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Interplot and intraplot border effects on maize genotypes under two levels of moisture availability

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INTERPLOT AND INTRAPLOT BORDER EFFECTS ON MAIZE GENOTYPES UNDER TWO LEVELS OF MOISTURE AVAILABILITY

by

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APPROVAL BY THESIS DIRECTOR

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22 August 1988
Date

DEDICATION

This thesis is dedicated to the memory of my mother Yao Asso Rose and to my father Ambroise Semon Lambert for their sacrifices, understanding and continuous support throughout my life.

This thesis is also dedicated to my daughter, Phyllis, to whom I wish self-determination in her ongoing life.

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ABSTRACT

The performance of three maize (*Zea mays* L.) hybrids, grown under two irrigation levels, was used to investigate the effects of soil moisture competition between adjacent plots, the transmission of these effects into multi-row adjacent plots and types of multi-row plots and plot borders most effective in shielding from these interplot competition effects. On the basis of grain yield, competition effects intended to the second rows of five-row plots necessitating more than five-row plots to accurately evaluate the full transmission of interplot competition effects into adjacent plots. Evaluation of genotypes in one-row plots all with the same common border row genotype to make them three-row plots would be more suitable for evaluation of relative competitiveness for soil moisture under soil moisture stress conditions compared to no border rows or border rows of the same genotype being evaluated.

CHAPTER I

INTRODUCTION

The identification of drought tolerant germplasm in grain crops is a major component of crop improvement in arid and semi-arid regions. The determination of the plant characteristics which may contribute to the relative ability of the plant to maintain growth and yield under soil moisture-stress (drought tolerance), and the precision with which genotypes may be evaluated for these characteristics are important to plant breeders. The relative ability of a plant to maintain growth and yield under moisture-stress appears to be influenced by the ability of the plant to take up soil moisture.

Plant competition results from the differential capacity of an experimental unit (plant or single-row plot) to express a measurement criterion under differing competing environments (Hanson, Brim and Hinson, 1961). It is believed that bias in the evaluation of genotypes is caused not only by the difference in performance of plants along the sides or ends of a multi-row plot from plants in the center (border effects) but also by border effects experienced by plants in the plots from plants in adjacent plots (Siao, 1935; Lin, Poushinsky and Voldeng, 1985).

Border effects can be minimized if adequate types of plot borders are used. By doing so, a more accurate evaluation of genotypes can be obtained under conditions where competition is a problem.

Previous studies suggest multi-row plots with exclusion of the border rows from evaluation to minimize border effects (Lin et al., 1985). The exclusion of border rows depends on the degree of moisture competition in the site of the experiment. For example, under sub-humid conditions of Minnesota, where considerable plant competition is observed between rod rows (4.95 m long), the Minnesota Experimental Station utilizes three-row plots for small grain variety tests, with the center rows harvested for grain yield (Hayes and Arny, 1917). Under humid conditions of New York where plant competition for soil moisture is not common, single-row or three-row plots are used for small grains. All rows are harvested for yield with little or no error due to border effects (Love and Craig, 1938). Additional research information on field plot configuration, size and performance under moisture-stress would be helpful to plant breeders to evaluate, with less error, grain crops in arid and semi-arid regions where plant competition for soil moisture is a major interplot competition problem.

CHAPTER II

LITERATURE REVIEW

Interplot Competition or Border Effects

In the field, plant competition may result primarily from plant genotypic characteristics, availability of nutrients, plant spacings, and row spacing (LeClerg, Leonard and Clark, 1962). Gomez and De Datta (1971) define border effects as the difference in performance of plants along the sides or ends of a multi-row plot from plants in the center. Border effect causes competition between plants for moisture, light, and nutrients.

LeClerg et al. (1962), in an extensive review of literature, emphasized the importance of border effects on plot yields in field experimentation. They stated that unlike expected inherent and uncontrolled errors such as soil-variability, other sources of experimental errors such as border effects can be avoided or minimized. They indicated that in many cultural and variety tests, plot yields may be either raised or lowered by contiguity to other treatments, crops, or interspaces. They observed that a vigorous variety may benefit when grown next to a less vigorous one, particularly in single-row plots. As a result, they suggested the use of multiple-row plots in experimental work with outside border rows discarded. This procedure is justified by Arny's (1921) conclusion that the ranking of yield may be changed when border rows are included in the plot yields.

Many studies have been conducted to determine the border effects of adjacent plots for the adoption of a specific plot size to minimize the phenomena. Nebraska experimenters tested tall and short corn varieties grown in alternate five-row plots with only the three center rows harvested. Their results showed that a shorter variety yielded 85% as much as a taller one (Kiesselbach, 1923). A yield comparison made in Kansas with combined-type grain sorghum (*Sorghum bicolor* L.) in bordered (four-row) and unbordered (two-row) plots showed that sorghums of similar growth habit could be tested without border rows (Ross, 1958). However, Ross (1958) suggested the use of border rows under certain experimental conditions where competition may be a problem. From a test of two soybean (*Glycine max* L.) varieties, Hartwig, Johnson, and Carr (1951), reported that yields from single-row plots failed to give an accurate representation of variety performance in areas where soybean varieties make a rank growth. Under such conditions, multiple-row plots with border rows discarded, were considered to afford more reliable results.

LeClerg et al. (1962) stated that under most environmental conditions, competition will also exist between adjacent plots in rate and date of planting tests. In their opinion, yields of rows with dense stands will profit at the expense of yields of adjacent rows with thinner stands. As with variety tests, they indicated that the effect could be avoided by using multiple-row plots with the border rows discarded.

LeClerg et al. (1962) summarized three basic methods of controlling interplot competition. These included: (1) grouping of varieties with similar growth habits, dates of maturity, etc.; (2) use of multiple row plots; and (3) discarding of outside border rows at the time of harvest. They also recommended the use of wider row spacing to control border effects.

Competition Effects and Breeding Methodologies

Competition effects can be a serious source of error in evaluating performance during variety development. Jennings and Aquino (1968) reported the role of competition as source of selection error in rice (*Oriza sativa* L.) cultivar development.

Pedigree Breeding

Competition in general, reduces reproductive rates of rice plants in the F2 generation, which can disturb markedly the composition of the pure-lined F3 generation and subsequent generations. Interline competition in advanced generations can be drastic and lead to line rejection for improper reasons (Jennings and Aquino, 1968).

Bulk Breeding

Oka (1960) demonstrated that F10 rice lines derived from material propagated in bulk were more competitive than F10 lines isolated from pedigreed material. Jennings and Aquino (1968) believed that the basic breeding consideration in rice is to devise a breeding system that eliminates competition while retaining the valuable features of the bulk population method.

Plant Characters and Competition in Plant Mixtures

Many authors have studied the association of specific plant characters with competitive ability in populations. There is evidence that height, maturity, and branching habits in soybeans (Mumaw and Weber, 1957), petiole length in clover (*Trifolium* species) (Black, 1960) and height in sorghum (Narasimha Rao and Rachie, 1964) infer competitive advantages in genotypic mixtures. However, Sakai (1955; 1961) concluded from numerous experiments with barley (*Hordeum vulgare* L.) and rice that there was no association between competitive ability for survival in populations and any observed character, including tiller number, height, maturity, vigor, seed size, spring or winter habit, plant weight, inflorescence weight, and grain yield. According to Oka (1960) and Sakai (1955; 1961) competitive ability in rice has been considered a quantitatively determined genetic character having low heritability.

Results from agricultural field experiments are subject to error due to soil heterogeneity, size and shape of plots, and plant biological variation. Plant variability may be due to genetic differences, plant competition within or between plots.

Many authors have suggested that root characteristics may control competition for nutrients or soil moisture (Sakai, 1955; Lee, 1960; Jensen and Federer, 1965). An analysis of border effect in rice led to the conclusion that the underground conditions, particularly those affecting the nutritional supply, make an important contribution to the magnitude of yield increases of the outermost plants. It was thus proposed that underground factors be taken into account along with aerial conditions when interpreting the phenomena of border effects.

Effects of Water Deficit on Maize

A water deficit during any growth stage of maize often results in yield reduction, the magnitude of which depends on the growth stage of the crop at the time of the stress, the severity and duration of the stress and the susceptibility of the genotype to water stress. Reduction in leaf expansion and growth of stem and roots during vegetative development under water stress were reported by Denmead and Shaw (1960). They also indicated that water stress affected the development of reproductive organs and yield potential of maize. Major stress before silking may cause ears to fail to develop fully, while stress after pollination results in limitation in kernel number or kernel abortion (Tollenaar, 1977). Herrero and Johnson (1981) report that maize is most sensitive to drought stress during pollination when delayed emergence of silks may reduce fertilization and subsequent grain yield because of poor seed set. In general, drought during the linear growth phase of kernel development primarily affects mean kernel weight by reducing assimilate production or duration of kernel fill or a combination of both (Tollenaar and Daynard, 1978; Jurgens, Johnson, and Boyer, 1978; Jones and Simmons, 1983).

According to Claassen and Shaw (1970), Harder, Carlson, and Shaw (1982), Moss and Downey (1971), and Robins and Domingo (1953), the maximum reduction in kernel number results from moisture stress in the silking and early kernel fill stages. Shaw (1974) emphasizes that the most crucial period for drought stress extends from 5 days before to 5 days after silking.

CHAPTER III

OBJECTIVES OF THE EXPERIMENT

There were two objectives for this research. The first objective was to evaluate the extent of the effects of interplot competition for soil moisture on an evaluated plot from an adjacent plot of a different hybrid. Multi-row plots were used to make it possible to measure the degree of transmission of the resulting intraplot competition effects among the evaluated rows within the plot.

Evaluation of the influences of moisture stress and non-stress on each of the three hybrids in non-competitive interplot situations was obtained from the plots used for the first objective. The center rows of the five-row plots were considered to have sufficient border to render them relatively free of interplot competition effects from adjacent plots. These evaluations were used as a measure of the direct response to moisture stress and non-stress of each of the three hybrids being evaluated. The three hybrids were selected to have genotypes for different responses to moisture stress.

The second objective was to evaluate three types of plot borders: one-row plots, three-row plots, and "semi" three-row plots. This was to determine the most effective type of plot border in minimizing intraplot border effects for a more accurate evaluation of grain crop plots under moisture stress.

The degree of interplot and intraplot competition for soil moisture was measured by comparisons of grain yield, grain yield components, and other agronomic characteristics of three of four commercial maize hybrids used in this research.

CHAPTER IV

MATERIALS AND METHODS

Field Experiment

This experiment was conducted at the University of Arizona, Marana Agricultural Center in the summer of 1986. The environment at the Marana Agricultural Center is warm to hot and semi-arid in nature (Table 1). The soil is classified as a Pima clay loam. The Pima clay loam is classified in the fine-loamy family and belongs to the pima series of soil. It is composed of 27% clay, 45% silt, 20% sand and 8% of coarser particles.

Normal cultural practices were used in seed bed preparation and planting. A preplant incorporation of 16-20-0 fertilizer at a rate of 448.4 kg ha^{-1} gave 71.7 kg ha^{-1} of N and 89.7 kg ha^{-1} of P_2O_5. These fertilizer rates were considered adequate to give normal production on this soil type. Two moisture levels (stress and non-stress) were applied using furrow irrigation throughout the growing season. A preirrigation of 456 mm preceded the planting on 27 May 1986. Timing of irrigation was based on observed stress symptoms in the field (Table 2). The non-stress treatments were irrigated to produce optimum growth and the stress treatments to produce sub-optimal growth. The seed

Table 1. Weekly mean temperatures at the University of Arizona, Marana Agricultural Center during the field study.

Week No.	1986 Week	Mean temp (°C)	Week No.	1986 Week	Mean temp (°C)
1	May 1	23.8	12	July 17	28.9
2	8	22.1	13	24	30.3
3	15	25.8	14	31	33.2
4	22	28.1	15	Aug. 7	31.2
5	29	29.7	16	14	30.6
6	June 5	29.2	17	21	29.5
7	12	31.7	18	28	29.1
8	19	30.9	19	Sept. 4	31.2
9	26	31.6	20	11	26.7
10	July 3	30.8	21	18	28.9
11	10	29.8	22¶	25	29.9
Seasonal mean:					28.8

¶Average of 6 days for week no. 22

Table 2. Dates and amounts of rainfall and irrigation water applied to the experiment.

Dates (1986)		Rain (mm)	Non-stress treatment (mm)	Stress treatment (mm)
May	16-17		456.00	456.00
	30		182.25	182.25
June	24¶		159.75	113.75
July	11		156.75	149.75
	15	12.75		
	16	19.00		
	17	3.25		
	21	10.25		
	22	63.50		
	29		158.00	
	31			124.50
Aug.	06	33.00		
	07		148.50	80.00
	09	13.25		
	12	2.50		
	17	50.75		
	20		114.25	
	23	9.50		
	25	2.00		
Subtotal		219.75	1375.50	1106.25
Total			1594.25	1326.00

¶First application of differential amounts of irrigation bed moisture availability for all plots was the same in order to give uniform emergence and resulting plot stands for all plots. The two treatments began receiving differential irrigations with the first irrigation after emergence (24 June 1986, see Table 2). Four separate tests were run under each level of moisture. All plot rows in the experiment were 6.1 m long and spaced 1.0 m apart. Plots were separated by 0.6 m alley.

Forty-five seeds per plot row were planted on 27 May 1986 and thinned to 41 seedlings on 11 June 1986. All the plots were treated with Atrazine (6-chloro-n-ethyl-n'-(1-methylethyl)-1,3,5-triazine-2,4-diamine), 80% active ingredient, at the rate of 1.8 $kgha^{-1}$ after emergence to control broadleaf weeds.

