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The effects of maturity differences on competition between adjacent rows of sorghum bicolor varieties at two levels of soil moisture

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THE EFFECTS OF MATURITY DIFFERENCES ON COMPETITION BETWEEN ADJACENT ROWS OF SORGHUM BICOLOR VARIETIES AT TWO LEVELS OF SOIL MOISTURE

by

Joseph BISSO EYA

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STATEMENT BY THE AUTHOR

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APPROVAL BY THESIS DIRECTOR

This thesis has been approved on the date shown below:

Robert L. Voigt — 1 May 1989

R. L. VOIGT
Professor of Plant Sciences

Date

DEDICATION

This thesis is dedicated to my father

Moïse EYA BEKALE

and mother, sister and wife

Anne-Valentine BISSO BISSA

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ABSTRACT

The objective of this study was to determine if and how grain sorghum hybrids (Sosghum bicolor (L.) Moench) of different maturity date compete with one another when planted in adjacent rows and at different moisture levels. Five sorghum varieties differing in their maturity were used: Taylor Evans Y-101-G coming to mid-bloom in 71 days, RS 610, Asgrow Corral, DK 64 and DK 69 coming to mid bloom in 56.8days, 61 days, 69.3 days and 75.6 days respectively . Six agronomic characters were measured to determine the effect and extend of competition. They included the number of days to mid-bloom, tiller ratio, grain yield, grain test weight and 300-seed weight.

According to the results, adjacent row competition took place due to differences in maturity date for grain yield and 300-seed weight. An almost equilibrium appeared between loss or gain or border rows compared to the loss or gain of the middle row. Also the lenght of time between day to mid-bloom of the border rows hybrids and the center row genotype was important in the extend of competition.

CHAPTER 1

INTRODUCTION

Sorghum (Sorghum bicolor (L.) Moench) is ranked fourth among the cereals used for human food in the world and seventh in terms of average yield (1774 kg/ha), but yields on a field basis have exceeded 11000 kg/ha. Where water is not a limiting factor, yields ranging from 7000 to 9000 kg/ha have been recorded, while under conditions of severe or limited moisture, yields as low as 300 to 1000 kg/ha have been obtained (Leland 1985). Sorghum is mainly used as feed in developed countries, but is basically a staple food for human in those areas of the world where climatic conditions are severe in terms of low water availability and high temperatures.

With the increasing need for efficiency in agriculture due to the worlds' growing population with limited farm land, positive contributions are being made by breeders and agronomists in producing high yielding varieties responding to appropriate field techniques. Nevertheless in those areas where food supply remains a daily problem, there is also a problem in the availability of seeds of appropriate adapted cultivars with satisfactory quality and quantity.

In order to attain their best potential yields, plants in general and cereals in particular, must be grown under near ideal conditions of light, nutrients and moisture. These conditions are seldom met in field conditions where plants encounter competition.

Many studies have been conducted to obtain explanations of field crop plant competition. Under conditions of restricted availability of necessary environmental and nutritional factors, there is a general agreement that the ultimate crop yield in a given area will depend on the individual ability of each plant to compete for these resources.

The importance of plant height, plant density, between and within row spacings, and water as factors of crop competition has been documented by a number of research studies (Grimes and Musick (1960), Broadhead et al. (1963), Yao and Shaw (1964), Atkins et al.(1968), Hooker (1985), Rees (1986)). But very little has been done to study competition between crops differing in their maturity dates.

OBJECTIVES

The objective of this study was to develop useful information regarding the competition effects on grain yield of <u>Sorghum</u> <u>bicolor</u> varieties differing in maturity date and grown in single row-plots side-by-side under normal and restricted conditions of soil moisture. More specifically the study was to determine how competition between adjacent row plots of sorghum varieties differing in maturity will affect their grain yield or yield characteristics.

Therefore the following research questions were posed in developing useful answers.

How are the 50% bloom date, tiller ratio, 'plant height, plant grain yield, 300 seed weight and grain test weight of a plot modified when it is bordered in adjacent plots by sorghum genotypes of the same or different maturity?

IMPORTANCE

From a scientific point of view, the information obtained will hopefully enable scientists to use more appropriate plot techniques to determine crop yield potentials in situations where varieties differing in maturity dates must be grown adjacent to each other. This step is often critical in breeding selection programs for yield potential when many varieties are grown in a very small area. To a lesser extent, these data will be important to agronomists and extension personnel who can use them to develop more accurate yields at the farm level.

Finally the study can help national projects in Cameroon such as the National Office for Participation in Development and the National Campaign for FOOD SELF-SUFFICIENCY achieve their main goal which is to increase cereal production by using differences in maturity date and improved farming techniques to enhance the yield potential of some local cropping techniques.

CHAPTER 2

LITERATURE REVIEW

There is abundant literature on the general topic of crop competition, but very little specific information on competition between adjacent plots differing in their maturity dates.

PLANT COMPETITION

According to Gomez and Gomez (1983), plant competition is commonly referred to as the interdependence of adjacent plants because of their common needs for limited sunshine, soil nutrients, moisture, carbon dioxide, oxygen and so on. Therefore two plants, no matter how close they are, will never compete with each other as long as factors for which they can compete are in excess of the needs of both. It is only when the immediate supply of one or more of these factors falls below their combined demand that competition begins.

Competition in plants occurs in two ways: the above ground competition for light, oxygen, carbon dioxide..., and the below ground competition for moisture and nutrients. Competition can take place among plants of the same or different species and within the same species between cultivars depending on their growth habits and their individual ability to compete.

ABOVE GROUND COMPETITION

Among the different factors for which plants can compete above ground, light is one of the most important because it induces the other types of above ground competition. According to Stoller and Woolley (1985), competition for light occurs when one plant grows taller than another and shades it at a given time of the day or growing season, reducing the yield potential of the shaded plant.

Within the same plant, competition can take place when one leaf shadows another leaf. Studying the effect of shade on soybean yields using three weeds and three weed densities ranging from 0.7 to 2.5 plants/m2, Stoller and Woolley (1985) estimated that 44 to 56% of the total sunlight reaching the plant was intercepted by the shade. They also discovered that both synthesis and CO^2 utilization were reduced and most important, the yield decreased from 12 to 54% due to the effect of shade.

Weaver and Tan (1983) reached a similar conclusion studying the critical period of weed interference in transplanted tomatoes. They observed that there was a reduction in stomatal conductance in tomatoes from infested plots due primarily to the decrease in available light caused by shading rather than water stress. They concluded that the observed decrease in plant total dry weight was caused by decreased rates of photosynthesis as the result of shading.

BELOW GROUND COMPETITION

Below ground competition has been studied in a number of ways and with various plants. There is general agreement that competition for nutrients and water occurs depending on the availability of moisture and nutrients present in the soil, the types of plant root systems, differences in plant height, between and within row plant spacing and other varietal genetic differences.

Bray (1953), studying plant competition, defined three plant competition situations in which competition between adjoining plants occurs. (1) when plants are far enough apart so that neither of their root sorption zones overlap or interpenetrate, no competition for water or nutrients occurs. (2) when the root system sorption zones of adjacent plants interpenetrates, it causes competition for mobile nutrients. (3) if root surface sorption zones of adjacent plants interpenetrate, only then competition for immobile nutrients occurs. As a major consequence, there is a reduction in the yield potential of some of the competing plants according to the individual ability of each of the plants to compete.

PLOT COMPETITION

Effects of population density and row spacing.

Many studies have been carried out to demonstrate the effects of population densities and row spacings on crop competition. Myers and Foale (1980) assessing the effect of row spacing and population density in Australian sorghum production, concluded that row spacing was more important than population density in controlling sorghum growth and yield.

Stickler and Wearden (1965) in 34 sorghum spacing experiments in Eastern and Central Kansas with two row-spacings (20- and 40 inch-rows) observed that yields from 20-inch row-spacing exceeded those from 40-inch rows by 7 to 10%. They explained the yield superiority of narrow row-spacings by an increase in tillering. The analysis of yield components data revealed that the observed yield superiority was mainly associated with more heads per unit area. There was little tendency for row width and stand density interaction. There was also a remarkable constancy of grain yield from widely varying stand densities due to intercompensation among individual yield components such as heads per unit area.

Rees (1986) reached different conclusions studying the effects of population density and row spacing on Sorghum bicolor in semi-arid conditions in Botswana. Using three row-spacings and three intra-row plant spacings, he found an optimum density for grain production which varied from 10,000 plants/ha in dry conditions to over 120,000 plants/ha in moist conditions. Increasing density resulted in considerable delays in time taken for 50% of stems to produce a flowering head, but there was little evidence of a row spacing effect separate from the effect of density. Leaf area index, total number of plant deaths and grain yield in treatments of similar density but differing in row spacing showed neglegible differences.

