybrid and row spacing on growing degree units to mid-silk

A significant interactive effect between hybrid and row spacing on growing degree units to mid-silk occurred in 2000 ($P < 0.05$) but did not occur in 1999 ($P > 0.05$). Hybrids required similar growing degree units to reach mid-silk for the 15 April and 15 May 2000 planting dates (Fig. 85). Hybrid 35N05 required significantly fewer ($P < 0.01$) growing degree units to reach mid-silk for the 8 June 2000 planting date than 33A14 and 34R07.

Interactive effects of row spacing and starter fertilizer on growing degree units to mid-silk

Significant interactive effects between row spacing and starter fertilizer occurred in 2000 ($P < 0.05$) but did not occur in 1999 ($P > 0.05$). Plots with no starter fertilizer in 76-cm row spacing required significantly more growing degree units ($P < 0.01$) than 38-cm row spacing and 76-cm/starter treated plots (Fig. 86).

Main effect of planting date on rows of kernels per ear, kernels per row, and total kernels per ear

Significant difference ($P < 0.01$) occurred among planting dates for rows of kernels per ear in 1999 and 2000. In 1999 no difference ($P > 0.05$) occurred between the 21 April and 25 May planting dates (Fig. 87). Significant difference ($P < 0.01$) occurred between the 14 June planting date and the 21 April and 25 May planting dates in 1999. The 21 April and 25 May planting dates produced significantly more rows of kernels per ear than the 14 June planting date. In 2000, significant difference ($P < 0.01$) occurred between each planting date with the 15 April planting date producing fewer rows of kernels per ear than the 15 May planting date and 8 June planting date (Fig. 88). The 15 May planting date produced fewer rows of kernels per ear then the 8 June planting date. This was different from 1999 where the early planting dates produced higher rows of kernels per ear than the June planting date. Potentially, the dry weather from the

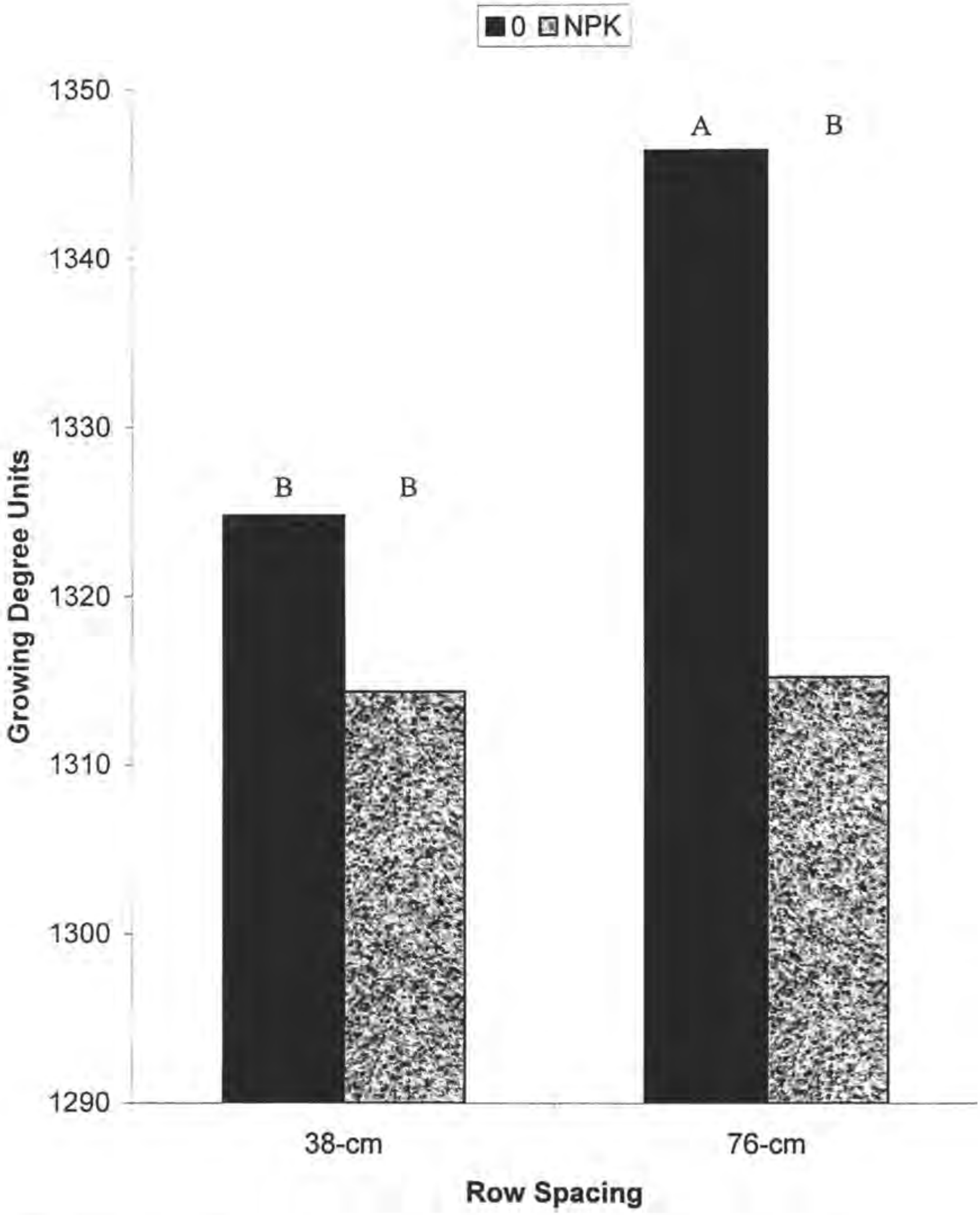


Fig. 86. Interactive effect of row spacing and starter fertilizer on growing degree units to mid-silk, Kanawha, IA, 2000.

Means with the same letter are not significantly different (P > 0.05).

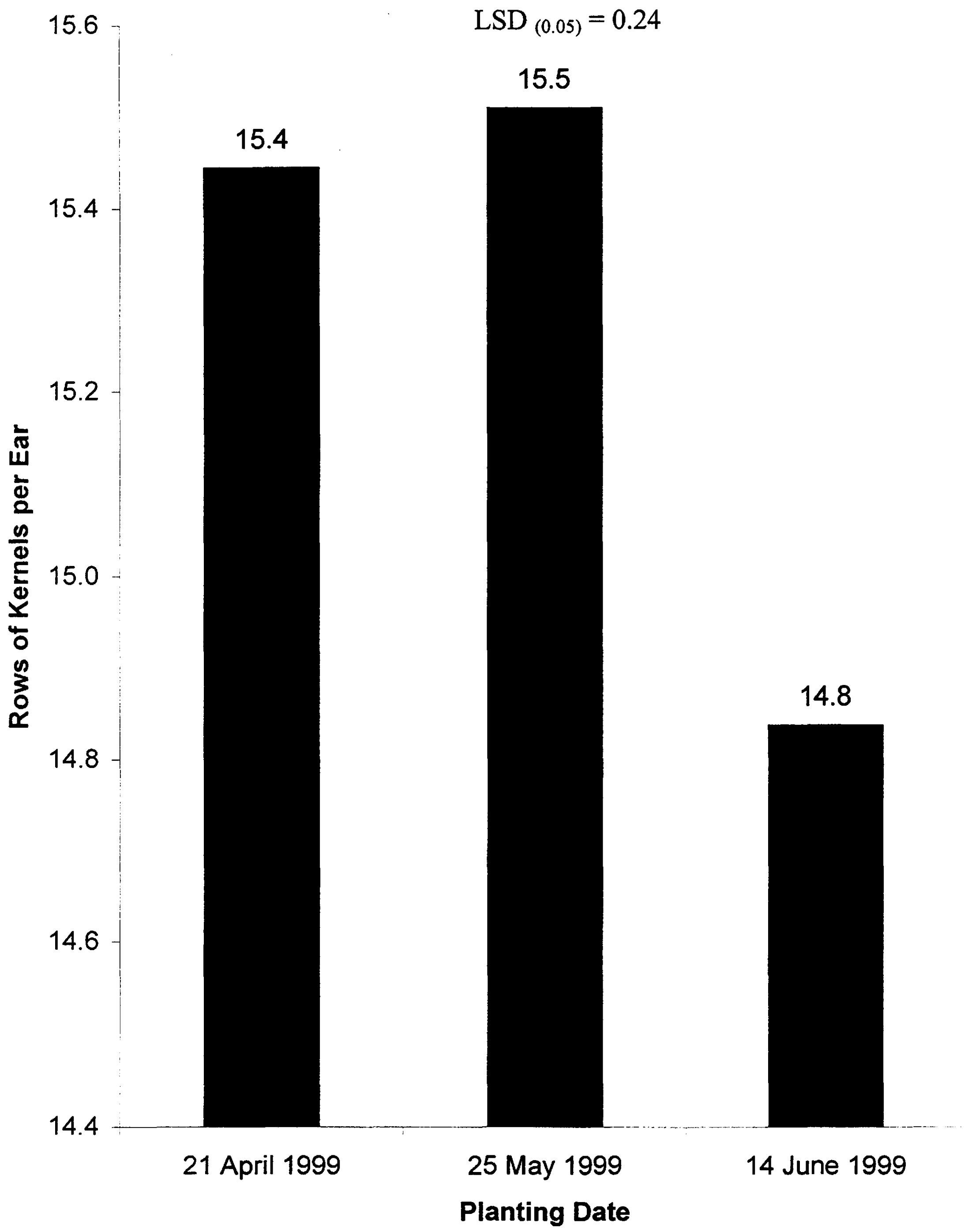


Fig. 87. Main effect of planting date on rows of kernels ear^{-1} at Kanawha, IA, 1999.

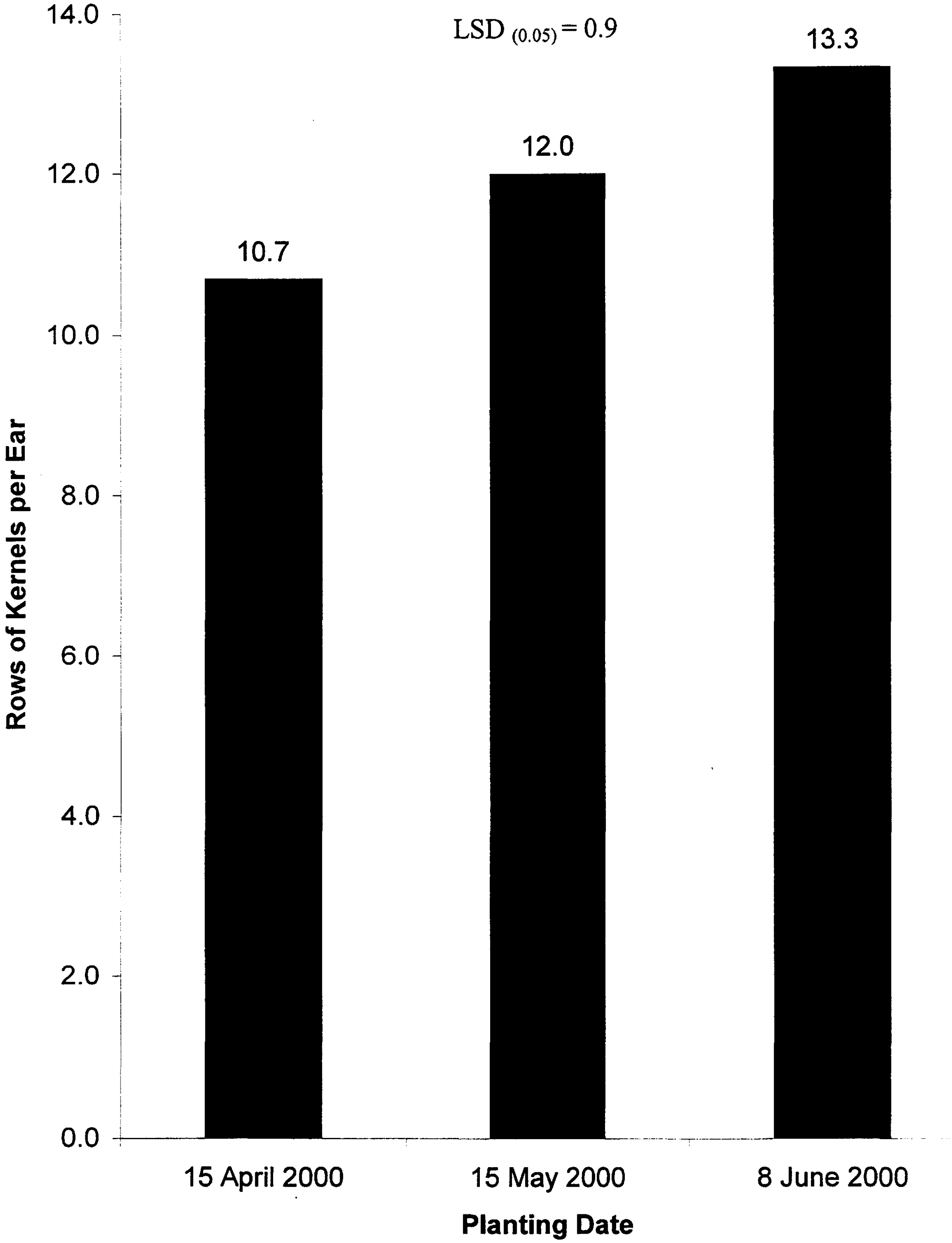


Fig. 88. Main effect of planting date on rows of kernels ear^{-1} at Kanawha, IA, 2000. Means with the same letters are not significantly different ($P > 0.05$).

previous fall and winter caused fewer rows of kernels per ear for the April and May planting dates in 2000 where more optimum soil moisture was available in 1999.

Significant difference ($P < 0.01$) occurred among planting dates for kernels per row in 2000 but no significant difference ($P > 0.05$) occurred in 1999. The 15 April planting date produced more kernels per row than the 15 May and 8 June planting dates and the 15 May planting date produced more kernels per row than the 8 June planting date (Fig. 89). Significant differences among planting dates did not occur ($P > 0.05$) for total kernels per ear in 1999 (Fig. 90). Significant difference between planting dates for total kernels ear^{-1} did occur in 2000 (Fig. 91). Results from 1999 are similar to what occurred in Ames and to what several have observed when comparing kernel number between planting dates (Cirilo and Andrade, 1994; Swanson and Wilhelm, 1996). Previous studies have shown that kernel abortion is likely the dominant factor in determining final kernel number due to delays in planting (Otegui and Melón, 1997; Cirilo and Andrade, 1994). Precipitation during 1999 was above normal for much of the growing season compared with precipitation during 2000, which was normal to slightly below normal. Differences among planting dates between years was likely due to differences in precipitation, with lower precipitation in 2000 being more conducive to kernel abortion than higher precipitation in 1999.

Main effect of hybrid, row spacing and starter fertilizer on rows of kernels per ear, kernels per row, and total kernels per ear

Significant difference ($P < 0.01$) occurred between hybrids for rows of kernels ear^{-1} in 1999 (Fig. 92). Hybrid 35N05 produced more rows of kernels ear^{-1} than 33A14 and 34R07 and 34R07 produced more rows of kernels ear^{-1} than 33A14. No differences ($P > 0.05$) occurred between hybrids in 2000. Hybrid did not have a significant ($P > 0.05$) effect on

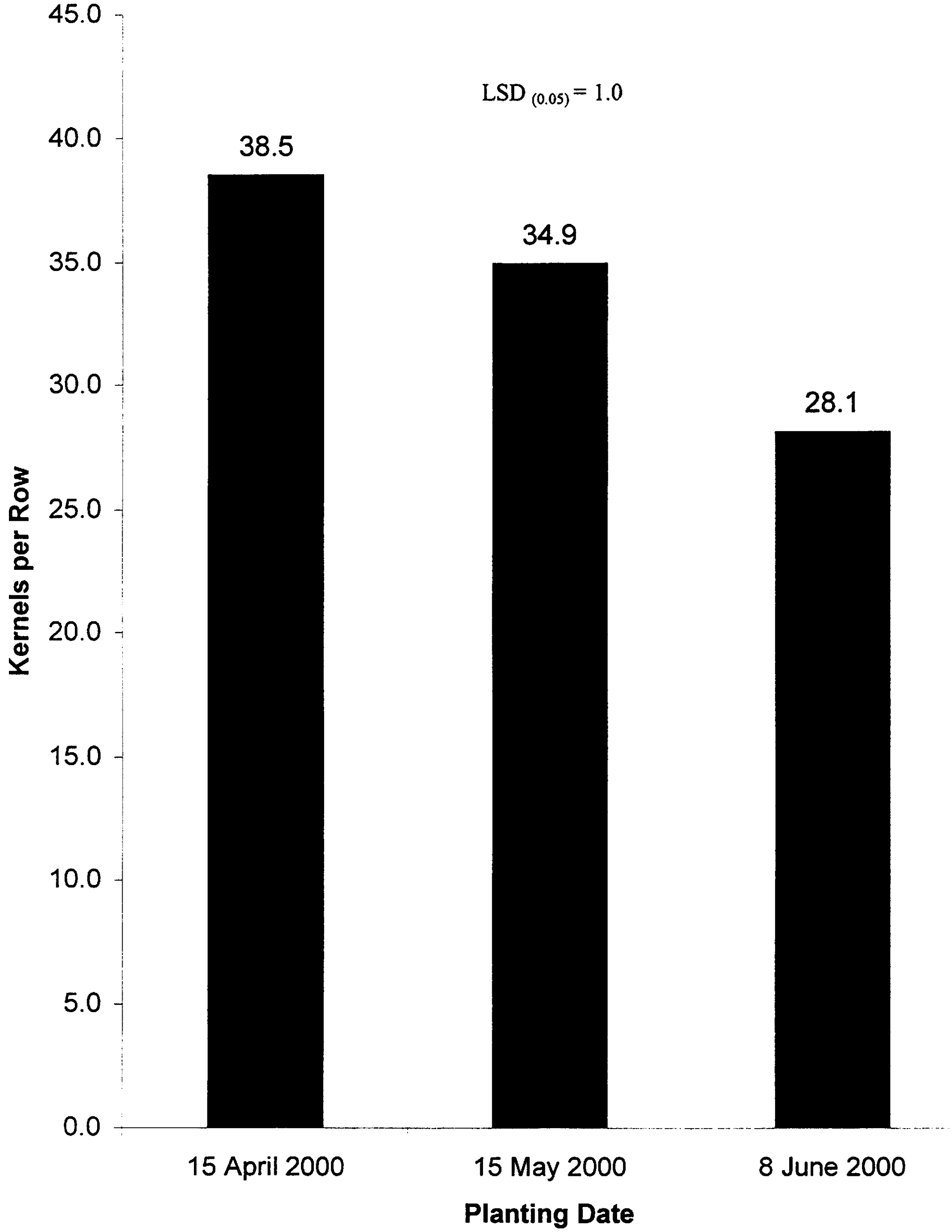


Fig. 89. Main effect of planting date on kernels row^{-1} at Kanawha, IA, 2000.

NS = no significant main effect ($P > 0.05$).

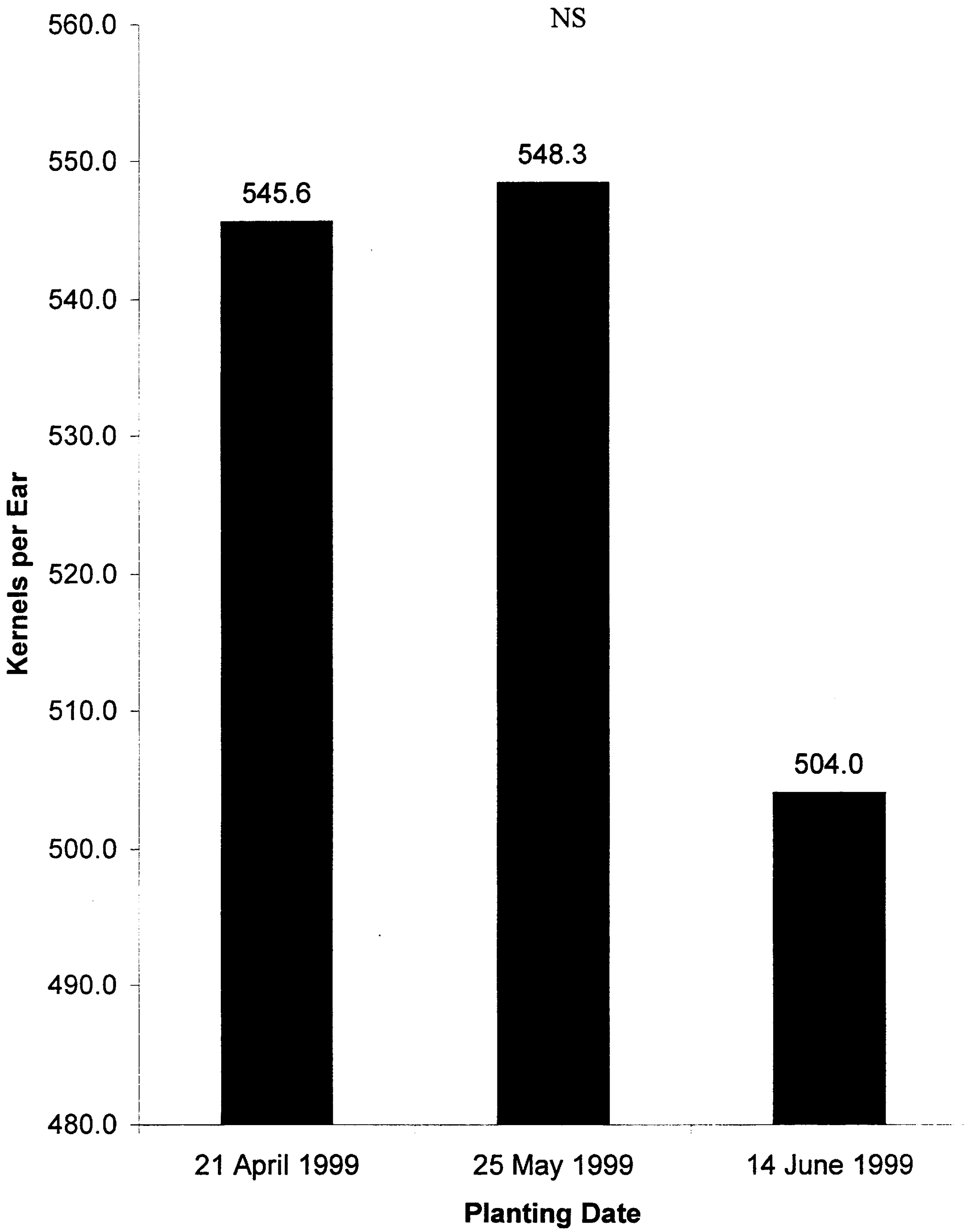


Fig. 90. Main effect of planting date on total kernels ear^{-1} at Kanawha, IA, 1999.

