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PRODUCTION CHARACTERISTICS OF HYBRID GRAIN SORGHUMS UNDER THREE PLANT POPULATIONS AND TWO PLANTING DATES

by

Mohammed Ahmed Saeed

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APPROVAL BY THESIS DIRECTOR

This thesis has been approved on the date shown below:

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14 March 1986
Date

DEDICATION

This thesis is dedicated to my mother Safia Ali and my father Ahmed Saeed El-Dalai.

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ABSTRACT

Two hybrid grain sorghums, Asgrow Topaz and Colt, were grown at three populations (64,583, 129,167 and 387,501 plants/ha) in two dates of planting simulating local full season and late planted double cropping practices.

Increased plant populations produced: significant increases in grain yield, number of heads, main head dry matter and peduncle length; no effect on seed weight, and test weight; and significant decreases in main plant leaf, stem and total plant dry matter, head length and main plant leaf area.

The later date of planting produced: a significant increase in grain test weight; no effect on number of heads per hectare, main plant head dry matter and head length and significant decreases in grain yield, seed weight, main plant leaf, stem and total dry matter, main plant height to upper leaf collar, peduncle length and total plant height, days to 50% bloom and main plant leaf area.

CHAPTER 1

INTRODUCTION

Sorghum (*Sorghum* *bicolor* (L.) Moench) has achieved importance as a well-adapted crop of the arid and semi-arid tropics, where water, temperatures and nutrients constantly limit yield. Sorghum is grown for total plant production in most areas of the world. In the United States it is grown primarily for grain only, but for both grain and forage in many developing countries. It is also a staple food for millions of people of the semi-arid tropics.

The world area of sorghum currently exceeds 50 million hectares; it has been increased by only 0.33%, i.e., 170,000 ha per annum over the period of 1961 to 1979 (Ryan and Oppen, 1984). In recent years, its economical benefit has been considerably extended by the development of high-yielding hybrids and new varieties.

The high-yielding hybrids are more specific in their agronomic production requirements than traditional varieties. Use of the optimum plant population for a particular environment, and the proper sowing date of the crop, will produce higher yields, when the growth requirements such as water, nutrients, and light are not limiting.

The objective of this study was to evaluate the effect of three plant populations and two planting dates, on the agronomic performance of two grain sorghum hybrids. The two planting dates used were full season (May planting) and mid-season double crop (July planting) which are typical of local farmer field crop rotational practices. Asgrow 'Topaz', a medium maturing grain sorghum hybrid, and Asgrow 'Colt', a medium-late maturing hybrid were the sorghum genotypes selected to be evaluated under the three populations and two dates of planting. The research was conducted on the University of Arizona Marana Agricultural Center at Marana, Arizona in 1984.

CHAPTER 2

LITERATURE REVIEW

Effect of Planting Date on Hybrid Sorghum

Early planting as compared to late planting increased sorghum grain yield (Blum, 1972). He attributed this to increased tillering, number of panicles per unit land area, and increased weight per grain. Very early maturing sorghum and maize hybrids appeared to be satisfactory for grain when planted in June (Camper, Genter, and Loope 1982). Mirhadi and Kobayashi (1981) stated that an optimum planting date resulted in an increase in plant height, panicle length, number of leaves per plant and number of grains per panicle, all of which are associated with increased grain yield. They also stated that postponement of planting from 1 May to 1 June and 15 June causes a decrease in number of grains per panicle. Pauli, Stickler and Lawless (1964) reported that date of planting greatly influenced time of half-bloom and of physiological maturity because of lower temperatures in late summer and early fall.

In a study of planting date associated with day and night temperatures, Downes (1972) reported that grain production and maximum dry matter accumulation on primary stems were greater at 27/22°C. Yield, however, had been drastically lowered at 33/28°C.

Planting date is a determining factor of production for all crops. Examples of research dealing with the effect of planting date on cereal and oil crops are presented here. Nelson et al. (1977) reported that on no-till, early planted (after small grain or forage) corn and grain sorghum produced higher yields than when planted late. Broadhead (1972) observed that sweet sorghum plant forage yields from April 1st planting were significantly lower than from May 1st plantings, and stages of sorghum plant seed maturities had no effect on total plant forage yields.

A study by Ezueh (1982) indicated that time of planting is a major determinant of damage by stem borer to maize in the field. An appropriate planting date for wheat reduces the damage of Hessian fly, a major pest of wheat. Pal (1973) reported high yield of pearl-millet (*Pennisetum typhoides* Burm.f.) planted during the first week of July, whereas delaying the planting date to the first fortnight of August caused a reduction of 82.7 kg/day/ha in grain yield.

Unger (1980), in his study on sunflower (*Helianthus annuus.* L), observed no significant difference in yield with plantings from late March to mid-June, but yields decreased with planting after 21 June. Also seed oil percent decreased with plantings after about 29 May.

Abel (1976) revealed that yields for safflower (Carthamus tinctorius L.) were higher in the crop planted on 15 December than that on 15 February. The same author observed an oil percent reduction of 3% due to the effects of late planting. Greater seed yields of meadowfoam (Limnanthes alba. Benth.) were obtained with an early planting of 21 September to mid-October, than mid-October to the first week of November (Johnson et al. 1980).

Effect of Row Spacing and Plant Population On Sorghum Yield

Porter, Jensen and Sletten (1960) observed that sorghum populations produced from higher planting rates were not proportional to the sum of the seed planted, in contrast to populations from the lowest planting rate. The similarity between lower plant populations at the wider row spacings and disproportion of plant populations to seeding rates were about the same. Thickly planted wider row spacings have a potential function of plant competition for moisture and quick spread of seedling diseases. In studies conducted by Grimes and Musick (1960), the interaction of row width with plant populations of 56,000, 112,000 and 224,000 plants per acre was not significant. They also indicated that grain yield may not be seriously affected because of the variation in plant population. However, a population of 100,000 plants per acre under excellent moisture condition produced maximum or near maximum yields in all years of the tests. Robinson et al. (1964) found that two of the components of yield: panicles per acre and seeds per panicle tended to increase with narrower row spacings; whereas the third component, seed weight, tended to decrease. Because of increased population, lodging and decreased seed weight occurred. Bond, Army and Lehman (1964) concluded their investigations by emphasizing that higher grain yields were produced at lower moisture levels with 40-inch rows than with 20-inch rows. Twenty inch rows, however, produced greater yields at the higher moisture levels, and increased soil moisture at sowing time helped a great deal in decreasing plant lodging.

Stickler and Wearden (1965) proposed a similar concept that grain yield from 20-inch rows had a 10% advantage over 40-inch rows and this yield superiority of narrow row was mainly due to increased tillering. According to Mann (1965) there were no significant yield differences between 21-inch and 42-inch row spacings. However, 21-inch row spacings showed superiority over 42-inch rows in increasing crop competition with weeds as well as decreasing the hazard of wind erosion.