Robinson et al. (1964) had reached the same conclusions as Myers and Foale (1980). Comparing four row-spacings (10-20-30 and 40-inch rows) each at three planting populations (78,408, 156,816 and 313,632 seeds per acre) in three Minnesota experimental farms, they found that spacings, but not populations, were important causes of yield differences. As rows narrowed from 40 to 10 inches, grain yields increased in a linear manner.

According to Atkins et al. (1968), both row and plant spacing can affect grain yield of sorghum. In an experiment in Iowa to evaluate the performance of two sorghum varieties under two row-spacings and four within-row spacings, they found that the within-row plant population showed an 11% advantage for 76cm (30-inch) over 102cm (40-inch) row-spacing. A within-row population of five plants/30 to 35cm produced the highest grain yield at each row spacing. Within each row spacing, seeds per head and heads per plant decreased progressively as the within-row plant population increased from four to eight plants/30 to 35cm.

Studying the effects of plant population and planting pattern at Ames (Iowa), Yao and Shaw (1964) using two populations and three row-spacings found that the grain yields were significantly different for both spacings and populations.

Broadhead et al. (1963) investigating the effects of sorgo spacings, plant arrangements, and plant arrangement x fertilizer interactions on yield of stalks and sirup per acre found that sirup and yields decreased as spacing increased.

Middleton et al. (1964) found similar results as Robinson et al.(1964). Growing three varieties of winter barley in two row-spacings and three rates of seeding within the row, they found that decreasing the rate of seeding decreased the number of fertile heads.

There were no significant differences in yield at both 8-and 16-inch row spacings or at the different rates of seeding within rows. The weight of 1,000 seeds and the test weight per bushel were not significantly affected.

Williams et al. (1965) studying productivity in relation to interception of solar radiation in vegetative growth of corn as affected by population density found that increasing plant density increased the leaf area index (LAI), and thus increasing the use of solar radiation by plants. This led to a higher grain yield and dry matter production per unit area.

Sartaj et al. (1984) looking at the effect of seeding rate on green fodder yields of four sorghums at two sites in Pakistan found that increasing sowing rates from 10kg/ha to 50kg/ha decreased plant height, but increased fodder yield and palatability.

Machado et al. (1986) found no significant effect of inter-row spacings on grain yield in field experiments in Brazil from 1977 to 1979 using three row spacings in combination with three plant densities.

Effect of water:

With the same plant density and same fertility level in different plots, water has been shown to be a factor affecting competition between plants or between plots of plants.

In field experiments from 1980 to 1984 in semi-arid conditions in Botswana, Rees (1986) pointed out that under conditions of reasonable water availability, increasing plant density resulted in increased leaf area index, dry weight production and grain yield. But under conditions of severely limited water availability, increasing plant density resulted in developmental delays, density dependent mortality, reduced plant dry weight with little increase in dry weight per ha.

Brown et al.(1964) were more explicite in studying the effects of irrigation and row-spacing on grain sorghum. Using three irrigation levels and two row spacings, they found significant differences in grain yield between low levels of irrigation and no irrigation. The irrigated sorghum in 12 to 20 inch rows produced significantly more grain per acre/inch of water used than the 30 to 40 inch rows. They attributed the higher grain yield of narrower spacing to a more uniform plant spacing, which resulted in more efficient use of moisture, nutrients and solar energy. Adequate irrigation had no effect on plant height but plant height decreased when irrigation was insufficient. Also the date of bloom came earlier in the non-irrigated plots.

Grimes and Musick (1960) found that a 7-inch row spacing produced significantly more than the 14 to 25 or the 28-inch row spacings when looking at the effects of plant spacing, fertility and irrigation management on grain sorghum production. They also found a significant interaction between plant spacing and irrigation management applied at selected phenological stages of plant development.

Abdelraahman (1986) in making selections by evaluating two families of sorghum with and without water stress at sites in Kansas and Nebraska found that water stress affected yields and yield components, but did not affect 50% flowering. The genotypes responded differently to timing and intensity of stress, but grain yield under stress was closely related to yield without stress.

Not only is water an important factor affecting plant competition, but more critical is the timing and number of irrigations. Hooker (1985) applied irrigation water treatments at different times during the growing season (presowing (PS), phase (a); presowing + growth differentiation (PS+GD), phase (b); presowing + growth differentiation + boot stage (PS+GD+B), phase (c); or presowing + initiation of irrigation at 50% available soil moisture, phase (d)) and found that highest yields were obtained each year when irrigation was initiated at phases (c) or (d). The timing of in-season water application (growth differentiation or boot stage) had no effect on grain yield.

Abeytunge (1983) reached different conclusions evaluating the response of sorghum to summer irrigation over two years and at two plant densities in Australia. He found that delayed irrigations resulted in lower grain yield compared to frequent irrigations. The correlations between yield, water use efficiency at various developmental stages and water use at anthesis were not significant. The measurement of leaf water relations indicated the existence of osmotic adjustment responses to water stress. This was inferred to be the primarly source of yield reduction.

Border plot, interplot or adjacent plot competition:

Many studies have been conducted to determine the extent to which plot yields are affected by border or adjacent plots. Generally researchers agree that plants growing along the sides of plots are more vigorous than are those inside the plot. Also more vigorous varieties benefit when grown next to less vigorous ones, particulary in single row-plots.

Using ten genotypes of barley and 10 genotypes of wheat with four types of borders (control, same genotype, unbordered winter wheat, and spring barley or wheat) to study the influence of the plot border and the ranking of cereal genotypes, May and Morrison (1985) found that plot yield increased as border competition decreased. The ranking of the genotype was not influenced by the type of border, except when a highly competitive barley genotype was used as a border with wheat.

Austin and Blackwell (1980) in two field experiments with winter wheat varieties showed that the grain yield per unit area calculated from the entire plot was 25% greater than the yield of the center row. In the extreme case when a short variety was bordered by a neighbor twice as tall, its grain yield relative to that of the tall variety was underestimated by 10 to 12%.

The extent of the plant root system, plant height and growth habits in general play major roles in plant competition. In their book Field Plot Technique, Le Clerg et al. (1921) gave evidence that competition effects between adjacent rows of different varieties of most plants differing in growth habits may introduce serious errors in yield tests.

Kempton et al. (1986) in a series of experiments to assess the extent of interplot competition and its effects in comparing triticale cultivars and triticale and wheat standards found that yields in both cases were affected by height of adjacent plots. When each variety occurred adjacent to all varieties including itself, exactly once at a right-hand and once as a left-hand, plot yield were increased or reduced by 1 to $2g/m^2$ for every cm by which the plot exceeded or was exceeded by the mean height of adjacent plots. Height difference between plots early in the growing season had no effect on final yield. Moreover the competition effect observed on test weight suggested that interplot competition was not intense during the grain filling period and that the primary source of competition was light interception.

Kempton and Lockwood (1984) reached a similar conclusion investigating on the effect of interplot competition on seed yields and plant heights of field beans, using experimental designs balanced for neighbors. The plot yield of the tallest variety increased by 20% compared to its pure stand when grown between plots of a dwarf variety. More controversial, a complementary reduction in yield was shown by a dwarf variety when grown between plots of the tall. When varieties were differing in their final height by less than 15cm, no differential effect of intervarietal competition on yield was shown.

The conclusions of Jensen and Federer (1964) on the extent of the reduction or the enhancement of the yield under conditions of plants differing in height were different from the above. Studying competition effects associated with varying heights of wheat at Ithaca (New York), they found that while yields of taller varieties were enhanced by 5.0 bushel per acre, those of shorter varieties were depressed by 2.0 to 3.0 bushel/ha. The two effects were not found to be compensatory and the enhancing effect was of a greater magnitude. These findings are in contradiction with those of Kempton and Lockwood (1984) and those of Sakai (1955) that the increment to one plant and the decrement to the other due to competition may be the same in their absolute value.

Fisher (1978) showed that the relative yields of selections contrasting in their height are distorted in favor of the tallest. Tall varieties gain more being adjacent to short ones than the short ones lose.

Varietal competition:

Within the same species, competition takes place among the different cultivars according to their height, their maturity date, their tolerence or not to drought, etc, in general according to their growth habits.

To determine if and how cultivars of differing growth habits compete with one another when planted in

sides. According to their results, competition took place between cultivar C and B where cultivar C, the late maturing and the tallest, gained 120 kg/ha while B lost approximately the same amount compared to their control. Cultivar A had no reduction in yield when bordered or bordering on both or one side by the late maturing cultivar. Cultivar C developed more strength to compete despite the fact that it matured after B and C.