NS = no significant main effect (P > 0.05).

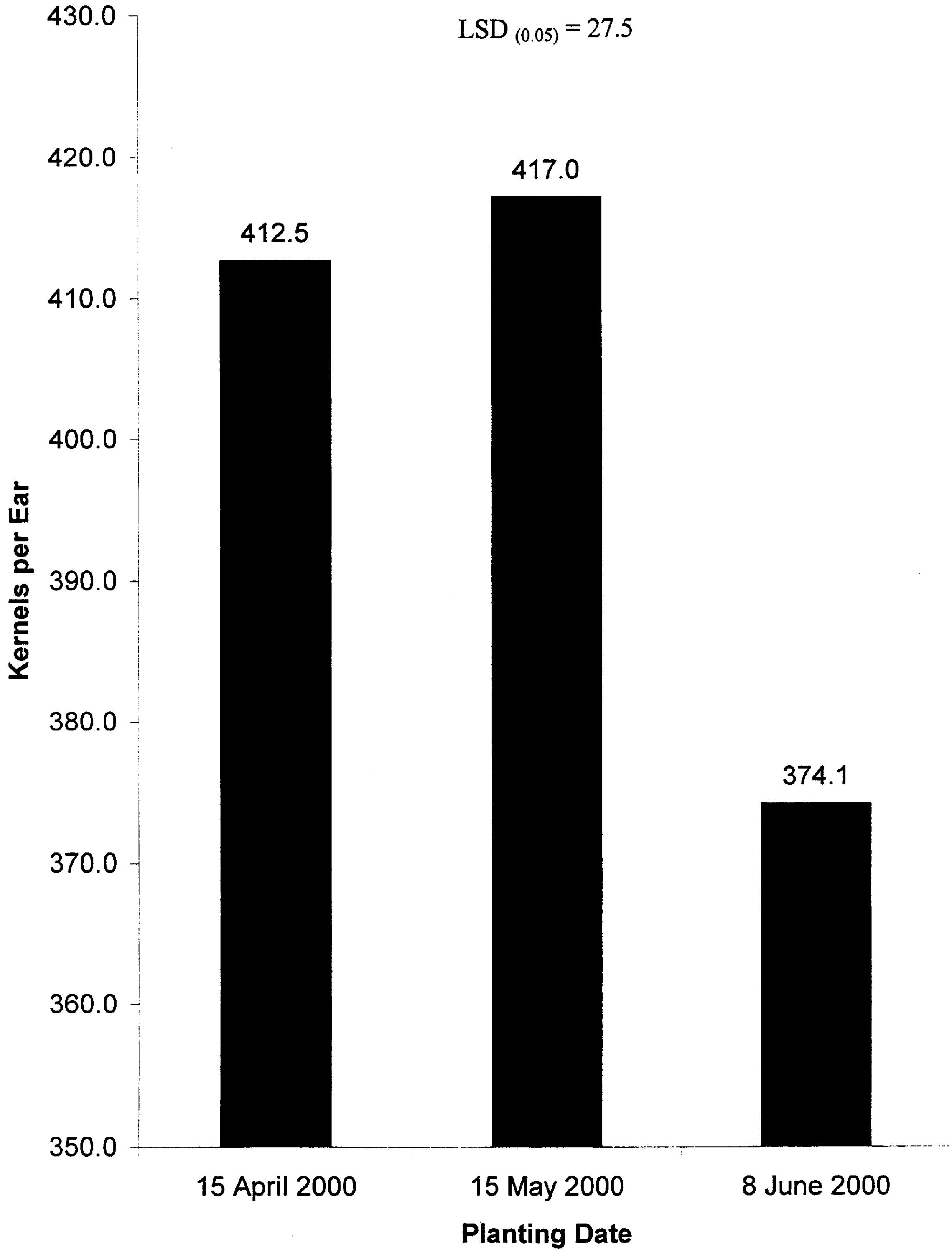


Fig. 91. Main effect of planting date on total kernels ear^{-1} at Kanawha, IA, 2000.

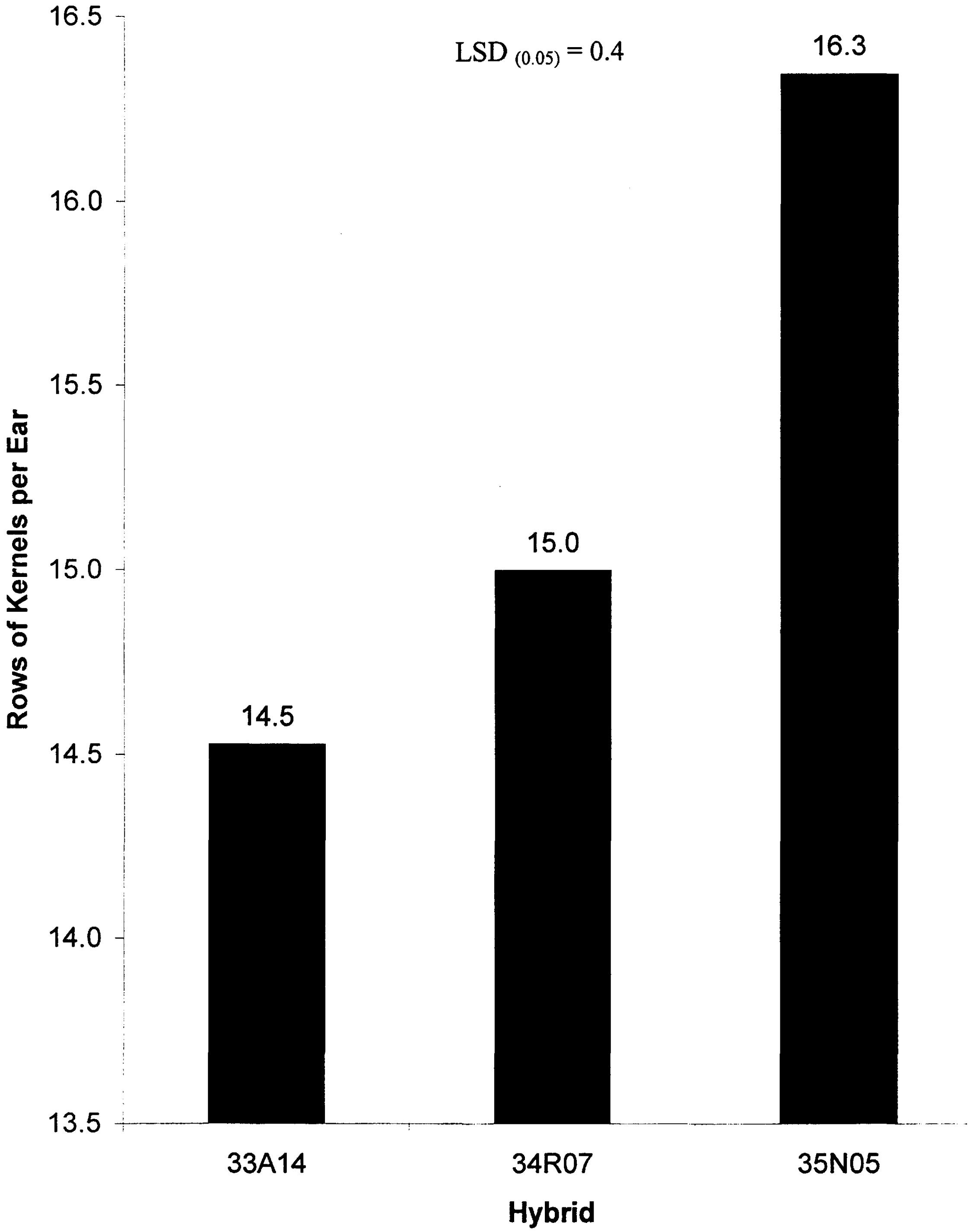


Fig. 92. Effect of hybrid on rows of kernels ear^{-1} at Kanawha, IA, 1999.

kernels row^{-1} or total kernels ear^{-1} in 1999 or 2000. A significant interaction between hybrid and starter fertilizer occurred in 1999 and will be covered later.

Differences between 38- and 76-cm row spacing were not significant ($P > 0.05$) for rows of kernels ear^{-1} and kernels row^{-1} in 1999 and 2000. Significant difference ($P < 0.05$) between 38- and 76-cm row spacing for total kernels ear^{-1} occurred in 2000 but did not occur in 1999 ($P > 0.05$) (Fig. 93). In 2000, 38-cm row spacing produced significantly more kernels ear^{-1} than 76-cm row spacing. Despite differences in measured kernels ear^{-1}, comparison of 38-cm with 76-cm row spacing for grain yield was not significant ($P > 0.05$) (Fig. 63). A significant ($P < 0.05$) interaction between planting date and row spacing for kernels row^{-1} and total kernels ear^{-1} occurred in 1999 and will be addressed later.
Starter fertilizer did not produce significant ($P > 0.05$) difference for rows of kernels ear^{-1}, kernels row^{-1}, or total kernels ear^{-1} in 1999 and 2000. A significant interaction between hybrid and starter fertilizer for total kernels ear^{-1} occurred in 2000 and will be addressed later.

Interactive effects of planting date and row spacing on kernels row^{-1} and total kernels ear^{-1}

Significant ($P < 0.05$) interactive effects between planting date and row spacing on kernels row^{-1} and total kernels ear^{-1} occurred in 1999 (Figs. 94 and 95). Significant interactive effects between planting date and row spacing did not occur in 2000 for rows of kernels ear^{-1}, kernels row^{-1}, and total kernels ear^{-1} ($P > 0.05$). In 1999, 38-cm row spacing produced significantly ($P < 0.05$) more kernels row^{-1} and total kernels ear^{-1} than 76-cm row spacing for the 21 April 1999 planting date. Differences between 38- and 76-cm row spacing for the 25 May 1999 and 14 June 1999 planting date were not significant ($P > 0.05$).

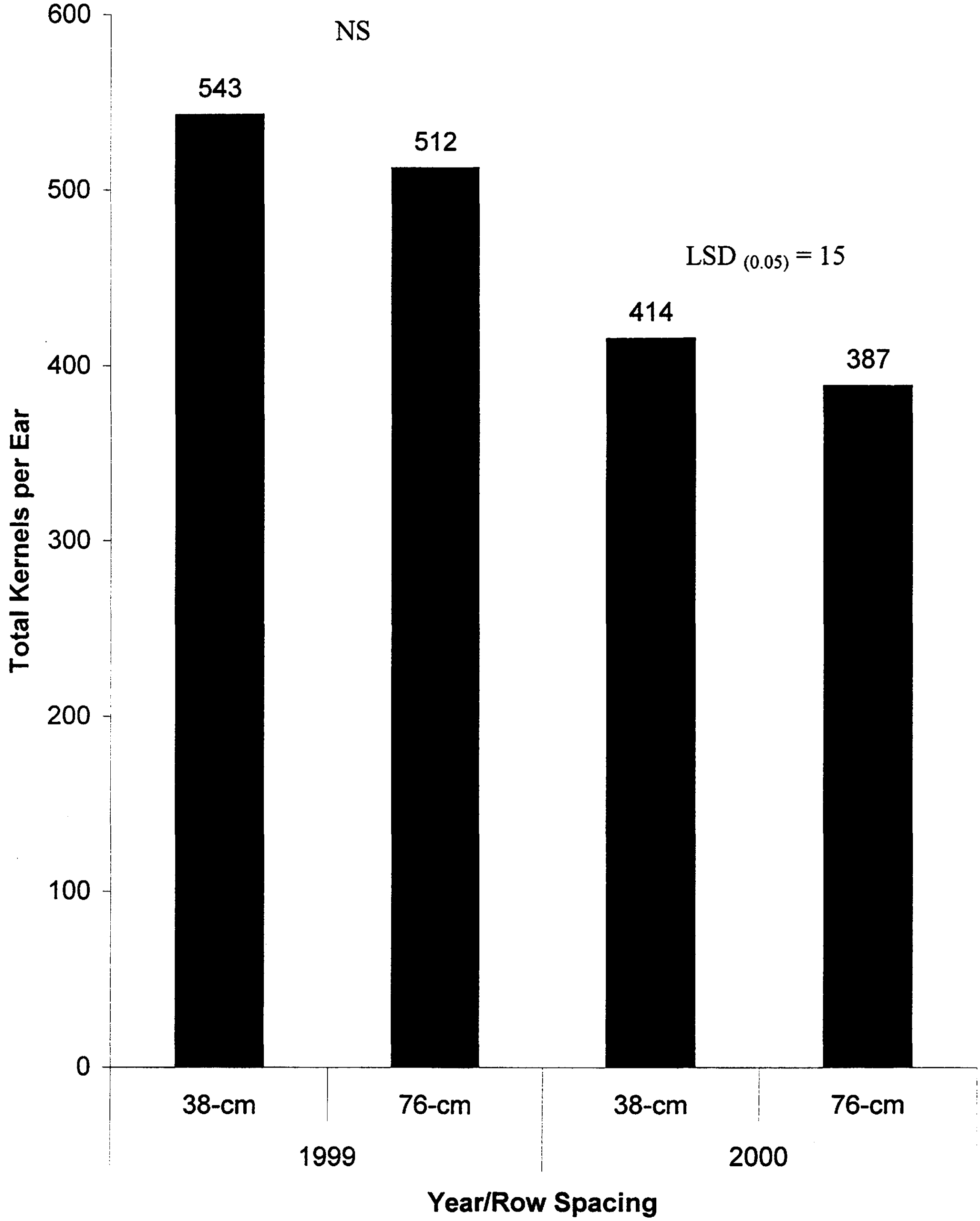


Fig. 93. Effect of row spacing on total kernels ear^{-1} at Kanawha, IA, 2000.

Mean comparisons are between row spacings within years.

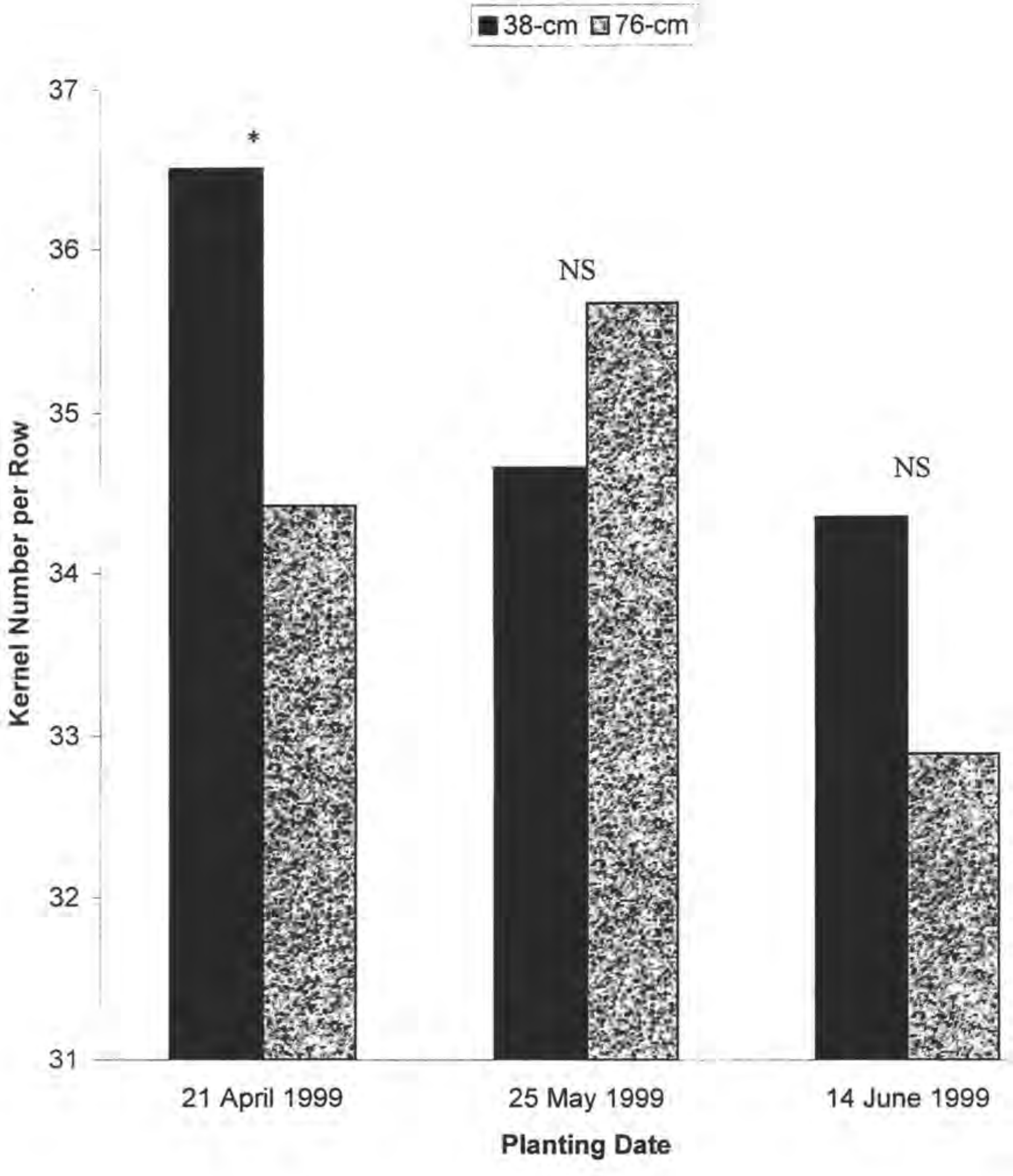


Fig. 94. Interactive effect of planting date and row spacing on kernels row^{-1} at Kanawha, IA.

NS = no significance between treatments ($P > 0.05$).

* = significant differences between treatments ($P < 0.05$).

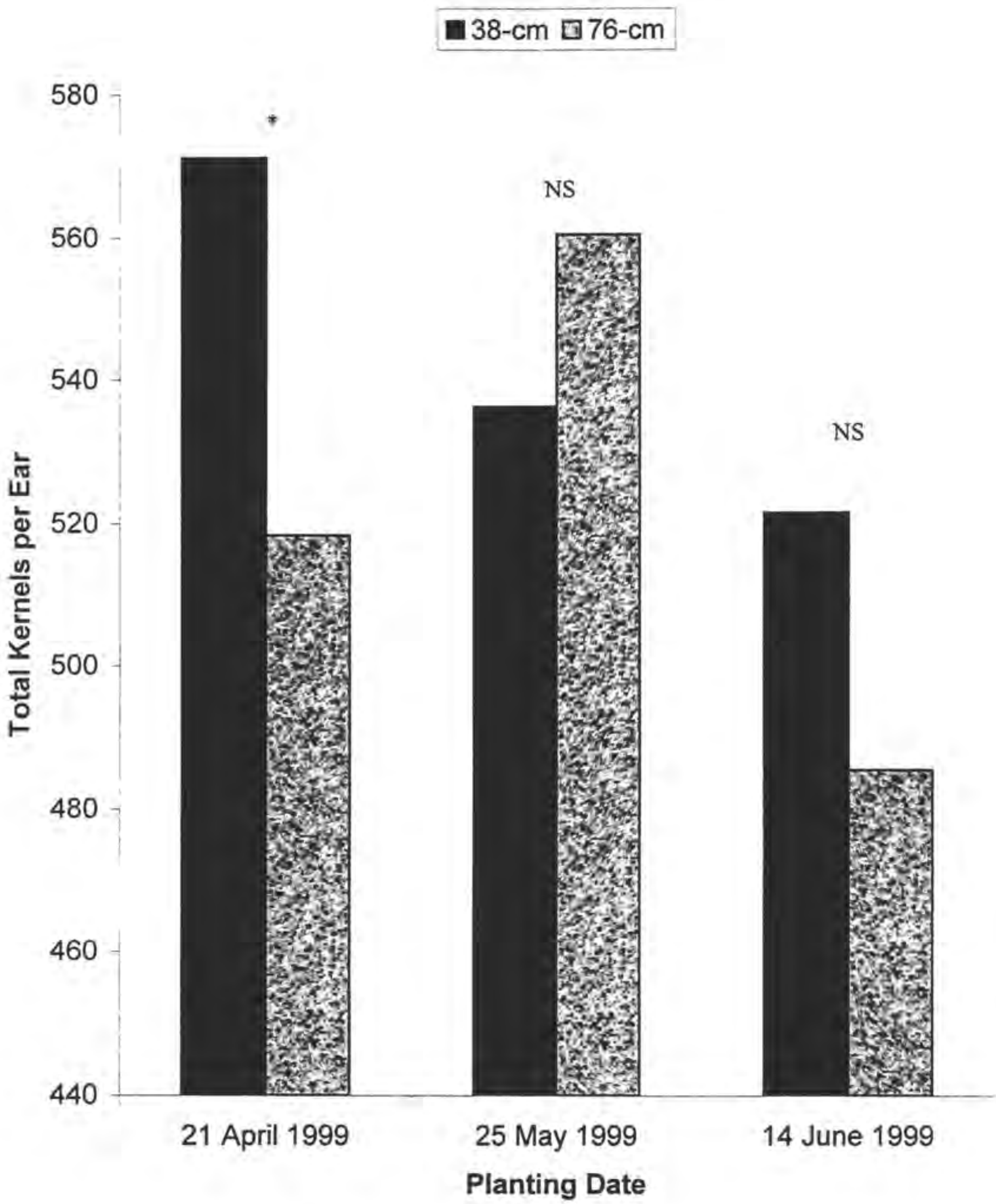


Fig. 95. Intereactive effect between planting date and row spacing for total kernels ear^{-1} at Kanawha, IA.