Stickler and Younis (1966) in a study of plant spacings observed that grains from 40-inch wide sorghum rows were slightly heavier than those from 20-inch rows (27.84 vs. 27.12 gr per 1000 seeds). Furthermore, with increased stand density seed weight decreased. The low stand density gave more seeds per head and greater seed weight relative to plants grown at higher stand densities. Atkins, Reich and Kern (1968) observed that the mean of two short-stature grain sorghum hybrids grown in four different within-row plant populations showed an average of 11% higher grain yield for 30-inch over 40-inch row spacings. No appreciable variation was detected on days to mid-bloom, plant height, or 100-seed weight due to row spacings and within-row plant population differences. A decrease in heads per plant and seeds per head at each row width was observed as the within-row populations increased from four through eight plants per 30.5 cm. A similar study on plant spacings was conducted by Blum (1970) in which he found that the grain yield of the late maturing hybrid sorghum was highest when planted under a low plant density, and that of an early maturing sorghum hybrid was best under a high plant density. The advantage of the early maturing hybrid sorghum at the highest plant density was its capability to possess larger grains in spite of increased interplant competition for water.

Chetty and Reddy (1979) reported that sorghum grain yields grown in a wet season were not affected by changes in distribution of plants within the row as long as plant population and row width were maintained at their optimum levels of 150,000 plants per ha and 45 cm, respectively.

Thomas et al. (1980) grew two sorghum hybrids at three row spacings of 0.36m, 0.71m and 1.07m and plant densities of 3.7, 8.6, 13.6 and 18.5 plants m^{-2}. Their results did not show a consistent effect of row spacing or population density on grain yield. But densities of 8.6 and 13.6 m^{-2} were equally optimum over the range of yield levels and row spacings involved.

Brathwaite (1982) reported that increased plant density of beans (*Vigna unguiculata*.L), resulted in seeds of good quality and high yield. The weight and number of pods per plant decreased as plant density increased. Similar work has been conducted on soybeans (*Glycine max*. (L) Merr) by Boerma and Ashly (1982). They found that the 51 cm row spacings yielded 17% (278 kg/ha) more seed than that of 91 cm row spacings.

Sorghum Grain Yield Components

A study was conducted by Stickler and Wearden (1965) on the effects of row spacing and plant populations on sorghum grain yield components from which they concluded that higher sorghum grain yields were due to increased tillering, heads per unit land area, seeds per head and seed weight. Stickler and Pauli (1961) found that tillers contributed, on various planting dates, 3 to 67% of the total grain yield among genotypes of grain sorghum. In a similar study by Downes (1968) sorghum grown at 32°C had an average of either 3.2 or 2.5 elongated tillers per plant at 12 or 16 hr. photoperiods respectively.

These yield components were reported on for other crops. Grafius (1956) reported that among over 40 varieties of oats (Avena sativa L.) the number of panicles per unit area and size of panicle influenced yield, but that the size of the produced seed had no affect. Among varieties, the variation in kernel weight was very small and therefore, it was not a major factor in grain yield variations. Darwinkel (1978) found that winter cereal main shoots had higher grain yield than tillers. The number of tillers, however, and their grain yields were very high, particularly at low seeding rates.

Dry Matter Components as Affected by Cultural Practices

Grain sorghum maximum dry weight accumulation occurred at 45 days after pollination with 23% moisture in 1958 and at 33 days at 30% moisture in 1959 (Kersting, Stickler and Pauli 1961).

Pearce, Brown and Blaser (1965) reported that in orchardgrass (Dactylis glomerta L.) more rapid dry matter and leaf area accumulation were observed in July than in September. Martin and Wedin (1974) observed that dry matter yield of forage and grain yield can be affected by plant populations and row-spacings. They also observed that when grain sorghum stover harvest was delayed 15 days past grain harvest (25% moisture), maximum stover dry matter accumulation was obtained.

Lawn (1982) observed that in four grain legumes Soybean (Glycine max), Black gram (Vigna mungo), Green gram (V. radiata) and Cowpea (V. unguiculata) dry matter accumulation was primarily a function of water use. Seed yield and water use efficiency for seed yield, however, depended on the seasonal pattern of water use.

Chamberlin and Wilson (1982) examining dry weight changes in sorghum, found that after anthesis total dry weight formation was more than enough to preserve grain growth.

Francis et al. (1978) reported that timing and intensity of competition highly affected grain and total dry matter production in maize. Competition among plants starts as early as 6 weeks after planting. Stoffer and Van Riper (1963) observed that dry matter formation was greater with higher soil temperatures and soil moisture levels.

Fischer and Wilson (1975) reported that in sorghum total dry matter yield per unit land surface was greater for the high population and least for the low population, and leaf area growth was more rapid at high plant density, because of more seedlings and not because of any differece in relative leaf growth rate.

Sorghum Agronomic Characteristics

Hedge et al. (1976) found that sorghum grain weight per panicle was increased as row spacing increased and panicles per plant decreased. As plant population increased, yield per panicle and panicles per plant decreased.

Krishnamurthy et al (1974), in their studies on three sorghum germplasms, observed that the most representative leaf, for leaf area determination, was found to be the largest one. Bruns and Horrocks (1984), studying the relationships of grain yield components of main culms and lateral tillers of grain sorghum, found that number of kernels produced by and weight of grains from main culm panicles decreased as number of tillers allowed to develop increased by 15 and 9%, respectively.

Liang, Overley and Casady (1969), in their studies on the agronomic characteristics in grain sorghum, found that grain yield was highly correlated with head weight, kernel number and half-bloom date.

The range of days to 50% bloom among cultivars during dry and wet seasons were 49 to 66 and 61 to 93, respectively, (Cabangbang, 1977). This means that maturity was delayed by about 13 to 17 days during the wet season due to longer days. In a study conducted by Voigt (1969), the higher temperatures of mid-summer months was reported to be the essential factor for increasing the physiological activity of grain sorghum resulting in earlier bloom dates. He also reported that grain dry matter accumulation was essentially complete by about 20 to 30 days after blooming. Decreased grain yield, shorter plant height, less head exsertion and lower grain test weight was observed in late July plantings compared to earlier plantings in the Marana area.

CHAPTER 3

MATERIALS AND METHODS

Plant Materials

This study was conducted at the University of Arizona's Marana Agricultural Center during the summer of 1984. The University of Arizona's Marana Agriculture Center is located near the town of Marana about 30 km northwest of Tucson, Arizona.

Two hybrid grain sorghum (*Sorghum bicolor* (L.) Moench) genotypes, one of medium maturity and the other of medium-late maturity, were selected. These were chosen as representative genotypes of the sorghum species to be tested and evaluated for their phenotypic response to three different plant populations within two dates of planting. They were also selected for their superior grain yield in 1982 and 1983 tests under both full season and double crop growing conditions (Bimpolo and Voigt, 1983; Bimpolo, 1984). These two hybrids are the medium-late maturing Asgrow 'Colt' genotype and the medium maturing Asgrow 'Topaz' genotype.