Hanis et al. (1976) obtained similar results studying interplot competition and yield estimates of four wheat cultivars in 'Seedmatic 6' microplot trials. Using four cultivars of wheat 'Zora','Kavkaz', 'UH1072' and 'M50B21-3-6-3' differing in height, tillering capacity and 1000 kernels weight in rows 2m long, 20cm apart and 80 seed-rows and then comparing each row to an adjacent three row-plot, they found that there were competitive differences among genotypes of wheat. The dwarf genotype M50B21 gave a marked decrease in yield along with reduction in microplot size when it had aggressive Zora cultivar as a neighbor. On the other hand, strongly competitive Zora cultivar had significantly higher grain yields as well as 1000 kernel weight when grown next to less competitive plants. The relatively short UH1072 cultivar with high tillering capacity showed little or no indication of an interaction effect between microplot size and yield, or 1000 kernel weight. The relatively tall Kavkaz cultivar with low tillering capacity exhibited weak competitive ability. They concluded that the effects of the interplot competition were better!eliminated by suitable grouping of the genotypes according to their competitive ability.

CHAPTER 3

MATERIALS AND METHODS

The experiment was conducted at the University of Arizona Marana Agricultural Center during the summer of 1987. The soil was a dark brown Pima clay loam (field A-3) that had been uniformly cropped with cotton the previous growing season.

Soil and seed bed preparation:

Full tillage of the soil was made in December 1986 followed by a double disking. In April 1987 the seed beds were prepared by furrowing out. The seeds were planted 3.5 cm deep on the top center of the beds and the furrows used to facililate and control irrigation water application between the raised seed beds. Before furrowing out, fertilizer was applied preplant in April 1987 at rates of 336.3 kg/ha of ammonium sulfate (16-20-0) and 112.1 kg/ha of urea (45-0-0).

Experimental design:

The experimental design used was a split plot design with moisture level as the main plot and a combination of varieties as sub-plots, in four replications. The main plots consisted of two levels of moisture (high moisture level or wet plot and low moisture level or dry plot) and each sub-plot had 14 treatments or combinations of varieties. Each plot was 6.1 m long. A five row-plot of each variety was used as a control for that variety (Table 1). Each variety appeared adjacent on one or both sides to one particular base variety, Taylor Evans Y101G.

Plant material:

Seed of the F_1 generation of five commercial varieties of sorghum differing in their maturity date were used (Table 2). The five hybrid genotypes were:

* Taylor Evans Y-101-G with mid-bloom in 71 days,
* RS 610 with mid-bloom in 15 days before Taylor Evans Y-101-G,
* Asgrow Corral with mid-bloom 10 days before Taylor Evans Y-101-G,
* DK 64 with mid-bloom 2 days before before Taylor-Evans Y-101-G, and
* DK 69 with mid-bloom 5 days after Taylor-Evans.

Taylor Evans Y-101-G, was the base genotype in the plot maturity competition arrangements. It appeared bordered on one or both side by the same or different varieties. The 14 treatments or combination or varieties are given in Table 1.

Table 1. Description of the 14 treatments according to the time each variety came to mid-bloom compared to Taylor Evans Y-101-G.

Treatment #	Combination of varieties				
1	L5	L5	L5	L5	L5
2	E2	E2	E2	E2	E2
3	C	C	C	C	C
4	E10	E10	E10	E10	E10
5	E15	E15	E15	E15	E15
6	L5	L5	C	L5	L5
7	E2	E2	C	E2	E2
8	E10	E10	C	E10	E10
9	E15	E15	C	E15	E15
10	L5	L5	C	E15	E15
11	E10	E10	C	L5	L5
12	E15	E15	C	E2	E2
13	E2	E2	C	E10	E10
14	E15	E10	C	E2	L5

C: stands for Taylor Evans Y101G;
E: stands for early compared to Taylor Evans maturity;
L: stands for late compared to Taylor Evans maturity.
2, 5, 10 and 15 represent the number of days the mid-bloom occurs before or after Taylor Evans mid-bloom date.

Table 2. Description of the five sorghum hybrids used, their expected and observed days to mid-bloom compared to Taylor Evans Y-101-G.

Variety	Days to mid-bloom		Notation
	Expected (Compared to T.E.)	Observed	
RS 610	-6	56.9	E15
Asgrow Corral	-3	61.0	E10
Taylor Evans Y-101-G	0	71.0	C
DK 64	+3	69.3	E2
DK 69	+6	75.6	L5

E: stands for early compared to Taylor Evans maturity date;
L: stands for late compared to Taylor Evans maturity date;
C: stands for Taylor Evans.
15, 10, 2 and 5 represent the number of days each variety came to mid-bloom before or after Taylor Evans.

Management:

Plots were sown on 30 May 1987 at rates of 145 seed per 6.1 m plot row. After emergence hand thinning was done within rows to adjust plant densities between and within rows. Plant populations were kept at a rate of approximately 179,000 plants/ha. During the season, hand weed control was done on the 24th, 29th, and 30th of June and the 1st and 2nd of July to remove larger weeds. On the 29th of June, atrazine weed control was applied with a tractor drawn sprayer at the rate of 0.4732 l/ha (with 1.35 kg/ha of active ingredient).

Irrigation:

The whole experiment received 438.9mm of water as a pre-irrigation treatment. Later on and according to the irrigation schedule, the wet plot received seven irrigation treatments or an equivalent of 600.7mm of water while the dry plot received five irrigation treatments or an equivalent of 457.4mm of water (Table 3). During the same period, the experiment received 99.5mm of rain.

Parameters of interest:

Measurements were taken on several agronomic characteristics responsive to competition at different stages of plant development. These characteristics included:

Table 3. Dates of irrigation, amount of irrigation water and rainfall water received in the sorghum field study at the experiment site.

Date	Amount of water (mm) received by Irrigation: High Moisture	Low Moisture	Rainfall
Pre irrigation	438.9	438.9	
May 15	-	-	7.62
May 21	-	-	25.40
June 3-4	81.70	81.70	-
June 18	136.10	-	-
June 22	-	133.30	-
July 2	111.50	-	-
July 14	151.60	97.20	-
July 26	-	-	13.21
July 27	-	-	2.03
August 3	-	-	5.08
August 4	-	-	1.27
August 5	-	-	2.79
August 7	-	73.60	-
August 11	-	-	14.73
August 13	48.20	-	-
August 21	71.60	71.60	-
August 25	-	-	24.13
September 4	-	-	3.30
Totals	1038.70	896.30	99.56
Treatment Total (Irrig.+ Rainfall)	1138.26	995.86	

* plant tiller ratio,
* 50% bloom date,
* plant height,
* grain yield of each variety,
* grain test weight by variety and
* 300 seed weight

according to the methodology used by Hanis et al. (1976), Kempton and Lockwood (1984), Rees (1986) and Kempton et al. (1986).

Tiller ratio:

It was the ratio of the number of sorghum heads counted in a row-plot before harvesting over the number of sorghum plants counted in the same row-plot after hand thinning was completed.

50% bloom date:

It was the number of days from the planting date to the time when 50% of sorghum plants in the considered row-plot were totally bloomed.

Plant height:

Measurements were made on four sorghum plants representative of the row and chosen in the center row of each treatment. The total plant height was the length of the plant from the soil to the top of its head.

Grain yield:

The research plots were harvested for grain yield with a Massey-Ferguson 35 self-propelled small plot combine. The harvested plot yields were adjusted for gaps within the plot rows and bird damage to the plot to obtain final corrected plot grain yields.

Grain Test weight:

During grain harvest of the plots, grain sample for each plot were taken to the laboratory, cleaned and allowed to reach approximately 10% moisture content. A special container of known volume was used to record the grain test weight which was therefore converted to kilograms per cubic meter.

300-seed weight:

For each of the above samples, 300 grains were counted using an electronic seed counter. After that, their weight in grams was obtained using an electronic balance.

STATISTICAL ANALYSIS

The statistical analysis of the data was done by computer using the SAS package. The variances were analysed according to Gomez and Gomez (1983). Means were separated using the Duncan Multiple Range Test (DMRT). Comparison of the results of the center row in each treatment to its monoculture or 'control' indicated whether or not competition took place. The regression analysis of days to mid bloom and the selected agronomic characteristics was carried out to determine whether or not there was a correlation, and the type and level of this correlation.

CHAPTER 4

RESULTS AND DISCUSSION

Days to 50% bloom:

The number of days to mid-bloom, the percentage increase compared to the sole crop or control and the mean separation by treatments, and by moisture levels are given in Tables 4, 5 and 6. The graphical representation of these results is given in Figure 1.

The average number of days for the control to reach 50% bloom was 70. This number varied however from 70 days in the wet plot to 72 days in the dry plot. The analysis of variance showed no interaction between irrigation levels and the treatments. Treatment 9 (where Taylor Evans Y101G appeared bordered by the very late-maturing variety) had the biggest percentage increase in days to mid-bloom (+1.89%), while treatment 13 (where Taylor Evans Y101G was bordered on both sides by varieties maturing early but at different times) had the lowest percentage (1.17%).

The mean separation using Duncan Multiple Range Test (DMRT) at 5% level showed a significant difference between Treatment 13 and the other treatments.

Table 4. Mean days to 50% bloom of a medium maturity grain sorghum hybrid (Taylor Evans Y-101-G) and its differences when grown competitively with earlier and later maturing hybrids under two levels of moisture.