NS = no significance between treatments (P > 0.05).

* = significant differences between treatements (P < 0.05).

Interactive effects between hybrid and starter fertilizer on total kernels ear^{-1}

Significant ($P < 0.05$) interactive effects between hybrid and starter fertilizer on total kernels ear^{-1} occurred in 2000 (Fig. 96). Interaction between hybrid and starter fertilizer was not significant in 1999. In 2000, 33A14 did not respond significantly ($P < 0.05$) to starter fertilizer for total kernels ear^{-1}. Hybrid 34R07 and 35N05 responded significantly ($P < 0.05$ and $P < 0.01$, respectively) to starter fertilizer for total kernels ear^{-1}. Gordon et al. (1997) reported a hybrid and starter fertilizer interaction for final grain yield. Despite increases in kernel number due to starter fertilizer for 34R07 and 35N05, a significant interaction between hybrid and starter fertilizer on final grain yield was not observed at Kanawha in either 1999 or 2000.

Main effect of planting date on weight kernel^{-1}

Significant effects ($P < 0.01$) for planting date effect on kernel weight occurred in 1999 and 2000 (Fig. 97). As planting date was delayed in both years, kernel weight was decreased significantly. This observation is similar to what was observed in Ames and similar to what Andrade and Cirilo (1996) observed. Total kernels ear^{-1} were not strongly correlated to yield in 1999 and 2000 ($R^2 = 0.04$ and 0.01, respectively). The differences in yield between planting dates were correlated to final kernel weight more strongly than to kernel number (Figs. 98, 99, 100, 101).

Main effects of hybrid, row spacing and starter fertilizer on weight kernel^{-1}

Significant differences ($P < 0.01$) between hybrids for weight kernel^{-1} occurred in 1999 and 2000 (Fig. 102). In both years, 33A14 and 34R07 produced similar kernel weight and produced heavier kernel weight compared with 35N05. This is similar to what occurred

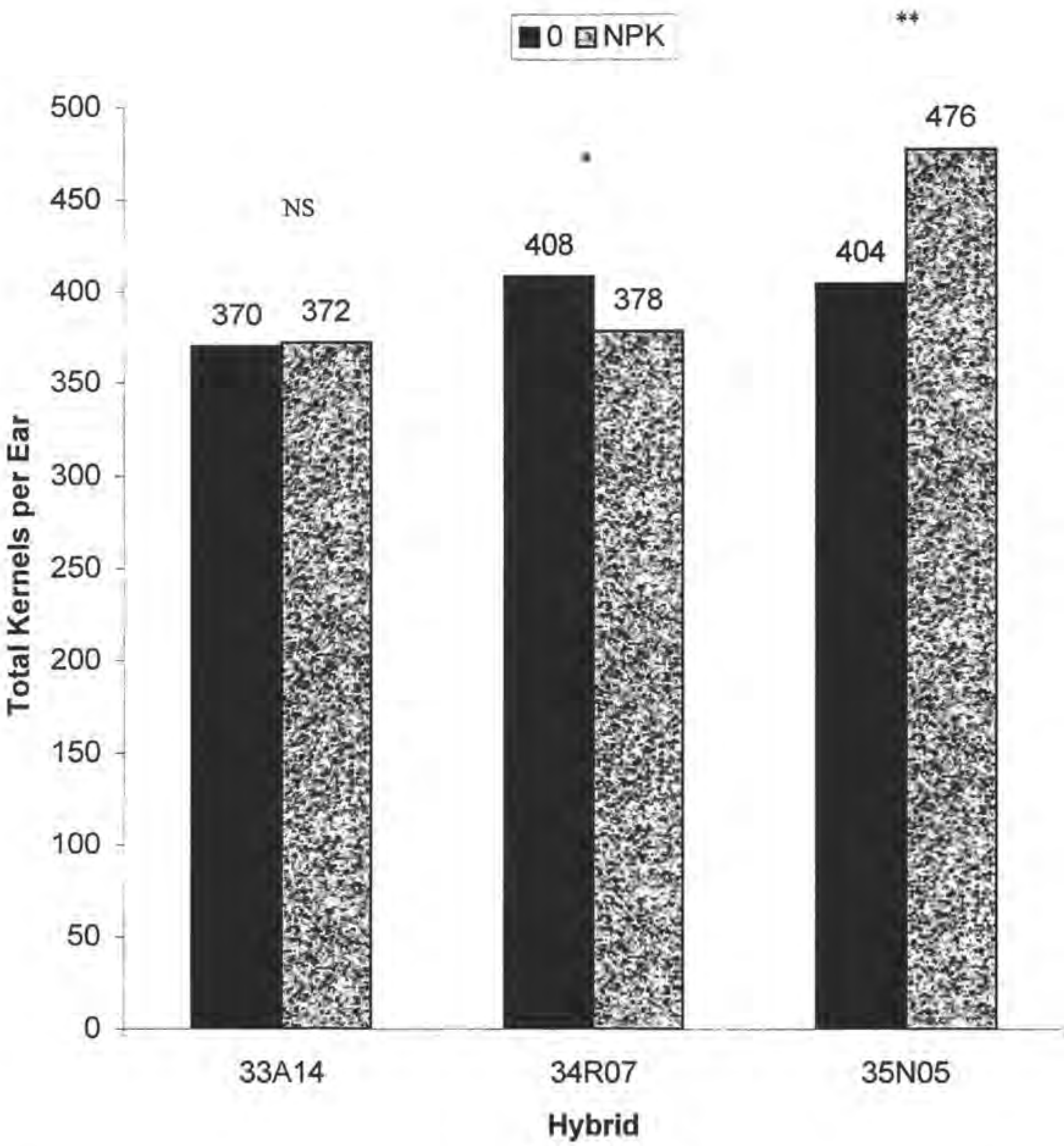


Fig. 96. Interactive effects between hybrid and starter fertilizer on total kernels ear^{-1} at Kanawha, IA, 2000.

NS = no significance between treatments (P > 0.05).

* = significant differences between treatments (P < 0.05).

** = significant difference between treatments (P < 0.01).

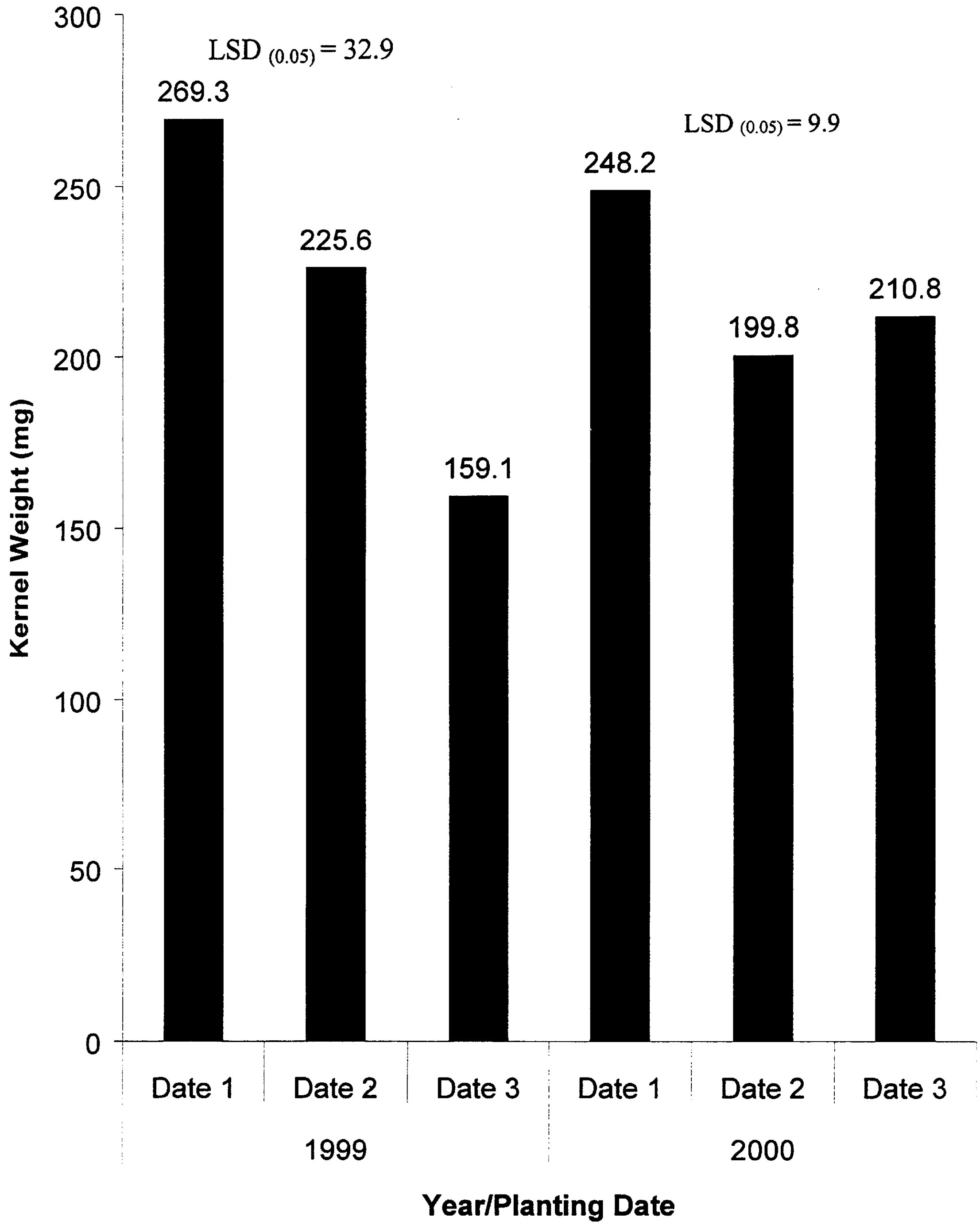


Fig. 97. Main effect of planting date on weight kernel^{-1} at Kanawha, IA.

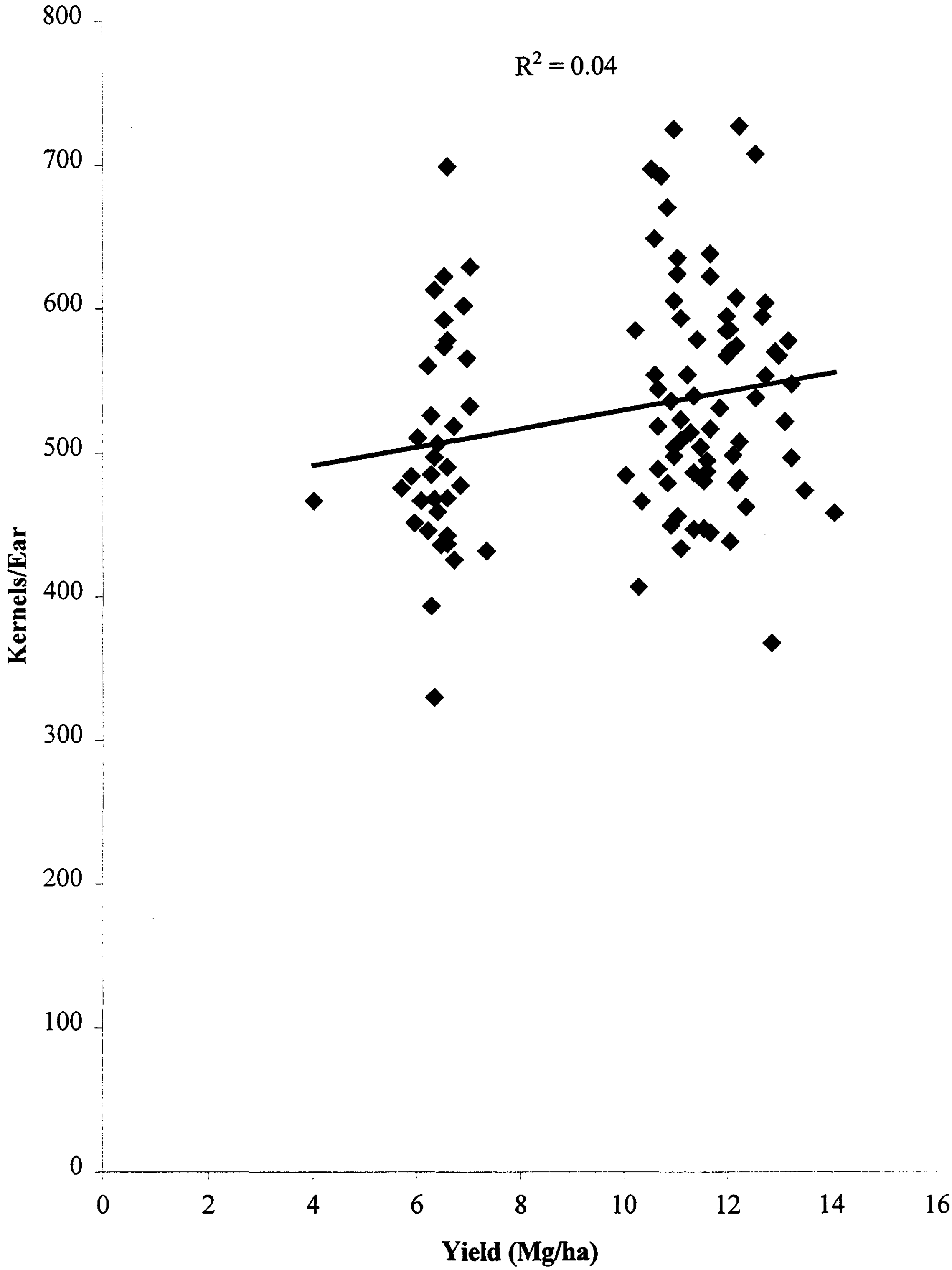


Fig. 98. Correlation between kernels ear^{-1} and final grain yield at Kanawha, IA, 1999.

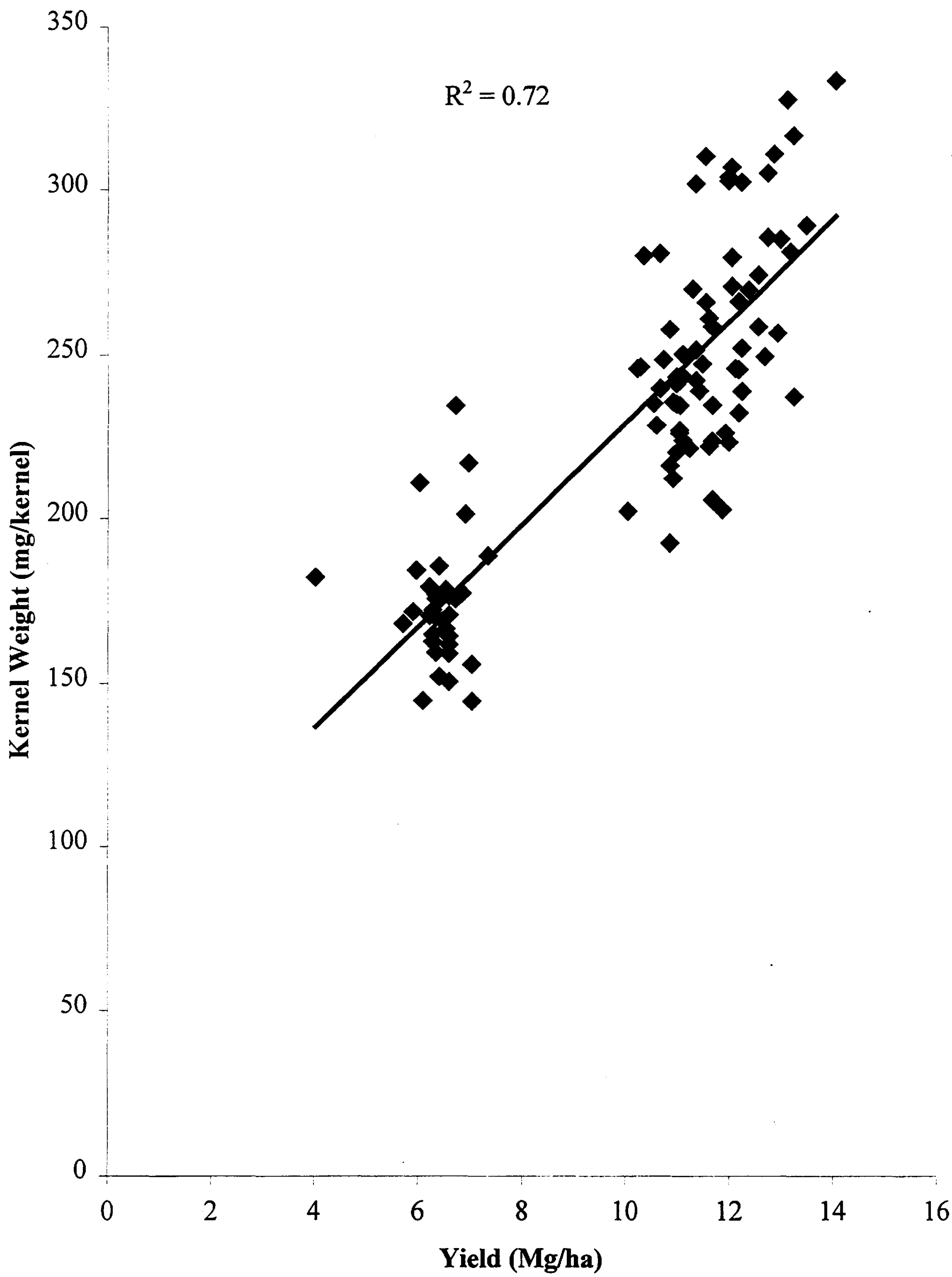


Fig. 99. Correlation between kernel weight and final grain yield at Kanawha, IA, 1999.

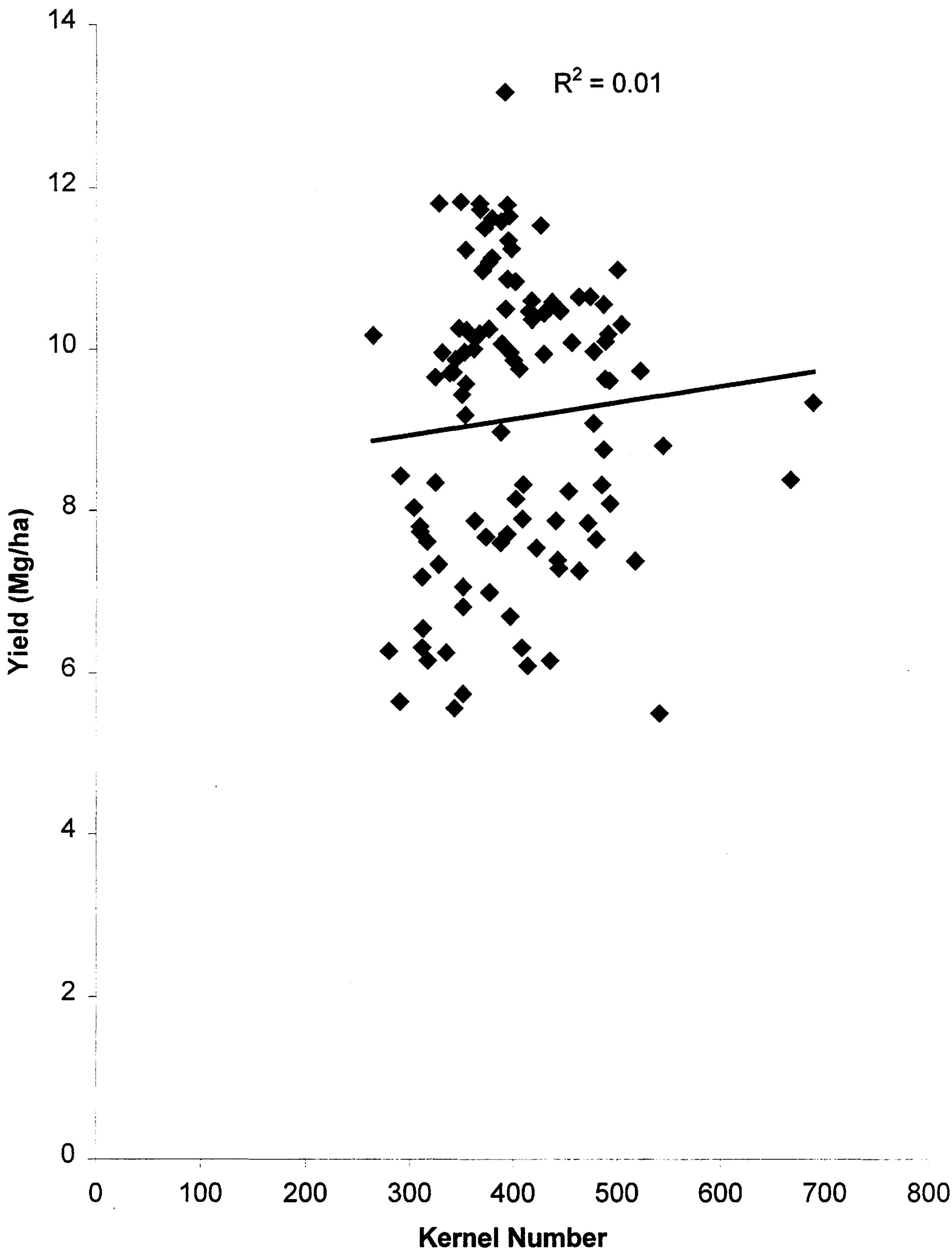


Fig. 100. Correlation between kernel number ear^{-1} and grain yield at Kanawha, IA, 2000.