Study Site Description

The soil of the experimental area (Field B-2) is a Pima clay loam of the family fine silty, mixed, thermic, and classified as a Typic Torrifluvent. The Pima series is an Entisol that formed in recent alluvial deposits in the flood plains of the Santa Cruz River. Slopes are 0 to 1 percent. The soil consists of a well-drained profile with a moderately slow permeability (USDA, 1972).

The Marana area has an arid to semi-arid climate, receiving less than 300 mm of precipitation in most years Sellers and Hill (ed.) (1964). Table 1 shows the mean monthly maximum and minimum temperatures during the months of the field trials.

Table 1. Average maximum and minimum monthly temperatures (^{o}C) during the sorghum field study at Marana, Arizona, 1984.

Month	Maximum	Minimum
May	38.4	17.7
June	38.4	20.1
July	38.9	23.1
August	39.2	21.8
September	38.2	19.7
October	31.1	11.9

Experiment Layout

The experimental design was a split plot with four blocks and six treatments for the two varieties at their three plant populations. The two sorghum hybrid genotypes were grown under full season and double crop production conditions. The full season planting was made in moisture on 22 May 1984 to simulate local farmers' full season production practices.

The double crop planting was made in moisture on 10 July 1984. The July planting was made to simulate a local practice of planting grain sorghum after harvest of barley or wheat in June for a double crop for the year on the same land area. Both grain sorghum test materials were grown at three population levels within both dates of planting. A plant spacing in 1.02 m rows of 15.24, 7.62 and 2.54 cm between plants provided populations of 1) 64,583, 2) 129,167, and 3) 387,501 plants per hectare, respectively.

The experimental area was divided into four blocks (replications), each block was divided into six plots, allowing for the three population treatments of both sorghum varieties. Each plot was four rows wide (4.08 m) and 6.096 m long with a 0.61 m alley between plot ends (Fig. 1). As mentioned earlier, only the two center rows in each plot were evaluated and harvested for research data. The additional plot border rows on either side were to provide

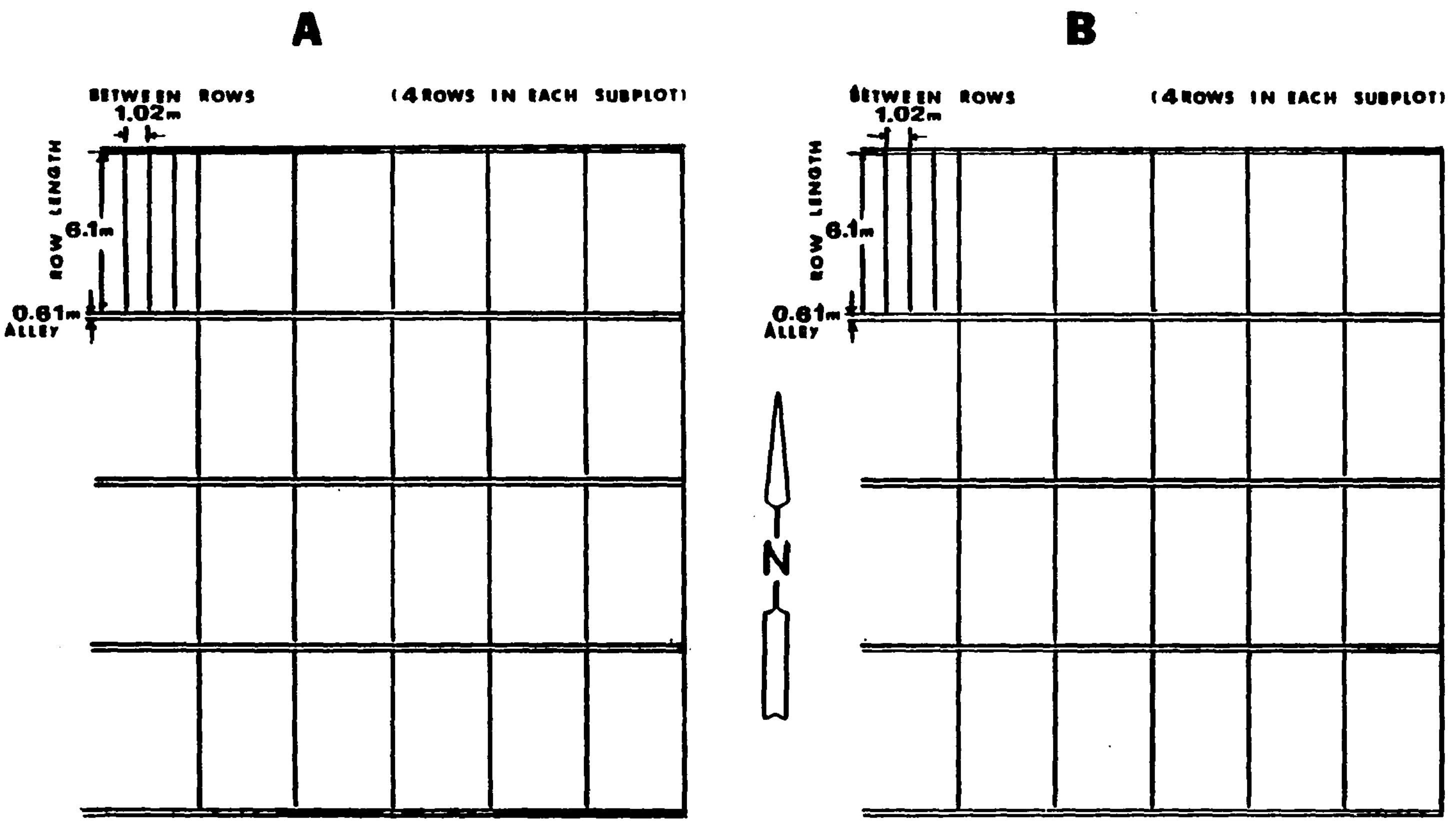

Figure 1. Experimental field layout showing 48 plots for the two planting dates: A) 22 May and B) 10 July, Marana, Arizona, 1984

proper environmental border protection for the two central rows. The plots were over-planted and then all the rows were hand-thinned when the plants were 5 to 8 cm high. Thinning was done to obtain 2, 4 and 12 plants per 30.5 cm of row representing the three plant populations 1, 2 and 3, respectively.

The plot area for the second planting date (10 July) was located 20.4 m (20 rows) away from the first plot area. These 20 rows were sown with sorghum.

Field Practices

Fertilizer was applied during seed bed preparation at the rate of 448 kg/ha of 16-20-0 (N-P-K). This supplied about 72 kg of N and 90 kg of P per hectare. No additional fertilizer was applied during the growing season.