Treatment #	Mean days to 50% bloom		Difference to the control	%Increase
Control	71.00	a	0.00	0.00
6	70.87	a	-0.13	-0.18
7	70.87	a	-0.13	-0.18
8	72.12	a	1.12	1.58
9	72.37	a	1.37	1.89
10	71.50	a	0.50	0.60
11	72.16	a	1.16	1.63
12	72.00	a	1.00	1.38
13	69.83	b	-1.17	-0.16
14	71.33	a	0.33	0.46

DMRT at 5% level. Numbers followed by the same letter are not statistically different.

T#6, T#7, T#8...,T#14 are characterized by different adjacent borders to Taylor Evans Y-101-G

T#6 = Taylor Evans Y-101-G bordered by (L5);
T#7 = Taylor Evans Y-101-G bordered by (E2);
T#8 = Taylor Evans Y-101-G bordered by (E10);
T#9 = Taylor Evans Y-101-G bordered by (E15);
T#10 = Taylor Evans Y-101-G bordered by (L5,E15);
T#11 = Taylor Evans Y-101-G bordered by (E10,L5);
T#12 = Taylor Evans Y-101-G bordered by (E15,E2);
T#13 = Taylor Evans Y-101-G bordered by (E2,E10);
T#14 = Taylor Ev. Y-101-G bordered by (E15,E10E2,L5).

(E15) = RS 610, (E10) = Asgrow Corral, (E2) = DK 64, (L5) = DK 69.

Table 5. Mean days to 50% bloom of a medium maturity sorghum (T.E. Y-101-G) and its differences when grown competitively with earlier and later maturing hybrids under high moisture.

Treatment #	Mean days to 50% bloom		Difference to the control	%Increase
Control	70.00	b	0.00	0.00
6	71.00	abc	1.00	1.42
7	70.25	a	0.25	0.35
8	71.75	abc	1.75	2.43
9	72.00	ac	2.00	2.85
10	71.75	abc	1.75	2.43
11	72.25	a	2.25	3.11
12	72.50	a	2.50	3.44
13	70.25	bc	0.25	0.35
14	72.00	ac	2.00	2.85

DMRT at 5% level. Numbers followed by the same letter are not significantly different.

Treatment descriptions are the same as in Table 4.

Table 6. Mean days to 50% bloom of a medium maturity grain sorghum hybrid (T.E. Y-101-G) and its differences when grown with earlier and later maturing varieties under low moisture.

Treatment #	Mean days to 50% bloom		Difference to the control	% Increase
Control	72.00	ab	0.00	0.00
6	70.75	ab	-1.25	-1.76
7	71.50	ab	-0.50	-0.69
8	72.50	a	0.50	0.69
9	72.75	a	0.75	1.03
10	71.00	ab	-1.00	-1.40
11	72.00	ab	-0.50	0.00
12	71.00	ab	-0.10	-1.40
13	69.00	b	-3.00	-4.16
14	72.00	ab	0.00	0.00

DMRT at 5% level. Mean folowed by the same letter are not significantly different.

Treatment descriptions are the same as in Table 4.

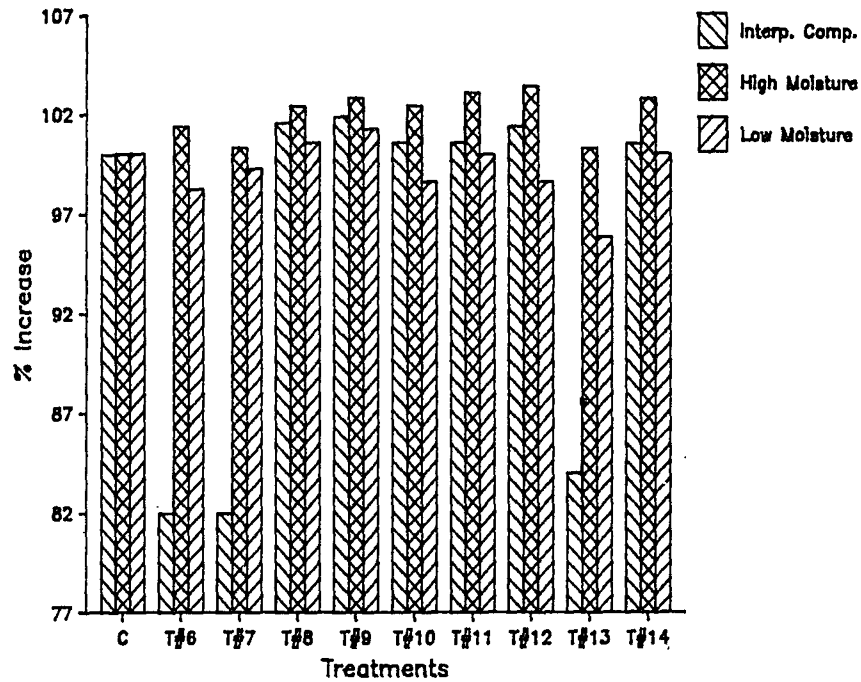

Figure 1. Mean days to 50% bloom of 10 treatments of sorghum hybrids grown at two levels of soil moisture in adjacent plot competition

Treatments are the same as those described in Table 4.

High moisture:

Treatment 13 (Taylor Evans bordered by DK 64 and Asgrow Corral) had the lowest percentage increase (.35%), while Treatment 12 (Taylor Evans Y-101-G bordered by RS 610 and DK 64) had the highest (3.44%). The mean separation using DMRT at 5% level showed significant differences among the treatments. Treatments 11 and 12 (Taylor Evans bordered on one side by an early-maturing variety and on the other by a late maturing variety) differed significantly with the control.

Low moisture:

The pattern observed at the high moisture level was the same at the low moisture level. Treatment 13 (Taylor Evans bordered by DK 64 and Asgrow Corral, or two varieties maturing early but at different dates) came earlier to mid-bloom compared to its control (3 days or -4.16%), while Treatment 9 (Taylor Evans bordered by the very early maturing variety RS 610) came to mid-bloom almost 1 day after the control (1.03% increase). The mean separation using DMRT at 5% level showed significant differences between some of the treatments. Treatment 13 had significantly earlier mid-bloom than Treatments 8 and 9.

The experiment failed to show an effect of maturity differences in the time taken by Taylor Evans to reach 50% bloom in the different combinations where it was adjacent to an-early/and or late-maturing variety. It did, however, show the effect of water on this characteristic. These results conflict in part with the assertion of Abdelraahman (1986) that water stress does not affect the time taken by sorghum plants to reach mid-bloom.

Tiller ratio:

The mean tiller ratio, the difference compared to the control, and the percentage increase of the 10 treatments, and the same data by moisture level are given in Tables 7, 8 and 9. The graphical representation of the same results are shown in Figure 2. The analysis of variance showed no interaction between the moisture levels and the different treatments. In terms of percentage increase, Treatment 7 (Taylor Evans bordered by DK 64) had the highest increase in tiller ratio (+3.82%), while treatment 10 (Taylor Evans bordered by DK 69 and RS 610) had the lowest (-3.20%). The DMRT at the 5% level showed no significant difference among all the treatments with Taylor Evans Y-101-G.

Table 7. Mean tiller ratio of a medium maturity grain sorghum hybrid (T.E. Y-101-G) and its differences when grown competitively with earlier and later maturing hybrids under two levels of soil moisture.

Treatment #	Mean tiller ratio	Difference to the control	% Increase
Control	0.933	0.000	0.00
6	0.969	0.035	3.70
7	0.970	0.037	3.82
8	0.970	0.036	3.80
9	0.965	0.031	3.23
10	0.904	-0.029	-3.20
11	0.954	0.020	2.19
12	0.937	0.003	0.41
13	0.954	0.021	2.18
14	0.960	0.026	2.79

6, 7, 8,...,14 characterize different adjacent borders to Taylor Evans Y-101-G.

T#6 = Taylor Evans Y-101-G bordered by (L5);
T#7 = Taylor Evans Y-101-G bordered by (E2);
T#8 = Taylor Evans Y-101-G bordered by (E10);
T#9 = Taylor Evans Y-101-G bordered by (E15);
T#10 = Taylor Evans Y-101-G bordered by (L5,E15)
T#11 = Taylor Evans Y-101-G bordered by (E10,L5);
T#12 = Taylor Evans Y-101-G bordered by (E15,E2);
T#13 = Taylor Evans Y-101-G bordered by (E2,E10);
T#14 = Taylor Ev. Y-101-G bordered by (E15,E10-E2,L5).

(E15) = RS 610, (E10) = Asgrow Corral, (E2) = DK 64, (L5) = DK 69.

Table 8. Mean tiller ratio of a medium maturity grain sorghum hybrid (T.E. Y-101-G) and its differences when grown with earlier and later maturing hybrids under high moisture.