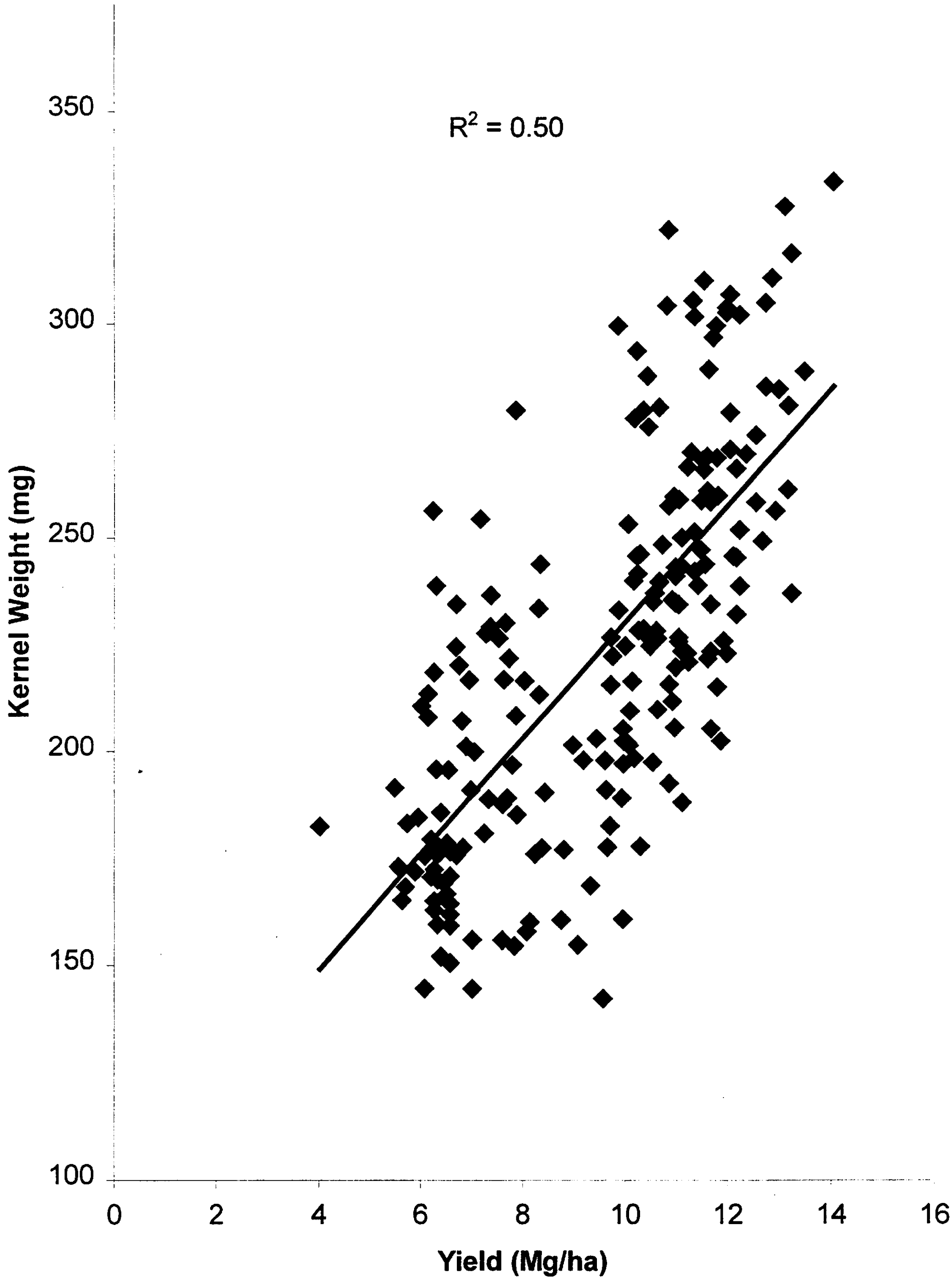


Fig. 101. Correlation between kernel weight and yield at Kanawha, IA, 2000.

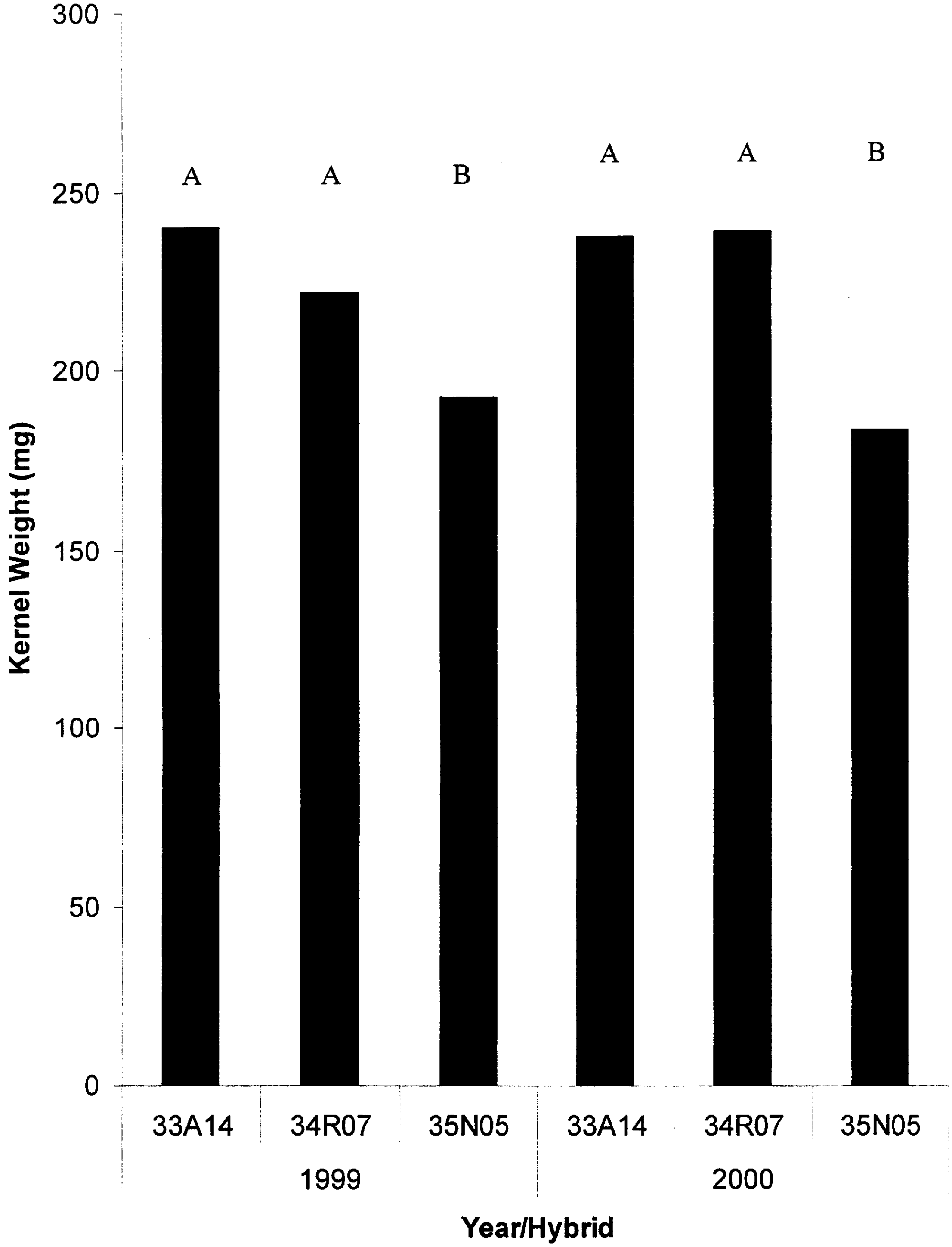


Fig. 102. Main effect of hybrid on weight kernel^{-1} at Kanawha, IA.

Means within year with the same letter are not significantly different (P > 0.05).

in Ames. Significant interactions between hybrid and starter fertilizer and an interaction between planting date and hybrid occurred in both years as well as an interaction between planting date, hybrid, and starter fertilizer occurred in 2000. These interactions will be addressed later. Row spacing and starter fertilizer did not have significant effects on weight kernel in 1999 or 2000.

Interactive effects of planting date and hybrid on weight kernel^{-1}

Significant ($P < 0.01$) interactive effects between planting date and hybrid occurred in 1999 and 2000. The 2000 interaction will be covered under the interaction between planting date, hybrid, and starter fertilizer. Hybrids 34R07 and 33A14 produced similar ($P > 0.05$) kernel weights for the 21 April 1999 planting date (Fig. 103). Hybrids 34R07 and 33A14 produced significantly ($P < 0.01$) heavier kernel weight compared with 35N05 for the 21 April 1999 planting date. Hybrids 33A14 and 35N05 produced similar ($P > 0.05$) kernel weights for the 25 May 1999 planting date. Hybrid 34R07 produced significantly lower kernel weight compared with 33A14 and 35N05 ($P < 0.01$ and $P < 0.05$, respectively). Hybrids 33A14 and 34R07 produced similar ($P > 0.05$) for the 14 June 1999 planting date and both produced significantly ($P < 0.01$) heavier kernel weight than 35N05.

Interactive effect of planting date and starter fertilizer on weight kernel^{-1}

Significant ($P < 0.05$) interactive effects between planting date and starter fertilizer occurred in 1999 but did not occur in 2000 ($P < 0.05$). In 1999, significant differences ($P < 0.05$) between fertility regimes occurred for the 25 May and 14 June planting dates (Fig. 104). Significant difference between fertility regimes did not occur ($P > 0.05$) for the 21 April 1999 planting date. Kernel weight for starter fertilizer treated plots was significantly

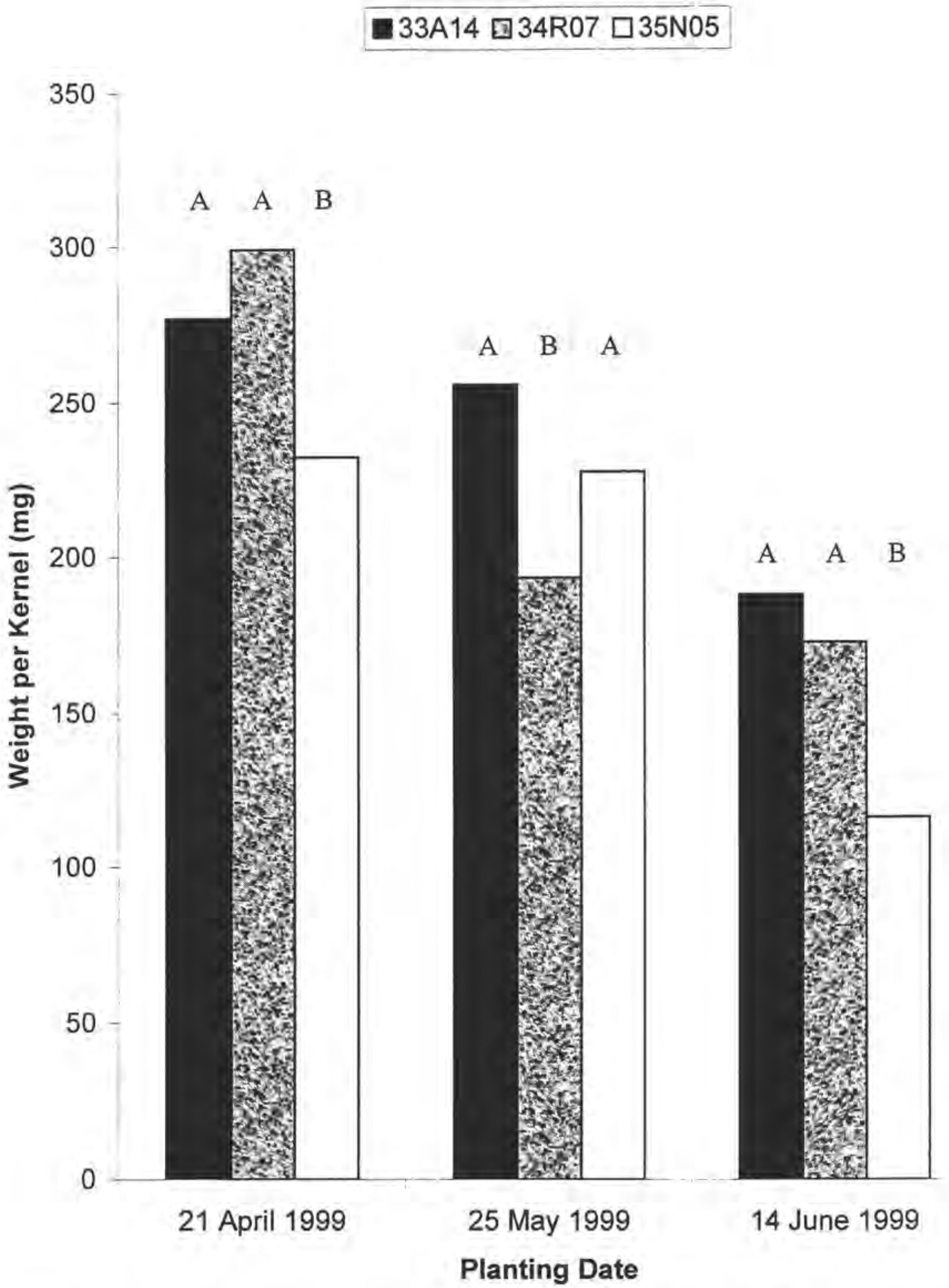


Fig. 103. Interactive effect of planting date and hybrid on weight kernel^{-1} at Kanawha, IA. Means within planting dates with the same letter are not significantly different ($P > 0.05$).

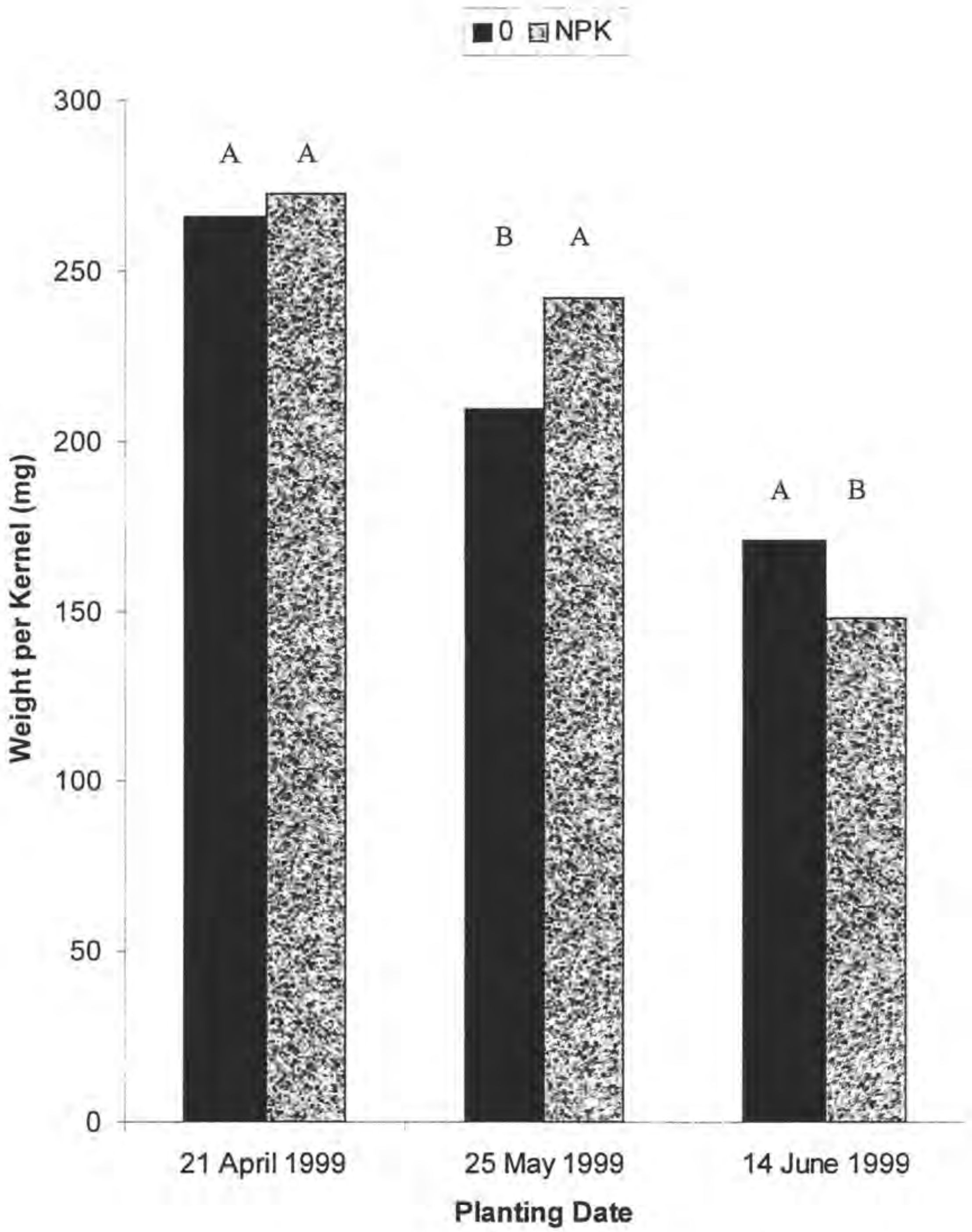


Fig. 104. Interactive effect of planting date and starter fertilizer on weight kernel^{-1} at Kanawha, IA.

Means within planting dates with the same letter are not significantly different ($P > 0.05$).

greater ($P < 0.05$) than plots with no starter fertilizer for the 25 May 1999 planting date and significantly less than plots with no starter fertilizer for the 14 June 1999 planting date.

Interactive effect of hybrid and starter fertilizer on weight kernel^{-1}

Significant interactive effect between hybrid and starter fertilizer for weight kernel^{-1} occurred in 1999 and 2000 ($P < 0.01$ and $P < 0.05$, respectively). The interaction between hybrid and starter fertilizer for kernel weight in 2000 will be covered later with the interaction between planting date, hybrid, and starter fertilizer. In 1999, 33A14 did not respond significantly ($P > 0.05$) to starter fertilizer for kernel weight (Fig. 105). Kernel weight for 34R07 was significantly greater ($P < 0.01$) for starter fertilizer treated plots compared with plots with no starter fertilizer. Kernel weight for 35N05 was significantly greater ($P < 0.01$) for plots with no starter fertilizer compared with plots with starter fertilizer. Significant interactions between hybrid and starter fertilizer did not occur for grain yield at Kanawha, however, both 34R07 and 35N05 produced significantly more kernels ear^{-1} for starter fertilizer treated plots compared with no starter fertilizer treated plots.