Weed control was obtained through the post emergence application of Atrazine at the application rate of 1.68 kg. of active ingredient per hectare. Stickler and Anderson (1964) reported that weed control obtained by early post-emergence application of Atrazine enhanced grain yield production of sorghum. Some mechanical weeding was accomplished by rotary hoeing of the sides of the furrows at early stages of growth. This rotary hoe treatment was primarily to make sure the furrows were open for irrigation and to throw soil around the base of the young sorghum plants so that the brace roots could root down and reduce later plant lodging.

Well-water irrigation was applied and controlled by the use of furrows and siphon tubes from a concrete lined ditch. Moisture for plant growth and production came from irrigation and rainfall for both planting dates. Table 2 shows dates and amounts of irrigation water and precipitation received during the experiment period.

Table 2. Amount of irrigation water and precipitation actually received by the sorghum field study at Marana, Arizona, 1984.

Months	Irrigaton	Rainfall	Total
	mm	mm	mm
May planting	1016.00	251.21	1267.21
July planting	914.40	235.97	1150.37

Data Collection and Analysis

Data were collected in the field on the growth and development of the two sorghum hybrids for all treatments for the purpose of evaluating plant characteristics such as: days to 50 percent bloom (50% of the head in anthesis), height of the plant to the upper leaf collar, head exsertion, head length, head count at harvest, percent bird damage of grain at harvest, mature main plant evaluation for leaf area, leaf dry matter, stem dry matter and head dry matter.

The two center plot rows were harvested with a Massey Ferguson 35 combine. The harvesting date for the 22 May planting was 1 November, and for the 10 July planting was 8 November 1984. Grain from each plot was weighed at harvest, and a sample saved in a plastic bag for further evaluation. The grain samples were later evaluated for grain volume-weight and weight per 1000 seed.

Number of days to 50% bloom was obtained for each plot by recording the date on which half of the total florets in the plot had bloomed or when the average plant per plot was half bloomed down the head. The number of days from the day after planting through the 50% bloom date became the days to 50% bloom.

Height to the upper leaf collar was obtained by measuring this height on an average plant in each plot. The amount of head exsertion was measured from the flag leaf to the base of the panicle and recorded as an average measurement among plants in the plot. The length of the panicle was an average of a number of typical plant heads in each plot. A total plant height to the top of the head was then obtained by adding all three measurements of height to the upper leaf collar, peduncle elongation, and panicle length.

All heads were counted in each two-row plot just before harvest for comparison with original plant populations and for a measure of degree of tillering between varieties and among treatments.

Birds, such as English sparrows and white wing dove, caused damage to the grain yield. Since bird damage varied between entries and among treatments, it was necessary to adjust grain yield for this damage. Estimates were made just prior to harvest as to the percent of grain eaten from each plot and then the harvested yield was adjusted upward to compensate for this loss.

Two typical main plants were selected from a border row from each plot at full bloom for evaluation of leaf area, leaf dry matter, stem dry matter and head dry matter. The above ground parts of two main plants (without tillers) were cut and put in a plastic bag to prevent drying during transport to the laboratory. In the laboratory, all leaves were numbered from the flag leaf downward, removed from the stem at the leaf collar, measured for leaf area using a leaf area meter (LI-3100, LI-COR, Inc. Lincoln, Nebraska, USA). The leaves and stem were cut into pieces and put in the oven at 70°C to dry for dry matter determination.

Grain samples were obtained from all plots to determine grain volume-weight. These grain samples were cleaned of straw and broken kernels prior to being evaluated for grain volume-weight. Random samples of seed of 1000 seeds each were counted out from the cleaned grain sub-samples and weighed as relative measures of seed weight.

Means, analyses of variances and Pearson correlation coefficients were used to evaluate the differences, or relationships between the various parameters. All data such as grain yield, yield components, dry matter components, and the agronomic characteristics were statistically analysed and tested using the Statistical Package of Social Sciences (SPSS) in a Cyber-175 computer HP 41-CV at the University of Arizona Computer Center.

CHAPTER 4

RESULTS AND DISCUSSION

The agronomic responses of two typical grain sorghum hybrids (Topaz and Colt) as represented by grain yield, and other various agronomic characteristics were studied in three plant populations under two planting dates.

Grain Yield

Average grain yields (Mg ha^{-1}) for the sorghum hybrids Topaz and Colt, and the least significant difference tests (LSD) are given in Table 3. The mean grain yield (Table 3) of Topaz was significantly higher in the May planting than the July planting by 20.2 and 19.7% in populations 1 and 2, but was not significantly different at the high plant population. This indicates Topaz is better suited to lower populations in a May (early) planting. The grain yield of Colt was significantly higher in the May planting in populations 2 and 3 by 43.8 and 29.5%, respectively. This indicates that Colt performs better at higher populations in early (May) plantings than in later (July) plantings.

In comparing the grain yield production of Topaz and Colt on the basis of planting dates, Topaz hybrid in the May

Table 3. Average grain yield of Topaz and Colt sorghum hybrids grown at three plant population levels in two dates of planting. Marana, Arizona, 1984.

Hybrid	Planting date	Plant population ha^{-1}		
		64,583	129,167	387,501
		Grain yields Mg ha^{-1}		
Topaz	22 May	7066[a+]	7192[a]	6202[a]
	10 July	5878[b]	6006[b]	6393[a]
Colt	22 May	5002[a]	6448[a]	6584[a]
	10 July	5067[a]	4481[b]	5084[b]

[+]Values followed by the same letter between dates of planting within hybrids within populations are not significantly different at the 0.05 level of probability.

planting gave significantly higher yields than Colt by 41.2 and 11.5%, respectively in populations 1 and 2, but a lower yield by -5.8% in population 3. In the July planting grain yields of Topaz were higher than Colt in populations 1, 2 and 3 by 16.0, 34.0 and 25.7%, respectively.

The analysis of variance for grain yield is presented in Table 4. The data for the single factor effect of hybrid, date of planting, and plant population were all highly significant. This indicates the large effect that each of these three factors has on the grain yield across the other factors. The three-way interaction of population x hybrid x date of planting was highly significant as well as the two-way interactions of hybrid x population and date

Table 4. Analysis of variance for grain yield (Mg ha^{-1}) for two grain sorghum hybrids grown at three population levels in two dates of planting. Marana, Arizona, 1984.