Treatment #	Mean tiller ratio		Difference to the control	% Increase
Control	0.893	a	0.000	0.00
6	0.933	ab	0.040	4.32
7	0.962	ab	0.069	7.21
8	0.961	ab	0.068	7.11
9	0.922	a	0.028	3.13
10	0.978	ab	0.085	8.70
11	0.992	b	0.099	10.00
12	1.019	b	0.126	12.42
13	1.010	b	0.117	11.59
14	1.001	b	0.108	10.92

DMRT at 5% level. Numbers followed by the same letter are not significantly different.

Treatment descriptions are the same as in Table 7.

Table 9. Mean tiller ratio of a medium maturing hybrid of grain sorghum (T. E. Y-101-G) and its differences when grown with earlier and later maturing hybrids under low moisture.

Treatment #	Mean tiller ratio		Difference to the control	% Increase
Control	0.974	a	0.000	0.00
6	1.005	a	0.031	3.13
7	0.979	a	0.004	0.50
8	0.979	a	0.005	0.56
9	1.008	a	0.033	3.33
10	0.758	b	-0.216	-28.53
11	0.917	a	-0.057	-6.26
12	0.773	b	-0.201	-25.98
13	0.901	a	-0.046	-4.72
14	0.919	a	-0.054	-5.95

DMRT at 5% level. Numbers followed by the same letter are not significantly different.

Treatment description are the same as in Table 7.

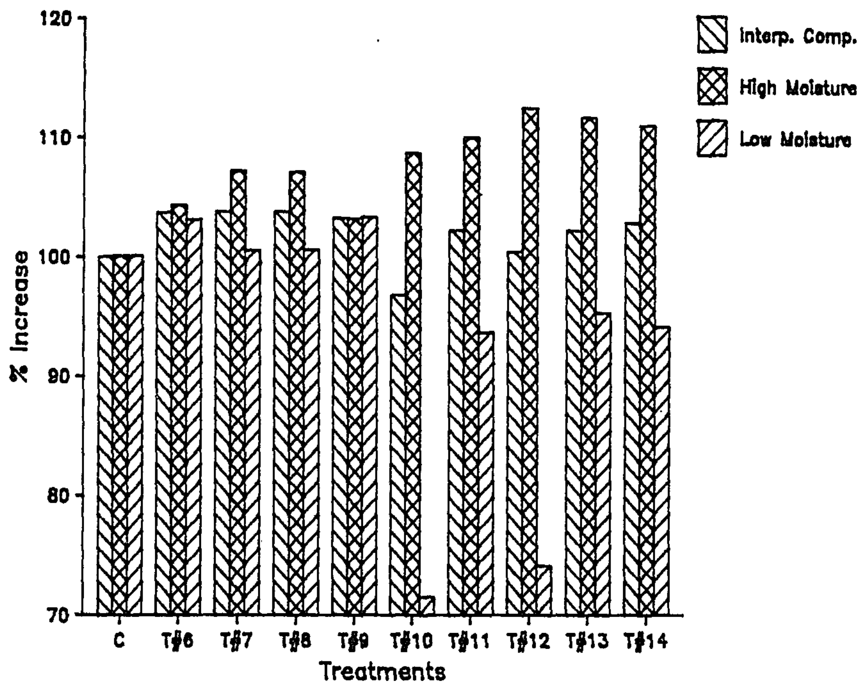

Figure 2. Mean values of tiller ratio of 10 treatments of sorghum hybrids grown at two levels of soil moisture.

Treatments are the same as described in Table 7.

High Moisture:

All treatments had a tiller ratio higher than the control. Treatment 9 (Taylor Evans bordered by RS 610 Corral and DK 64) had the lowest percentage increase (3.13%), while treatment 12 (Taylor Evans bordered by RS 610 and DK 64) had the highest (12.42%). Treatments 12 and 13, where Taylor Evans was bordered by two different early-maturing varieties on both sides, were significantly different compared with treatment 9 and the control. Also, there were no significant differences between all treatments where Taylor Evans appeared bordered in one or both sides by an early- and/or late-maturing variety.

Low moisture:

Treatment response at the low moisture level differed from the response at a high moisture level. Treatment 12 had the lowest percentage increase in tiller ratio (-25.9%), while Treatment 9 (Taylor Evans bordered by the most early maturing variety RS 610) had the highest (3.33%). There was no significant difference between the treatments where Taylor Evans was adjacent to an early-and/or late-maturing variety, showing no real effect of water on this characteristic. Nevertheless, Taylor Evans tiller ratio decreased when it was bordered on one side by the most late maturing DK 69 and on the other side by the most early-maturing variety RS 610, or when it was bordered on one side by the most early-maturing RS 610 and the other side by the least early-maturing DK 64 (Treatments 10 and 12 respectively).

Although no competition took place according to the maturity date of the adjacent plot, moisture level seems to have played an important role in modifying tillering habits of Taylor Evans. This ability was enhanced in conditions of high moisture (12.42%) when Taylor Evans Y101G was bordered on both sides by RS 610 and DK 69 and totally reduced in conditions of low moisture (-25.98%).

Plant height:

The mean plant height, the difference between each treatment and the control, the percentage increase, and the mean separation for the experiment and at the different moisture levels are given in Tables 10, 11 and 12, while the graphical representation of these results is shown in Figure 3.

The mean plant height for the experiment varied from 103.5cm in Treatment 9 (Taylor Evans Y-101-G bordered by RS 610 and DK 69) to 111.1cm in Treatment 6,

Table 10. Mean plant height (cm) of a medium maturity grain sorghum hybrid (T. E. Y-101-G) and its differences when grown competitively with earlier and later maturing hybrids under 2 levels of soil moisture.

Treatment #	Mean plant height	Difference to the control	% Increase
	cm		
Control	105.4	0.0	0.00
6	111.1	5.7	5.09
7	108.7	3.3	3.06
8	110.1	4.6	4.21
9	103.5	-1.7	-1.79
10	106.4	1.0	0.93
11	105.0	-0.4	-0.41
12	107.6	2.2	2.03
13	110.4	4.9	4.47
14	110.3	4.9	4.43

T#6, T#7, T#8,... T#14 are characterized by different adjacent varieties.

T#6 = Taylor Evans Y-101-G bordered by (L5);
T#7 = Taylor Evans Y-101-G bordered by (E2);
T#8 = Taylor Evans Y-101-G bordered by (E10);
T#9 = Taylor Evans Y-101-G bordered by (E15);
T#10 = Taylor Evans Y-101-G bordered by (L5,E15);
T#11 = Taylor Evans Y-101-G bordered by (E10,L5);
T#12 = Taylor Evans Y-101-G bordered by (E15,E2);
T#13 = Taylor Evans Y-101-G bordered by (E2,E10);
T#14 = Taylor Ev. Y-101-G bordered by (E15,E10-E2,L5).

(E15) = RS 610, (E10) = Asgrow Corral, (E2) = DK 64, (L5) = DK 69.

Table 11. Mean plant height (cm) of a medium maturity grain sorghum hybrid (T.E. Y-101-G) and its differences when grown with later anf earlier maturing hybrids under high moisture level.

Treatment #	Mean plant height		Difference to the control	%Increase
	cm			
Control	110.3	ab	0.0	0.00
6	111.7	ab	1.7	1.31
7	113.8	ab	3.6	3.12
8	115.5	a	5.3	4.55
9	107.2	b	-3.0	-0.05
10	110.2	ab	-0.1	-0.05
11	107.4	b	-2.8	-2.63
12	112.8	ab	2.5	2.22
13	112.9	ab	2.6	2.33
14	111.3	ab	1.1	0.98

DMRT at 5% level. Numbers followed by the same letter are not significantly different.

Treatment descriptions are the same as in Table 10.

Table 12. Mean plant height (cm) of a medium maturity grain sorghum hybrid (T.E. Y-101-G) and its differences when grown with earlier and later maturing hybrids under low moisture.

Treatment #	Mean plant height	Difference to the control	% Increase
	cm		
Control	100.6	0.00	0.00
6	110.4	9.86	8.92
7	103.7	3.09	2.98
8	104.6	4.02	3.84
9	99.9	-0.69	-0.69
10	98.9	-1.62	-1.64
11	100.1	-0.50	-0.50
12	97.3	-3.30	-3.39
13	105.3	4.74	4.50
14	108.2	7.63	7.05

Treatment descriptions are the same as in Table 9.