The moisture stress plots were harvested between 5 and 10 Sept. 1986. The non-stress tests were harvested between 12 and 17 Sept. 1986. Harvest of all rows in a plot was by hand.

Experimental Plant Materials

The four hybrids used were developed for general environmental adaptation to the southern area of Texas by DeKalb-Pfizer Genetics Seed Company (Table 3). The latitude of the Arizona research location is similar to southern Texas, thus providing the same photoperiods. Two of these hybrids have been developed and sold commercially as

Table 3. Characteristics of maize hybrids selected to evaluate interplot and intraplot plant competition in two levels of soil moisture at the University of Arizona, Marana Agricultural Center.

	DeKalb-Pfizer Genetics descriptive characteristics		
Hybrid	Commercial hybrid designation	Relative maturity (days)	Drought tolerance rating
1	DeKalb XL72aa	115	Very good
2	DeKalb XL73	117	Outstanding
3	DeKalb 689	118	Excellent
4	DeKalb 789¶	128	Excellent

¶Common border genotype

possessing outstanding and excellent drought tolerance. A third hybrid was rated as "very good" in drought tolerance by its developers. Three of the hybrids were within 2 to 3 days of the same maturity which minimized bias due to longer growth periods.

The hybrid used as the common border in one of the test plots was a hybrid that matured later than the three experimental hybrids so that all three competing hybrids being bordered were assured of intraplot competition during their entire growth cycles.

Experimental Procedures

This field research was composed of the following four tests: five-row plots, three-row plots, "semi" three-row plots and one-row plots. A randomized complete block design with nine replications was used for all four tests. The field test design was the same as described by Gomez and Gomez (1984).

The five-row plots were utilized to evaluate the extent of border effects from adjacent plots into rows of the evaluated plots. The three-row plots, the "semi" three-row plots and the one-row plots made up the three types of plot borders. These three types of plot borders were evaluated to determine the most favorable in minimizing border effects for a more accurate evaluation of three of the four hybrids utilized.

The first type of plot border contained three rows of the same hybrid with only the center row harvested. The two outside border rows were of the same or like genotype. These two outside rows were not evaluated in order to remove border effects. This type of plot border has been designated "like borders" (LB). The second type of plot border was a "semi" three-row or "common borders" (CB) with only the center row planted with the designated hybrid to be evaluated. The two outside rows were planted with DeKabl 789 (Table 3), a later maturing hybrid. This particular border row hybrid was used on all hybrids. The common border served as border for the adjacent plot of the hybrid being evaluated. Thus, there was only one border row between evaluated plots versus two border rows in full three-row plots. The third type of plot contained a single row planted immediately adjacent to the other single row of a different hybrid. This type of plot has been designated as "no borders" (NB).

Measurement of Agronomic Characteristics

Days to tassel and silk emergence, green leaf number at pollination, main ear leaf area at pollination, plant height, ear height, plant number, ear number, grain yield, grain volume weight, weight of 300 kernels, and kernel number per ear were determined for all harvested rows. Days to tasselling and silking were calculated by summing the number of days from planting to full tasselling and full silking respectively. Green leaf number at pollination was the average number of green leaves on three randomly selected plants from each harvested row. At pollination, ear leaf area was obtained using Montgomery's (1911) method after measuring the length and the largest width on three randomly selected plants from each plot row to be harvested. Plant heights were measured at pollination from soil surface to the collar of the last top leaf. Ear height was measured from soil surface to the main ear insertion on the plant. Plant number per row was determined by counting the main stalks in the harvested row. Ear number per row was the number of kernel-bearing ears per harvested plot row. Grain yield was the weight of grain obtained after shelling all the ears from a plot. Grain volume weight and weight of 300 kernels were measured using cleaned kernels. Kernel number per ear was the number of kernels divided by the number of ears in each plot.

Some plots experienced a loss of some plants creating gaps. Under non-stress conditions, 85.2% of the five-row plots, 77.8% of the three-row plots, 85.2% of the one-row plots and 92.6% of the "semi" three-row plots were evaluated to have an average of 6.2%, 4.5%, 5.7% and 6.9%, respectively, of the plot lengths as gap. Under moisture-stress conditions, 45.9% of the five-row plots, 44.4% of the three-row plots, 25.9% of the one-row plots and 51.9% of the "semi" three-row plots were evaluated to have, respectively, 3.1%, 6.2%, 2.7% and 3.3% of the plot lengths as gap. These plots with gaps were adjusted to a full or complete plot basis for ears per plot and grain yield by means of the following formula:

(obtained yield or ear number x row length)/
(row length - gap)

The percentages for gaps presented for the two moisture levels appear to indicate only about half as many gaps and lengths of gap in the moisture stressed plots. The actual gaps under both moisture levels were actually equal in frequency and length. A measurable gap under non-stress conditions can actually cause a yield loss. The same gap under moisture stress can actually enhance the grain yield of plants adjacent to the gap due to the availability of additional soil moisture to these adjacent plants. Field experienced judicial judgment was used not to count some smaller gaps and count only a part of larger gaps in the moisture stress plots. Gaps in plots under moisture non-stress were measured in the normal manner for grain yield adjustment.

Statistical Analyses

The five-row plots test was analyzed as per Gomez and Gomez (1984). In this analysis, adjacent plots were the outside plots. The evaluated plots were the central ones. In these central plots, the outside plot-rows on either side next to the adjacent plots were numbered 1 and the next inside adjacent rows numbered 2. The remaining center rows were numbered 3. These center rows (Row 3) served as additional rows to extend the distance of possible interplot competition effects. The mean of a given character was computed for each hybrid in Row 1, Row 2 and the center row (Row 3), respectively. Finally, for each hybrid and with respect to the adjacent hybrid, the difference between Rows 1 and 2 was computed. The significance of the difference was determined by the chi-square test at 5% level with one degree of freedom.

Analyses of variance were performed only on LB, NB and CB plot data. These three types of plot borders were compared for the lowest experimental error as well as degree of precision in ranking hybrids based on their performance under moisture stress. This was done to determine which type of plot border was best in minimizing interplot competition effects for a more accurate evaluation of these hybrids.

CHAPTER V

RESULTS AND DISCUSSION

This chapter is presented in two parts. The first part deals with the first objective of the research which was to evaluate the extent of soil moisture competition between adjacent plots and provide information on the influences of soil moisture stress on plots free of interplot competition. The second part discusses the second objective to evaluate 3 types of plot borders. Additional discussion on consumptive water use to produce grain is also presented.

The three maize hybrids, selected for their differences in magnitude of grain yield response to soil moisture stress, have been evaluated by this research. Their overall agronomic responses were basically the same as given by DeKalb-Pfizer Genetics (Table 3). Their relative agronomic responses in this research to moisture stress and to interplot competition under moisture stress is reflected in the following relative characterizations:

DeKalb XL72aa = poor competitor,

DeKalb XL73 = average competitor, and

DeKalb 689 = best competitor.

These characterizations are used throughout the presentations of the results and discussions of this research.

PART I

Interplot Soil Moisture Competition Effects on Intraplot Emergence Dates of Reproductive Organs

Days to Tassel Emergence

Days to tassel emergence, without the effects of interplot competition, are shown in plot row 3 (Table 4). Moisture stress alone caused tassels to emerge one day earlier for the poor and average competitors (DeKalb XL72aa and DeKalb XL73). The best competitor (DeKalb 689) had no change in tassel emergence by soil moisture stress compared to non-stress. This difference of one day is small but has not been tested for significance. This small difference indicates a good degree of physiological stability of tassel emergence to moisture stress.

Tassel emergence date among intraplot rows of all three hybrids (DeKalb 689, DeKalb XL73, DeKalb XL72aa) was not affected at all by interplot competition under either soil moisture stress or non-stress conditions (Table 4).

Days to Silk Emergence

Soil moisture stress caused only the average competitor (DeKalb XL73) to be one day earlier in silk emergence (Table 5). The other two hybrids had the same days to silk emergence under both non-stress and stress.

Table 4. Interplot effects of competition for soil moisture on intraplot days from planting to tassel emergence of maize hybrids.

Moisture treatment	Hybrid	Adjacent plot hybrid	plot row number 1	2	3	Dif. bet. rows 1-2	%1-2
			-----------	days	---------		
Non-stress							
		2	55	55		0NS	0
	3				55		
		1	55	55		0NS	0
		3	55	55		0NS	0
	2				55		
		1	55	55		0NS	0
		3	55	55		0NS	0
	1				55		
		2	55	55		0NS	0
Stress							
		2	55	55		0NS	0
	3				55		
		1	55	55		0NS	0
		3	54	54		0NS	0
	2				54		
		1	54	54		0NS	0
		3	54	54		0NS	0
	1				54		
		2	54	54		0NS	0

1 = DeKalb XL72aa (poor competitor)
2 = DeKalb XL73 (average competitor)
3 = DeKalb 689 (best competitor)
NS = Not significant at 5% level of the Chi-square test

Table 5. Interplot effects of competition for soil moisture on intraplot days from planting to silk emergence of maize hybrids.

Moisture treatment	Hybrid	Adjacent plot hybrid	plot row number 1	2	3	Dif. bet. rows 1-2	%1-2
			----------days---------				
Non-stress							
		2	58	58		ONS	0
	3				58		
		1	58	58		ONS	0
		3	58	58		ONS	0
	2				58		
		1	58	58		ONS	0
		3	59	59		ONS	0
	1				59		
		2	59	59		ONS	0
Stress							
		2	58	58		ONS	0
	3				58		
		1	58	58		ONS	0
		3	57	57		ONS	0
	2				57		
		1	57	57		ONS	0
		3	59	59		ONS	0
	1				59		
		2	59	59		ONS	0

1 = DeKalb XL72aa (poor competitor)
2 = DeKalb XL73 (average competitor)
3 = DeKalb 689 (best competitor)
NS = Not significant at 5% level of the Chi-square test

There was no interplot competition sufficient to cause intraplot differences in days to silk emergence between Rows 1 and 2. Silk emergence appears to have a good degree of physiological stability to soil moisture stress at the levels imposed in this research.

Differences Between Days to Tassel Emergence and Days to Silk Emergence

The number of days between tassel emergence and silk emergence, 3 days, remained the same under moisture stress and non-stress for the best competitor (DeKalb 689) and the average competitor (Table 6). The poor competitor had 4 days between tassel and silk emergence under non-stress and 5 days under moisture stress. This 67% and 33% greater time between tassel and silk emergence under moisture stress and non-stress respectively very likely contributed to poor pollination, lower seed set and more barren ears. This physiological factor may have contributed to a lower yield even under non-stress.

Interplot Soil Moisture Competition Effects on Intraplot Morphological Characters

Green Leaf Number at Pollination

Green leaf number at pollination, without the effects of interplot competition, are shown in Row 3 (Table 7). The green leaf numbers for the average and best competitors (DeKalb XL73 and DeKalb 689) were the same in Row 3 under both moisture non-stress and moisture stress.

Table 6. Effects of soil moisture stress on difference between days to tassel emergence and days to silk emergence of maize hybrids.

Moisture treatment	Hybrid	Days to tassel emergence	Days to silk emergence	Days difference
Non-stress				
	DeKalb 689	55	58	3
	DeKalb XL73	55	58	3
	DeKalb XL72aa	55	59	4
Stress				
	DeKalb 689	55	58	3
	DeKalb XL73	54	57	3
	DeKalb XL72aa	54	59	5

DeKalb 689 = Best competitor
DeKalb XL73 = Average competitor
DeKalb XL72aa = Poor competitor

Table 7. Interplot effects of competition for soil moisture on intraplot green leaf number at pollination of maize hybrids.

Moisture treatment	Hybrid	Adjacent plot hybrid	plot row number 1	2	3	Dif. bet. rows 1-2	%1-2
			-------leaf number-----				
Non-stress							
		2	14	14		ONS	0.0
	3				14		
		1	14	14		ONS	0.0
		3	13	13		ONS	0.0
					14		
	2	1	14	14		ONS	0.0
		3	13	13		ONS	0.0
					13		
	1	2	14	13		+1NS	+7.7
Stress							
		2	13	14		-1NS	-7.1
	3				14		
		1	13	15		-2NS	-13.3
		3	14	13		+1NS	+7.7
	2				14		
		1	13	13		ONS	0.0
		3	13	12		+1NS	+8.3
	1				10		
		2	11	11		ONS	0.0

1 = DeKalb XL72aa (poor competitor)
2 = DeKalb XL73 (average competitor)
3 = DeKalb 689 (best competitor)
NS = Not significant at 5% level of the Chi-square test

Soil moisture stress caused the poor competitor to have three green leaves less under moisture stress than under moisture non-stress. No statistical analysis for significance of this difference was made. Under moisture stress, there were non-significant differences in green leaf number of one to two leaves for four of the six intraplot row comparisons. Under non-stress conditions, there was only one non-significant difference in green leaf number. The greater number of variations between Rows 1 and 2 under moisture stress indicates some physiological instability for green leaf number at pollination under the soil moisture stress imposed in this research. Greater stress may cause significant differences.

Ear-Leaf Area

Ear-leaf areas without the effects of interplot competition are shown in Row 3 (Table 8). The ear-leaf areas of all three hybrids increased under soil moisture stress. The greatest ear-leaf area increase under soil moisture stress was produced by the best competitor (DeKalb 689). The lowest ear-leaf area increase was produced by the poor competitor (DeKalb XL72aa). No statistical analyses for significance of these differences were made. Normally, leaf area reduction is observed under moisture stress (Denmead and Shaw, 1960).

Table 8. Interplot effects of competition for soil moisture on intraplot ear-leaf area of maize hybrids.