Source of Variation	df	Mean Square	F Observed
Sorghum hybrid (Hybrid)	1	12,282,645.02	66.60**
Error 1	3	184,416.35	-
Date of planting (Date)	1	10,390,893.52	201.20**
Hybrid x Date	1	496,743.52	9.62*
Error 2	3	51,645.08	-
Plant population	2	470,284.64	5.67**
Hybrid x Population	2	992,995.02	11.98**
Date x Population	2	1,258,521.64	15.18**
Population x Hybrid x Date	2	2,268,535.02	27.37**
Within + Residual+	24	82,870.00	-

+ The three-way interaction was tested against a pooled error (within + residual).
* Significant at .05 level
** Signiicant at .01 level

x population. The interaction of hybrid x date was significant at the .05 level. These interactions indicate that the grain yield response of the two hybrids was not similar over the two dates of planting and three plant populations (Table 3). These dissimilar responses may illustrate genetic differences in phenotypic responses to the environmental effects of different plant competition among the three populations and the temperature and day length effects from different dates of planting.

These results suggest that for Topaz earlier planting dates and lower plant populations in the range of about 65,000 to 130,000 plants per hectare produce more optimum yields. Higher plant populations may be required for Colt for more optimum grain yield. It was observed that plots planted at the first and second population levels produced more tillers (more heads) which, in turn, increased grain yield. This observation agrees with that of Blum (1970) who reported that sorghum plants at the highest densities had a reduced number of panicles (tillers) per plant, and at the lower plant densities had an increased number of panicles (tillers) per plant.

The grain yield data were adjusted to compensate for damages caused by birds. The amount of bird damage experienced was estimated on a basis of percent of grain eaten within each plot by date of harvest. Table 5 indicates that the greatest percentage of bird damage was on Colt in the May planting. This damage of 38.0% in population 1, 51.0% in population 2, and 61.5% in population 3 indicated uniformity of damage among populations. Even though Colt bloomed 6 days later than Topaz, the damage was serious and it might be related to plant height. This observation does not fit with that of Voigt and Schmalzel (1984) who emphasized that the earlier maturing (first blooming) varieties in a test area are usually subjected to greatest bird damage.

Table 5. Estimated average (%) bird damage of two sorghum hybrids grown at three plant population levels in two dates of planting. Marana, Arizona, 1984.

Hybrid	Planting date	Plant population ha^{-1}		
		64,583	129,167	387,501
		percent bird damage %		
Topaz	22 May	4.50	3.25	9.00
	10 July	1.25	2.50	14.00
Colt	22 May	38.00	51.00	61.50
	10 July	3.75	4.00	4.25

Weight of 1000 Seed

Weight of 1000 seeds (seed size) was studied since this characteristic is an important component of grain yield. The average weights of 1000 seeds (g) of the two hybrids, and their least significant difference tests (LSD) are given in Table 6.

The weight of 1000 seed of Topaz (Table 6) was significantly higher in the May planting than in the July planting for populations 1 and 2 with relative increases of 11.6 and 15.0% respectively. The weight of 1000 seed of Colt (Table 6) was significantly greater for populations 2 and 3 by 11.5 and 11.7%, respectively in the May planting than in the July planting.

Table 6. Average weights of 1000 seeds of Topaz and Colt sorghum hybrids grown at three plant population levels in two dates of planting. Marana, Arizona, 1984.

Hybrid	Planting date	Plant population ha^{-1}		
		64,583	129,167	387,501
		Weight of 1000 seed g		
Topaz	22 May	26.14^{a+}	25.90^{a}	25.24^{a}
	10 July	23.42^{b}	22.51^{b}	23.92^{a}
Colt	22 May	23.54^{a}	24.17^{a}	25.39^{a}
	10 July	22.88^{a}	21.66^{b}	22.73^{b}

[+]Values followed by the same letter between dates of planting within hybrids within populations are not significantly different at the 0.05 level of probability.

The single factor effects of hybrid and date of planting for weight of 1000 seed (Table 7) were highly significant. Seed weight is a manifestation of seed size which is a genetically controlled characteristic in sorghum. Topaz sorghum hybrid apparently has significant genetically

Table 7. Analysis of variance for weight of 1000 seeds (g) for two grain sorghum hybrids grown at three population levels in two dates of planting. Marana, Arizona, 1984.

Source of Variation	df	Mean Square	F Observed
Sorghum hybrid (Hybrid)	1	15.23	36.26**
Error 1	3	0.42	-
Date of planting (Date)	1	58.43	292.15**
Hybrid x Date	1	0.86	4.30
Error 2	3	0.20	-
Plant population	2	2.32	3.05
Hybrid x Population	2	1.20	1.58
Date x Population	2	1.76	2.32
Population x Hybrid x Date	2	2.98	3.92*
Within + Residual[+]	24	0.76	-

+ The three-way interaction was tested against a pooled error (Within + Residual).

* Significant at .05 level

** Significant at .01 level

heavier seed weight than Colt. The later date of planting produced significantly lighter (smaller) seed than the earlier planting date in both hybrids across populations (Table 7). This indicates a similar response of both hybrids to the different growth environments of the two planting dates (Table 6).

The population factor was non-significant (Table 7). All three two-way interactions were non-significant, however, the .05 level of significance of the three-way interaction indicated some variation in the response of the two hybrids for weight of 1000 seed across planting dates and populations (Table 6).

These results are not in total consistent agreement with those of Miyata (1978), or of Thomas et al (1981) who reported that the weight of 1000 seed responded to higher plant population with a reduction in grain size. Fairey (1983), concluded that sorghum grain weight was reduced as a result of late planting as were the seed weights in this test.

Grain Volume-Weight

The grain volume-weight (Table 8) for Topaz was significantly higher in the July planting than in the May planting with increases of 0.9, 2.0 and 2.6% in population 1, 2 and 3, respectively. The grain volume-weight for Colt (Table 8) was also significantly higher in the July planting than the May planting by 3.4, 2.8 and 3.8% in populations 1, 2 and 3, respectively.

Table 8. Average grain volume-weight of Topaz and Colt sorghum hybrids grown at three plant population levels in two dates of planting. Marana, Arizona, 1984.

Hybrid	Planting date	Plant population ha^{-1}		
		64,583	129,167	387,501
		Grain volume-weight Kg m^3		
Topaz	22 May	775.60^{a+}	773.88^{a}	769.60^{a}
	10 July	782.70^{b}	790.12^{b}	789.90^{b}
Colt	22 May	751.00^{a}	751.90^{a}	746.52^{a}
	10 July	776.40^{b}	773.42^{b}	774.85^{b}

$^{+}$Values followed by the same letter between dates of planting within hybrids within populations are not significantly different at the 0.05 level of probability.

These results are not in general agreement with those of Thomas, et al (1980) who reported that population density and narrow spacing can cause grain test weight reduction.

The single factor effect of hybrid and date of planting for grain volume-weight (Table 9) were both highly significant. While population was non-significant, the differences for grain volume-weight should be and are inverse of the weight of 1000 seed. Smaller seed weights give smaller seeds which produce heavier volume-weights.

Two of the two-way interactions, hybrid x population and date x population, were non-significant while the hybrid x date interaction showed significance at the .05 level. The three-way interaction was non-significant indicating similarity in response of both hybrids to dates of planting and populations.