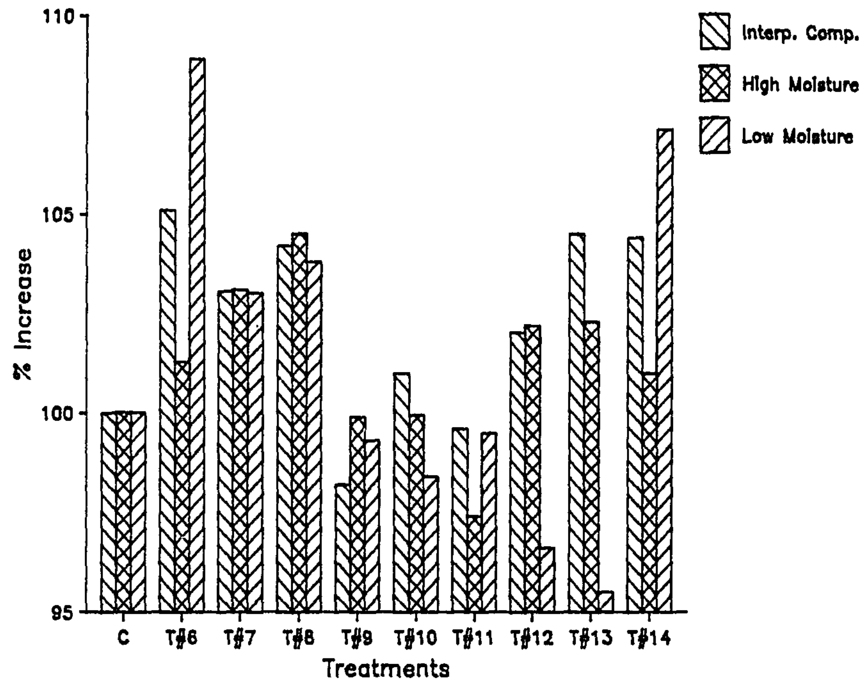

Figure 3. Mean total plant height of 10 treatments of sorghum hybrids grown at two levels of soil moisture.

Treatments are the same as described in Table 10.

corresponding to percentage increases of -1.79% and 5.09%, respectively. The analysis of variance showed no interaction between the moisture levels and the treatments. The mean separation failed to show any significant differences between the treatments.

High moisture:

There were some significant differences between the treatments mean height under high moisture (Table 11). Treatment 8 (Taylor Evans Y-101-G bordered by Asgrow Corral) had the highest mean height (115.5cm) while Treatment 9 (Taylor Evans Y-101-G bordered by RS 610) had the lowest (107.2cm). The mean separation using DMRT at 5% level did not show any significant difference between all the treatments where Taylor Evans Y-101-G was bordered on one or both sides by varieties of different maturity dates. Plant height of Treatment 8 was significantly higher than Treatments 9 or 11.

Low moisture:

There was a general decrease in plant height at the low moisture level as one might expect. Treatment 12 (Taylor Evans bordered by DK 64 and RS 610) had the lowest percentage increase (-3.39%) compared to the control, while Treatment 6 (Taylor Evans bordered by DK 69) had the highest (8.92%). There were no statistical differences between any of the treatments.

Overall, the experiment revealed a decrease in plant mean height due to low moisture level. However it did not show any modification in Taylor Evans Y-101-G mean height as a result of competition between itself and adjacent varieties differing in maturity date. This confirms the findings Brown et al. (1964) that plant height decreases when irrigation is insufficient.

Grain yield:

The mean grain yield and the percentage decrease of five sorghum hybrids grown under two levels of soil moisture are given in Table 13. The grain yields for the same genotypes planted as sole crop and four of them as border plots on a common but diferent mid-maturity genotype under high and low soil moisture levels is given in Table 14.

The low soil moisture level treatment caused decreased grain yields for all five maturity genotypes as compared to the non stress high soil moisture level treatment (Table 13). The earliest maturity genotype, E-15 had the lowest decrease in grain yield of 4.7% from soil moisture stress. The later maturity genotypes had increasingly greater grain yield decreases indicating that the soil moisture stress level for the

Table 13. Mean grain yield (kg/ha) and percentage decrease of five different sorghum maturity genotypes grown under two levels of soil moisture.

Variety	Moisture Level		Decrease (%)
	High	Low	
RS 610	4301	4096	-4.72
Asgrow Corral	4692	4343	-7.43
DK 64	5275	4280	-18.86
T.E. Y-101-G	5610	4337	-22.69
DK 69	5466	4310	-20.78

RS 610 = (E-15) or variety maturing 15 days before Taylor Evans Y-101-G;
Asgrow Corral = (E10) or variety maturing 10 days before Taylor Evans Y-101-G;
DK 64 = (E2) or variety maturing 2 days before Taylor Evans Y-101-G;
DK 69 = (L5) or variety maturing 5 days after Taylor Evans Y-101-G.

Table 14. Grain yield of five different sorghum maturity genotypes as sole crop and with four of them used as border plots on a common but different mid-maturity genotype under two levels of soil moisture.

Treatment #	Plot position	High Moisture: Mean Grain Yield: Sole Crop	High Moisture: Mean Grain Yield: Treat.	High Moisture: % Difference@	Low Moisture: Mean Grain Yield: Sole Crop	Low Moisture: Mean Grain Yield: Treat.	Low Moisture: % Difference@
		kg/ha	kg/ha		kg/ha	kg/ha	
	Border Plots	5466	5600	2.4	4314	4060	-5.9
6	Center Plot	5610	5859	4.4	4337	4806	10.8
	3-row Plot	5514	5686	3.1	4321	4308	-.3
	Border Plots	5275	4510	-14.5	4280	3746	-12.5
7	Center Plot	5610	5969	6.4	4337	5766	32.9
	3-row Plot	5386	4996	-7.2	4299	4419	2.8
	Border Plots	4692	4326	-7.8	4343	4157	-4.3
8	Center Plot	5610	5919	5.5	4337	5410	24.7
	3-row Plot	4998	4857	-2.8	4346	4574	5.2
	Border Plots	4304	4035	-6.2	4096	3712	-9.4
9	Center Plot	5610	6009	7.1	4337	5601	29.1
	3-row Plot	4739	4693	-.9	4176	4342	4.0

T#6 = Center plot bordered by a 5 day later maturity (DK 69);
T#7 = Center plot bordered by a 2 day earlier maturity (DK 64);
T#8 = Center plot bordered by a 10 day earlier maturity (Asgrow Corral);
T#9 = Center Plot bordered by a 15 day earlier maturity (RS 610).

@ = % difference from sole crop.

test increased with time during the field test. The later maturing genotypes, E-2, C and L-5 had increased soil moisture stress resulting in greater yield percent decreases of 18.8%, 22.7% and 20.8% respectively from the high soil moisture treatment. All four maturity genotypes, E-15, E-10, E-2, and L5 when used as border rows had moderate losses in grain yield, compared to their sole crop grain yields, from inter-row competition with the center row medium maturity genotype under both high and low soil moisture. Except for the L-5 maturity under high soil moisture (Table 14), the common medium maturity center plot row gained moderately in grain yield in all four inter-row competition situations at about the same magnitude of percent change as the border rows lost. Under low soil moisture, the center row maturity genotype greatly increased in grain yield compared to moderate losses by both border rows. These gains ranged from 10.8% with L-5 maturity borders to 24.7% to 32.9% with E-10 and E-2 maturity borders respectively.

Early maturity borders produced less inter-plot competition for the center row during its final seed-filling days, giving greater yield to the center row. This effect was rather like "wide row spacing" or "relay cropping". Since the center plot maturity genotype gained in grain yield under low soil moisture stress with even the later maturity (L-5) border row indicated that the center row genotype likely has a greater competitive root system under soil moisture stress than the L-5 maturity genotype.

The sole crop and plot treatment grain yields of both border rows and the center row were evaluated together as a 3-row plot. For all four treatments, the gains and losses within each 3-row plot were combined to obtain total average 1-row yield. There was a great amount of compensation between border rows and center rows among all plot border treatments within both high and low soil moisture treatments. The center row of plot border Treatment 7 gained 33% under low soil moisture but the 3-row plot total compensation value gain was only 2.8%. The decrease and/or increase in yield observed due to differences in maturity date of competing rows was in accord with the findings of Lin et al. 1986, that late maturing varieties tend to increase yield when grown adjacent to early maturing varieties.

300-seed weight:

The mean weight of 300-seed, the difference compared to the control, the percentage increase of each treatment, and the mean separation are given in Table

16. The same data for the high and low moisture level are found in Tables 17 and 18 respectively. The graphical representation of these data is given in Figure 5.

All treatments had a greater but not significant 300-seed weight than the control. Treatment 6 (Taylor Evans Y-101-G bordered by the most late-maturing variety DK 69) had the lowest arithmetic increase in 300-seed weight compared to the control (1.07%), while Treatment 12 (Taylor Evans bordered by RS 610 and DK 64) had the highest (9.42%). The mean separation showed no significant difference between the control and Treatment 6 (Taylor Evans bordered by the most late-maturing variety), but a significant difference between the control and Treatment 9 (Taylor Evans bordered by the most early maturing variety), and between Treatments 6 and Treatment 9.

High moisture:

The analysis of variance showed significant differences among the treatments. Treatment 6 had arithmetically the lowest 300-seed weight while Treatment 12 had the highest. Treatments 6 and 7 (Taylor Evans bordered by RS 610 and DK 64) and the control were not significantly different, but had

Table 15. Mean 300-seed weight (g) of a medium maturity grain sorghum hybrid (T. E. Y-101-G) and its differences when grown competitively with earlier and later maturing hybrids under two levels of soil moisture.