Moisture treatment	Hybrid	Adjacent plot hybrid	plot row number 1	2	3	Dif. bet. rows 1-2	%1-2
			----------cm2	----------			
Non-stress							
		2	558	521		+67NS	+12.9
	3				571		
		1	553	574		-21NS	-3.7
		3	568	534		+34NS	+6.4
	2				540		
		1	548	500		+48NS	+9.6
		3	583	597		-14NS	-2.3
	1				609		
		2	621	606		+15NS	+2.5
Stress							
		2	615	614		+ 1NS	+0.2
	3				617		
		1	593	581		+12NS	+2.0
		3	573	602		-29NS	-4.8
	2				561		
		1	585	611		-26NS	-4.2
		3	646	674		-28NS	-4.2
	1				620		
		2	650	650		0NS	0.0

1 = DeKalb XL72aa (poor competitor)
2 = DeKalb XL73 (average competitor)
3 = DeKalb 689 (best competitor)
NS = Not significant at 5% level of the Chi-square test

All interplot effects on Row 1 for all plots were statistically non-significant but the trends of the variation were very interesting. There was twice as much intraplot numerical difference among Rows 1 and 2 for ear-leaf area under moisture non-stress compared to moisture stress with half as much intraplot variation. One interplot comparison under moisture stress had no intraplot difference on the part of one plot. The higher intraplot variability among moisture non-stress plot interfaces compared to moisture stress was unexpected.

Under non-stress conditions, the average competitor (DeKalb XL73) experienced a non-significant gain of 6.4% in ear-leaf area in Row 1 when adjacent to the best competitor (DeKalb 689). This best competitor itself experienced a greater gain of 12.9% in Row 1 ear-leaf area from this same interface with the average competitor. The poor competitor (DeKalb XL72aa) under non-stress gained 2.5% when interfaced with the average competitor (DeKalb XL73) which in turn gained 9.6% in ear-leaf area. All hybrids in these two interplot interfaces gained in ear-leaf area but the better competitor always gained the most in leaf area. The interface under non-stress of the best competitor and the poor competitor results in a loss of 3.7% for the best competitor and a loss of only 2.3% for the poor competitor. This interplot interaction of the better competitor losing ear-leaf area was the reverse of all the previous interface situations.

The intraplot effects under moisture stress, all statistically non-significant, were variable in reactions at the various interfaces. The magnitude of these interactions was less than half of those under moisture non-stress.

Ear Height and Plant Height

Ear heights and plant heights without the effects of interplot competition under both soil moisture levels are expressed in Row 3 (Tables 9 and 10). The ear and plant heights of the best and average competitive hybrids (DeKalb 689 and DeKalb XL73) were not affected by soil moisture stress. The poor competitor (DeKalb XL72aa) had rather large reductions in ear and plant height caused by moisture stress of 7.4% and 8.6% respectively. It appears that stalk elongation for ear and plant height is an affected character in less competitive genotypes under moisture stress.

The interplot competition effects for ear and plant height under both moisture levels were very small and insignificant as shown by the intraplot differences between Rows 1 and 2 (Tables 9 and 10). These many small gains and losses by Row 1 over Row 2 are probably best explained as random variability.

Table 9. Interplot effects of competition for soil moisture on intraplot ear height of maize hybrids.

Moisture treatment	Hybrid	Adjacent plot hybrid	plot row number 1	2	3	Dif. bet. rows 1-2	%1-2
			-----------	cm	----------		
Non-stress							
		2	121	118		+3NS	+2.5
	3				122		
		1	115	116		-1NS	-0.9
		3	95	101		-6NS	-5.9
	2				99		
		1	97	100		-3NS	-3.0
		3	112	115		-3NS	-2.6
	1				121		
		2	118	117		+1NS	+0.8
Stress							
		2	120	114		-6NS	-5.3
	3				123		
		1	120	120		0NS	0.0
		3	100	106		-6NS	-5.7
	2				98		
		1	100	100		0NS	0.0
		3	118	115		+3NS	+2.6
	1				112		
		2	111	108		+3NS	+2.7

1 = DeKalb XL72aa (poor competitor)
2 = DeKalb XL73 (average competitor)
3 = DeKalb 689 (best competitor)
NS = Not significant at 5% level of the Chi-square test

Table 10. Interplot effects of competition for soil moisture on intraplot height of maize hybrids.

Moisture treatment	Hybrid	Adjacent plot hybrid	plot row number 1	2	3	Dif. bet. rows 1-2	%1-2
			-----------cm----------				
Non-stress							
		2	223	212		+11NS	+5.2
	3				215		
		1	212	212		0NS	0.0
		3	195	197		- 2NS	-1.0
	2				190		
		1	193	201		- 8NS	-3.9
		3	214	207		+ 7NS	+3.4
	1				221		
		2	205	214		- 9NS	-4.2
Stress							
		2	222	214		+ 8NS	+3.7
	3				218		
		1	214	214		0NS	0.0
		3	193	204		-11NS	-5.4
	2				187		
		1	189	192		- 3NS	-1.6
		3	208	208		0NS	0.0
	1				202		
		2	200	207		- 7NS	-3.4

1 = DeKalb XL72aa (poor competitor)
2 = DeKalb XL73 (average competitor)
3 = DeKalb 689 (best competitor)
NS = Not significant at 5% level of the Chi-square test

Interplot Soil Moisture Competition Effects on Intraplot Grain Yield and Grain Yield Components

Grain Yield

The separate effects of moisture stress and moisture non-stress on grain yield for each of the three hybrids, without interplot influence, are presented in Row 3 (Table 11). The average competitor hybrid, DeKalb XL73, and the best competitor hybrid, DeKalb 689, each had approximately 70% reductions in grain yield under moisture stress relative to non-stress. The poor competitor, DeKalb XL72aa, had an 88% reduction in grain yield under moisture stress. These responses indicate that grain yield can be greatly reduced by moisture stress and that there is very likely genetic variability for resistance to these soil moisture stress effects.

Results presented in Table 11 indicate some significant interplot competition effects on grain yields under both moisture treatments. Under non-stress conditions, the grain yield difference between Row 1 and Row 2 of the best competitor hybrid was significantly larger (11.1%) when the adjacent hybrid was the poor competitor. Under the same conditions, the row difference for the average competitor (DeKalb XL73) was significantly larger only when the poor competitor (DeKalb XL72aa) was the adjacent hybrid. Finally, the yield difference for the poor competitor (DeKalb XL72aa) was a positive 3.8% and significantly large

Table 11. Interplot effects of competition for soil moisture on intraplot grain yield of maize hybrids.

Moisture treatment	Hybrid	Adjacent plot hybrid	plot row number 1	2	3	Dif. bet. rows 1-2	%1-2
			---------kg ha^{-1}			--------	
Non-stress							
		2	6210	6083		+127NS	+2.0
	3				5982		
		1	5942	6602		-659*	-11.1
		3	5696	5725		- 29NS	-0.5
	2				5321		
		1	4789	5083		-294*	-6.1
		3	5037	5083		- 46NS	-0.9
	1				6248		
		2	5686	5471		+215*	+3.8
Stress							
		2	1848	1831		+ 17NS	+0.9
	3				1736		
		1	1649	1932		-283*	-17.2
		3	2052	2075		- 23NS	-1.1
	2				1659		
		1	1605	2096		-491*	-30.6
		3	894	1104		-210*	-23.5
	1				745		
		2	1092	903		+ 88*	+8.0

1 = DeKalb XL72aa (poor competitor)
2 = DeKalb XL73 (average competitor)
3 = DeKalb 689 (best competitor)
* = Significant at 5% level of the Chi-square test
NS = Not significant

when the adjacent hybrid was the average competitor (DeKalb XL73). These significant yield differences indicate the existence of interplot and intraplot competition under the non-stress conditions of this test.

Under conditions of moisture stress, yield differences between Row 1 and Row 2 of the average competitor (DeKalb XL73) and the best competitor (DeKalb 689) were both negative and significantly large only when the adjacent hybrid was the poor competitor (DeKalb XL72aa). When DeKalb XL73 and DeKalb 689 were grown adjacent to each other, non-significant yield difference was obtained. This may suggest that these hybrids have similar competitive abilities under moisture stress. However, the best competitor (DeKalb 689) had a significant 17.2% decrease in row yield as compared to a significant 30.6% for the average competitor (DeKalb XL73) when both were adjacent to the low yielding hybrid DeKalb XL72aa. The degree of soil moisture competition was apparently higher when the two competing hybrids differed markedly in competitive ability.

Kernel-bearing Ear Number per Plot

The separate effects of soil moisture stress and non-stress on ear number for each of the three hybrids, without interplot competition influence, are presented in plot Row 3 in Table 12. Intraplot ear number was not significantly affected by interplot competition under either

Table 12. Interplot effects of competition for soil moisture on intraplot ear number per plot of maize hybrids.

Moisture treatment	Hybrid	Adjacent plot hybrid	plot row number 1	plot row number 2	plot row number 3	Dif. bet. rows 1-2	Dif. bet. rows %1-2
			-----ears per plot-----				
Non-stress							
		2	41	42		-1NS	-2.4
	3				39		
		1	37	41		-4NS	-9.7
		3	37	34		+3NS	+8.8
	2				35		
		1	33	38		-5NS	-13.1
		3	33	34		-1NS	-2.9
	1				36		
		2	35	34		+1NS	+2.9
Stress							
	3	2	14	18		-4NS	-22.2
					16		
		1	20	17		+3NS	+17.6
	2	3	20	21		-1NS	-4.8
					17		
		1	20	22		-2NS	-9.1
	1	3	10	12		-2NS	-16.6
					9		
		2	8	11		-3NS	-27.3

1 = DeKalb XL72aa (poor competitor)
2 = DeKalb XL73 (average competitor)
3 = DeKalb 689 (best competitor)
NS = Not significant at 5% level of the Chi-square test

moisture stress or non-stress conditions. Ear number differences ranged from 2.4 to 13.1% under non-stress and from 4.8 to 27.3% under moisture stress. The greater but non-significant increases in ear number differences between Rows 1 and 2 under moisture stress indicates that this plant characteristic within plots is susceptible to interplot moisture stress. Ear number of Row 3 of the poor competitor (DeKalb XL72aa) under moisture stress was 25% of that of its non-stress treatment. Ear numbers of Row 3 of the best competitor (DeKalb 689) and the average competitor (DeKalb XL73) decreased by moisture stress to 41 and 49% respectively of those of their non-stress treatment values. No analyses were made for the significance of these values.

Ear number is a plant characteristic greatly influenced by moisture stress (Tollenaar, 1977). Reduction in the number of ears is likely to cause lower grain yields. The poor competitor (DeKalb XL72aa) experienced the greatest ear number reduction by soil moisture stress, suggesting intraspecific genetic variability for ear number under moisture stress.

Kernel Number per Ear

The separate effects of soil moisture stress and non-stress on kernel number per ear for each of the three hybrids, without interplot competition influence, are expressed in Row 3 in Table 13. Soil moisture stress

Table 13. Interplot effects of competition for soil moisture on intraplot kernel number per ear of maize hybrids.

Moisture treatment	Hybrid	Adjacent plot hybrid	plot row number 1	2	3	Dif. bet. rows 1-2	%1-2
			-----kernels per ear----				
Non-stress							
		2	448	493		-5NS	-1.0
	3				459		
		1	550	445		+5NS	+1.1
		3	428	493		-65*	-13.2
	2				417		
		1	476	385		+91*	+23.6
		3	450	451		-1NS	-0.2
	1				443		
		2	434	458		-24NS	-5.2
Stress							
		2	513	353		+160*	+45.3
	3				325		
		1	319	431		-112*	-25.9
		3	398	347		+51*	+14.7
	2				319		
		1	410	282		+128*	+45.4
		3	407	342		+65*	+19.0
	1				357		
		2	350	333		+17NS	+5.1

1 = DeKalb XL72aa (poor competitor)
2 = DeKalb XL73 (average competitor)
3 = DeKalb 689 (best competitor)
* = Significant at 5% level of Chi-square test
NS = Not significant

reduced the kernel number per ear of all three hybrids by 29.2%, 23.5% and 19.4% for the best, average and poor competitor respectively. No analyses were made to test the significance of these reductions. Increases in severity of soil moisture stress would be expected to produce greater reductions in kernel number per ear.

Intraplot kernel numbers per ear under moisture non-stress were mostly small and non-significant as expected from random variability with the exception of the average competitor (DeKalb XL73). The average competitor in interface with the best competitor (DeKalb 689) experienced an intraplot significant loss in kernel number per ear in Row 1. The average competitor in interface with the poor competitor (DeKalb XL72aa) had an intraplot significant gain in kernel number per ear in Row 1. Both of these significant differences are as would be expected under moisture stress but not under moisture non-stress.

Under moisture stress conditions, significant intraplot competition effects were observed regardless of the competitor. These variable intraplot differences in kernel number per ear cannot be explained in a simple way for this character alone. Kernel number per ear is one of three components of grain yield which can fluctuate among each other to produce the final grain yield. Kernel numbers per ear under moisture stress must be evaluated against ear number per plot and weight of 300 kernels also under moisture stress.

Weight of 300 Kernels (kernel size)

The separate effects of soil moisture stress and non-stress on weight of 300 kernels for each of the three hybrids, without interplot competition influence, are expressed in Row 3 in Table 14. The soil moisture stress imposed in this test reduced the weight of 300 kernels for each of the three hybrid competitors. The best competitor (DeKalb 689) had a 25.4% reduction in weight of 300 kernels. The poor competitor (DeKalb XL72aa) had a nearly equal reduction of 26.0%. The average competitor (DeKalb XL73) had a 19.1% reduction in weight of 300 kernels under moisture stress. All three hybrid competitors experienced similar reductions in kernel weights indicating less intraspecific variation for this component of yield under moisture stress than for ear number or kernels per ear. No statistical analyses were made of these differences to test for significance.