Number of Heads

The number of heads (Table 10) of Topaz shows an increase as plant population increased, however, there were no significant differences between planting dates within each plant population. Colt (Table 10) had a significant increase in number of heads in the July planting in population 3, but no difference in the other two plant populations.

The single factor of plant population was highly significant for head numbers (Table 11). This would be expected since head numbers reflect original plant counts plus any tillers that develop. Increased plant populations for both hybrids produced greater numbers of heads, but these greater total head numbers were not directly proportional to the increased populations. The average total number of heads per plant for populations 1, 2 and 3 were 3, 2.1 and 1.4 respectively. These counts indicate an average tiller per plant production for populations 1, 2 and 3 of 2,

Table 9. Analysis of variance for grain volume-weight (Kg m3) for two grain sorghum hybrids grown at three population levels in two dates of planting. Marana, Arizona, 1984.

Source of Variation	df	Mean Square	F Observed
Sorghum hybrid (Hybrid)	1	3,866.43	109.09**
Error 1	3	35.44	-
Date of planting (Date)	1	4,712.40	221.66**
Hybrid x Date	1	332.85	15.66*
Error 2	3	21.26	-
Plant population	2	17.97	0.54
Hybrid x Population	2	18.82	0.57
Date x Population	2	67.59	2.05
Population x Hybrid x Date	2	47.13	1.43
Within + Residual+	24	32.90	-

+ The three-way interaction was tested against a pooled error (Within + Residual).
* Significant at .05 level
** Significant at .01 level

Table 10. Average number of heads of Topaz and Colt sorghum hybrids grown at three plant population levels in two dates of planting. Marana, Arizona, 1984.

Hybrid	Planting date	Plant Population ha^{-1}		
		64,583	129,167	387,501
			Number of heads ha^{-1}	
Topaz	22 May	220,226[a+]	280,102[a]	558,973[a]
	10 July	223,918[a]	272,310[a]	567,586[a]
Colt	22 May	189,469[a]	271,080[a]	508,120[a]
	10 July	191,109[a]	248,934[a]	581,119[b]

[+]Values followed by the same letter between dates of planting within hybrids within populations are not significantly different at the 0.05 level of probability.

1.1 and .4, respectively. Increased competition within the higher populations suppressed tiller formation.

The single factor of hybrid was significant at the .05 level across dates and population (Table 11). This significance could have been caused by a genetic difference for tiller production between the two hybrids.

The two-way interaction of date x population was highly significant (Table 11). This indicates that head numbers (tillers) for both hybrids were not produced similarly across dates and populations. The three-way interaction of plant population x hybrid x date of planting was significant at the .05 level of probability (Table 11). This indicates that the hybrids did not produce the number

Table 11. Analysis of variance for number of heads (ha^{-1}) for two grain sorghum hybrids grown at three population levels in two dates of planting. Marana, Arizona, 1984.

Source of Variation	df	Mean Square	F Observed
Sorghum hybrid (Hybrid)	1	5,921,540,000.00	14.36*
Error 1	3	412,230,428.72	-
Date of planting (Date)	1	1,083,210,000.00	3.88
Hybrid x Date	1	767,408,114.08	2.74
Error 2	3	279,172,344.47	-
Plant population	2	550,625,000,000.00	1168.04**
Hybrid x Population	2	280,757,904.94	0.60
Date x Population	2	3,250,930,000.00	6.89**
Population x Hybrid x Date	2	1,794,210,000.00	3.80*
Within + Residual+	24	471,408,601.44	-

+ The three-way interaction was tested against a pooled error (Within + Residual)
* Significant at .05 level
** Significant at .01 level

of heads (tillers) in a similar manner over the two dates of planting and three plant populations (Table 10).

The greater total number of heads for the higher plant populations consisted of shorter (smaller) heads that produced less seed per head. The gain in seed numbers through greater head numbers by increased populations was not consistently offset by loss in seed numbers through smaller heads by increased populations. This variability in net seed number gain or loss between hybrids and among plant populations will influence the variability of final grain yields between hybrids and between plant populations.

Total Plant Dry Matter

Total plant dry matter in this experiment is the sum of the dry matter of leaf, stem and head of a main plant at date of 50% bloom (just prior to seed formation). Total plant dry matter per main plant of the two hybrids shows progressive decreases proportional to plant populations (Table 12).

Topaz plant dry matter per main plant was statistically higher in the May planting than in the July planting in population 3 but not with populations 1 or 2.

Colt (Table 12) also produced more plant dry matter in the May planting than in the July planting at all three plant population levels. The increases of 57.7, 78.4 and

40.0% in populations 1, 2 and 3, respectively were all significant.

In comparing the total plant dry matter production per main plant of the two hybrids, Colt showed superiority over Topaz with relative increases obtained in the May planting by 35.6, 38.9 and 10.2% for populations 1 to 3, respectively. Also, in the July planting Colt had a higher plant dry matter production than Topaz by 4.6 and 16.4% in populations 1 and 3, and less by -3.3% in population 2. This shows that increasing plant populations resulted in a decrease in total main plant dry matter of both hybrids in the two planting dates.

Table 12. Average total plant dry matter per main plant for Topaz and Colt sorghum hybrids grown at three plant population levels in two dates of planting. Marana, Arizona, 1984.

Hybrid	Planting date	Plant population ha^{-1}		
		64,583	129,167	387,501
		Total plant dry matter g/main plant		
Topaz	22 May	78.68a+	65.80a	40.38a
	10 July	64.69a	53.02a	27.30b
Colt	22 May	106.75a	91.44a	44.52a
	10 July	67.68b	51.26b	31.80b

+Values followed by the same letters between dates of planting within hybrids within populations are not significantly different at the 0.05 level of probability.

The single factor effect of planting date and plant population on total plant dry matter were highly significant (Table 13). Sorghum, when planted late produces smaller plants with decreased grain yields. The increased competition of higher plant populations causes individual plants to be smaller and with fewer tillers. The single factor of hybrid was significant at the .05 level indicating some genetic difference in plant size between the two hydrids over planting date and population.

The only two-way interaction that was significant was date x population which was highly significant. This indicated that the two hybrids did not vary equally in main plant dry matter across dates of planting and plant populations. The three-way interaction of plant population x hybrid x planting date (Table 13) was significant at the .05 level of probability indicating some statistical variability in the hybrid response for main plant size over dates of planting and plant populations.

Tables 14 and 15 present the mean dry matter plant production per main plant for Topaz and Colt respectively for both planting dates and all three plant population levels. The percent of each plant component (leaf, stem and head) of the total plant are also presented.

Table 13. Analysis of variance for total plant dry matter (g/main plant) for two grain sorghum hybrids grown at three population levels in two dates of planting. Marana, Arizona, 1984.