Treatment #	Mean 300-seed weight		Difference to the control	% Increase
	(g)			
Control	7.73	a	0.00	0.00
6	7.81	a	0.08	1.07
7	8.06	ab	0.33	4.15
8	8.28	b	0.55	6.64
9	8.38	b	0.66	7.90
10	8.39	b	0.66	7.93
11	8.25	b	0.52	6.33
12	8.53	b	0.80	9.42
13	8.26	b	0.53	6.43
14	8.39	b	0.66	7.86

DMRT at 5% level. Numbers followed by the same letter are not significantly different.

T#6, T#7, T#8,...,T#14 are characterized by different adjacent borders to Taylor Evans Y-101-G.

T#6 = Taylor Evans bordered by (L5);
T#7 = Taylor Evans bordered by (E2);
T#8 = Taylor Evans bordered by (E10);
T#9 = Taylor Evans bordered by (E15);
T#10 = Taylor Evans bordered by (L5,E15);
T#11 = Taylor Evans bordered by (E10,L5);
T#12 = Taylor Evans bordered by (E15,E2);
T#13 = Taylor Evans bordered by (E2,E10);
T#14 = Taylor Evans bordered by (E15,E10-E2,L5).

(E15) = RS 610, (E10) = Asgrow Corral, (E2) = DK 64, (L5) = DK 69.

Table 16. Mean 300-seed weight (g) of a medium maturity grain sorghum hybrid (T. E. Y-101-G) and its differences when grown with earlier and later maturing hybrids under high moisture.

Treatment #	Mean 300-seed weight		Difference to the control	% Increase
	(g)			
Control	7.92	a	0.00	0.00
6	7.89	a	-0.02	-0.35
7	7.95	a	0.03	0.40
8	8.36	ab	0.44	5.30
9	8.67	b	0.75	8.70
10	8.45	ab	0.53	6.32
11	8.34	ab	0.42	5.05
12	8.68	b	0.76	8.77
13	8.34	ab	0.42	5.09
14	8.64	b	0.71	8.29

DMRT at 5% level. Numbers followed by the same letter are not significantly different.

Table 17. Mean 300-seed weight (g) of a medium maturity grain sorghum hybrid (T. E. Y-101-G) and its differences when grown with adjacent earlier and later maturing hybrids under low moisture.

Treatment #	Mean 300 seed weight		Difference to the control	% Increase
	(g)			
Control	7.54	a	0.00	0.00
6	7.73	a	0.19	2.49
7	8.17	ab	0.63	7.80
8	8.19	ab	0.65	7.98
9	8.11	ab	0.57	7.06
10	8.27	ab	0.73	8.88
11	8.16	ab	0.62	7.63
12	8.23	ab	0.69	8.43
13	8.09	b	0.55	6.85
14	8.14	ab	0.60	7.40

DMRT at 5% level. Numbers followed by the same letter are not significantly different.

Treatment descriptions are the same as in Table 16.

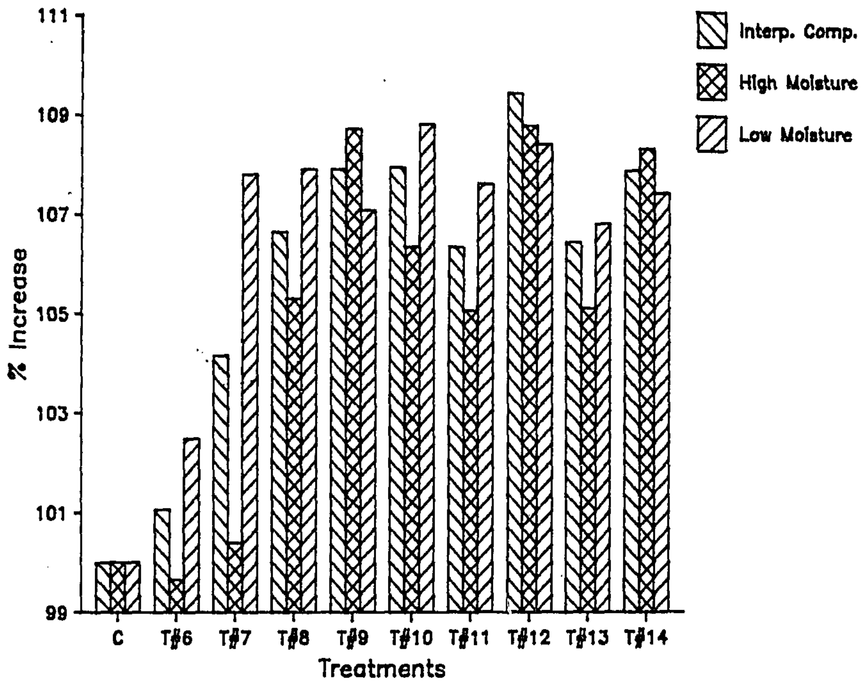

Figure 4. Mean 300-seed weight of 10 treatments of sorghum hybrids grown at two levels of soil moisture.

Treatments are the same as described in Table 16.

significant higher 300-seed weights than Treatments 9, 12 and 14. Treatment 6 (Taylor Evans Y-101-G bordered by the most early-maturing variety) had the lowest percentage increase (-0.35%), while Treatment 9 and 12 had the highest (8.70% and 8.77%, respectively).

Low moisture:

In terms of percentage increase, the trend observed at the high moisture level also prevailed at the low moisture level. Treatment 6 had the lowest percentage increase compared to the control (2.49%), while Treatments 10 (Taylor Evans bordered by the most late and the most early-maturing variety) and 12 (Taylor Evans Y-101-G bordered by DK 64 and RS 610) had the highest (8.88% and 8.43% respectively).

Based on the above results, it therefore appears as if Taylor Evans, bordered by early-maturing varieties, produced more heavier grains, no matter what moisture level on which it was grown and tended to loose grain-weight when grown adjacent to late maturing-varieties.

These results confirms our findings regarding maturity differences effects on competition for grain yield between adjacent varieties. When late-maturing varieties are grown adjacent to early-maturing varieties, their yield increase. This increase is mainly expressed in term of more heavier seeds, meaning that late-maturing plants have additional time and nutrients to complete their grain filling process while the early-maturing varieties are already physiologically mature.

Grain test weight:

The mean grain test weight, the difference compared with the control, the mean separation, and the percentage increase of all treatments are given in Table 19. The same data for the high and low moisture levels are given in Table 20 and 21, respectively. The graphical representation of all the results is given in Figure 6. The analysis of variance showed no significant difference between any of the treatments and their control.

High moisture:

The results over the high moisture level were slightly different than when averaged over both moisture levels. Treatments 6, 7 and 13 had the lowest percentage increase (-0.31%, -0.22% and 0.40%,

Table 18. Mean grain test weight (kg/m^3) of a emedium maturity grain sorghum hybrid (T. E. Y-101-G) and its differences when grown competitively with earlier and late maturin hybrids under two levels of soil moisture.

Treatment #	Mean grain test weight		Difference to the control	% Increase
	(kg/m^3)			
Control	769.11	a	0.00	0.00
6	773.69	ab	4.58	0.59
7	771.22	ab	2.11	0.27
8	774.05	ab	4.94	0.64
9	773.69	ab	4.58	0.59
10	773.91	ab	4.80	0.62
11	775.83	ab	6.72	0.87
12	777.07	ab	7.78	1.03
13	772.13	ab	3.02	0.39
14	777.14	ab	8.03	1.04

T#6, T#7, T#8,..., T#14 are characterized by different adjacent borders.

T#6 = Taylor Evans bordered by (L5);
T#7 = Taylor Evans bordered by (E2);
T#8 = Taylor Evans bordered by (E10);
T#9 = Taylor Evans bordered by (E15);
T#10 = Taylor Evans bordered by (L5,E15);
T#11 = Taylor Evans bordered by (E10,L5);
T#12 = Taylor Evans bordered by (E15,E2);
T#13 = Taylor Evans bordered by (E2,E10);
T#14 = Taylor Evans bordered by (E15,E10-E2,L5).

(E15) =RS 610, (E10) = Asgrow Corral, (E2) = DK 64, (L5) = DK 69.

Table 19. Mean grain test weight (kg/m^3) of a medium maturity grain sorghum hybrid (T. E. Y-101-G) and its differences when grown with ealier and later maturing hybrids under high moisture.

Treatment #	Mean grain test weight		Difference to the control	% Increase
	(kg/m^3)			
Control	772.09	b	0.00	0.00
6	769.62	b	-2.47	-0.31
7	770.34	b	-1.75	-0.22
8	776.01	ab	3.92	0.57
9	775.80	ab	3.71	0.48
10	775.70	ab	3.61	0.46
11	775.70	ab	3.61	0.46
12	778.58	a	6.49	0.84
13	775.18	b	3.09	-0.40
14	777.96	a	5.87	0.76

Treatment descriptions are the same as in Table 19.