Intraplot variation in weights of 300 kernels under both soil moisture non-stress and soil moisture stress were mostly small as from random variability and all were non-significant. Kernel weights appeared to be a stable characteristic among the three different hybrids evaluated under the level of moisture stress imposed in this

Table 14. Interplot effects of competition for soil moisture on intraplot kernel size of maize hybrids.

Moisture treatment	Hybrid	Adjacent plot hybrid	plot row number 1	2	3	Dif. bet. rows 1-2	%1-2
			---g per 300 kernels---				
Non-stress							
		2	61	60		+1NS	+1.6
	3				63		
		1	62	62		0NS	0.0
		3	71	65		+6NS	+9.2
	2				68		
		1	64	66		-2NS	-3.0
		3	70	67		+3NS	+4.5
	1				73		
		2	71	72		-1NS	-1.4
Stress							
		2	51	54		-3NS	-5.6
	3				47		
		1	48	49		-1NS	-2.0
		3	51	55		-4NS	-7.3
	2				55		
		1	50	48		+2NS	+4.2
		3	63	54		+9NS	+16.7
	1				54		
		2	60	61		-1NS	-1.7

1 = DeKalb XL72aa (poor competitor)
2 = DeKalb XL73 (average competitor)
3 = DeKalb 689 (best competitor)
NS = Not significant at 5% level of the Chi-square test

experiment. The greatest influence of 19.1% to 26.0% decrease in kernel weight was across all hybrids under moisture stress. Intraplot moisture stress effects on kernel weights were minimal.

Effects of Soil Moisture Stress on Grain Yield and Components of Grain Yield

Soil moisture stress reduced the kernel-bearing ear numbers per plot more than kernel number per ear or kernel weight for all three hybrids (Table 15). The poor competitor (DeKalb XL72aa) had the lowest ear number of only 25% under moisture stress as compared to 41 to 49% for the best and average competitors. All three hybrids had from 71 to 81% of kernel number per ear and weight of kernels under moisture stress. The grain yield of the poor competitor (DeKalb XL72aa) under moisture stress was only 12% of its moisture non-stress yield compared to about 30% for the best and average competitors. The low number of kernel-bearing ears per plot were very likely caused by poor pollination (Table 6).

Grain Volume Weight

The separate effects of soil moisture stress and non-stress on grain volume weight for each of the three hybrids, without interplot competition influence, are presented in Row 3 in Table 16. The soil moisture stress imposed in this test reduced the grain volume weights for

Table 15. Effects of soil moisture stress on grain yield and its contributing components of maize hybrids.

Hybrid	Grain yield and its components			
	Grain Yield	Ear number per plot	Kernel number per ear	Weight of 300 kernels
	------------% of non-stress------------			
DeKalb 689 (best competitor)	29.0	41.0	70.8	74.6
DeKalb XL73 (average competitor)	31.2	48.6	76.5	80.9
DeKalb XL72aa (poor competitor)	11.9	25.0	80.6	74.0

Table 16. Interplot effects of competition for soil moisture on intraplot grain volume weight of maize hybrids.

Moisture treatment	Hybrid	Adjacent plot hybrid	plot row number 1	2	3	Dif. bet. rows 1-2	%1-2
			---------kg m^{-3}--------				
Non-stress							
		2	746	746		0NS	0.0
	3				709		
		1	758	758		0NS	0.0
		3	783	783		0NS	0.0
	2				734		
		1	783	783		0NS	0.0
		3	734	734		0NS	0.0
	1				709		
		2	734	746		-12NS	-1.6
Stress							
		2	734	721		+13NS	+1.7
	3				685		
		1	721	721		0NS	0.0
		3	734	734		0NS	0.0
	2				697		
		1	734	721		+13NS	+1.7
		3	709	709		0NS	0.0
	1				673		
		2	697	709		-12NS	+1.7

1 = DeKalb XL72aa (poor competitor)
2 = DeKalb XL73 (average competitor)
3 = DeKalb 689 (best competitor)
NS = Not significant at 5% level of the Chi-square test

best, average and poor competitor by 3.4%, 5.0% and 5.1% respectively. These are small reductions compared to the 19.1% to 26.0% reductions in kernel weight.

Intraplot variation in grain volume weights under both non-stress and soil moisture stress were very small and all were statistically non-significant. Moisture stress seemed to have a uniform influence on all three hybrids with little or no influence through interplot competition.

PART II

Interplot Effects of Types of Plot Borders on Emergence Dates of Reproductive Organs

Days to Tassel Emergence

The average days to tassel emergence for the three individual hybrids within the two moisture levels and within the three plot-border types are presented in Table 17. The deviation of days to tassel emergence from the normal non-stress condition to the soil moisture stress condition by each of the three hybrids evaluated are also presented in Table 17 as a percent of change from the non-stress soil condition.

The observed variation for days to tassel emergence among the three hybrids within each of three plot-border types within the two moisture levels could be expected to come from two sources: (1) difference in maturity of the genotypes of the three hybrids and (2) the variation of

Table 17. Average number of days to tassel emergence for the three individual hybrids within the two levels of irrigation and within the three types of plot borders.

Moisture treatment	Hybrid	Type of plot border LB plot	 NB plot	 CB plot
		-------------	days	------------
	DeKalb 689	54.11b¶	54.78	54.33b
Non-stress	DeKalb XL73	55.00ab	55.22	55.33ab
	DeKalb XL72aa	55.56a	55.44	55.78a
	LSD (0.05)	0.97	NS	1.10
	DeKalb 689	54.33b	54.78b	55.78
Stress	DeKalb XL73	55.00ab	55.56a	56.22
	DeKalb XL72aa	55.67a	55.78a	56.56
	LSD (0.05)	0.82	0.69	NS
	DeKalb 689	+0.40	0.00	+2.67
Deviation† (%)	DeKalb XL73	0.00	+0.61	+1.61
	DeKalb XL72aa	+0.19	+0.61	+1.39

LB = Three-row plots test
NB = One-row plots test
CB = "Semi" three-row plots test
NS = Not significant
¶Means followed by the same letters are not statistically different.
†Percent reduction by the moisture stress treatment.

response of each of the three hybrids to the different plot-border types. The order of occurrence of mean days to tassel emergence for the three hybrids within all six comparisons were all in the same sequence of from early to late of best competitor (DeKalb 689), average competitor (DeKalb XL73) and poor competitor (DeKalb XL72aa). Neither different plot-border types nor moisture stress had sufficient differential effects on days to tassel emergence among the three hybrids to change the sequence of tassel emergence.

The differences in mean days to tassel emergence among the three hybrids were from a fraction of a day to over one day within plot-border types and moisture levels. Statistical analyses were made of these variations among the three hybrids within the six variable environments of the three plot-border types within the two moisture levels (Table 18). The statistical significant rankings among the three hybrids in all six comparisons are shown in Table 17. The differences in mean days among the three hybrids in two of the six sets of comparisons, the NB plot type under non-stress and the CB plot type under stress, were too small to show significance.

The overall average number of days to tassel emergence for all three hybrids within the two moisture levels and within the three types of plot borders are

Table 18. Analysis of variance of days to tassel emergence of the three hybrids within the two levels of irrigation and within the three types of plot borders.

Source of variation	Degree of freedom	Type of plot border			Required F-ratio	
		LB plot	NB plot	CB plot	1%	5%
		-------mean squares------				
Non-stress						
Total	26					
Block	8	0.50	0.17	0.76		
Treatment	2	4.78	1.04	4.93		
Error	16	0.94	0.37	1.22		
F-ratio treatments		5.06*	2.80NS	4.05*	6.23	3.23
Moisture stress						
Total	26					
Block	8	1.42	1.95	1.51		
Treatment	2	4.00	2.48	1.37		
Error	16	0.67	0.48	0.70		
F-ratio treatments		6.00*	5.15*	1.95NS	6.23	3.23

NS = Not significant
LB = Three-row plots test
NB = One-row plots test
CB = "Semi" three-row plots test
* = Significant at 5% level
NS = Not significant

presented in Table 19. The deviations of those overall average days to tassel emergence from the normal non-stress condition to the soil moisture stress condition within types of plot borders are also presented in Table 19. With the exception of hybrids in the LB plot type, hybrids in the NB and the CB plot types experienced an overall average 0.5% and 2.6% delay in days to tassel emergence, respectively.

Days to Silk Emergence

The average number of days to silk emergence for the three individual hybrids within the two moisture levels and within the three types of plot borders are presented in Table 20. The deviations of days to silk emergence from the normal non-stress condition to the soil moisture stress condition by each of the three hybrids evaluated are also presented in Table 20 as a percent of change from the non-stress condition.

The observed variation for days to silk emergence among the three hybrids within each of the three types of plot borders within the two moisture levels could be expected to come from differences in maturity of the genotypes of the three hybrids and the variation of response of each of the three hybrids to the different types of plot borders. The order of occurrence of the average number of days to silk emergence for the three hybrids within five of the six comparisons were all in the same sequence of from

Table 19. Overall average number of days to tassel emergence for all three hybrids within the two levels of irrigation and within the three types of plot borders.

Moisture treatment	Type of plot border		
	LB plot	NB plot	CB plot
	--------------days---------------		
Non-stress	55.9	55.1	55.1
Stress	55.0	55.4	56.2
Deviation† (%)	-1.6	+0.5	+2.0

LB = Three-row plots test
NB = One-row plots test
CB = "Semi" three-row plots test
†Percent reduction by the moisture stress treatment.

Table 20. Average number of days to silk emergence for the three individual hybrids within the two levels of irrigation and within the three types of plot borders.

		Type of plot border		
Moisture treatment	Hybrids	LB plot	NB plot	CB plot
		------------days------------		
	DeKalb 689	57.56a¶	57.78b	57.56b
Non-stress	DeKalb XL73	56.67b	57.44b	57.11b
	DeKalb XL72aa	58.11a	59.00a	58.78a
	LSD (0.05)	0.63	0.61	1.04
	DeKalb 689	58.56b	58.11	59.11
Stress	DeKalb XL73	58.22b	58.44	58.89
	DeKalb XL72aa	59.78a	59.22	59.78
	LSD (0.05)	0.78	NS	NS
	DeKalb 689	+1.74	+0.57	+2.69
Deviation† (%)	DeKalb XL73	+2.73	+1.74	+3.11
	DeKalb XL72aa	+2.87	+0.37	+1.70

LB = Three-row plots test
NB = One-row plots test
CB = "Semi" three-row plots test
NS = Not significant
¶Means followed by the same letters are not statistically different.
†Percent reduction by the moisture stress treatment.

early to late of average competitor (DeKalb XL73), best competitor (DeKalb 689) and poor competitor (DeKalb XL72aa). The three hybrids in the sixth comparison (NB under moisture stress) were in the sequence of from early to late of best competitor (DeKalb 689), average competitor (DeKalb XL73) and poor competitor (DeKalb XL72aa). However, this change in hybrid sequence was not statistically significant. It may thus be concluded that neither different type of plot borders nor moisture stress had sufficient effects on days to silk emergence among the three hybrids to change the sequence of average days to silk emergence.

The differences in average number of days to silk emergence among the three hybrids were from a fraction of a day to over one day within plot border types and moisture levels. Statistical analyses were made of these differences within the variable environments of the three plot-border types within the two moisture levels (Table 21). The statistical significant rankings among the three hybrids in all six comparisons are shown in Table 20. The differences in average number of days to silk emergence among the three hybrids in two of the six sets of comparisons, the NB and the CB plot types under moisture stress, were too small to show significance. The percent of deviation of days to silk emergence from the non-stress condition decreased from the LB to the NB plot types and increased from the NB to the CB

Table 21. Analysis of variance of days to silk emergence within the two levels of irrigation and within the three types of plot borders.

Source of variation	Degree of freedom	Type of plot border: LB plot	NB plot	CB plot	Required F-ratio: 1%	5%
		------mean squares-------				
Non-stress						
Total	26					
Block	8	1.04	0.59	1.26		
Treatment	2	7.81	5.81	7.70		
Error	16	0.65	0.52	0.58		
F-ratio treatments		12.06**	11.12**	13.31**	6.23	3.23
Stress						
Total	26					
Block	8	0.51	1.29	1.25		
Treatment	2	12.48	16.15	10.11		
Error	16	0.27	0.48	0.98		
F-ratio treatments		45.69**	33.54**	10.25**	6.23	3.23

LB = Three-row plots test
NB = One-row plots test
CB = "Semi" three-row plots test
** = Significant at 1% level

plot types for each of the three individual hybrids (Table 20).

The overall average number of days to silk emergence for all three hybrids within the two moisture levels and within the three types of plot borders are presented in Table 22. There was a 0.9 to 2.5% delay in days to silk emergence by moisture stress and within the three types of plot borders.

Effects of Moisture Stress and Type of Plot Borders on Average Day Difference Between Tasselling and Silking

The average day difference between tassel emergence and silk emergence for the three individual hybrids within the two moisture levels and within the three types of plot borders are presented in Table 23. The plot border types produced equal direction of response in the LB and the CB plot types under moisture stress and non-stress. No statistical analyses were made of those responses. The order of occurrence of average day difference for the three hybrids within the LB and the CB plot types under moisture stress and non-stress were all in the same sequence of from small to large of the average competitor (DeKalb XL73), the poorest competitor (DeKalb XL72aa) and the best competitor (DeKalb 689). The three hybrids within the NB plot type under moisture stress and non-stress were of the same sequence of from small to large of the average competitor,

Table 22. Overall average number of days to silk emergence for all three hybrids within the two levels of irrigation and within the three types of plot borders.