Interactive effect of planting date, hybrid and starter fertilizer on weight kernel^{-1}

Significant ($P < 0.01$) interactive effects between planting date, hybrid, and starter fertilizer occurred in 2000 but did not occur in 1999 ($P > 0.05$). In 2000, kernel weight for 33A14 was significantly less ($P < 0.01$) for starter fertilizer treated plots compared plots with no starter fertilizer for the 15 April planting date (Fig. 106). Differences between fertility regimes for 33A14 for the 15 May 2000 planting date were not significant ($P < 0.05$). Starter fertilizer significantly ($P < 0.01$) enhanced yields for 33A14 for the 8 June 2000 planting date. Hybrid 34R07 did not respond significantly ($P > 0.05$) to fertility regime for any of the

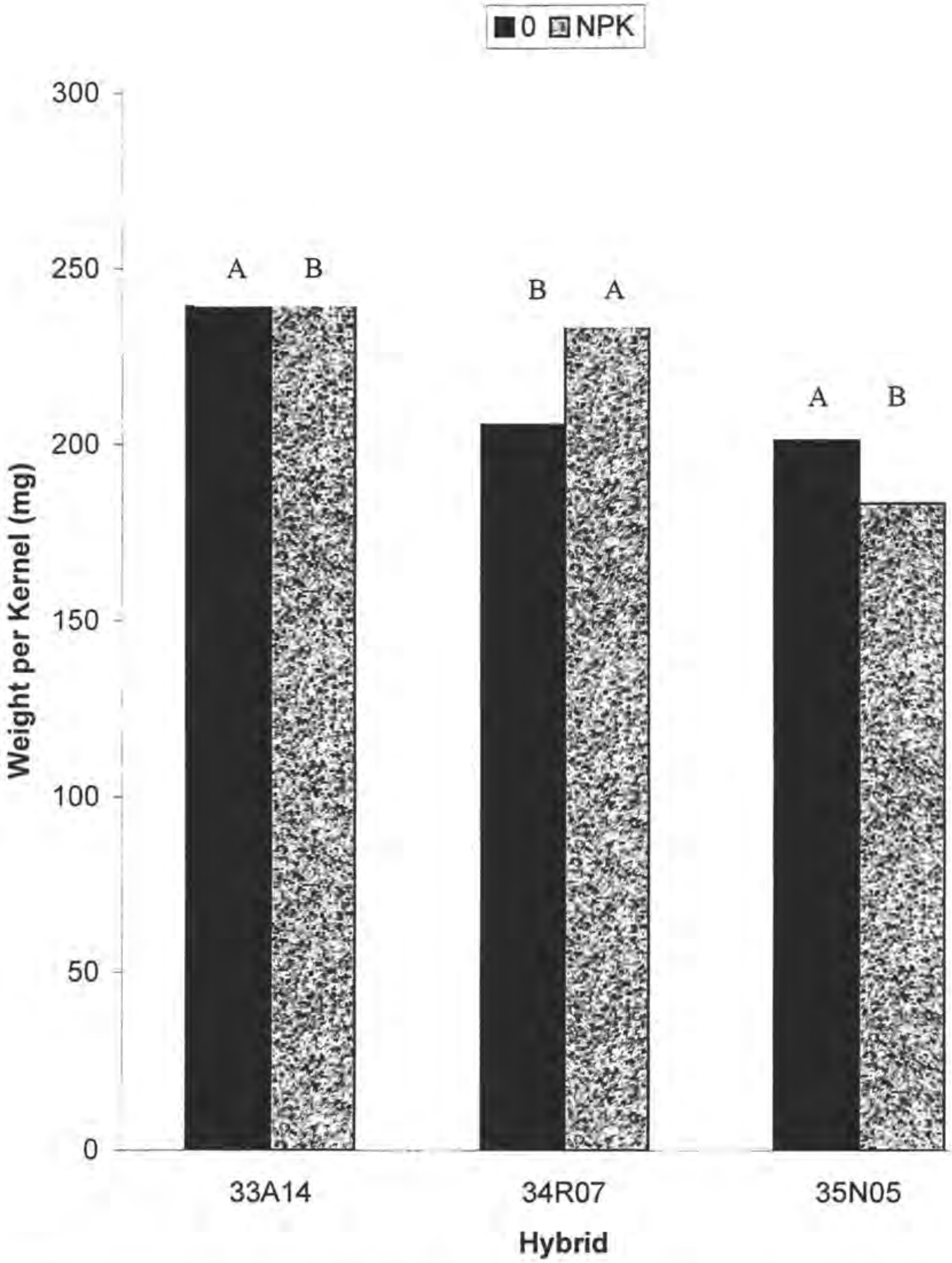


Fig. 105. Interactive effect of hybrid and starter fertilizer on weight kernel^{-1} at Kanawha, IA, 1999.

Means within hybrid with the same letter are not significantly different (P > 0.05).

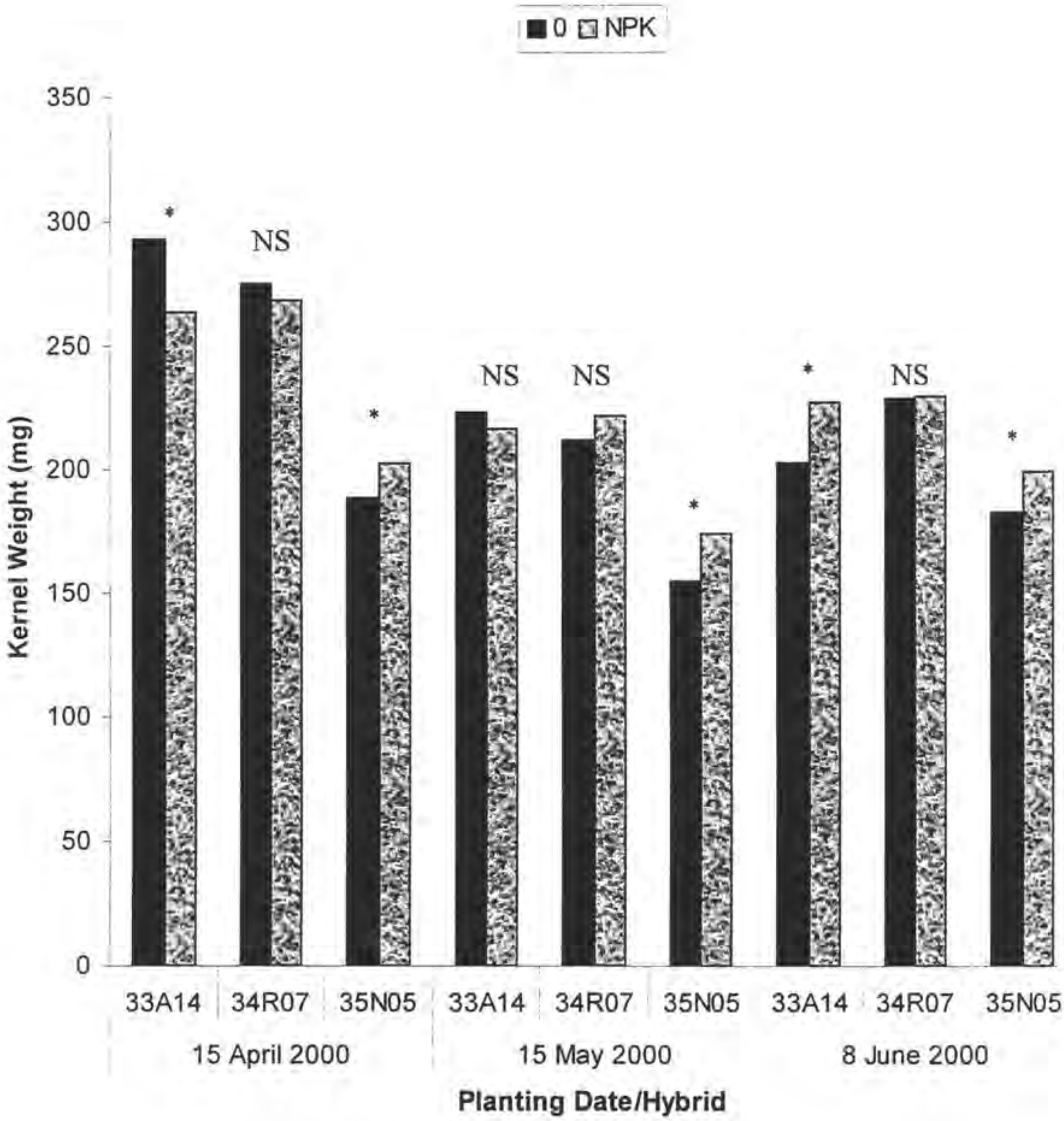


Fig. 106. Interactive effect of planting date, hybrid, and starter fertilizer on kernel weight at Kanawha, IA.

* = significant difference between fertility regimes within planting date and hybrid.

NS = no significant difference between fertility regimes within planting date and hybrid.

three planting dates in 2000. Starter fertilizer significantly enhanced yields for 35N05 for each of the three planting dates in 2000 (15 April, $P < 0.05$; 15 May, $P < 0.01$; 8 June, $P < 0.01$).

SUMMARY AND CONCLUSIONS

Large weather differences occurred between years and both the Ames and Kanawha locations. Weather during 1999 was wet and cool during the spring with timely rainfall occurring throughout the growing season with a dry period starting in August and continuing through the fall. The dry period continued into the spring of 2000, with precipitation well below the 50-year average at Ames. Precipitation at Kanawha was close to the 50-year average in 2000 from April through August followed by a dry September and a normal October. Differences in yield and yield components between years can be largely attributed to differences in precipitation.

Delays in planting caused significant decreases in yield at both locations. Significant decreases in yield occurred as planting date was delayed in all cases except for the 3 May 1999 and 10 May 1999 planting dates at Ames. In the case where significant decrease in yield as planting date was delayed was not found, it was due to a small delay in planting. Similar research has also found decreases in yield as planting date is delayed (Lauer, 1997; Mulder and Doll, 1994, Nafziger, 1994, Swanson and Wilhelm, 1996). The yield decreases in this study were larger than recent studies in Iowa (Farnham, unpublished). The higher magnitude is potentially due to differences in genetics used in each experiment or year and location differences. Yield differences between planting dates are highly correlated to kernel weight at Ames in 1999 and for both years at Kanawha. During 2000, kernel number and kernel weight were similarly correlated to yield at Ames. Previous research has found that potential kernel number is not altered by delays in planting suggesting that kernel abortion is the dominant factor causing differences in kernel number (Otegui and Melón, 1997; Cirilo and Andrade, 1994). Results from this study agree with these findings suggesting that delays in planting date do not alter potential kernel number and yield decreases are largely due to decreases in kernel weight. An inverse relationship between grain moisture and planting date occurred in each year. Significant difference did not occur between 3 May 1999 planting date compared with the 10 May planting date and the 11 April 2000 planting date compared with the 11 May 2000 planting date at Ames. Sufficient time and weather that was optimum for drying allowed the second planting dates to dry to levels similar to the first planting date. Significant differences occurred between each planting date at Kanawha in both years. Conditions at Ames were warmer than Kanawha, which is potentially the reason for the differences in grain drying.

Delays in planting caused decreases in days to mid-silk. Growing degree units to mid-silk decreased due to delays in planting in all cases except for 1999 at Kanawha, IA, where the 25 May 1999 planting date required more growing degree units to mid-silk and the 21 April and 14 June planting required similar growing degree units to mid-silk. Several studies have showed that maize development is influenced by temperature and photoperiod differences (Yan and Wallace, 1998; Birch et al., 1998; Ellis et al., 1992; Bonhomme et al., 1994; Ellis et al., 1992). The differences between planting dates, where hastened development to mid-silk occurred, were likely due to seasonal temperature and photoperiod differences.

Interactions between planting date and hybrid on grain yield and moisture occurred at both Ames and Kanawha. Grain moisture increased at a higher rate as planting date was delayed in the longer season hybrids in this trial in all cases except for 1999 in Ames. This is similar to what has been observed in recent trials in Iowa by Farnham (unpublished) and to what Lauer et al. (1999) observed in Wisconsin. Yield decreased at a slower rate with 35N05, which is a shorter season hybrid than 34R07 and 33A14. Recent research in Iowa has shown a similar relationship between maturity ranges (Farnham, unpublished). Lauer et al. (1999) also observed that shorter season hybrids tend to have a slower rate of yield decrease as planting date is delayed. Shifts in planting intentions based on hybrid maturity should occur in mid-late May in the areas from this study based on expected yield and harvest moisture.

Significant interaction between planting date and row spacing occurred in 1999 at both Ames and Kanawha and in 2000 at Kanawha for yield. Significant differences between 38-cm row spacing compared with 76-cm row spacing occurred for the June planting dates in 1999. Increased yield resulted from 38-cm row spacing treatments. Roth et al. (1999) reported increased corn silage yields as planting date was delayed from 38-cm row spacing. Barbieri et al. (2000) reported increased grain yields for 38-cm row spacing compared with 76-cm row spacing for corn grown under nitrogen limitations. The findings in this experiment and from other studies, suggest that advantages to using 38-cm row spacing may exist when conditions that may limit carbon assimilation exist.

Means of 38-cm and 76-cm row spacing averaged over all other treatments were not significantly different in either year. Several others have suggested that yield differences due to narrower row spacing are small and inconsistent (Alessi and Power, 1974; Benson, 1995; Blitzer and Herbeck, 1997; Dysinger and Kells, 1997; Farnham, 2001; Johnson et al, 1998; Lutz et al., 1970; Ottman and Welch, 1989; Rzewnicki, 1997; Westgate et al., 1997). Differences between 38- and 76-cm row spacing for fraction of intercepted photosynthetic radiation tended to be insignificant around period of reproductive development. Westgate et al. (1997) suggested that the opposite and alternate pattern of leaf display in maize potentially restricts improved light interception through narrower row spacing. Farnham (personal communication) suggested that the inability of maize to produce secondary ears, tillers or branches with ears at high populations, even when planted in narrow rows, restricts yield improvements in 38-cm row spacing compared with 76-cm row spacing.

Seasonal pattern of leaf area index expressed as a function of growing degree units improved at a faster rate for 38-cm row spacing compared with 76-cm row spacing in most cases. Potential advantages to using 38-cm row spacing to close the canopy sooner may include improved crop competitiveness with weed species and reduced soil erosion. While this study did not observe weed species presence and survival, Teasdale (1995) reported improved crop competitiveness with weed species for 38-cm row spacing compared with 76-cm row spacing. Potentially, differences in canopy closure for 38-cm row spacing compared with 76-cm occurs during the time when weed species are a problem and any escapes need to be treated with a post-emergence herbicide. Differences between fertility regimes were not significantly different for leaf area index with the exception of the 9 June 2000 planting date at Ames. This is different from what Bullock et al. (1993) observed where leaf area index was significantly higher at points up to flowering. Potentially, differences between years, soil conditions, and nutrient levels may create differences between fertility regimes where leaf area index will be improved for starter fertilizer treatments.

Producers should rely on calendar date recommendations in determining optimum planting date. Planting dates between late April to early May should result in maximum yields in most years. Decisions based on hybrid maturity should be based on calendar date, drydown characteristics, and yield performance. As planting date is delayed into late May and June, a shift from full season hybrids to shorter season hybrids should occur to take advantage of more stable yields and lower grain moisture from shorter season hybrids at late planting dates. Narrow row spacing will produce small and inconsistent increases in yield. Decisions to use narrower row spacing should be based on equipment cost and potential returns. Other crops such as soybeans may provide economic advantages to narrower row spacing over time but maize is unlikely to provide advantages in terms of increased yield. As planting date is delayed into June, in some cases use of narrow row spacing may improve yields. Producers who are equipped to plant and harvest maize in narrow rows may consider this option under delayed planting situations. Advantages to the use of starter fertilizer are likely to occur under conditions where soil test levels are low and/or soil conditions are cool and wet. Decisions to use starter fertilizer should be based initially on soil test values and secondly on soil conditions at planting.

CROP MODELING

Introduction

Interest in crop modeling has increased with advances in computers. Crop modelers attempt to capture experience from previous research to develop a forecasting tool for subsequent experiences. Some models are used in practical applications such as by commodity traders and by producers in actual production decisions. A program that probably isn't considered strongly in crop modeling but does forecast economic loss due to weed presence is Weedsoft®, marketed by the University of Nebraska to serve as a learning tool and potentially a guide for economic weed control. This program forecasts results based on levels of weed infestation and predicted yield loss, then develops a recommendation or beginning plan of action. Other models such as CERES-maize forecast crop growth and development and yield based on soil, environment and genetic variables. A model that has recently gained commercial interest is the CROPGRO-Soybean model due to its success in predicting final yields and accounting for variability between years (Batchelor et al., 2000).

Attempts have been made to improve the accuracy of crop models over a wide range of conditions. In some cases, crop models are able to reasonably estimate yields based on genetic and environmental variables (Batchelor, personal communication). With continued improvements, crop modeling may be able to serve as a tool to predict interactions between genetics and environment allowing improved product placement as well as guide seasonal decisions such as nitrogen application.

Despite some promises, some view problems in using crop models due to the variable and complicated relationships between plants and the environment (Poluektov and Topaj, 2001; Sirontenko, 2001). Poluektov and Topaj (2001) stated that empirical models usually present reasonable calculations, however, their use in guiding scientific research is not valuable, ignoring potential practical applications. Despite opinions that crop modeling will not guide scientific research, scientific research may be able to improve crop modeling to serve as a tool that may help guide producers' input decisions. The purpose of this exercise is to apply the collected data from this experiment to a commonly used and adapted crop model to gain an understanding of crop modeling potential and limitations.

Materials and Methods

Data from the 1999 and 2000 experiments at Ames, IA and Kanawha, IA was used for this exercise. Planting date and hybrid were the treatments compared in the model output. Plant density, canopy weight, leaf area index, kernel weight, kernel number m^{-2}, and grain weight m^{-2} from the experiments was entered into a File T spreadsheet. Operations data including fertilizer applications, irrigation, planting date, and hybrid was entered into a text file. Calibration of genetic coefficients was done through comparing ratios for grain weight, kernel number, and silking date among the three hybrids for 1999 and 2000. Soils data was obtained from a previously established database. Weather data was obtained from weather stations near the research farms at Ames and Kanawha. The crop models used were CERES-maize and IACER990 – MAIZE. IACER990-MAIZE was used for final data comparison due to its ability to predict potential problems from excessive rainfall.

Results and Discussion

The crop model tended to predict lower maximum leaf area index than measured values at Ames for 2000 (Figs. 107, 108, and 109). Potentially, the total number of leaves predicted by the crop model was less than the actual number of leaves produced by the plant (Lizaso, personal

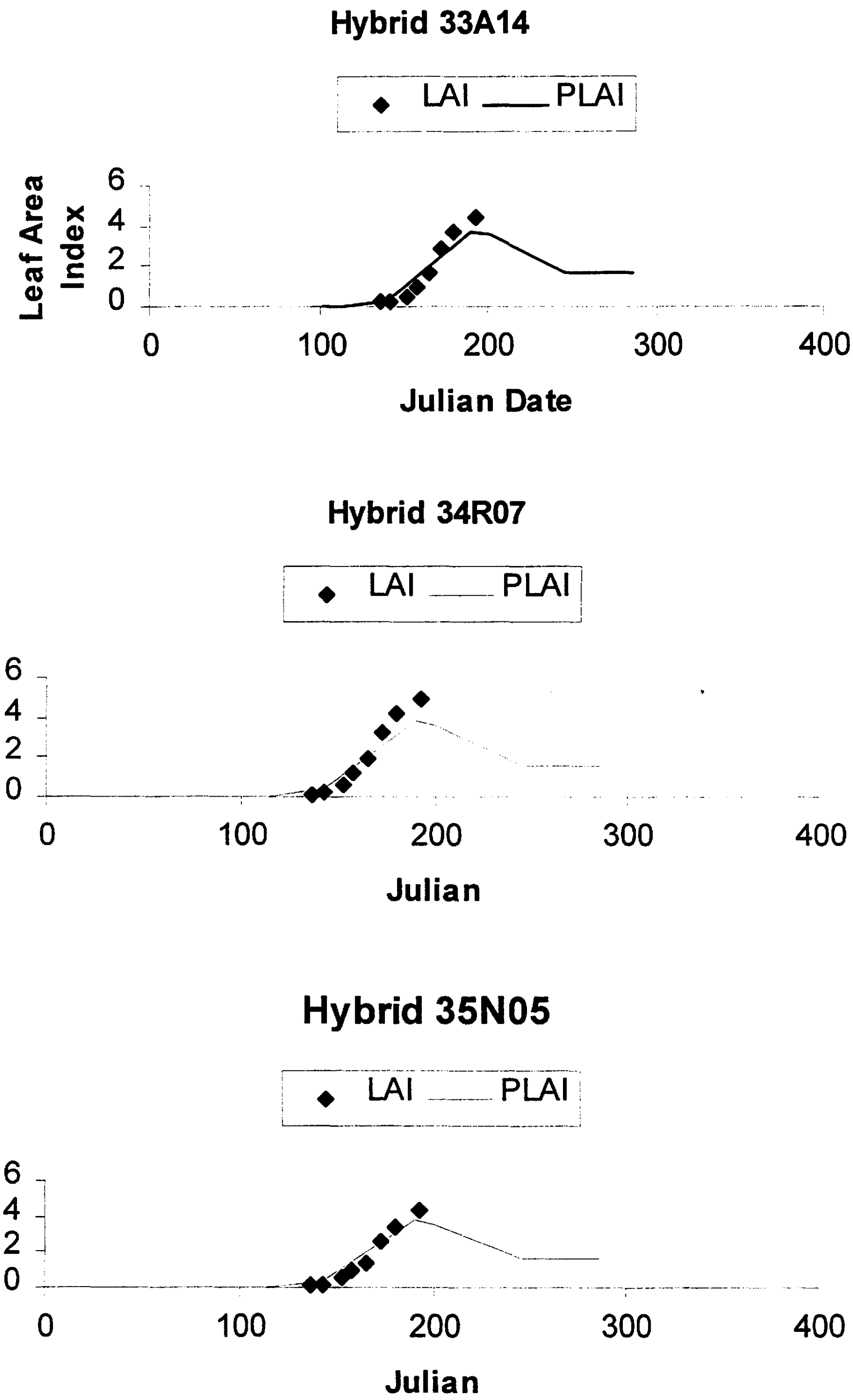
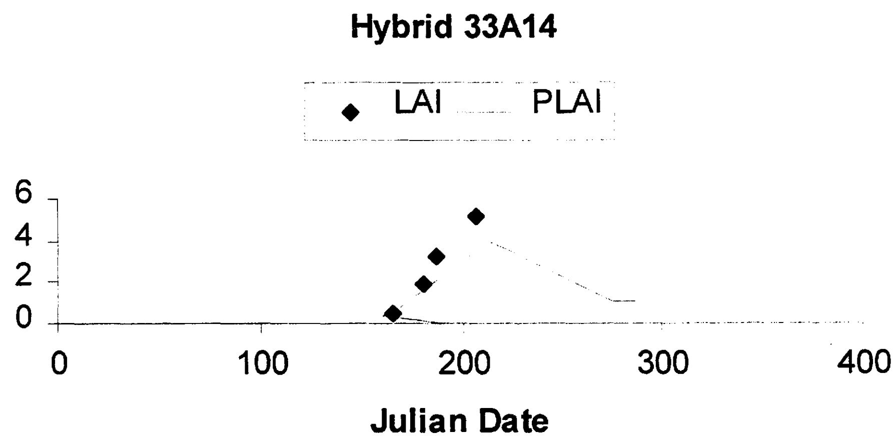
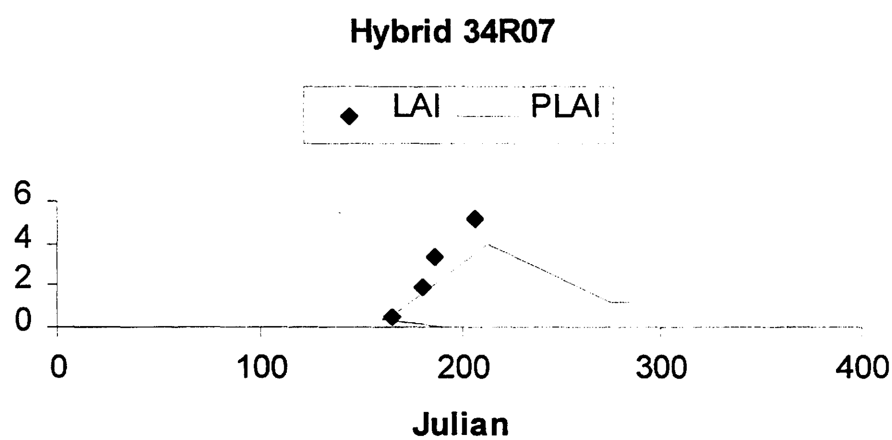


Fig. 107. Comparison of actual leaf area index readings (LAI) to predicted leaf area index (PLAI) readings for the 11 April 2000 planting date at Ames, IA.