Source of Variation	df	Mean Square	F Observed
Sorghum hybrid (Hybrid)	1	1,347.79	16.00*
Error 1	3	84.24	-
Date of planting (Date)	1	5,791.07	28.10**
Hybrid x Date	1	906.28	4.40
Error 2	3	206.05	-
Plant population	2	7,863.65	165.02**
Hybrid x Population	2	130.96	2.74
Date x Population	2	246.88	5.18**
Population x Hybrid x Date	2	237.21	4.98*
Within + Residual+	24	47.65	-

\+ The three-way interaction was tested against a pooled error (Within + Residual).
* Significant at .05 level
** Significant at .01 level

Table 14. Mean data for leaf, stem and head dry matter of an average main plant for Topaz sorghum hybrid grown at three plant population levels in two dates of planting. Marana, Arizona, 1984.

Planting Date	Plant Dry Matter	Plant population ha^{-1} 64,583		129,167		387,501		
22 May		g	(%)	g	(%)	g	(%)	(x%)
	Leaf dry matter	25.28	(32.1)	21.42	(32.6)	11.82	(29.3)	(31.3)
	Stem dry matter	38.78	(49.3)	33.84	(51.4)	22.38	(55.4)	(52.0)
	Head dry matter	14.62	(18.6)	10.55	(16.0)	6.18	(15.3)	(16.6)
Total plant dry matter		78.68	(100%)	65.81	(100%)	40.38	(100%)	
10 July		g	(%)	g	(%)	g	(%)	(x%)
	Leaf dry matter	21.00	(32.5)	16.82	(31.7)	8.46	(30.9)	(31.7)
	Stem dry matter	28.91	(44.6)	24.50	(46.2)	14.32	(52.5)	(47.8)
	Head dry matter	14.78	(22.9)	11.71	(22.1)	4.52	(16.6)	(20.5)
Total plant dry matter		64.69	(100%)	53.03	(100%)	27.30	(100%)	

Table 15. Mean data for leaf, stem and head dry matter of an average main plant for Colt sorghum hybrid grown at three plant population levels in two dates of planting. Marana, Arizona, 1984.

Planting Date	Plant Dry Matter	Plant population ha^{-1}						
		64,583		129,167		387,501		
22 May		g	(%)	g	(%)	g	(%)	(x%)
	Leaf dry matter	30.84	(28.8)	26.27	(28.7)	13.32	(30.0)	(29.2)
	Stem dry matter	58.68	(55.0)	50.92	(55.7)	24.84	(55.8)	(55.5)
	Head dry matter	17.25	(16.2)	14.25	(15.6)	6.36	(14.2)	(15.3)
Total plant dry matter		106.77	(100%)	91.44	(100%)	44.52	(100%)	
10 July		g	(%)	g	(%)	g	(%)	(X%)
	Leaf dry matter	18.76	(27.7)	14.26	(27.8)	8.48	(26.6)	(27.4)
	Stem dry matter	35.68	(52.7)	27.05	(52.8)	17.82	(56.0)	(53.8)
	Head dry matter	13.24	(19.6)	9.95	(19.4)	5.52	(17.4)	(18.8)
Total plant dry matter		67.68	(100%)	51.26	(100%)	31.82	(100%)	

Leaf Dry Matter

Topaz had significantly more leaf dry matter in the May planting than in the July planting at population levels 2 and 3 with no statistical difference at the lowest plant population (Table 16). The relative increases were 27.3% in population 2 and 39.7% in population 3. Colt produced significantly higher leaf dry matter in the May planting than in the July planting in all three populations.

The percentage increases for Colt for the May over July planting date were 64.4, 84.2 and 57.2% for populations 1, 2 and 3, respectively.

Table 16. Average leaf dry matter per main plant for Topaz and Colt sorghum hybrids grown at three plant population levels in two dates of planting. Marana, Arizona, 1984.

Hybrid	Planting date	Plant population ha^{-1}		
		64,583	129,167	387,501
		Leaf dry matter g/main plant		
Topaz	22 May	25.28^{a+}	21.42^{a}	11.82^{a}
	10 July	21.00^{a}	16.82^{b}	8.46^{b}
Colt	22 May	30.84^{a}	26.27^{a}	13.32^{a}
	10 July	18.76^{b}	14.26^{b}	8.47^{b}

+Values followed by the same letters between dates of planting within hybrids within populations are not significantly different at the 0.05 level of probability.

The single factor effect of date of planting on main plant leaf dry matter was highly significant (Table 17). The different growth environment of second date of planting caused both hybrids to have less leaf area than the first date of planting (Table 34). Less leaf area automatically produced less leaf dry matter (Table 16).

The single factor effect of plant population on main plant leaf dry matter was highly significant (Table 17). The increased plant competition within the higher populations caused smaller individual plants with corresponding smaller plant components (Table 16).

The two-way interaction of date x population was significant at the .05 level of probability (Table 17). This indicates that the leaf dry matter of the two hybrids did not change the same across planting date and plant population.

Stem Dry Matter

The relative dry matter production rates of stem dry matter for both hybrids at two dates of planting at all three population levels were similar to those for total dry matter and leaf dry matter production.

A significant increase of stem dry matter for Topaz was observed in the May planting over that of the July planting for all plant populations (Table 18). The relative increases were 34.1, 38.1, and 56.2% in population 1, 2

Table 17. Analysis of variance for leaf dry matter (g/main plant) for two grain sorghum hybrids grown at three plant population levels in two dates of planting. Marana, Arizona, 1984.

Source of Variation	df	Mean Square	F Observed
Sorghum hybrid (Hybrid)	1	17.05	2.70
Error 1	3	6.30	-
Date of planting (Date)	1	565.33	47.90**
Hybrid x Date	1	93.16	7.89
Error 2	3	11.80	-
Plant population	2	756.25	165.84**
Hybrid x Population	2	.82	.18
Date x Population	2	22.80	4.99*
Population x Hybrid x Date	2	12.50	2.74
Within + Residual+	24	4.56	-

+ The three-way interaction was tested against a pooled error (Within + Residual).
* Significant at .05 level.
** Significant at .01 level.

and 3, respectively. Colt (Table 18) also displayed significant increases of stem dry matter in the May planting over the July planting with relative values of 64.4, 88.2, and 39.4% in populations 1, 2 and 3, respectively.

The three single factor effects of hybrid, date of planting and plant population on main plant stem dry matter were all highly significant at the .01 level of probability (Table 19). The two hybrids differed from each other for stem dry matter at the same dates and populations (Table 18). Each hybrid differed among population and between hybrids (Table 18) but at variable rates of change. Higher

Table 18. Average stem dry matter per main plant for Topaz and Colt sorghum hybrids grown at three plant population levels in two dates of planting. Marana, Arizona, 1984.