Moisture treatment	Type of plot border		
	LB plot	NB plot	CB plot
	days		
Non-stress	57.5	58.1	57.8
Stress	58.9	58.6	59.3
Deviation† (%)	+2.5	+0.9	+2.5

LB = Three-row plots test
NB = One-row plots test
CB = "Semi" three-row plots test
†Percent reduction by the moisture stress treatment.

Table 23. Average day differences between tassel emergence and silk emergence for the three individual hybrids within the two levels of irrigation and within the three types of plot borders.

Moisture treatment	Hybrid	Type of plot border		
		LB plot	NB plot	CB plot
		------------days------------		
	DeKalb 689	3.45	3.00	3.23
Non-stress	DeKalb XL73	1.67	2.22	1.78
	DeKalb XL72aa	2.55	3.56	3.00
	DeKalb 689	4.23	3.33	3.33
Stress	DeKalb XL73	3.22	2.88	2.67
	DeKalb XL72aa	4.11	3.44	3.22

LB = Three-row plots test
NB = One-row plots test
CB = "Semi" three-row plots test

the best competitor and the poorest competitor. Moisture stress seemed not to have sufficient differential effects on these day differences to change their sequence among hybrids.

The average competitor had always the least number of days delay within type of plot borders and within moisture levels. This could have contributed to its better drought tolerance ability described by the seed company. If so, there could be a possibility of selecting genotypes for drought tolerance based upon the amount of time between tassel emergence and silk emergence. For that purpose, the LB plot type would be appropriate although no statistical analyses were made of these day differences within this type of plot borders to prove probable difference among the three hybrids.

Effects of Types of Plot Borders on Morphological Characters

Green Leaf Number at Pollination

The average green leaf number at pollination for the three individual hybrids within the two moisture levels and within the three types of plot borders are presented in Table 24. The deviations of green leaf number at pollination from the normal non-stress condition to the soil moisture stress condition by each of the three hybrids

Table 24. Average number of green leaves at pollination for the three individual hybrids within the two levels of irrigation and within the three types of plot borders.

Moisture treatment	Hybrid	LB plot	NB plot	CB plot
		Type of plot border		
		------green leaf number------		
	DeKalb 689	14.22a¶	14.00a	14.22a
Non-stress	DeKalb XL73	14.11a	13.89a	13.78a
	DeKalb XL72aa	12.56b	12.56b	12.44b
	LSD (0.05)	0.80	0.72	0.76
	DeKalb 689	14.22a	13.89a	14.00a
Stress	DeKalb XL73	13.33b	12.78b	13.11a
	DeKalb XL72aa	11.89c	11.22c	11.89b
	LSD (0.05)	0.52	0.69	0.99
	DeKalb 689	0.00	- 0.78	-1.54
Deviation†	DeKalb XL73	-5.52	- 7.99	-4.86
(%)	DeKalb XL72aa	-5.33	-10.66	-4.42

LB = Three-row plots test
NB = One-row plots test
CB = "Semi" three-row plots test
¶Means followed by the same letters are not statistically different.
†Percent reduction by the moisture stress treatment.

evaluated are also presented in Table 24 as a percent of change from the non-stress condition.

The observed variation for green leaf number at pollination among the three hybrids within each of the three types of plot borders within the two moisture levels could be expected to come from four sources: (1) difference in maturity of the three hybrids (the later maturing hybrid is more likely to produce more biomass (more leaves)), (2) the variation of response of each of the three hybrids to the different types of plot borders, (3) the variation of response of each of the three hybrids to the moisture stress and (4) the combination of the three.

The plot border types produced equal directions of responses in the LB, the NB and the CB plot types under non-stress and moisture stress. The order of increase in average green leaf number at pollination for the three hybrids within all six comparisons were all in the same sequence of from the lowest number to the highest number of poor competitor (DeKalb XL72aa), average competitor (DeKalb XL73) and best competitor (DeKalb 689). It appeared that (1) the longer the maturity period of the hybrid, the more green leaves it had at pollination and (2) the better competitor the hybrid, the higher number of green leaves it had at pollination. This indicated that the better competitor was more likely to produce more grain yield due to its higher number of green leaves at pollination. Neither different types of plot border nor moisture stress had sufficient effects on green leaf number at pollination among the three hybrids to change the sequence of green leaf number.

The differences in average green leaf number at pollination among the three hybrids were from one to two leaves within plot-border types and moisture levels. Statistical analyses were made of these differences among the three hybrids within the six variable environments of the three plot-border types within the two moisture levels (Table 25). The statistical significant rankings among the three hybrids in all six comparisons are shown in Table 24. The difference in average green leaf number at pollination among the three hybrids in all six sets of comparison were all significant. However, only the LB and the NB plot types showed that the three hybrids were statistically different from one another.

The overall average number of green leaves at pollination for all three hybrids within the two moisture levels and within the three types of plot borders are presented in Table 26. The overall average green leaf numbers were decreased by moisture stress in all three types of plot border.

Table 25. Analysis of variance of green leaf number at pollination within the two levels of irrigation and within the three types of plot borders.

Source of variation	Degree of freedom	Type of plot border LB plot	NB plot	CB plot	Required F-ratio 1%	5%
		------mean	squares	-------		
Non-stress						
Total	26					
Block	8	1708	4183	1247		
Treatment	2	214	7470	10340		
Error	16	1665	2627	2389		
F-ratio treatments		0.13NS	2.84NS	4.33*	6.23	3.23
Stress						
Total	26					
Block	8	2928	1265	2205		
Treatment	2	13810	8853	9506		
Error	16	1501	2035	721		
F-ratio treatments		9.20**	4.35*	13.2**	6.23	3.23

LB = Three-row plots test
NB = One-row plots test
CB = "Semi" three-row plots test
** = Significant at 1% level

Table 26. Overall average number of green leaves at pollination for all three hybrids within the two levels of irrigation and within the three types of plot borders.

Moisture treatment	Type of plot border		
	LB plot	NB plot	CB plot
	---------green leaf number---------		
Non-stress	13.6	13.5	13.5
Stress	13.1	12.6	13.0
Deviation† (%)	-3.5	-6.3	-3.6

LB = Three-row plots test
NB = One-row plots test
CB = "Semi"three-row plots test
†Percent reduction by the moisture stress treatment.

Ear-Leaf Area

The average area of the leaf supporting the main ear for the three individual hybrids within the two moisture levels and within the three types of plot borders are presented in Table 27. The deviations of mean ear-leaf area of the soil moisture stress condition from the normal non-stress condition by each of the three hybrids evaluated are also presented in Table 27 as a percent of change from the non-stress soil condition.

The observed variation for ear-leaf area among the three hybrids within each of the three types of plot borders within the two moisture levels could be expected to come from three sources: (1) genetic differences among the hybrids, (2) the variation of response of each of the three hybrids to the different plot-border types and (3) the variation of response of each of the three hybrids to the moisture stress condition. The order of occurrence of differences in mean ear-leaf area for the three hybrids within four of the six comparisons were all in the same sequence of from small to large for the average competitor (DeKalb XL73), best competitor (DeKalb 689) and poor competitor (DeKalb XL72aa). Only the LB plot type, under non-stress, and the NB plot type under moisture stress experienced a change in hybrid sequence. However, the change in hybrid sequence in the LB plot type under

Table 27. Average ear-leaf area for the three individual hybrids within the two levels of irrigation and within the three types of plot borders.

Moisture treatment	Hybrid	Type of plot border: LB plot	NB plot	CB plot
		-------------	cm^2	-------------
Non-stress	DeKalb 689	581.0	586.6	618.0ab
	DeKalb XL73	587.6	575.7	585.1b
	DeKalb XL72aa	590.6	630.2	652.9a
	LSD (0.05)	NS	NS	48.8
Stress	DeKalb 689	583.3b¶	580.1b	572.3b
	DeKalb XL73	544.8b	585.7b	547.4b
	DeKalb XL72aa	623.1a	637.0a	611.9a
	LSD (0.05)	38.7	45.1	26.8
Deviation† (%)	DeKalb 689	+0.4	-1.2	-7.4
	DeKalb XL73	-7.3	+1.7	-6.4
	DeKalb XL72aa	+5.5	+1.1	-6.3

LB = Three-row plots test
NB = One-row plots test
CB = "Semi"three-row plots test
NS = Not significant
¶Means followed by the same letters are not statistically different.
†Percent reduction by the moisture stress treatment.

non-stress was not significant. It may thus be concluded that the normal sequence of hybrid was the one of the four comparisons and so, the change in hybrid sequence observed in the NB plot type under moisture stress may be attributed to random experimental error. It appeared thus that neither different types of plot borders nor moisture stress had sufficient differential effects on ear-leaf area among the three hybrids to change the sequence of ear-leaf area variation among the hybrids.

The differences in mean ear-leaf area among the three hybrids were from 6.6 cm^2 to 78.3 cm^2 within types of plot borders and moisture levels. Statistical analyses were made of these variations among the three hybrids within the six variable environments of the types of plot border within the two moisture levels (Table 28). The statistical significant rankings among the three hybrids in all six comparisons are shown in Table 27. The differences in mean ear-leaf area among the three hybrids in two of the six sets of comparisons, the LB and the NB plot-types under non-stress, were too small to show significance.

The overall mean ear-leaf area within types of plot border and within soil moisture levels are presented in Table 29. No statistical analyses were made of the differences between the two moisture conditions as well as among the three types of plot borders. However, the

Table 28. Analysis of variance of ear-leaf area within the two levels of irrigation and within the three types of plot borders.

Source of variation	Degree of freedom	Type of plot border			Required F-ratio	
		LB plot	NB plot	CB plot	1%	5%
		-------mean squares------				
Non-stress						
Total	26					
Block	8	1708	4183	1247		
Treatment	2	214	7470	10340		
Error	16	1665	2627	2389		
F-ratio treatments		0.13NS	2.84NS	4.33*	6.23	3.23
Stress						
Total	26					
Block	8	2928	1265	2205		
Treatment	2	13810	8853	9506		
Error	16	1501	2035	721		
F-ratio treatments		9.20**	4.35*	13.2**	6.23	3.23

LB = Three-row plots test
NB = One-row plots test
CB = "Semi"three-row plots test
* = Significant at 5% level
** = Significant at 1% level
NS = Not significant

Table 29. Overall average ear-leaf area for all three hybrids within the two levels of irrigation and within the three types of plot borders.

Moisture treatment	Type of plot border: LB plot	NB plot	CB plot
	---------------- cm^2 ----------------		
Non-stress	586.4	597.6	618.7
Stress	583.7	600.9	577.2
Deviation† (%)	-0.5	+0.5	-6.7

LB = Three-row plots test
NB = One-row plots test
CB = "Semi"three-row plots test
†Percent reduction by the moisture stress treatment.

deviations of overall mean ear-leaf area from the normal non-stress condition to the soil moisture stress condition indicated very small differences between soil moisture conditions (Table 29). Among types of plot borders, only the hybrids in the CB plot type experienced a larger decrease.

In conclusion, there were increases and decreases in ear-leaf area among the three hybrids within the LB and the NB plot types. The CB plot type with relatively higher plot border competition caused greater decreases in ear-leaf area under soil moisture stress. Leaf area apparently is susceptible to decrease under high moisture stress. Reduction in leaf area by moisture stress was also reported by Denmead and Shaw (1960).

Ear Height and Plant Height

The average ear height and plant height for the three individual hybrids within the two moisture levels and within the three types of plot borders are presented in Tables 30 and 31, respectively. The deviation of mean ear height and mean plant height from the normal non-stress condition by soil moisture stress by each of the three hybrids evaluated are also respectively presented in Tables 30 and 31 as a percent of change from the non-stress soil condition.

Table 30. Average ear height for the three individual hybrids within the two levels of irrigation and within the three types of plot borders.

Moisture treatment	Hybrid	Type of plot border: LB plot	NB plot	CB plot
		-------------	cm	-------------
Non-stress	DeKalb 689	123.3a¶	110.6a	117.9a
	DeKalb XL73	98.9b	98.9b	100.6c
	DeKalb XL72aa	119.0a	108.3a	110.6b
	LSD (0.05)	7.17	3.51	6.49
Stress	DeKalb 689	104.1a	118.2a	107.8a
	DeKalb XL73	90.2b	102.8b	91.8c
	DeKalb XL72aa	94.9ab	108.2b	102.1b
	LSD (0.05)	10.12	5.96	5.66
Deviation† (%)	DeKalb 689	-15.6	+6.9	-8.6
	DeKalb XL73	-8.8	+3.9	-8.8
	DeKalb XL72aa	-20.3	-0.1	-7.7

LB = Three-row plots test
NB = One-row plots test
CB = "Semi"three-row plots test
¶Means followed by the same letters are not statistically different.
†Percent reduction by the moisture stress treatment.

Table 31. Average plant height for the three individual hybrids within the two levels of irrigation and within the three types of plot borders.

Moisture treatment	Hybrid	Type of plot border: LB plot	NB plot	CB plot
		---------------	cm	---------------
Non-stress	DeKalb 689	210.8a¶	207.6a	211.0a
	DeKalb XL73	197.1b	194.3b	196.9b
	DeKalb XL72aa	204.9ab	205.2a	201.8b
	LSD (0.05)	8.23	6.79	7.08
Stress	DeKalb 689	198.7a	205.7a	199.2a
	DeKalb XL73	184.8b	189.1b	178.0b
	DeKalb XL72aa	182.9b	193.0b	182.3b
	LSD (0.05)	6.96	7.82	7.19
Deviation† (%)	DeKalb 689	- 5.7	- 0.9	- 5.6
	DeKalb XL73	- 6.2	- 2.7	- 9.6
	DeKalb XL72aa	-10.7	- 5.9	- 9.7

LB = Three-row plots test
NB = One-row plots test
CB = "Semi"three-row plots test
¶Means followed by the same letters are not statistically different.
†Percent reduction by the moisture stress treatment.