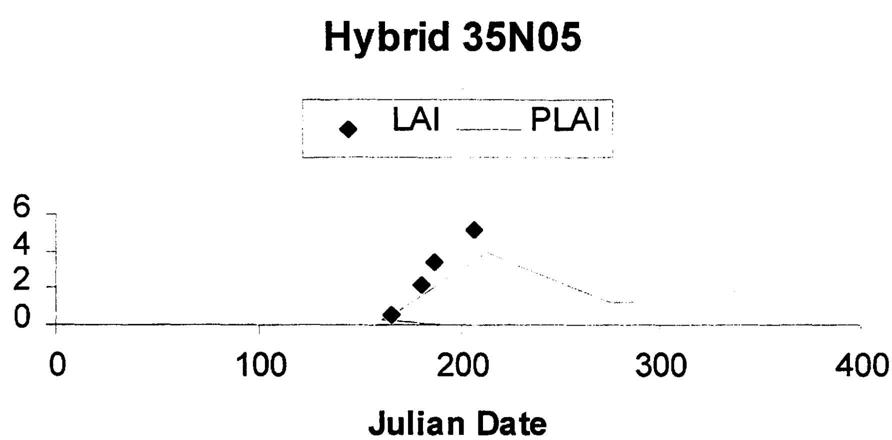


Fig. 108. Comparison of actual leaf area index readings (LAI) to predicted leaf area index (PLAI) readings for the 11 May 2000 planting date at Ames, IA.

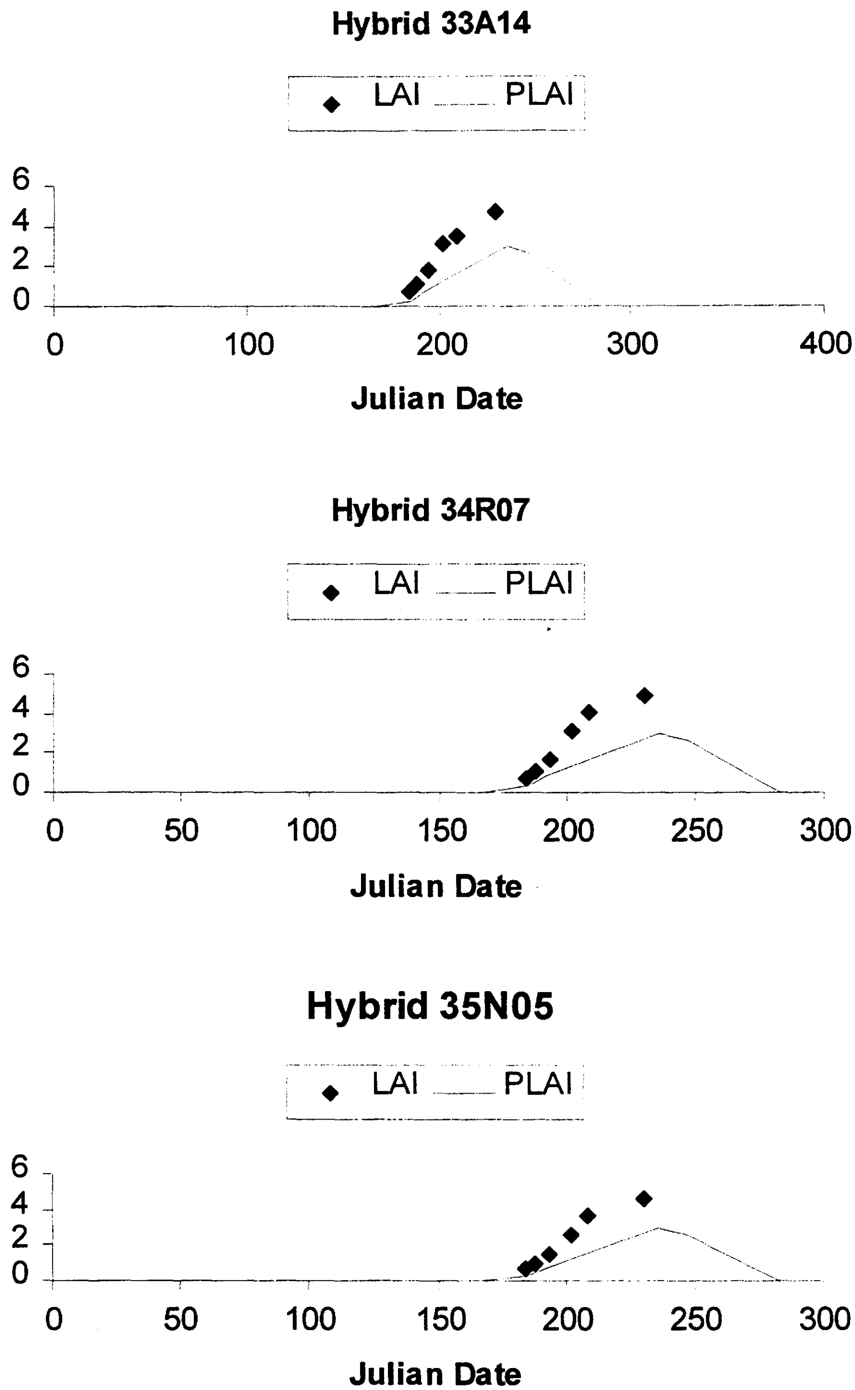


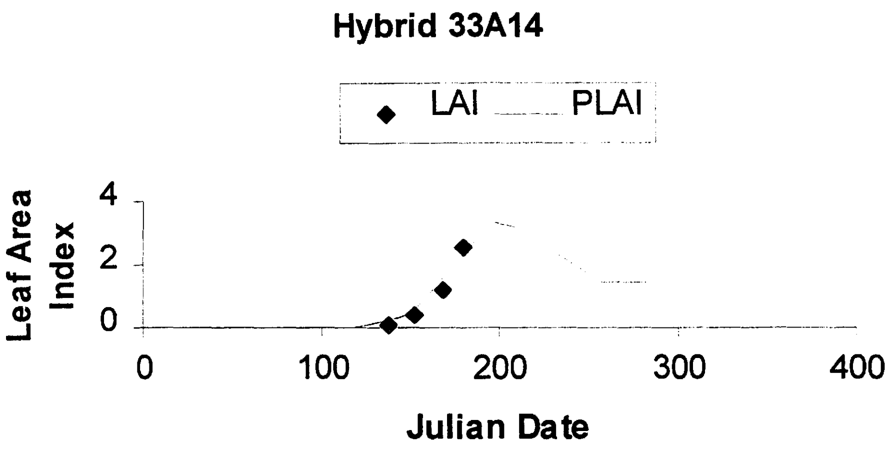
Fig. 109. Comparison of actual leaf area index readings (LAI) to predicted leaf area index (PLAI) readings for the 9 June 2000 planting date at Ames, IA.

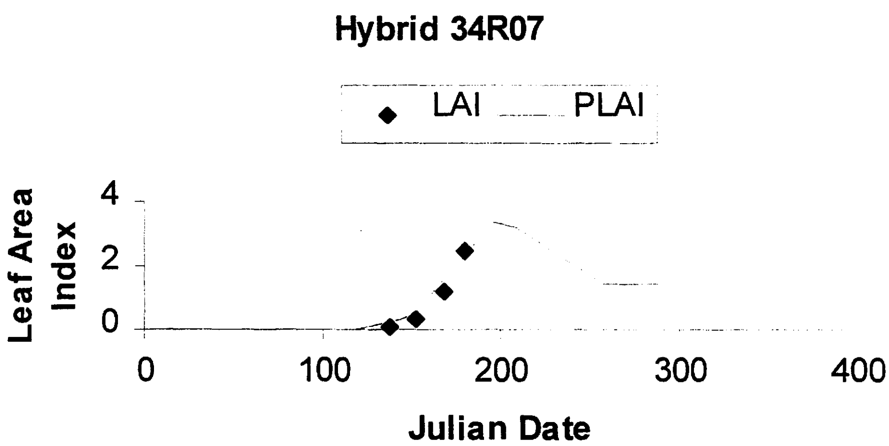
communication). Maximum leaf area index was not measured at Kanawha so it is impossible to compare model prediction of maximum leaf area index and actual maximum leaf area index (Figs. 110, 111 and 112). An exception is the second planting date at Kanawha where the model does under-predict maximum leaf area index, indicating that the model may not predict the actual number of leaves accurately (Fig. 111). Model prediction of leaf area index seems to produce a comparable slope to the actual data (Figs. 107, 108, 109, 110, 111, and 112).

The crop model tended to under-predict kernel number, kernel weight and grain weight more for the last planting date than the first or second planting dates in both years (Tables 12, 13, and 14). This was expected due to the difficulty in predicting late planting dates (Batchelor, personal communication). In some cases, kernel development was predicted to cease due to cold temperatures. Corn previously was thought to react this way under cold temperatures, however, it has been found that corn will still develop and the model has not been changed to reflect continued development (Batchelor, personal communication). In 1999, the model closely predicted yields at Ames compared to actual yields but did not predict yields closely at Kanawha (Table 13). In 2000, the model tended to under-predict yields at both locations.

Conclusions

Exposure to crop modeling provided an idea of the current limitations and future potential uses of crop modeling. Potential uses may include modeling of nutrient use and application timing, predicting interactions between genetics and environment, predicting effects of pest and disease pressure on crop performance, and as a tool in developing prescriptions in precision agriculture (Batchelor, personal communication). Advantages may exist in developing crop models as practical tools to aid producers and crop advisors in developing cropping plans allowing less potential for overlooking potential opportunities for economic gain.





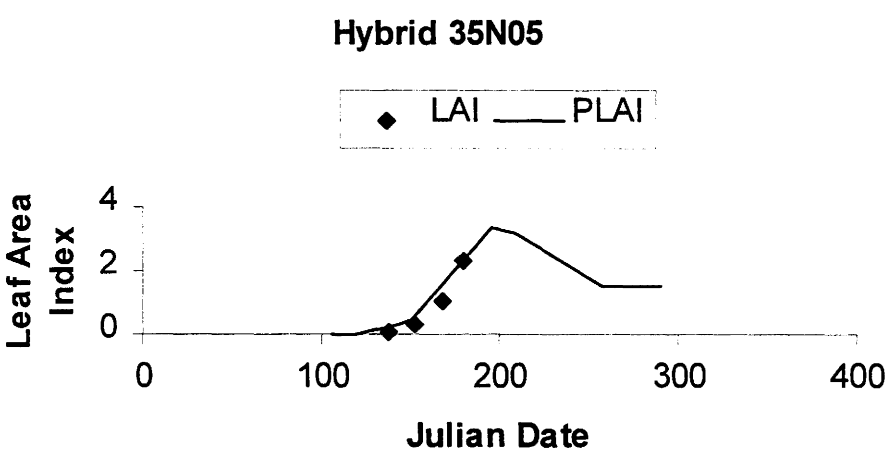
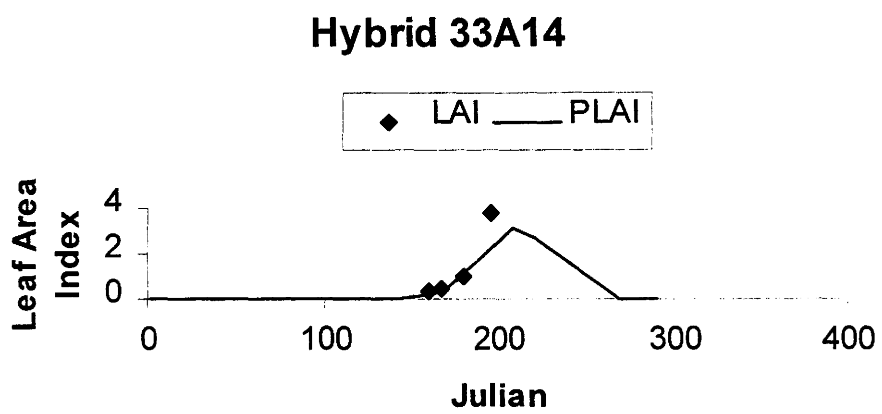
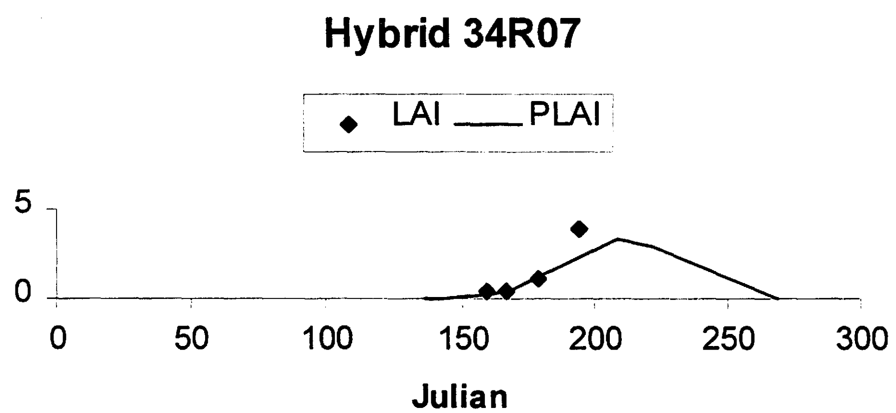


Fig. 110. Comparison of actual leaf area index readings (LAI) to predicted leaf area index (PLAI) readings for the 15 April 2000 planting date at Kanawha, IA.





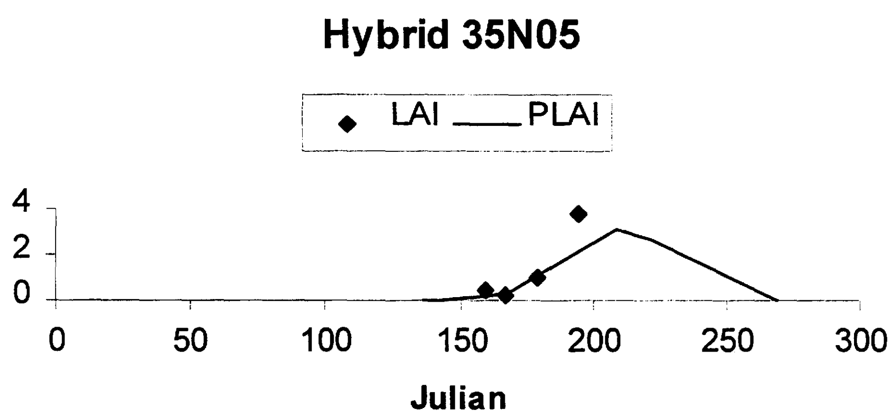
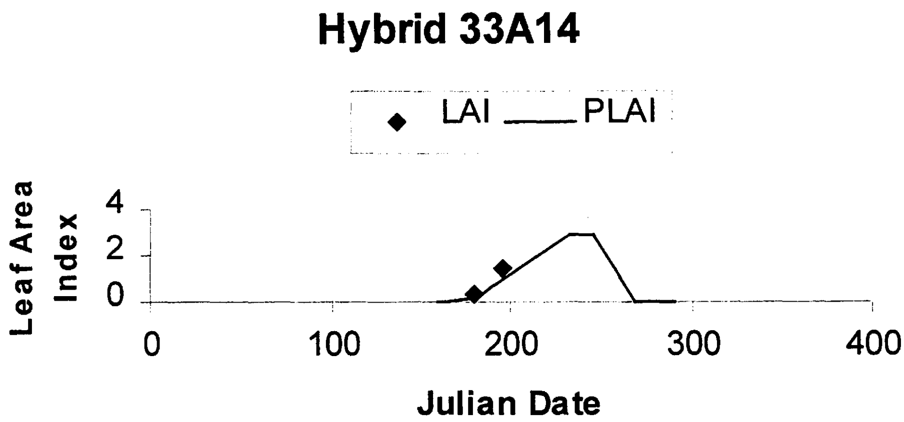
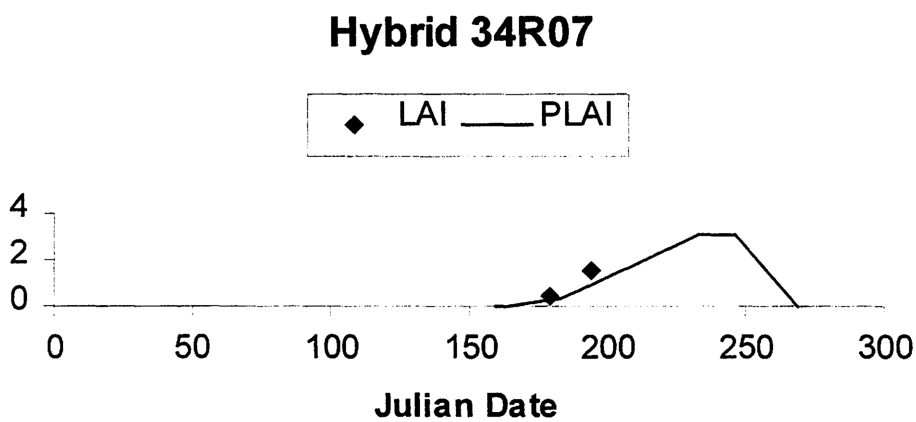


Fig. 111. Comparison of actual leaf area index readings (LAI) to predicted leaf area index (PLAI) readings for the 15 May 2000 planting date at Kanawha, IA.





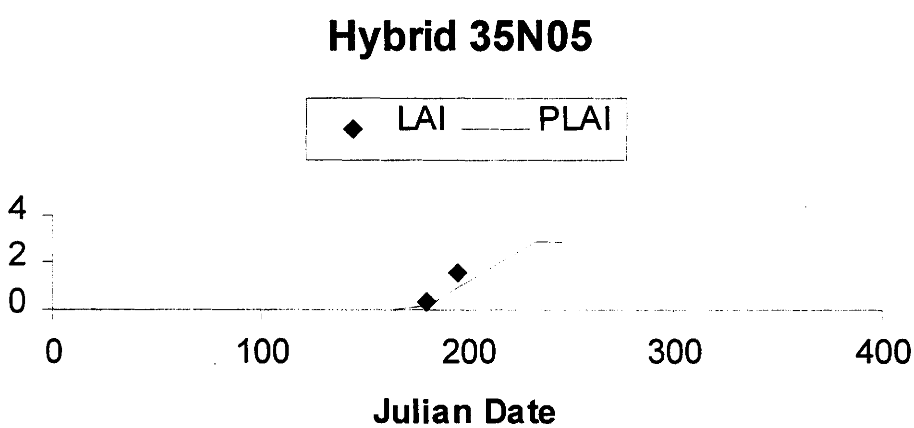


Fig. 112. Comparison of actual leaf area index readings (LAI) to predicted leaf area index (PLAI) readings for the 8 June 2000 planting date at Kanawha, IA.

Table 12. Average kernel number, average predicted kernel number, and difference between actual and predicted values for the treatments listed.