Table 20. Mean grain test weight (kg/m^3) of amedium maturity grain sorghum hybrid (T.E. Y-101-G) and its differences when grown with earlier and later maturing hybrids at low moisture.

Treatment #	Mean grain test weight	Difference to the control	% Increase
	(kg/m^3)		
Control	766.12	0.00	0.00
6	777.76	11.62	1.51
7	772.09	5.97	0.77
8	772.09	5.97	0.77
9	771.58	5.46	0.71
10	770.34	4.22	0.55
11	776.11	9.99	1.30
12	774.05	7.93	0.03
13	766.02	-0.10	-0.01
14	775.49	9.37	1.22

Treatment descriptions are the same as in Table 19.

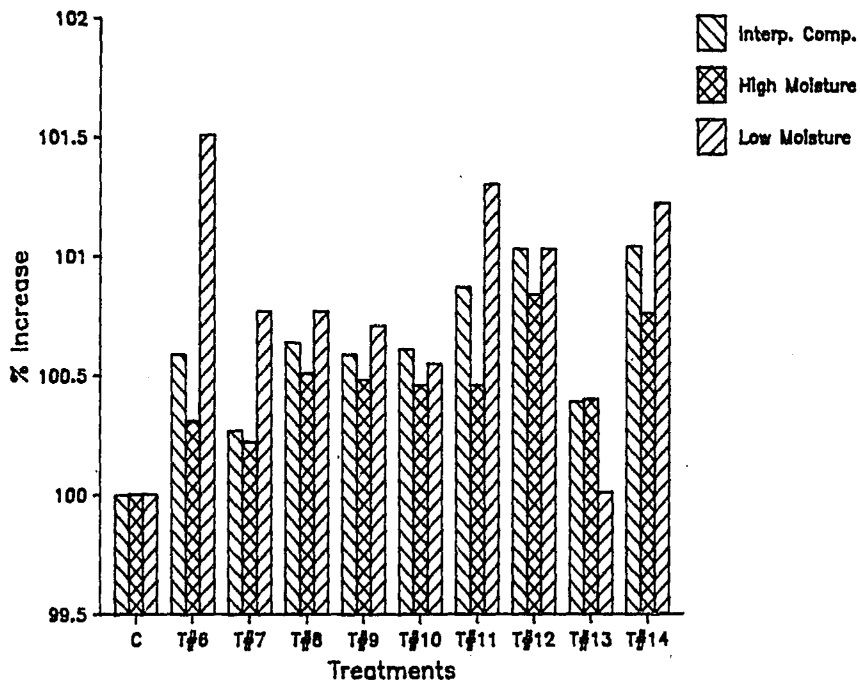

Figure 5. Mean values of grain test weight of 10 treatments of sorghum hybrids grown at two levels of soil moisture.

Treatments are the same as described in Table 18.

respectively), and they were not significantly different than the control. Treatments 12 and 14 had statistically greater test weight than Treatments 6, 7 13 and the control.

Low moisture:

There were arithmetic differences between treatments under the low moisture level but there were no statistical differences among the treatment means.

Correlations:

It is evident from the correlations in Table 22 that the number of days to mid-bloom of Taylor Evans Y101G had little or no effect on most of the agronomic characteristics observed in the study.

Using Taylor Evans number of days to mid-bloom as a predictor and each of the observed agronomic characteristics as the dependent variable, we reach the following conclusions:

*There was a negative and weak correlation between days to mid-bloom and plant height at all the levels of the study.

*The correlation between days to mid-bloom and treatment yield across the two levels of the study was

Table 21. Regression analysis between days to mid-bloom and the selected agronomic characteristics at all the of the study.

Correlations	Coefficients					
	Average@		High Moisture		Low moisture	
	r	r^2	r	r^2	r	r^2
50% Bloom vs. Tiller ratio	-.39	.019	.06	.004	.306	.093
50% Bloom vs. Plant height	-.56	.319	-.29	.085	-.43	.193
50% Bloom vs. Grain yield	.08	.007	.015	.248	.49	.248
50% Bloom vs. 300-Seed weight	.21	.044	.46	.21	-.026	.000
50% Bloom vs. Grain Test wt.	.56	.316	.73*	.553	.35	.128

* Significant at 5% level.
@ Average over both moistures.

positive but weak for the whole experiment, but negative at all the levels of soil moisture.

*There was a negative and non significant correlation between days to mid-bloom of Taylor Evans and plant tiller ratio.

*There was a positive but weak correlation between days to mid-bloom of Taylor Evans and the 300-seed weight. This correlation was negative and non significant at the low moisture level.

*The only significant correlation was the correlation between days to mid-bloom and the grain test weight at the high moisture level treatment.

Looking closely at the mean separation within the same agronomic characteristics and across the moisture treatments, and the regression analysis of the number of days to mid-bloom of Taylor Evans Y-101-G across the different treatments and the selected agronomic characteristics, we can say that our study did show an effect of maturity differences on competition between the center and border rows in our experiment and specially for grain yield and 300-seed weight.

CHAPTER 5

SUMMARY AND CONCLUSIONS

Fourteen treatments made of combinations of five grain sorghum varieties were used to study adjacent plot competition between sorghum hybrids differing in their maturity date. The sorghum varieties used were: Taylor Evans Y-101-G reaching mid-bloom in 71 days, RS 610, Asgrow Corral and DK 64 reaching mid-bloom 15 days, 10 days and 2 days respectively before Taylor Evans Y-101-G, and DK 69 which reached mid-bloom 5 days after Taylor Evans Y-101-G. The statistical design used was a split plot design, in four replications, with water levels as main plots and combinations of the different varieties as sub-plots. A five-row plot of each variety was used as a control for this variety.

For each treatment , and from May to September, measurements were taken on specific agronomic characteristics such as the days to mid-bloom, tiller ratio, total plant ehight, grain yield per hectare, grain test-weight and the 300-seed weight to determine whether or not competition took place due to maturity differences of the different genotypes grown in adjacent row plots. The analysis of variance and the mean separation using DMRT at the 5% level showed that no competition occurred due to differences in the maturity dates of adjacent genotypes for days to mid-bloom, tiller ratio, total plant height and the grain test weight, but did occur for grain yield and 300-seed weight. The total grain yield was affected not only by the moisture level treatment, but also by the mid-bloom date of the genotype grown in the border rows or the center row. The gain in grain yield of the variety in the center row increased as the day to mid-bloom of varieties in the border rows decreased. At the low moisture level, the gain in grain yield of the center row was greater compared to moderate losses by its border rows. The analysis of 300-seed weight confirmed the assumption that the gain in grain yield of the center row was primarily due to greater seed weight from the extra time the plant had to develop seeds with less border row competition. The later maturing row could fill its seeds with less competition from early maturity bordder rows. The center row could further develop its root system and gain more moisture while the early maturing varieties were in a less physiologically active phase in terms of water needs.

Given the unprecedented aspect of this study, the above results appear to offer potentially valuable assets for breeders involved in selection programs for the aforementioned agronomic characteristics. Nevertheless a second test with more data will lend additional credence to our conclusions.

APPENDIX A

SIGNIFICANCE OF F VALUES FROM ANALYSES OF VARIANCE OF 10 TREATMENTS OF SORGHUM HYBRIDS GROWN AT TWO LEVELS OF SOIL MOISTURE IN ADJACENT PLOTS.

Table 22. Significance of F values from analyses of variance of 10 treatments of sorghum hybrids grown at two levels of soil moisture.

Argonomic characteristics	Components of variation		
	Moisture level(MP)	Treatments (SP)	Interaction
Days to mid-bloom	.19 ns	77.26 **	1.00 ns
Tiller ratio	13.49 **	2.22 ns	5.85 ns
Plant height	56.79 **	8.51 **	1.82 ns
Grain yield	20.26 **	4.60 **	.86 ns
300-seed weight	.58 **	11.80 **	1.22 ns
Test weight	.19 ns	77.26 **	1.07 ns

(MP) = Main plot;
(SP) = Sub-plot;
ns = Non significant;
** = Significant at 1% level.

APPENDIX B

SIGNIFICANCE OF F VALUES FROM ANALYSES OF VARIANCE OF 10 TREATMENTS OF SORGHUM HYBRIDS BY MOISTURE LEVEL

Table 23. Significance of F values from analyses of variance of 10 treatments of sorgum hybrids maturity competition experiment at two levels of soil moisture.

Agronomic characteristics	F Values	
	High moisture	Low moisture
Days to mid-bloom	84.49 **	2.35 ns
Tiller ratio	3.01 **	2.35 ns
Plant height	11.78 **	40.88 **
Grain yield	3.75 **	6.64 **
Grain test-weight	43.28 **	3.92 **
300-seed weight	6.05 **	3.28 **

ns = Non significant;
** = Significant at 1%level.

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