The observed variation for ear height (Table 30) among the three hybrids within each of the three types of plot borders within the two moisture levels could come from three sources: (1) genetic differences among the three hybrids, (2) the variation of response of each of the three hybrids to the different plot border types, (3) the variation of response of each of the three hybrids to the moisture stress condition. The order of occurrence of average ear height for the three hybrids within all six comparisons were all in the same sequence of from short to tall of the average competitor (DeKalb XL73), poor competitor (DeKalb XL72aa) and best competitor (DeKalb 689). Neither different types of plot border nor moisture stress had sufficient differential effects on ear height among the three hybrids to change the sequence of ear height.

Concerning plant height (Table 30), the order of occurrence for the three hybrids within five of the six comparisons were all in the same sequence as ear height. Only the hybrids in the LB plot types under moisture stress experienced a change in height sequence which may be attributed to experimental error. Thus, neither different types of plot borders nor moisture stress had sufficient effects on ear height and plant height among the three hybrids to change the sequence of height.

The differences in average heights among the three hybrids were from 4.7 cm to 24.4 cm for ear height and from 1.9 cm to 21.2 cm for plant height within types of plot borders and moisture levels. Statistical analyses were made of these variations among the three hybrids within the six variable environments of the types of plot borders within the two moisture levels (Table 32 and 33). The statistical significant rankings among the three hybrids in all six comparisons are shown in Table 30 for ear height and Table 31 for plant height. The differences in average ear height or average plant height among the three hybrids were all significant. However, ear heights differed statistically from one hybrid to the other only in the CB plot type under the two moisture levels.

The overall average ear height and average plant height within plot borders and within soil moisture levels are presented in Tables 34 and 35, respectively. No statistical analyses were made of the differences between moisture conditions as well as the differences among types of plot borders. However, the deviations of overall mean ear height from the normal non-stress condition to the soil moisture stress condition indicated a decrease in ear height in both the LB (-15.2%) and the CB (-8.3%) plot types (Table 34). Concerning plant height, decreases in overall plant height was observed in all three types of plot

Table 32. Analysis of variance of ear height within the two levels of irrigation and within the three types of plot borders.

Source of variation	Degree of freedom	Type of plot border			Required F-ratio	
		LB plot	NB plot	CB plot	1%	5%
		------mean squares-------				
Non-stress						
Total	26					
Block	8	65.5	63.9	46.6		
Treatment	2	1531	345	681		
Error	16	51.6	12.4	42.2		
F-ratio treatments		29.7**	27.9**	16.2**	6.23	3.23
Stress						
Total	26					
Block	8	56.3	98.9	184		
Treatment	2	450	552	592		
Error	16	103	35.6	32.1		
F-ratio treatments		4.38*	15.5**	18.4**	6.23	3.23

LB = Three-row plots test
NB = One-row plots test
CB = "Semi"three-row plots test
* significant at 5% level
** significant at 1% level

Table 33. Analysis of variance of plant height within the two levels of irrigation and within the three types of plot borders.

Source of variation	Degree of freedom	Type of plot border			Required F-ratio	
		LB plot	NB plot	CB plot	1%	5%
		------mean squares-------				
Non-stress						
Total	26					
Block	8	129.60	94.45	26.00		
Treatment	2	422.90	448.30	462.10		
Error	16	67.88	46.13	50.28		
F-ratio treatments		6.23**	9.76**	9.19**	6.23	3.23
Stress						
Total	26					
Block	8	102.50	181.40	385.30		
Treatment	2	668.10	674.50	1132		
Error	16	48.53	61.23	62.80		
F-ratio treatments		13.77**	11.02**	18.02**	6.23	3.23

LB = Three-row plots test
NB = One-row plots test
CB = "Semi"three-row plots test
** significant at 1% level

Table 34. Overall average ear height for all three hybrids within the two levels of irrigation and within the three types of plot borders.

Moisture treatment	Type of plot border		
	LB plot	NB plot	CB plot
	---------------cm---------------		
Non-stress	113.7	105.9	109.7
Stress	96.4	109.7	100.6
Deviation† (%)	-15.2	+3.6	-8.3

LB = Three-row plots test
NB = One-row plots test
CB = "Semi"three-row plots test
†Percent reduction by the moisture stress treatment.

Table 35. Overall average plant height for all three hybrids within the two levels of irrigation and within the three types of plot borders.

Moisture treatment	Type of plot border		
	LB plot	NB plot	CB plot
	---------------cm---------------		
Non-stress	204.3	202.4	203.2
Stress	188.8	195.9	186.5
Deviation† (%)	-7.6	-3.2	-8.2

LB = Three-row plots test
NB = One-row plots test
CB = "Semi"three-row plots test
†Percent reduction by the moisture stress treatment.

borders. Decreases in height have been reported by workers such as Kirkham et al. (1972). Kirkham et al. (1972) explained plant height reduction under stress as loss in turgor pressure of plant cells due to water stress.

Effects of Type of Plot Borders on Grain Yield and Grain Yield Components

Grain Yield

Grain yield is a composite result of three other plant characteristics called components of yield: ear number, kernel number per ear, and kernel size. The overall balance of these components of grain yield for each hybrid determine the ultimate grain yield for that genotype. The description of "drought tolerant" in this experiment refers to "yield potential under moisture stress."

The average grain yield per hectare for the three individual hybrids within the two moisture levels and within the three types of plot borders are presented in Table 36. The deviations of average grain yield per hectare from the normal non-stress condition to the soil moisture stress condition by each of the three hybrids evaluated are also presented in Table 36 as a percent of change from the soil moisture non-stress condition.

The observed variation for average grain yield per hectare (Table 36) among the three hybrids within each of the three types of plot borders within the two moisture

Table 36. Average grain yield for the three individual hybrids within the two levels of irrigation and within the three types of plot borders.

Moisture treatment	Hybrid	Type of plot border: LB plot	NB plot	CB plot
		-----------kg ha^{-1}-----------		
Non-stress	DeKalb 689	6590a	4154b	3617
	DeKalb XL73	5274b¶	5342a	4075
	DeKalb XL72aa	4742b	4163b	3541
	LSD (0.05)	743	874	NS
Stress	DeKalb 689	1703a	1724a	1974a
	DeKalb XL73	1867a	1506a	1091b
	DeKalb XL72aa	859b	877b	687c
	LSD (0.05)	379	451	292
Deviation† (%)	DeKalb 689	-74.1	-58.5	-45.4
	DeKalb XL73	-64.6	-71.8	-73.2
	DeKalb XL72aa	-81.9	-78.9	-80.6

LB = Three-row plots test
NB = One-row plots test
CB = "Semi" three-row plots test
¶Means followed by the same letters are not statistically different.
†Percent reduction by the moisture stress treatment.

levels could be expected to come from sources such as: (1) genetic differences among the three hybrids, (2) the variation of response of each of the three hybrids to moisture stress, and (3) the variation of response of the hybrids to types of plot borders. The variable responses of these three hybrids are primarily from competition for soil moisture due to stress, differential effect of stress on contributing components of grain yield, differences in asynchrony between anthesis and silk emergence among the three hybrids, differences in pollen viability and silk receptivity. The order of occurrence of the average grain yield per hectare for the three hybrids within all six comparisons were not all in the same sequence. The three hybrids in the LB plot type under non-stress and the NB and the CB plot types under moisture stress were in the same sequence of from lowest to highest of the poor competitor (DeKalb XL72aa), the average competitor (DeKalb XL73) and the best competitor (DeKalb 689). The three hybrids in the CB plot type, under non-stress, and the LB plot type under stress were all in the same sequence of from lowest to highest of poor competitor (DeKalb XL72aa), best competitor (DeKalb 689) and average competitor (DeKalb XL73). The three hybrids in the NB plot type were in the sequence of from lowest to highest of best competitor (DeKalb 689), poor competitor (DeKalb XL72aa) and average competitor (DeKalb

XL73). These changes in grain yield rankings indicated that type of plot borders and moisture stress had a sufficient effect on these hybrids to change the sequence of grain yield.

The differences in average grain yield per hectare among the three hybrids were from 404 kg ha^{-1} to 1008 kg ha^{-1} within plot border types and moisture levels. Statistical analyses were made of these differences among the three hybrids within the six variable environments of the three plot border types within the two moisture levels (Table 37). The statistical significant rankings among the three hybrids in five of the six comparisons are shown in Table 37. Of all six sets of comparisons, only the CB plot type, under moisture stress condition, indicated statistical differences among the three hybrids. This indicated that the use of the later maturing hybrid as common border under moisture stress was necessary to differentiate one hybrid from another on the basis of grain yield. This result also suggests this type of plot borders for selection for grain yield under moisture stress conditions.

Individual hybrids had different grain yield decreases in the three types of plot borders. DeKalb XL73 had the least yield decrease of 64.6% in the LB plot type. With the NB and the CB plot types, DeKalb 689 had a small amount of grain yield reduction (Table 36). Reduced corn

Table 37. Analysis of variance of grain yield within the two levels of irrigation and within the three types of plot borders.

Source of variation	Degree of freedom	Type of plot border			Required F-ratio	
		LB plot	NB plot	CB plot	1%	5%
		-------mean squares-------				
Non-stress						
Total	26					
Block	8	455700	7518000	1079000		
Treatment	2	8145000	4204000	752000		
Error	16	552400	765100	954800		
F-ratio treatments		14.75**	5.49*	0.79NS	6.23	3.23
Stress						
Total	26					
Block	8	646000	1080000	390800		
Treatment	2	2334000	1743000	1395000		
Error	16	177700	204000	85340		
F-ratio treatments		14.82**	8.54**	16.34**	6.23	3.23

LB = Three-row plots test
NB = One-row plots test
CB = "Semi" three-row plots test
* = Significant at 5% level
** = Significant at 1% level
NS = Non-significant

grain yield by moisture stress was also reported by Denmead and Shaw (1960) and Herrero and Johnson (1981) who attributed yield reduction to the effect of moisture stress on development of reproductive organs and on pollination. Drought tolerance is defined as the relative ability of a genotype to maintain growth and grain yield under moisture stress. In that respect, DeKalb XL73 may be considered more drought tolerant than DeKalb 689 and DeKalb XL72aa in the LB plot. In both the NB and the CB plot types, DeKalb 689 may be considered more drought tolerant than DeKalb XL73 and DeKalb XL72aa. In the LB plot type, where intraplot competition for soil moisture was not severe, grain yield of DeKalb XL73 was less reduced. In the CB and the NB plot types, where competition for soil moisture was more severe, the yield of DeKalb 689 was less reduced. These may indicate that DeKalb XL73 and DeKalb 689 are similar in drought tolerance. But, these two hybrids differ in their ability to express their drought tolerance potential under differing competition for moisture situations. The slightly better yield potential hybrid (DeKalb 689) is able to express its drought tolerance ability under more severe competitive situations (NB, CB). This indicates that the better yield potential hybrid (DeKalb 689) was a better competitor for moisture than DeKalb XL73.

The overall average grain yield for all three hybrids within the two levels of moisture and within the three types of plot borders are presented in Table 38. Grain yield of all three hybrids was substantially reduced by moisture stress within all three types of plot borders. Differences of grain yield among types of plot borders within moisture levels were more likely to be significant, but they were not tested for. Overall average grain yield was reduced by moisture stress almost in the same proportion in all three types of plot borders (LB: -73.3%, NB: -69.9%, CB: -71.0%).

Kernel-bearing Ear Number per Plot

The average number of kernel-bearing ear per plot for the three individual hybrids within the two moisture levels and within the three plot-border types are presented in Table 39. The deviations of the average number of kernel-bearing ears per plot from the normal non-stress condition to the soil moisture stress condition by each of the three hybrids evaluated are also presented in Table 39 as a percent of change from the non-stress soil condition.

The observed differences for the average number of kernel-bearing ears per plot among the three hybrids within each of the three plot-border types within the two moisture levels could be expected to come from: (1) none to poor seed set caused by the effects of soil moisture stress

Table 38. Overall average grain yield for all three hybrids within the two levels of irrigation and within the three types of plot borders.

Moisture treatment	Type of plot border		
	LB plot	NB plot	CB plot
	--------------kg ha^{-1}--------------		
Non-stress	5535	4553	3745
Stress	1476	1369	1084
Deviation† (%)	-73.3	-69.9	-71.0

LB = Three-row plots test
NB = One-row plots test
CB = "Semi"three-row plots test
†Percent reduction by the moisture stress treatment.

Table 39. Average number of kernel-bearing ears per plot for the three individual hybrids within the two levels of irrigation and within the three types of plot borders.

Moisture treatment	Hybrid	Type of plot border: LB plot	NB plot	CB plot
		--------ears per plot--------		
	DeKalb 689	42.02a	36.05a	33.57a
Non-stress	DeKalb XL73	32.73b¶	31.26ab	28.18b
	DeKalb XL72aa	33.61b	25.78b	24.59b
	LSD (0.05)	3.42	5.93	5.33
	DeKalb 689	19.26a	19.78a	15.31a
Stress	DeKalb XL73	20.19a	14.38b	13.54a
	DeKalb XL72aa	12.38b	9.07c	8.63b
	LSD (0.05)	2.76	4.68	2.98
	DeKalb 689	-54.16	-45.13	-54.39
Deviation†	DeKalb XL73	-38.31	-53.99	-51.95
(%)	DeKalb XL72aa	-63.16	-64.81	-64.90

LB = Three-row plots test
NB = One-row plots test
CB = "Semi" three-row plots test
¶Means followed by the same letters are not statistically different.
†Percent reduction by the moisture stress treatment

and/or high temperature on pollen viability and/or silk receptivity, and (2) the variation of response of each of the three hybrids to the different plot border types. The plot border types produced equal direction of response in the NB and CB plot types under non-stress and moisture stress.