Year	Location	Hybrid	Planting Date	Ave. Kernel Number	Ave. Predicted Kernel Number	Difference
1999	Ames	33A14	1	498	511	13.4
			2	483	489	5.88
			3	352	411	59.1
		34R07	1	527	494	-32.5
			2	518	482	-35.9
			3	401	438	37.4
		35N05	1	610	547	-62.7
			2	595	549	-45.8
			3	464	488	23.8
	Kanawha	33A14	1	416	532	116
			2	375	483	108
			3	311	493	182
		34R07	1	451	510	58.9
			2	417	551	134
			3	346	472	126
		35N05	1	528	599	71.3
			2	487	611	124
			3	423	551	128
2000	Ames	33A14	1	382	385	2.96
			2	430	377	-53.5
			3	281	259	-21.7
		34R07	1	417	421	4.48
			2	465	388	-76.9
			3	317	285	-32.3
		35N05	1	494	528	34.3
			2	542	405	-137
			3	393	341	-52.5
	Kanawha	33A14	1	335	382	47.3
			2	357	364	7.19
			3	264	367	103
		34R07	1	370	397	26.7
			2	398	401	2.91
			3	259	382	123
		35N05	1	447	459	11.7
			2	469	486	17.0
			3	376	375	-1.24

Table 13. Average kernel weight, average predicted kernel weight, and difference between actual and predicted values for the treatments listed.

Year	Location	Hybrid	Planting Date	Ave. Kernel Weight	Ave. Predicted Kernel Weight	Difference
1999	Ames	33A14	1	300 mg	367 mg	-67.0
			2	285	375	-89.8
			3	213	179	33.5
		34R07	1	308	345	-37.6
			2	295	341	-45.6
			3	219	147	72.2
		35N05	1	232	284	-52.2
			2	229	296	-66.3
			3	202	158	44.2
	Kanawha	33A14	1	277	302	-24.7
			2	256	223	32.8
			3	188	88.0	99.9
		34R07	1	299	275	24.0
			2	232	194	37.6
			3	173	82.0	90.9
		35N05	1	232	240	-7.66
			2	228	197	31.0
			3	160	77.5	82.1
2000	Ames	33A14	1	242	281	-39.3
			2	217	219	-1.63
			3	203	151	51.7
		34R07	1	223	261	-37.5
			2	196	200	-3.98
			3	176	142	33.5
		35N05	1	184	236	-51.8
			2	160	165	-5.32
			3	170	133	36.7
	Kanawha	33A14	1	278	332	-53.7
			2	219	288	-69.2
			3	214	122	92.5
		34R07	1	271	303	-32.1
			2	216	252	-36.3
			3	228	92.0	136
		35N05	1	195	273	-78.0
			2	164	254	-89.9
			3	190	107	83.1

Table 13. Average grain yield, average predicted grain yield, and difference between actual and predicted values for the treatments listed.

Year	Location	Hybrid	Planting Date	Ave. Grain Yield	Ave. Predicted Grain Yield	Difference
1999	Ames	33A14	1	13.9 Mg ha^{-1}	13.3 Mg ha^{-1}	0.607
			2	13.5	13.2	0.324
			3	6.63	4.60	2.03
		34R07	1	13.5	13.3	0.212
			2	13.6	12.9	0.696
			3	6.94	4.30	2.64
		35N05	1	12.9	12.6	0.234
			2	12.6	12.8	-0.226
			3	7.52	5.35	2.17
	Kanawha	33A14	1	12.2	9.17	3.00
			2	11.4	6.11	5.24
			3	6.34	2.00	4.35
		34R07	1	12.5	9.05	3.49
			2	11.2	5.91	5.25
			3	6.35	2.09	4.26
		35N05	1	12.0	9.25	2.78
			2	10.7	6.99	3.73
			3	6.50	2.39	4.11
2000	Ames	33A14	1	11.9	7.85	4.05
			2	9.61	6.86	2.75
			3	7.24	3.11	4.14
		34R07	1	10.9	7.94	2.99
			2	9.56	6.78	2.79
			3	6.97	3.29	3.68
		35N05	1	10.1	8.50	1.61
			2	8.55	6.53	2.02
			3	6.70	3.83	2.88
	Kanawha	33A14	1	11.6	8.12	3.53
			2	10.1	7.52	2.53
			3	7.66	2.34	5.32
		34R07	1	10.5	8.20	2.30
			2	10.1	7.33	2.80
			3	7.10	1.75	5.35
		35N05	1	10.1	8.91	1.19
			2	8.48	8.71	-0.230
			3	6.38	2.94	3.45

Model limitations exist due to the complex nature of the variables controlling crop growth and development (Poluektov and Topaj, 2001; Sirontenko, 2001). Much interest is devoted to these areas through research and conclusions are sometimes inconsistent due to year or location effects. Differences in responses over time and space make modeling attempts difficult. Some of these limitations may be overcome through continued research and discovery, however, some variables may not be consistently quantifiable and the effect of field variability may be hard to predict. Crop models may not be able to guide physical science, however, conclusions from physical science should be able to improve the accuracy and use of crop models to develop more efficient and productive cropping systems.

APPENDIX

Table A1. Mean squares from the analysis of variance of 1999 for the parameters measured at Ames, IA.

Source:	df	Yield	Moisture	Rows of Kernels ear^{-1}	Kernels Row^{-1}	Total Kernels ear^{-1}	Weight Kernel^{-1}
Date	2	468.93**	1939.62**	3.33	166.69	48773.78*	49091.31**
Blk*Date	6	1.83	12.02	0.71	32.79	7783.81	620.56
Hybrid	2	1.36	150.68**	23.54**	21.25	40849.15**	29285.91**
Date*Hybrid	4	4.23**	9.50	0.51	6.59	1728.02	3871.87**
Blk*Date*Hybrid	12	0.50	6.69	0.65	9.99	3799.54	521.85
RW	1	0.37**	0.12	2.90**	124.69**	42575.98**	14.67
Date*RW	2	3.51**	0.83	0.97	64.86*	18692.17*	499.26
Hybrid*RW	2	0.44	0.48	0.88	19.59	1787.79	27.03
Date*Hybrid*RW	4	0.42	0.25	0.51	29.41	9410.13	549.56
Blk*Date*Hybrid*RW	18	0.37	2.52	0.28	12.77	3897.49	489.09
TRT	1	3.86**	14.43*	2.70*	17.26	8213.08	396.75
Date*TRT	2	0.01	0.17	0.98	5.15	3078.17	222.89
Hybrid*TRT	2	0.27	4.75	0.22	4.48	513.44	835.57
Date*Hybrid*TRT	4	1.049*	7.42*	1.42	7.92	4587.18	51.79
RW*TRT	1	0.01	0.03	0.07	125.13**	24241.35*	751.03
Date*RW*TRT	2	0.59	0.29	1.65	19.32	8152.76	847.97
Hybrid*RW*TRT	2	0.50	7.32	0.30	13.29	1878.09	45.79
Date*Hybrid*RW*TRT	4	0.863*	7.53	0.67	10.94	3712.57	651.48
Blk*Date*Hybrid*RW*TRT	36	0.29	2.69	0.53	15.59	4357.98	366.56

[1] * and ** denote significance at the 0.05 and 0.01 levels of probability, respectively.

Table A2. Mean squares from the analysis of variance of 2000 for the parameters measured, Ames, IA.

Source:	df	Yield	Moisture	Rows of Kernels ear^{-1}	Kernels Row^{-1}	Total Kernels ear^{-1}	Weight $Kernel^{-1}$
Date	2	141.47**	2168.93**	16.51**	872.14**	199207.85**	9752.51*
Blk*Date	6	3.83	9.94	0.47	2.47	1598.01	1266.05
Hybrid	2	11.44**	25.56**	29.25**	60.59**	67836.31**	23744.91**
Date*Hybrid	4	1.53**	10.02**	2.17	22.53	10467.75	1036.02
Blk*Date*Hybrid	12	0.15	0.72	2.03	5.25	5115.78	1280.75
RW	1	0.35	2.49*	0.84	46.61*	353.89	652.24
Date*RW	2	0.50	1.83	4.11	5.27	5816.01	753.15
Hybrid*RW	2	0.11	0.06	0.19	4.73	1033.90	2047.27
Date*Hybrid*RW	4	0.36	0.20	0.24	10.19	2107.79	261.35
Blk*Date*Hybrid*RW	18	0.19	0.56	1.90	9.81	5219.76	756.52
TRT	1	0.00	10.45**	0.35	0.09	40.97	124.67
Date*TRT	2	0.04	7.21**	2.78	1.30	2859.26	4.24
Hybrid*TRT	2	0.58	1.25	0.71	2.41	876.94	3029.69
Date*Hybrid*TRT	4	0.38	0.40	0.20	2.69	1172.61	1794.69
RW*TRT	1	0.14	0.08	1.02	0.01	332.43	148.85
Date*RW*TRT	2	0.06	0.00	1.58	25.37	3351.60	221.07
Hybrid*RW*TRT	2	0.12	0.35	0.16	7.45	559.95	2495.64
Date*Hybrid*RW*TRT	4	0.17	0.47	0.24	2.11	408.72	931.34
Blk*Date*Hybrid*RW*TRT	36	0.18	1.11	1.74	7.34	4114.41	1086.15

[1] * and ** denote significance at the 0.05 and 0.01 levels of probability, respectively.

Table A3. Mean squares from the analysis of variance of individual years for the parameters measured, Ames, IA.

Source:	df	1999 Growing Degree Units to Mid-silk	1999 Days after Planting to Mid-silk	2000 Growing Degree Units to Mid-silk	2000 Days after Planting to Mid-silk
Date	2	66868.43*	4820.95**	70087.93**	7596.77**
Blk*Date	6	7194.64	9.99	1606.96	2.10
Hybrid	2	6152.405*	9.93*	345.22	1.67*
Date*Hybrid	4	2549.83	5.11	489.29	1.72*
Blk*Date*Hybrid	12	1096.94	1.45	199.11	0.38
RW	1	11203.70**	20.45**	1221.74*	2.31
Date*RW	2	730.94	2.79	33.58	0.18
Hybrid*RW	2	2026.18	3.81	37.86	0.12
Date*Hybrid*RW	4	1679.24	3.86	251.05	0.33
Blk*Date*Hybrid*RW	18	1070.67	2.43**	269.73	0.62
TRT	1	41512.80**	80.08	5952.45**	15.91**
Date*TRT	2	4930.99**	18.69**	370.84	3.24*
Hybrid*TRT	2	1809.66	2.11	68.69	0.19
Date*Hybrid*TRT	4	1833.98	2.01	266.29	0.59
RW*TRT	1	3731.21*	4.90	611.79	1.77
Date*RW*TRT	2	960.59	1.23	297.25	1.21
Hybrid*RW*TRT	2	28.45	0.04	183.35	0.65
Date*Hybrid*RW*TRT	4	785.99	1.08	701.54	1.75
Blk*Date*Hybrid*RW*TRT	36	861.12	1.25	367.50	0.68

[1] * and ** denote significance at the 0.05 and 0.01 levels of probability, respectively.

Table A4. Mean squares from the analysis of variance of 1999 for the parameters measured, Kanawha, IA.

Source:	df	Yield	Moisture	Rows of Kernels ear^{-1}	Kernels Row^{-1}	Total Kernels ear^{-1}	Weight Kernel^{-1}
Date	2	344.40**	1113.62**	4.74**	29.50	19783.88	110952.23**
Blk*Date	6	0.99	0.69	0.26	24.92	5077.77	2137.79
Hybrid	2	0.68	169.66**	28.16**	22.55	71308.49**	21288.06**
Date*Hybrid	4	0.75	67.31**	0.12	40.98	8839.46	10700.15**
Blk*Date*Hybrid	12	0.36	1.89	0.33	25.66	9104.55	987.07
RW	1	0.00	0.61	1.57*	16.28	9853.14	94.83
Date*RW	2	1.12*	1.53	1.16**	23.14	13387.21	288.49
Hybrid*RW	2	0.27	4.42*	0.05	31.00	4714.00	58.57
Date*Hybrid*RW	4	0.30	2.24	0.35	8.80	1012.10	40.28
Blk*Date*Hybrid*RW	18	0.26	0.99	0.32	25.61	6866.57	3815.69
TRT	1	1.18*	0.42	0.00	88.42	18445.07	813.45
Date*TRT	2	0.74	0.04	0.35	17.65	3688.66	6916.25
Hybrid*TRT	2	0.15	0.82	0.02	54.65	11670.76	5748.23
Date*Hybrid*TRT	1	0.00	1.10	0.29	15.83	6444.94	3814.94
RW*TRT	4	0.55	2.07	0.01	25.82	3104.30	65.96
Date*RW*TRT	2	0.70	0.86	0.36	1.91	642.55	258.36
Hybrid*RW*TRT	2	0.87*	0.60	0.09	43.72	10438.77	955.12
Date*Hybrid*RW*TRT	4	0.05	0.33	0.16	31.94	10213.54	265.38
Blk*Date*Hybrid*RW*TRT	36	0.24	1.12	0.25	22.92	6236.31	2564.83

[1] * and ** denote significance at the 0.05 and 0.01 levels of probability, respectively.

Table A5. Mean squares from the analysis of variance of 2000 for the parameters measured, Kanawha, IA.

Source:	df	Yield	Moisture	Rows of Kernels ear^{-1}	Kernels Row^{-1}	Total Kernels ear^{-1}	Weight $Kernel^{-1}$
Date	2	128.27**	1881.07**	16.51	872.14	199207.85	23223.85**
Blk*Date	6	0.22	0.62	0.47	2.47	1598.01	316.87
Hybrid	2	19.72**	105.64**	29.25	60.59	67836.31	35972.00**
Date*Hybrid	4	1.66	8.50**	2.17	22.53	10467.75	2757.17**
Blk*Date*Hybrid	12	0.94	0.74	2.03	5.25	5115.78	457.24
RW	1	1.02	1.04	0.84	46.61	353.89	695.84
Date*RW	2	1.34*	0.35	4.11	5.27	5816.01	193.47
Hybrid*RW	2	0.46	1.15	0.19	4.73	1033.90	446.58
Date*Hybrid*RW	4	0.35	1.00	0.24	10.19	2107.79	577.39
Blk*Date*Hybrid*RW	18	0.36	1.24	1.90	9.81	5219.76	267.53
TRT	1	1.28	2.14	0.35	0.09	40.97	525.92
Date*TRT	2	0.99	1.39	2.78	1.30	2859.26	1042.55**
Hybrid*TRT	2	0.02	0.37	0.71	2.41	876.94	974.28**
Date*Hybrid*TRT	4	0.33	0.53	0.20	2.69	1172.61	659.77**
RW*TRT	1	0.04	0.05	1.02	0.01	332.43	70.47
Date*RW*TRT	2	0.14	0.58	1.58	25.37	3351.60	214.52
Hybrid*RW*TRT	2	0.15	1.58	0.16	7.45	559.95	247.12
Date*Hybrid*RW*TRT	4	0.21	1.05	0.24	2.11	408.72	682.36**
Blk*Date*Hybrid*RW*TRT	36	0.32	1.39	1.74	7.34	4114.41	225.27

[1] * and ** denote significance at the 0.05 and 0.01 levels of probability, respectively.

Table A6. Mean squares from the analysis of variance for the parameters measured, Kanawha, IA.

Source:	df	1999 Growing Degree Units to Mid-silk	1999 Days after Planting to Mid-silk	2000 Growing Degree Units to Mid-silk	2000 Days after Planting to Mid-silk
Date	2	91545.93**	8339.36**	139577.39**	6967.40**
Blk*Date	6	477.24	0.41	917.50	1.74
Hybrid	2	11099.27**	23.44**	2296.66	4.62
Date*Hybrid	4	1093.43	3.31*	1404.61	2.68
Blk*Date*Hybrid	12	586.00	0.82	659.84	1.37
RW	1	1099.21	3.00	3382.96*	7.26*
Date*RW	2	2633.94*	4.19*	68.46	0.18
Hybrid*RW	2	492.64	0.78	2912.438*	5.73*
Date*Hybrid*RW	4	1347.22	2.89*	659.33	1.23
Blk*Date*Hybrid*RW	18	556.00	0.83	744.56	1.58
TRT	1	3658.10**	6.26**	11701.05**	25.04**
Date*TRT	2	697.31	0.56	44.06	0.12
Hybrid*TRT	2	354.51	0.70	985.34	2.01
Date*Hybrid*TRT	4	748.56	1.26	408.92	0.76
RW*TRT	1	41.75	0.15	2874.22*	6.26*
Date*RW*TRT	2	77.94	0.18	649.18	1.56
Hybrid*RW*TRT	2	9.55	0.26	57.95	0.12
Date*Hybrid*RW*TRT	4	152.11	0.29	611.16	1.26
Blk*Date*Hybrid*RW*TRT	36	402.76	0.72	456.47	1.00

[1] * and ** denote significance at the 0.05 and 0.01 levels of probability, respectively.

Table A7. Mean squares from the analysis of variance of combined years for the parameters measured.

Source	df	Ames Yield	Ames Moisture	Kanawha Yield	Kanawha Moisture
Year	1	247.923*	380.385**	33.05*	21.224*
Blk(Year)	2	4.43	3.51	0.70	0.40
Date	2	544.663**	4045.931**	432.489**	2847.597**
Year*Date	2	71.339**	3.17	27.563**	72.714**
Blk*Date	4	3.21	27.10	0.30	0.72
Hybrid	2	10.405**	141.302**	12.686**	264.171**
Year*Hybrid	2	2.539**	31.514**	6.936**	4.844**
Date*Hybrid	4	5.080**	17.505**	1.07	41.258**
Year*Date*Hybrid	4	0.72	2.07	1.34	32.322**
Blk(Year)*Date*Hybrid	12	0.22	3.05	0.81	0.69
RW	1	0.75	1.39	0.56	0.02
Year*RW	1	2.972**	1.08	0.53	1.55
Date*RW	2	3.281**	1.85	0.90	1.12
Year*Date*RW	2	0.696*	0.42	1.561*	0.71
Date*Hybrid*RW	4	0.41	0.04	0.40	2.03
Year*Date*Hybrid*RW	4	0.36	0.31	0.27	1.13
BLK(Year)*Date*Hybrid*RW	18	0.18	1.61	0.28	0.89
TRT	1	1.886*	27.629**	2.518**	2.24
Year*TRT	1	2.003*	0.51	0.00	0.35
Hybrid*TRT	2	0.18	1.55	0.05	0.92
Year*Hybrid*TRT	2	0.71	5.37	0.13	0.28
Date*Hybrid*TRT	4	0.31	2.01	0.75	1.84
Year*Date*Hybrid*TRT	4	1.129*	5.25	0.14	0.73
RW*TRT	1	0.09	0.00	0.04	0.35
Year*RW*TRT	1	0.05	0.13	0.03	0.78
Date*RW*TRT	2	0.52	0.01	0.68	0.61
Year*Date*RW*TRT	2	0.15	0.03	0.17	0.81
Hybrid*RW*TRT	2	0.35	4.59	0.31	0.76
Year*Hybrid*RW*TRT	2	0.29	1.96	0.74	1.42
Blk*Date*Hybrid*RW*TRT	40	0.31	2.45	0.29	1.46

[1] * and ** denote significance at the 0.05 and 0.01 levels of probability, respectively.

Table A8. Mean squares from the analysis of variance of combined years for the parameters measured.

	df	Ames Growing Degree Units to Mid-silk	Ames Days after Planting to Mid-silk	Kanawha Growing Degree Units to Mid-silk	Kanawha Days after Planting to Mid-silk
Year	1	270890.95	28753.45	171732.36**	1655.57**
Blk(Year)	2	20694.50	19308.87	270.63	0.34
Date	2	169515.59**	5121.99	101701.74**	15013.85**
Year*Date	2	23878.79	20837.48	129421.57**	292.91**
Blk*Date	4	4570.14	19881.84	1315.79	1.80
Hybrid	2	19340.12	19556.95	10513.19**	21.73**
Year*Hybrid	2	6976.27	19926.74	2882.74*	6.34*
Date*Hybrid	4	5981.06	19503.21	966.86	4.02*
Year*Date*Hybrid	4	16876.29	18935.90	1531.18	1.96
Blk(Year)*Date*Hybrid	12	9394.68	17463.22	660.63	1.05
RW	1	30789.91*	13530.67	4169.45**	9.80**
Year*RW	1	717.21	15049.04	312.72	0.46
Date*RW	2	7100.87	14155.83	1051.10	1.35
Year*Date*RW	2	3920.04	14655.81	1651.31*	3.02
Date*Hybrid*RW	4	7485.21	13828.40	1088.82	2.76*
Year*Date*Hybrid*RW	4	2910.00	14316.24	917.73	1.37
BLK(Year)*Date*Hybrid*RW	18	5698.85	11841.16	451.83	0.88
TRT	1	10711.82	22734.44	14222.02**	28.17**
Year*TRT	1	33385.26*	19101.56	1137.13	3.13
Hybrid*TRT	2	16647.51	19435.47	901.22	1.01
Year*Hybrid*TRT	2	4894.74	20001.10	438.63	1.70
Date*Hybrid*TRT	4	5787.38	19530.83	339.24	0.97
Year*Date*Hybrid*TRT	4	10537.94	19253.96	818.24	1.05
RW*TRT	1	2597.24	14686.44	1804.40*	4.17
Year*RW*TRT	1	18706.21	13942.57	1111.57	2.24
Date*RW*TRT	2	3585.61	14591.74	587.74	1.39
Year*Date*RW*TRT	2	5875.57	14380.27	139.37	0.35
Hybrid*RW*TRT	2	5026.82	14468.96	12.21	0.01
Year*Hybrid*RW*TRT	2	4109.37	14501.31	55.29	0.37
Blk*Date*Hybrid*RW*TRT	40	7476.65	17297.22	425.10	0.79

[1] * and ** denote significance at the 0.05 and 0.01 levels of probability, respectively.

Table A9. Mean squares from the analysis of variance of combined years for the parameters measured.

Source	df	Ames Grain Protein	Ames Grain Oil	Ames Grain Starch	Ames Grain Density
Year	1	11.25*	0.23	110.06**	0.0007
Blk(Year)	2	0.33	0.07	0.17	0.0003
Date	2	8.11*	0.25*	64.98**	0.0308**
Year*Date	2	1.27	1.756**	2.93*	0.0011
Blk*Date	4	0.49	0.02	0.35	0.0002
Hybrid	2	3.38**	2.23**	8.85**	0.0010**
Year*Hybrid	2	0.62*	1.03**	0.56*	0.0001
Date*Hybrid	4	0.15	0.21*	0.71**	0.0005**
Year*Date*Hybrid	4	0.17	0.07	0.09	0.0002
Blk(Year)*Date*Hybrid	12	0.13	0.04	0.09	0.0001
RW	1	0.40	0.00	0.06	0.0000
Year*RW	1	0.04	0.00	0.21	0.0001
Date*RW	2	0.11	0.05	0.02	0.0000
Year*Date*RW	2	0.31	0.04	0.03	0.0001
Date*Hybrid*RW	4	0.09	0.04	0.12	0.0000
Year*Date*Hybrid*RW	4	0.01	0.04	0.03	0.0002
BLK(Year)*Date*Hybrid*RW	18	0.09	0.04	0.16	0.0001
TRT	1	0.01	0.00	0.00	0.0004
Year*TRT	1	0.02	0.02	0.25	0.0000
Hybrid*TRT	2	0.00	0.02	0.15	0.0000
Year*Hybrid*TRT	2	0.09	0.01	0.28*	0.0000
Date*Hybrid*TRT	4	0.03	0.03	0.13	0.0002
Year*Date*Hybrid*TRT	4	0.01	0.03	0.10	0.0001
RW*TRT	1	0.00	0.07	0.02	0.0000
Year*RW*TRT	1	0.00	0.00	0.00	0.0001
Date*RW*TRT	2	0.09	0.03	0.02	0.0000
Year*Date*RW*TRT	2	0.20*	0.02	0.54**	0.0001
Hybrid*RW*TRT	2	0.04	0.02	0.01	0.0000
Year*Hybrid*RW*TRT	2	0.07	0.11*	0.04	0.0000
Blk*Date*Hybrid*RW*TRT	40	0.05	0.02	0.07	0.0001

[1] * and ** denote significance at the 0.05 and 0.01 levels of probability, respectively.

Table A10. Mean squares from the analysis of variance of combined years for the parameters measured.

Source	df	Kanawha Grain Protein	Kanawha Grain Oil	Kanawha Grain Starch	Kanawha Grain Density
Year	1	31.50**	0.83	470.22**	0.0001
Blk(Year)	2	0.05	0.09	0.73	0.0011
Date	2	5.34*	6.75**	216.19**	0.0613**
Year*Date	2	1.32	0.53	5.62**	0.0009
Blk*Date	4	0.44	0.12	0.19	0.0003
Hybrid	2	1.45**	2.74**	9.96**	0.0073**
Year*Hybrid	2	0.73*	0.45	2.11*	0.0003
Date*Hybrid	4	0.65*	0.20	1.26	0.0004
Year*Date*Hybrid	4	0.86*	0.06	1.78*	0.0001
Blk(Year)*Date*Hybrid	12	0.18	0.16	0.52	0.0005
RW	1	0.18	0.19	0.00	0.0001
Year*RW	1	0.09	0.04	0.16	0.0002
Date*RW	2	0.23	0.04	0.29	0.0001
Year*Date*RW	2	0.05	0.01	0.45	0.0001
Date*Hybrid*RW	4	0.23	0.06	0.21	0.0000
Year*Date*Hybrid*RW	4	0.14	0.02	0.54	0.0001
BLK(Year)*Date*Hybrid*RW	18	0.27	0.06	0.65	0.0002
TRT	1	0.00	0.00	0.47	0.0001
Year*TRT	1	0.02	0.00	0.18	0.0004
Hybrid*TRT	2	0.15	0.00	0.14	0.0001
Year*Hybrid*TRT	2	0.04	0.03	0.17	0.0000
Date*Hybrid*TRT	4	0.09	0.01	0.10	0.0001
Year*Date*Hybrid*TRT	4	0.04	0.01	0.15	0.0000
RW*TRT	1	0.01	0.00	0.01	0.0004
Year*RW*TRT	1	0.10	0.00	0.02	0.0007
Date*RW*TRT	2	0.43	0.02	0.19	0.0003
Year*Date*RW*TRT	2	0.18	0.09	0.19	0.0001
Hybrid*RW*TRT	2	0.09	0.02	0.96*	0.0002
Year*Hybrid*RW*TRT	2	0.10	0.08	1.26**	0.0000
Blk*Date*Hybrid*RW*TRT	40	0.21	0.06	0.20	0.0002

[1] * and ** denote significance at the 0.05 and 0.01 levels of probability, respectively.

Table A11. Individual corn grain treatment means for protein (%) at Ames, IA.

Date 1			Protein (%) Year		Date 2			Year		Date 3			Year	
Row Spacing	Fertilizer	Hybrid	1999	2000	Row Spacing	Fertilizer	Hybrid	1999	2000	Row Spacing	Fertilizer	Hybrid	1999	2000
38-cm	0	33A14	6.7	7.1	38-cm	0	33A14	6.7	7.8	38-cm	0	33A14	7.0	8.0
		34R07	7.5	7.6			34R07	7.3	7.4			34R07	7.6	8.1
		35N05	6.9	6.7			35N05	6.8	7.6			35N05	7.3	7.7
76-cm	0	33A14	6.7	7.1	76-cm	0	33A14	6.8	7.8	76-cm	0	33A14	7.6	8.0
		34R07	7.4	7.4			34R07	7.2	7.8			34R07	8.1	8.1
		35N05	6.9	7.1			35N05	6.7	7.7			35N05	7.6	7.5
38-cm	NPK	33A14	6.7	6.9	38-cm	NPK	33A14	6.8	7.6	38-cm	NPK	33A14	7.2	8.0
		34R07	7.4	7.3			34R07	7.3	7.4			34R07	7.8	8.1
		35N05	6.6	6.9			35N05	6.7	7.7			35N05	7.3	7.7
76-cm	NPK	33A14	6.8	7.4	76-cm	NPK	33A14	7.2	8.0	76-cm	NPK	33A14	7.4	8.0
		34R07	7.2	7.6			34R07	7.8	8.1			34R07	8.0	8.2
		35N05	6.9	7.1			35N05	7.3	7.7			35N05	7.4	7.7

Table A12. Individual corn grain treatment means for oil (%) at Ames, IA.

			Oil (%)											
Date 1			Year		Date 2			Year		Date 3			Year	
Row Spacing	Fertilizer	Hybrid	1999	2000	Row Spacing	Fertilizer	Hybrid	1999	2000	Row Spacing	Fertilizer	Hybrid	1999	2000
38-cm	0	33A14	3.1	3.2	38-cm	0	33A14	3.1	3.3	38-cm	0	33A14	3.1	4.0
		34R07	3.8	3.6			34R07	3.7	3.7			34R07	3.3	3.9
		35N05	3.7	3.3			35N05	3.6	3.5			35N05	3.6	3.6
76-cm	0	33A14	3.2	3.3	76-cm	0	33A14	3.1	3.3	76-cm	0	33A14	3.1	3.7
		34R07	3.8	3.5			34R07	3.7	3.2			34R07	3.3	3.7
		35N05	3.6	3.4			35N05	3.6	3.4			35N05	3.4	4.0
38-cm	NPK	33A14	3.1	3.4	38-cm	NPK	33A14	3.1	3.2	38-cm	NPK	33A14	3.0	3.6
		34R07	3.8	3.6			34R07	3.8	3.4			34R07	3.3	3.6
		35N05	3.7	3.6			35N05	3.7	3.5			35N05	3.6	3.6
76-cm	NPK	33A14	3.2	3.5	76-cm	NPK	33A14	3.1	3.2	76-cm	NPK	33A14	3.2	3.8
		34R07	3.7	3.5			34R07	3.7	3.3			34R07	3.3	3.7
		35N05	3.8	3.5			35N05	3.7	3.4			35N05	3.6	3.8

Table A13. Individual corn grain treatment means for starch (%) at Ames, IA.

Date 1			Starch (%) Year		Date 2			Year		Date 3			Year	
Row Spacing	Fertilizer	Hybrid	1999	2000	Row Spacing	Fertilizer	Hybrid	1999	2000	Row Spacing	Fertilizer	Hybrid	1999	2000
38-cm	0	33A14	62.8	61.5	38-cm	0	33A14	62.8	61.1	38-cm	0	33A14	61.1	59.1
		34R07	61.4	60.4			34R07	61.6	61.1			34R07	60.5	58.6
		35N05	62.1	61.4			35N05	62.2	61.2			35N05	61.0	59.3
76-cm	0	33A14	62.7	61.4	76-cm	0	33A14	62.8	60.9	76-cm	0	33A14	61.3	59.1
		34R07	61.7	60.6			34R07	61.8	60.5			34R07	60.5	58.8
		35N05	62.1	61.2			35N05	62.6	61.0			35N05	60.6	59.3
38-cm	NPK	33A14	62.5	61.5	38-cm	NPK	33A14	62.8	61.5	38-cm	NPK	33A14	60.9	59.0
		34R07	61.6	60.6			34R07	61.8	60.3			34R07	60.6	59.1
		35N05	62.4	61.3			35N05	62.5	60.7			35N05	61.1	59.3
76-cm	NPK	33A14	62.8	61.2	76-cm	NPK	33A14	62.5	61.2	76-cm	NPK	33A14	61.1	58.8
		34R07	61.7	60.5			34R07	61.9	61.0			34R07	60.7	58.7
		35N05	62.0	60.9			35N05	62.4	60.8			35N05	61.3	59.0

Table A14. Individual corn grain treatment means for kernel density at Ames, IA.

			Density											
Date 1			Year		Date 2			Year		Date 3			Year	
Row Spacing	Fertilizer	Hybrid	1999	2000	Row Spacing	Fertilizer	Hybrid	1999	2000	Row Spacing	Fertilizer	Hybrid	1999	2000
38-cm	0	33A14	1.27	1.27	38-cm	0	33A14	1.27	1.27	38-cm	0	33A14	1.22	1.23
		34R07	1.29	1.29			34R07	1.29	1.28			34R07	1.24	1.25
		35N05	1.29	1.29			35N05	1.29	1.28			35N05	1.25	1.27
76-cm	0	33A14	1.27	1.27	76-cm	0	33A14	1.27	1.28	76-cm	0	33A14	1.23	1.23
		34R07	1.29	1.28			34R07	1.29	1.29			34R07	1.24	1.25
		35N05	1.29	1.28			35N05	1.29	1.29			35N05	1.23	1.28
38-cm	NPK	33A14	1.27	1.26	38-cm	NPK	33A14	1.27	1.27	38-cm	NPK	33A14	1.22	1.25
		34R07	1.29	1.29			34R07	1.29	1.29			34R07	1.25	1.25
		35N05	1.29	1.29			35N05	1.29	1.29			35N05	1.26	1.28
76-cm	NPK	33A14	1.27	1.27	76-cm	NPK	33A14	1.27	1.28	76-cm	NPK	33A14	1.24	1.23
		34R07	1.29	1.29			34R07	1.29	1.29			34R07	1.24	1.25
		35N05	1.29	1.29			35N05	1.29	1.29			35N05	1.26	1.27

Table A15. Individual corn grain treatment means for protein (%) at Kanawha, IA.

Date 1			Protein (%) Year		Date 2			Year		Date 3			Year	
Row Spacing	Fertilizer	Hybrid	1999	2000	Row Spacing	Fertilizer	Hybrid	1999	2000	Row Spacing	Fertilizer	Hybrid	1999	2000
38-cm	0	33A14	6.7	7.4	38-cm	0	33A14	6.4	7.5	38-cm	0	33A14	5.4	7.6
		34R07	7.4	7.8			34R07	7.0	7.3			34R07	6.2	7.2
		35N05	6.7	7.2			35N05	7.0	7.5			35N05	6.9	7.1
76-cm	0	33A14	6.6	7.1	76-cm	0	33A14	6.9	7.3	76-cm	0	33A14	6.2	7.6
		34R07	7.2	7.5			34R07	7.1	7.5			34R07	6.3	7.2
		35N05	5.9	7.2			35N05	7.0	7.6			35N05	6.2	7.1
38-cm	NPK	33A14	6.6	7.3	38-cm	NPK	33A14	6.5	7.3	38-cm	NPK	33A14	5.4	7.5
		34R07	7.2	7.6			34R07	7.3	7.7			34R07	6.5	7.0
		35N05	6.6	7.2			35N05	7.0	7.6			35N05	6.9	7.0
76-cm	NPK	33A14	6.8	7.1	76-cm	NPK	33A14	6.7	7.4	76-cm	NPK	33A14	5.8	7.1
		34R07	7.0	7.7			34R07	6.9	7.7			34R07	6.1	7.4
		35N05	6.7	7.3			35N05	7.0	7.8			35N05	5.8	6.9

Table A16. Individual corn grain treatment means for oil (%) at Kanawha, IA.

Date 1			Oil (%) Year		Date 2			Year		Date 3			Year	
Row Spacing	Fertilizer	Hybrid	1999	2000	Row Spacing	Fertilizer	Hybrid	1999	2000	Row Spacing	Fertilizer	Hybrid	1999	2000
38-cm	0	33A14	3.3	3.1	38-cm	0	33A14	3.1	3.3	38-cm	0	33A14	2.3	2.8
		34R07	3.7	3.4			34R07	3.6	3.4			34R07	3.1	2.9
		35N05	3.8	3.3			35N05	3.8	3.4			35N05	3.3	3.2
76-cm	0	33A14	3.3	3.2	76-cm	0	33A14	3.3	3.3	76-cm	0	33A14	2.7	2.6
		34R07	3.6	3.4			34R07	3.6	3.5			34R07	2.7	2.8
		35N05	3.6	3.4			35N05	3.7	3.3			35N05	3.0	3.1
38-cm	NPK	33A14	3.3	3.1	38-cm	NPK	33A14	3.2	3.3	38-cm	NPK	33A14	2.6	2.6
		34R07	3.7	3.5			34R07	3.5	3.6			34R07	3.0	3.0
		35N05	3.8	3.3			35N05	3.7	3.3			35N05	3.4	3.1
76-cm	NPK	33A14	3.4	3.1	76-cm	NPK	33A14	3.0	3.3	76-cm	NPK	33A14	2.7	2.9
		34R07	3.6	3.4			34R07	3.3	3.4			34R07	2.8	2.7
		35N05	3.8	3.1			35N05	3.7	3.4			35N05	2.9	3.2

Table A17. Individual corn grain treatment means for starch (%) at Kanawha, IA.

Date 1			Starch (%) Year		Date 2			Year		Date 3			Year	
Row Spacing	Fertilizer	Hybrid	1999	2000	Row Spacing	Fertilizer	Hybrid	1999	2000	Row Spacing	Fertilizer	Hybrid	1999	2000
38-cm	0	33A14	63.4	60.8	38-cm	0	33A14	62.2	59.6	38-cm	0	33A14	60.5	56.2
		34R07	63.1	59.9			34R07	62.1	59.2			34R07	60.0	56.0
		35N05	63.7	60.9			35N05	63.3	60.5			35N05	60.1	57.4
76-cm	0	33A14	63.6	60.9	76-cm	0	33A14	62.5	59.9	76-cm	0	33A14	61.2	55.9
		34R07	63.0	60.1			34R07	62.1	59.0			34R07	60.1	56.9
		35N05	62.3	61.1			35N05	63.1	60.3			35N05	60.1	57.1
38-cm	NPK	33A14	63.7	60.9	38-cm	NPK	33A14	62.7	59.6	38-cm	NPK	33A14	61.1	56.7
		34R07	62.8	60.0			34R07	61.7	58.9			34R07	60.0	56.6
		35N05	63.7	61.1			35N05	62.9	60.5			35N05	60.1	57.7
76-cm	NPK	33A14	63.3	61.3	76-cm	NPK	33A14	61.7	59.8	76-cm	NPK	33A14	60.5	56.4
		34R07	63.3	60.2			34R07	62.2	59.0			34R07	60.3	56.9
		35N05	63.5	61.0			35N05	62.8	60.1			35N05	60.9	57.7

Table A18. Individual corn grain treatment means for kernel density at Kanawha, IA.

			Density											
Date 1			Year		Date 2			Year		Date 3			Year	
Row Spacing	Fertilizer	Hybrid	1999	2000	Row Spacing	Fertilizer	Hybrid	1999	2000	Row Spacing	Fertilizer	Hybrid	1999	2000
38-cm	0	33A14	1.26	1.27	38-cm	0	33A14	1.28	1.25	38-cm	0	33A14	1.22	1.22
		34R07	1.29	1.27			34R07	1.28	1.26			34R07	1.23	1.22
		35N05	1.30	1.28			35N05	1.29	1.28			35N05	1.23	1.24
76-cm	0	33A14	1.28	1.27	76-cm	0	33A14	1.26	1.24	76-cm	0	33A14	1.21	1.22
		34R07	1.28	1.28			34R07	1.27	1.27			34R07	1.22	1.23
		35N05	1.27	1.29			35N05	1.28	1.28			35N05	1.22	1.23
38-cm	NPK	33A14	1.27	1.27	38-cm	NPK	33A14	1.24	1.25	38-cm	NPK	33A14	1.21	1.22
		34R07	1.29	1.28			34R07	1.26	1.26			34R07	1.22	1.23
		35N05	1.29	1.29			35N05	1.28	1.28			35N05	1.23	1.24
76-cm	NPK	33A14	1.27	1.27	76-cm	NPK	33A14	1.28	1.26	76-cm	NPK	33A14	1.21	1.22
		34R07	1.28	1.28			34R07	1.26	1.26			34R07	1.22	1.22
		35N05	1.29	1.29			35N05	1.28	1.28			35N05	1.22	1.24

Table A19. Treatment means and comparisons of leaf area index at Ames, IA.

Treatment	Planting Date 3-May-1999	10-May-1999	17-Jun-1999
Starter	0.71	0.81	2.31
No Starter	0.65	0.76	2.08
LSD(0.05)	NS	NS	NS
15 inch	0.76	0.78	2.37
30 inch	0.61	0.79	2.02
LSD(0.05)	NS	NS	NS

Table A20. Treatment means and comparisons of leaf area index at Kanawha, IA.

Treatment	Planting Date 21-Apr-1999	25-May-1999	14-Jun-1999
Starter	0.85	0.72	****
No Starter	0.71	0.69	****
LSD(0.05)	NS	NS	****
15 inch	0.80	0.64	****
30 inch	0.76	0.78	****
LSD(0.05)	NS	0.08	****

*Data from the 14 June planting date at Kanawha was not retrieved due to an error with the data logger.

Table A21. Treatment means for leaf area duration at Ames, IA.

			Planting Date		
Hybrid	Row Spacing	Fertilizer	11-Apr-2000	11-May-2000	9-Jun-2000
35N05	38-cm	0	105.51	128.01	135.71
		NPK	121.72	129.11	145.10
	76-cm	0	94.79	117.69	129.44
		NPK	89.27	124.25	146.19
34R07	38-cm	0	136.64	128.85	151.05
		NPK	134.21	131.73	156.82
	76-cm	0	120.75	116.45	146.84
		NPK	113.05	113.82	161.77
33A14	38-cm	0	118.08	123.63	148.51
		NPK	113.19	127.88	146.31
	76-cm	0	105.53	115.55	137.90
		NPK	114.85	108.87	144.55

Table A22. Treatment means for leaf area duration at Kanawha, IA.

			Planting Date	
Hybrid	Row Spacing	Fertilizer	15-Apr-2000	15-May-2000
35N05	38-cm	0	33.10853725	50.72681313
		NPK	31.60870947	42.03450492
	76-cm	0	26.96674475	43.33793764
		NPK	33.13917485	36.00233168
34R07	38-cm	0	31.70462425	52.55006779
		NPK	36.92358978	47.69493113
	76-cm	0	32.83207481	46.87796936
		NPK	37.6352708	37.83437723
33A14	38-cm	0	37.19686683	46.4107924
		NPK	39.98794215	49.44919238
	76-cm	0	33.32552145	40.72151945
		NPK	32.69094929	44.30770301

Table A23. Genetic coefficient values for crop modeling exercise.

	Parameter					
Hybrid	P1	P2	P5	G2	G3	PHINT
35N05	240.00	0.75	800.00	812.00	7.50	49.00
34R07	250.00	0.75	825.00	735.00	8.00	49.00
33A14	240.00	0.75	850.00	700.00	8.50	49.00

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