The order of occurrence of the average number of kernel-bearing ears per plot for the three hybrids within the NB and the CB plot types, under moisture non-stress and stress, were all in the same sequence of from lowest to highest of the poor competitor (DeKalb XL72aa), the average competitor (DeKalb XL73), and the best competitor (DeKalb 689). The average of kernel-bearing ears per plot of the three hybrids in the LB plot type, under moisture non-stress, were in the sequence of from lowest to highest of the average competitor (DeKalb XL73), the poor competitor (DeKalb XL72aa) and the best competitor (DeKalb 689). The number of kernel-bearing ears per plot of the three hybrids in the LB plot type, under soil moisture stress, were in the sequence of from lowest to highest of poor competitor, best competitor and average competitor. It may be concluded that moisture stress did not have sufficient differential effect on the number of kernel-bearing ears per plot among the three hybrids to change the sequence in the NB and the CB plot types. However, it did change the sequence in the LB plot type.

The differences in average kernel-bearing ears per plot among the three hybrids were from a fraction of an ear to over ten ears within plot-border types and moisture levels. Statistical analyses were made of these differences among the three hybrids within the six variable environments of the three types of plot borders within the two moisture levels (Table 40). The statistical significant rankings among the three hybrids in all six comparisons are shown in Table 39. Of all six comparisons, only the NB plot type under moisture stress indicated statistical differences from one hybrid to the other. But, the differences in average number of kernel-bearing ears per plot of all six comparisons were all significant.

The average number of kernel-bearing ears per plot deviations by moisture stress in the LB plot type were in the sequence of from lowest to highest of the average competitor (DeKalb XL73), the best competitor (DeKalb 689) and the poor competitor (DeKalb XL72aa). However, in the NB and the CB plot types, the deviations by moisture stress were in the sequence of from lowest to highest of best competitor, average competitor and poor competitor. These are indications that the low yield experienced by the poor competitor, as compared to the best and average competitors,

Table 40. Analysis of variance of number of kernel-bearing ears per plot within the two levels of irrigation and within the three types of plot borders.

Source of variation	Degree of freedom	Type of plot border: LB plot	NB plot	CB plot	Required F-ratio: 1%	5%
		-------mean squares------				
Non-stress						
Total	26					
Block	8	14.23	100.10	39.53		
Treatment	2	238.00	237.80	183.70		
Error	16	11.70	35.25	28.41		
F-ratio treatments		20.34**	6.74**	6.46**	6.23	3.23
Stress						
Total	26					
Block	8	50.76	59.29	37.99		
Treatment	2	163.80	258.10	107.70		
Error	16	7.62	21.94	8.88		
F-ratio treatments		21.48**	11.77**	12.13**	6.23	3.23

LB = Three-row plots test
NB = One-row plots test
CB = "Semi"three-row plots test
** significant at 1% level

may be partly due to the low number of kernel-bearing ears per plot under moisture stress.

The average numbers of kernel-bearing ears per plot for all three hybrids within the three types of plot and within the two moisture levels are presented in Table 41. The deviations of these average numbers by moisture stress are also presented in Table 41. No statistical analyses were made of the differences in average numbers of kernel-bearing ears per plot between moisture condition within types of plot borders as well as of the deviations from one type of plot border to the other. However, there was a sequence in deviations of from lowest to highest of the low competition condition (LB), the medium competition condition (NB) and the high competition condition (CB).

Kernel Number per Ear

The average number of kernels per ear for the three individual hybrids within the two moisture levels and within the three types of plot borders are presented in Table 42. The deviations of the average number of kernels per ear from the normal non-stress condition to the soil moisture stress condition by each of the three hybrids evaluated are also presented in Table 42 as a percent of change from the non-stress soil condition.

The observed differences for the average number of kernels per ear among the three hybrids within each of the

Table 41. Overall average number of kernel-bearing ears per plot for all three hybrids within the two levels of irrigation and the three types of plot borders.

Moisture treatment	Type of plot border: LB plot	NB plot	CB plot
	----------ears per plot----------		
Non-stress	36.1	31.0	28.8
Stress	17.2	14.4	12.5
Deviation† (%)	-52.2	-53.6	-56.6

LB = Three-row plots test
NB = One-row plots test
CB = "Semi" three-row plots test
†Percent reduction by the moisture stress treatment.

Table 42. Average number of kernels per ear for the three individual hybrids within the two levels of moisture and within the three types of plot borders.

Moisture treatment	Hybrid	Type of plot border: LB plot	NB plot	CB plot
		----kernel	number per	ear----
Non-stress	DeKalb 689	436.8	485.3	310.6
	DeKalb XL73	434.9	533.3	396.1
	DeKalb XL72aa	391.5	499.8	412.9
	LSD (0.05)	NS	NS	NS
Stress	DeKalb 689	293.9	330.5	319.0a
	DeKalb XL73	300.1	332.3	295.9ab
	DeKalb XL72aa	233.7	300.5	256.8b
	LSD (0.05)	NS	NS	48.7
Deviation† (%)	DeKalb 689	-32.7	-31.9	+ 2.7
	DeKalb XL73	-30.9	-37.7	-25.3
	DeKalb XL72aa	-40.3	-39.9	-37.8

LB = Three row-plots test
NB = One-row plots test
CB = "Semi" three-row plots test
NS = Not significant
¶Means followed by the same letters are not statistically different.
†Percent reduction by the moisture stress treatment.

three types of plot borders within the two moisture levels could be expected to come from sources such as: (1) genetic differences among the three hybrids, (2) the variation of response of each of the three hybrids to moisture stress, and (3) the variation of response of the hybrids to different types of plot borders. Responses of these hybrids to moisture stress and different types of plot borders could be reduction in ear size, reduced fertilization due to asynchrony of anthesis and silk emergence, competition for photosynthate produced by the plant among different sinks and competition for soil moisture among the hybrids. Kernel number reduction by soil moisture stress has been reported by many researchers who indicate that maximum reductions in kernel number resulted from stress in the silking and early grain fill stages (Claassen et al., 1970; Harder et al., 1982; Moss and Downey, 1971; and Robins and Domingo, 1953).

The differences in the average number of kernels per ear among the three hybrids were from 1.8 to 102.3 kernels within plot border types and moisture levels. Statistical analyses were made of these variations among the three hybrids within the six variable environments of the three plot-border types within the two moisture levels (Table 43).

The types of plot borders produced unequal direction of response under non-stress conditions. Under the same moisture condition, differences among hybrids within types

Table 43. Analysis of variance of kernel numbers per ear within the two levels of moisture and within the three types of plot borders.

Source of variation	Degree of freedom	Type of plot border			Required F-ratio	
		LB plot	NB plot	CB plot	1%	5%
		------mean squares-------				
Non-stress						
Total	26					
Block	8	3624	153000	18980		
Treatment	2	5902	94540	27080		
Error	16	2963	30650	17330		
F-ratio treatments		1.99NS	3.08NS	1.56NS	6.23	3.23
Stress						
Total	26					
Block	8	5034	4276	4063		
Treatment	2	12110	2859	8897		
Error	16	5968	2857	2371		
F-ratio treatments		2.03NS	1.00NS	3.75*	6.23	3.23

LB = Three row-plots test
NB = One-row plots test
CB = "Semi" three-row plots test
* = Significant at 5% level
NS = Not significant

of plot borders were not significant indicating random error among the results (Table 42). However, there were differences in kernel numbers per ear produced by each hybrid from one type of plot border to the other (Table 42). Those differences were never tested for. Fewer kernel numbers per ear were produced by hybrids within the CB plot type under non-stress. This could be the result of the effects of stronger competition for moisture caused by the common border hybrid in this type of plot border.

Under stress conditions, the LB and the NB plot types produced equal directions of responses on the hybrids (Table 42). Differences among the three hybrids within these two types of plot borders were not significant. The CB plot type, however, produced significant differences among the three hybrids (Table 43), probably because DeKalb 689 experienced an unusual increase in kernel numbers per plot within the CB plot type under moisture stress (Table 42). This may be due to random experimental error. In all other cases, reduction in kernel number per ear by moisture stress was obtained (Table 42). Under moisture stress, the poor competitor (DeKalb XL72aa) experienced larger reductions in number of kernels per ear than the other two hybrids in all three types of plot borders. This may indicate a possible relationship between competitiveness for soil moisture and the number of kernels per ear produced by a genotype.

The average number of kernels per ear for all three hybrids within the three types of plot borders and within the two moisture levels are presented in Table 44. The percent deviations of these average numbers of kernels by moisture stress from the moisture non-stress condition within types of plot borders are also presented in Table 44. No statistical analyses were made of these deviations. The average number of kernels per ear for all three hybrids was the least reduced in CB plot types.

Weight of 300 Kernels (kernel size)

The average kernel size for the three individual hybrids within the two moisture levels and within the three types of plot borders are presented in Table 45. The deviations of the average kernel size from the normal non-stress condition by the soil moisture stress condition for each of the three hybrids evaluated are also presented in Table 45 as a percent of change from the non-stress soil condition.

The observed differences for the average kernel size among the three hybrids within each of the three types of plot borders within the two moisture levels could be expected to come from sources such as (1) genetic differences among the three hybrids, (2) the variation of

Table 44. Overall average number of kernels per ear for all three hybrids within the two levels of irrigation and within the three types of plot borders.

Moisture treatment	Type of plot border LB plot	NB plot	CB plot
	------kernel	number per	ear------
Non-stress	421.1	458.2	373.0
Stress	275.9	321.1	290.5
Deviation† (%)	-34.5	-29.9	-22.1

LB = Three-row plots test
NB = One-row plots test
CB = "Semi" three-row plots test
†Percent reduction by the moisture stress treatment.

Table 45. Average weight of 300 kernels for the three individual hybrids within the two levels of irrigation and within the three types of plot borders.

Moisture treatment	Hybrid	Type of plot border: LB plot	NB plot	CB plot
		------g per 300 kernels------		
	DeKalb 689	66.94	67.86	68.30
Non-stress	DeKalb XL-73	69.11	66.31	70.03
	DeKalb XL-72aa	67.68	65.67	67.52
	LSD (0.05)	NS	NS	NS
	DeKalb 689	55.18	48.18b	55.67
Stress	DeKalb XL-73	57.40	57.04a¶	50.46
	DeKalb XL-72aa	55.01	57.98a	58.61
	LSD (0.05)	NS	6.82	NS
	DeKalb 689	-17.56	-29.00	-18.49
Deviation† (%)	DeKalb XL-73	-16.94	-13.97	-27.94
	DeKalb XL-72aa	-18.72	-11.71	-13.19

LB = Three-row plots test
NB = One-row plots test
CB = "Semi" three-row plots test
NS = Not significant
¶Means followed by the same letters are not statistically different.
†Percent reduction by the moisture stress treatment.

response of each of the three hybrids to the different types of plot borders, and (3) the variation of response of the hybrids to moisture stress. Responses of these hybrids to moisture stress and different types of plot borders could be reduction in kernel size and inadequate grain filling.

The moisture stress produced unequal directions of hybrid responses within types of plot borders. Also, types of plot borders produced unequal directions of hybrid responses within moisture levels. It seemed that types of plot borders and moisture stress had sufficient differential effects on kernel size to change the response rank sequence of these hybrids (Table 45). Five of the six comparisons are statistically non-significant which might indicate only random error among the results within stress and non-stress levels. The deviations between stress and non-stress are most likely significant but were never tested for.

The differences in average kernel size among the three hybrids were from 0.17 g to 9.80 g per 300 kernels within plot border types and moisture levels. Statistical analyses were made of these variations among the three hybrids within the six variable environments of the three plot border types within the two moisture levels (Table 46). The statistical rankings among the three hybrids in NB only, under moisture stress, are shown in Table 45. This is because the differences in kernel size among the three

Table 46. Analysis of variance of weight of 300 kernels within the two levels of moisture and within the three types of plot borders.

Source of variation	Degree of freedom	Type of plot border: LB plot	NB plot	CB plot	Required F-ratio: 1%	5%
		-------mean squares------				
Non-stress						
Total	26					
Block	8	18.45	104.80	61.15		
Treatment	2	10.93	11.39	14.87		
Error	16	19.22	16.74	28.61		
F-ratio treatments		0.59NS	0.68NS	0.52NS	6.23	3.23
Stress						
Total	26					
Block	8	36.15	65.67	85.04		
Treatment	2	16.01	263.30	26.59		
Error	16	50.14	46.67	28.26		
F-ratio treatments		0.32NS	5.65*	0.94NS	6.23	3.23

LB = Three-row plots test
NB = One-row plots test
CB = "Semi" three-row plots test
* = Significant at 5% level
NS = Not significant

hybrids in the remaining five sets of comparisons were too small to show significance.

The average kernel size for all three hybrids within the three types of plot borders and within the two moisture levels are presented in Table 47. The percent deviations of these average kernel sizes by moisture stress within types of plot borders are also presented in Table 47. No statistical analyses were made of these deviations. Kernel size was the most reduced in the CB plot type. A trend in kernel size reduction from the CB to the LB plot type indicated that the stronger the stress produced by a plot border type the larger the reduction in overall kernel size.

Effects of Types of Plot Borders and Moisture Stress on Grain Yield and Its Contributing Components

The percent deviations of grain yield and its contributing components for all individual hybrids are presented in Table 48. These deviations represent the percent of change of grain yield and each of its contributing component from the non-stress condition. Within type of plot borders and within each of the characteristics, deviation differences among the three hybrids were not tested for. In all three types of plot borders, the deviation values were larger for grain yield, followed by kernel-bearing ear number per plot, kernel number per plot

Table 47. Overall average weight of 300 kernels for all three hybrids within the two levels of irrigation and within the three types of plot borders.

Moisture treatment	Type of plot border		
	LB plot	NB plot	CB plot
	--------g per 300 kernels--------		
Non-stress	67.9	66.6	68.6
Stress	55.9	54.4	54.9
Deviation† (%)	-17.7	-18.3	-19.9

LB = Three row-plots test
NB = One-row plots test
CB = "Semi" three-row plots test
†Percent reduction by the moisture stress treatment.

Table 48. Effect of soil moisture stress and types of plot borders on grain yield and its contributing components of maize hybrids.

Types of plot borders	Hybrid	Grain yield	Ear number per plot	Kernel number per ear	Weight of 300 kernels
		Grain yield and its components			
		----% deviation from non-stress---			
	DeKalb 689	-74.1	-54.16	-32.7	-17.56
LB Plot	DeKalb XL73	-64.6	-38.31	-30.9	-16.94
	DeKalb XL72aa	-81.9	-63.16	-40.3	-18.72
	DeKalb 689	-58.5	-45.13	-31.9	-29.00
NB Plot	DeKalb XL73	-71.8	-53.99	-37.7	-13.97
	DeKalb XL72aa	-78.9	-64.81	-39.9	-11.71
	DeKalb 689	-45.4	-54.39	+2.7	-18.49
CB Plot	DeKalb XL73	-73.2	-51.95	-25.3	-27.94
	DeKalb XL72aa	-80.6	-64.90	-37.8	-13.19

LB = Three-row plots test
NB = One-row plots test
CB = "Semi" three row plots test

and weight of 300 kernels for all individual hybrids. All exceptions were attributed to random experimental error.

Within the LB plot type, the poor competitor experienced the largest deviation of all three hybrids. The average competitor (DeKalb XL73) had the least reduction in all characteristics. This indicates that under normal condition (LB: isogenic plants grown next to each other), the yield and its contributing components of the average competitor are less susceptible to moisture stress. This may have been the reason why the seed company rated this hybrid as the best drought tolerant of all three hybrids.

Within the NB plot type, the poor competitor experienced the largest deviation in grain yield and its contributing components of all three hybrids. The best competitor (DeKalb 689) had the least deviation (-58.5%) in grain yield of all three hybrids. This deviation was about 6% less than the deviation of the average competitor in the LB plot type. This indicates that under competition situations (NB: different genotypes grown side by side), the best competitor is less susceptible to soil moisture stress than the other two hybrids.

Within the CB plot type, the poor competitor still had the largest deviation in grain yield of all three hybrids. Like in the NB plot type, the best competitor experienced less deviation in grain yield (-45.4%) than the other two hybrids. Under competition situations (NB, CB), grain yield of the best competitor was the least reduced by moisture stress.

Deviations in grain yield of the average competitor and the poor competitor varied very little from one type of plot border to the other. No statistical analyses were made of these little differences to determine their significance. Differences in percent deviation in grain yield of the best competitor (DeKalb 689) from one type of plot border to the other seemed more likely to be significant, but were not tested for. Because the best competitor (DeKalb 689) seems to be the only hybrid with a decrease in grain yield deviation as the competition condition increases, it may be concluded that this hybrid possesses a broad genetic basis for competitiveness for soil moisture. The other two hybrids may be considered as having a narrow genetic basis.

Grain Volume Weight

The average grain volume weight for the three individual hybrids within the two moisture levels and within the three types of plot borders are presented in Table 49. The deviation of the average grain volume weight from the normal non-stress condition to the soil moisture stress condition are also presented in Table 49 as a percent of change from the non-stress soil condition.

Table 49. Average grain volume weight for the three individual hybrids within the two levels of irrigation and within the three types of plot borders.

Moisture treatment	Hybrid	Type of plot border: LB plot	NB plot	CB plot
		------------kg m^{-3}	-----------	
	DeKalb 689	753.6b	756.6a¶	751.1
Non-stress	DeKalb XL-73	777.1a	759.0a	750.6
	DeKalb XL-72aa	728.3c	744.0b	755.2
	LSD (0.05)	9.98	11.67	NS
	DeKalb 689	733.8a	694.6b	725.0a
Stress	DeKalb XL-73	749.8a	734.6a	726.0a
	DeKalb XL-72aa	688.7b	719.0a	697.8b
	LSD (0.05)	17.60	26.74	14.62
	DeKalb 689	- 2.6	- 8.2	- 3.5
Deviation†	DeKalb XL-73	- 3.5	- 3.2	- 3.3
(%)	DeKalb XL-72aa	- 5.4	- 3.4	- 7.6

LB = Three-row plots test
NB = One-row plots test
CB = "Semi" three-row plots test
¶Means followed by the same letters are not statistically different.
†Percent reduction by the moisture stress treatment.

The observed differences for the average grain volume weight among the three hybrids within the two moisture levels could be expected from source such as (1) genetic differences among the three hybrids, (2) the variation of response of each of the three hybrids to the different types of plot borders, and (3) the variation of responses of the hybrids to moisture stress. The order of occurrence of average grain volume weight for the three hybrids were the same within four of the six comparisons. These four sets of comparisons were the LB and the NB plot types under non-stress, and the LB and the CB plot types under moisture stress. In these four types of plot borders, the order of occurrence of average grain volume weight were in the sequence of from the lowest to the highest of the poor competitor (DeKalb XL72aa), the best competitor (DeKalb 689), and the average competitor (DeKalb XL73).

The high number of significances among the three hybrids in five of the six comparisons (Table 50) may be due primarily to basic genetic differences as expressed by LB non-stressed. Four of the six comparisons had the same sequence thus showing mostly genetic differences and not so much from plot border types. The poor competitor seems to be more affected by stress in many characters, thus it has a higher percent deviation in two of the three plot-border types (LB, CB).

Table 50. Analysis of variance of grain volume weight within the two levels of moisture and within the three types of plot borders.

Source of variation	Degree of freedom	Type of plot border			Required F-ratio	
		LB plot	NB plot	CB plot	1%	5%
		------mean squares-------				
Non-stress						
Total	26					
Block	8	361.3	1344	2424		
Treatment	2	5371	581.2	58.4		
Error	16	99.8	136.3	235		
F-ratio treatments		53.83**	4.26*	0.25NS	6.23	3.23
Stress						
Total	26					
Block	8	247.1	1191	605.8		
Treatment	2	9023	3667	2301		
Error	16	310.3	715.9	214.1		
F-ratio treatments		29.07**	5.12*	10.74**	6.23	3.23

LB = Three-row plots test
NB = One-row plots test
CB = "Semi" three-row plots test
* = Significant at 5% level
** = Significant at 1% level
NS = Not significant

The differences in average grain volume weight among the three hybrids were from 0.5 kgm^{-3} to 61.1 kgm^{-3} within plot border types and moisture levels. Statistical analyses were made of these variations among the three hybrids within the six variable environments of the three plot border types within the two moisture levels (Table 50). The statistical rankings among the three hybrids in five of the six comparisons are shown in Table 49.

The overall average grain volume weight for all three hybrids within the three types of plot borders and within the two moisture levels are presented in Table 51. The percent deviations of these average grain volume weights by moisture stress within types of plot borders are also presented in Table 51. No statistical analyses were made of these deviations. Average grain volume weight for all three hybrids was most reduced in the NB and the CB plot-types almost in the same proportion.

Consumptive Water Use to Produce Grain Yield

The averages of consumptive use of water to produce 1 kg of grain for the three individual hybrids within the two moisture levels and within the three plot-border types are presented in Table 52. The deviations of the consumptive use of water from the normal non-stress condition to the soil moisture stress condition by each of

Table 51. Overall average grain volume weight for all three hybrids within the two levels of irrigation and within the three types of plot borders.

Moisture treatment	Type of plot border: LB plot	NB plot	CB plot
	--------------kg m^{-3}--------------		
Non-stress	753.0	753.2	752.3
Stress	724.1	716.1	716.3
Deviation† (%)	- 3.8	- 4.9	- 4.8

LB = Three-row plots test
NB = One-row plots test
CB = "Semi" three-row plots test
†Percent reduction by the moisture stress treatment.

Table 52. Average consumptive use of water to produce 1 kg of grain by the three individual hybrids within the two levels of irrigation and within the three types of plot borders.

Moisture treatment	Hybrid	Type of plot border LB plot	 NB plot	 CB plot
		-----------	mm kg^{-1}	-----------
	DeKalb 689	0.2	0.4	0.4
Non-stress	DeKalb XL73	0.3	0.3	0.4
	DeKalb XL72aa	0.3	0.4	0.4
	DeKalb 689	0.8	0.8	0.7
Stress	DeKalb XL73	0.8	0.9	1.2
	DeKalb XL72aa	1.5	1.5	2.0

LB = Three-row plots test
NB = One-row plots test
CB = "Semi" three-row plots test

the three hybrids evaluated are also presented in Table 52 as a percent of change from the non-stress soil condition.

The observed variation for consumptive use of water to produce 1 kg grain yield among the three hybrids could be expected to come from three sources: (1) genetic differences among the hybrids, (2) variation of response of the hybrids to types of plot borders and (3) variation of responses of the hybrids to moisture stress. These variations are mainly dependent upon the amount of grain yield because the moisture factor remained constant for all hybrids within types of plot borders and within moisture levels.

Within moisture levels, consumptive use of water to produce grain yield of a hybrid were more likely to be significantly different from one type of plot borders to the other. But, these differences were not tested for. Within moisture levels, the poor competitor required more water to produce grain than the other two hybrids. Under both moisture stress and non-stress, hybrids in the CB plot type required more water to produce grain. Within the CB plot type, the average competitor (DeKalb XL73) required less water under non-stress to produce grain. Within the same type of plot border, but under stress condition, the best competitor (DeKalb 689) showed smaller value of water use to produce grain.

The overall averages of consumptive use of water to produce grain for all three hybrids within the two levels of irrigation and within the three types of plot borders are presented in Table 53. Within moisture levels, the amount of water required by all three genotype to produce grain increased with increased competition (from LB to CB). This indicated that the genotypes reacted to increased competition by being less efficient in water use per unit of grain produced. Within types of plot borders, genotypes reacted to moisture stress also by being less efficient in water use per unit of grain produced.

Table 53. Overall average consumptive use of water to produce 1 kg of grain by all three hybrids within the two levels of irrigation and within the three types of plot borders.

Moisture treatment	Type of plot border		
	LB plot	NB plot	CB plot
	------------mm kg^{-1}----------		
Non-stress	0.2	0.3	0.4
Stress	0.9	0.9	1.2

LB = Three-row plots test
NB = One-row plots test
CB = "Semi" three-row plots test

CHAPTER VI

SUMMARY AND CONCLUSIONS

The emergence of reproductive organs (tassel and silk) of each of the three hybrids was not affected by interplot competition for soil moisture. However, the better competitors (DeKalb 689 and DeKalb XL73) and the poor competitor experienced respectively 33% and 67% of time between tassel and silk emergence under non-stress and moisture stress condition. This may have contributed to poor pollination, less seed set and more barren ears. Morphological characteristics (leaf number, leaf area, ear height, plant height), and yield components such as ear number, kernel number per ear, and seed size were not affected by interplot competition for soil moisture. Grain yield and kernel number were affected by soil moisture competition. Both were substantially reduced by moisture stress. Competition effect was extended to the second row in the 5-row plot test. In this respect, larger plot size (more than five rows) may be required to evaluate interplot competition effects accurately.

Leaf area, ear height, plant height, and grain volume weight were not affected by types of plot borders. The types of plot borders seemed not to have differential effects on the time between tassel and silk emergence of all three hybrids. The average competitor rated outstanding drought tolerant hybrid by the seed company had fewer days between tassel and silk emergence in all six sets of comparisons. This may suggest a possibility of selecting genotype for drought tolerance based on time interval between tassel and silk emergence. For that purpose, three-row plots with the outside rows discarded would be appropriate.

Under low competition situations (LB), the average competitor (DeKalb XL73) experienced less reduction in grain yield. Under increased competition situations (NB, CB), the best competitor (DeKalb 689) showed the least reduction in grain yield. The percent reduction in yield of both the average competitor and the poor competitor (DeKalb XL72aa) was almost the same in all three types of plot borders. This may indicate that these two hybrids are stable in their respective degree of drought tolerance. The best competitor (DeKalb 689) experienced a decrease in percent of yield reduction as the competition situation became stronger. The decrease in yield reduction of this hybrid under increasing competition condition indicates a broad genetic basis of the same hybrid for drought tolerance. The average and poor competitors maintained their percent yield reduction under the three types of plot borders because of their narrow genetic basis for their individual degree of drought tolerance. The CB plot type had a small error term (MSE) for grain yield under moisture stress. It also was the only type of plot border where differences among all three hybrids for grain yield were observed. This suggests the CB plot type as the only effective type of plot border for the evaluation of the competitiveness and/or drought tolerance of these hybrids under the moisture stress conditions of this research.

Within the five-row plots test and within each of the three types of plot borders, soil moisture stress reduced kernel-bearing ear numbers per plot more than kernel numbers per ear or kernel weight for all three hybrids. It seemed thus that increase of grain yield per unit area may come primarily from increase of the numbers of kernel-bearing ear per unit area.

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