Hybrid	Planting date	Plant population ha^{-1}		
		64,583	129,167	387,501
		Stem dry matter g/main plant		
Topaz	22 May	38.78[a+]	33.84[a]	22.38[a]
	10 July	28.91[b]	24.50[b]	14.32b
Colt	22 May	58.68[a]	50.92[a]	24.84[a]
	10 July	35.68[b]	27.05[b]	17.82[b]

[+]Values followed by the same letters between dates of planting within hybrids within populations are not significantly different at the 0.05 level of probability.

populations caused lower main stem dry matter due to higher plant competition that caused smaller plants. The later planting date caused shorter (Table 22) and smaller plants (Table 14 and 15).

The two-way interaction of hybrid x population was highly significant for stem dry matter (Table 19) indicating a difference in rate of stem dry matter production by the two hybrids among populations. The two-way interaction of date x population was highly significant for stem dry matter (Table 19) indicating a difference in change of stem dry matter between dates and among populations (Table 18).

The three-way interaction of population x hybrid x date for main stem dry matter was significant at the .05 level of probability (Table 19) indicating some differences in amount of change in stem dry matter between hybrids, between dates and among populations (Table 18).

As a result of the later planting date, total stem dry matter decreased. This result is in agreement with that of Mirhadi and Kobayashi, (1981) who reported a decrease in the stem and leaf dry matter per plant of sorghum when planting was postponed from 1 May to 15 June and 1 July.

Head Dry Matter

Mean head dry matter (g/main plant) of heads at date of 50% bloom (prior to grain formation) and their least significant difference tests (LSD) are given in Table 20.

Table 19. Analysis of variance for stem dry matter (g/main plant) for two grain sorghum hybrids grown at three population levels in two dates of planting. Marana, Arizona, 1984.

Source of Variation	df	Mean Square	F Observed
Sorghum hybrid (Hybrid)	1	910.36	29.74**
Error 1	3	30.61	-
Date of planting (Date)	1	2,194.56	35.69**
Hybrid x Date	1	236.56	3.84
Error 2	3	61.48	-
Plant population	2	1,790.56	119.53**
Hybrid x Population	2	110.94	7.40**
Date x Population	2	107.61	7.18**
Population x Hybrid x Date	2	74.14	4.94*
Within + Residual+	24	14.98	-

+ The three-way interaction was tested against a pooled error (Within + Residual).
* Significant at .05 level
** Significant at .01 level

Head dry matter of Topaz was not affected by planting date within each population. The head dry matter of both Topaz and Colt showed a strong tendency for decrease as the plant populations increased (Table 20 and 21).

The Colt hybrid (Table 20) had significantly more head dry matter in May than in the July planting only in population 2. 3, respectively.

There was no statistically significant difference between hybrids for head dry matter (Tables 20 and 21). The single factor of plant population was the only factor affecting head dry matter in a statistically significant

Table 20. Average head dry matter per main plant for Topaz and Colt sorghum hybrids grown at three plant population levels in two dates of planting. Marana, Arizona, 1984.

Hybrid	Planting date	Plant population ha^{-1}		
		64,583	129,167	387,501
		Head dry matter g/main plant		
Topaz	22 May	14.62^{a+}	10.55^{a}	6.18^{a}
	10 July	14.78^{a}	11.71^{a}	4.52^{a}
Colt	22 May	17.25^{a}	14.25^{a}	6.36^{a}
	10 July	13.24^{a}	9.95^{b}	5.52^{a}

+Values followed by the same letters between dates of planting within hybrids within populations are not significantly different at the 0.05 level of probability.

manner. Population was highly significant for its effect on head dry matter (Table 21). Heads decreased in size in the higher populations due to the increased competition of more plants which caused smaller plants.

The three-way interaction of population x hybrid x date had a small statistical mean squares value but was still highly significant at the .01 level of probability for its influence on head dry matter (Table 21). This indicates that head dry matter was not reacting similarly for both hybrids over two dates and three populations. There was a general but non-significant trend for less head dry matter in the later date of planting (Table 21).

The lower head dry matter production that accompanies later seasonal dates of planting is very much like the lower July planting date dry matter production for total plant, leaf, and stem compared to the May planting date. The entire plant structure of stem, leaves and head without seed in g/main plant decreased with the later planting date. There is little possibility of increased grain yield of later dates of planting over earlier dates of planting with totally less entire plant structure material to produce and support it.

Some of this loss of plant structure with later planting dates can be made up with increased seeding rates (populations), also the differences between Topaz and Colt

Table 21. Analysis of variance for head dry matter (g/main plant) for two grain sorghum hybrids grown at three population levels in two dates of planting. Marana, Arizona, 1984.

Source of Variation	df	Mean Square	F Observed
Sorghum hybrid (Hybrid)	1	5.86	2.16
Error 1	3	2.71	-
Date of planting (Date)	1	30.12	2.68
Hybrid x Date	1	25.84	2.30
Error 2	3	11.20	-
Plant population	2	356.86	180.23**
Hybrid x Population	2	.22	.11
Date x Population	2	.46	.23
Population x Hybrid x Date	2	10.98	5.54**
Within + Residual+	24	1.98	-

+ The three-way interaction was tested against a pooled error (Within + Residual).
** Significant at .01 level

indicate that higher grain yield in genotypes can be selected that produce greater amounts of plant support structure per population level and per dates of planting.

Total Plant Height

Total plant height is composed of height to the upper leaf collar, peduncle exsertion between the upper leaf collar and the base of the head, and head length. The mean total plant heights of both hybrids (Topaz and Colt) in three populations in two dates of planting are presented with least significant differences tests (LSD) in Table 22.

Topaz and Colt both showed significantly greater total plant height for the May planting date in all three populations. The Topaz hybrid was significantly taller in May than in July by 11.6, 19.6 and 8.8% in populations 1, 2 and 3, respectively. Total plant height for Colt in the May planting was significantly greater by 21.2, 14.5 and 7.4% in populations 1, 2 and 3, respectively.

There was no significant difference between hybrids for total plant height (Table 23) as evidence by the very similar heights for both hybrids at the same date of planting and population level (Table 22). This indicates that the two hybrids are genetically quite similar for total height. There were highly significant differences in plant height between planting dates and among populations (Table 23). These differences are evident in Table 22. Plant

Table 22. Average total plant height for Topaz and Colt sorghum hybrids grown at three plant population levels in two dates of planting. Marana, Arizona, 1984.

Hybrid	Planting date	Plant population ha^{-1}		
		64,583	129,167	387,501
		Total plant height m		
Topaz	22 May	1.34^{a+}	1.46^{a}	1.48^{a}
	10 July	1.20^{b}	1.22^{b}	1.36^{b}
Colt	22 May	1.37^{a}	1.42^{a}	1.44^{a}
	10 July	1.13^{b}	1.24^{b}	1.34^{b}

+Values followed by the same letters between dates of planting within hybrids within populations are not significantly different at the 0.05 level of probability.

heights increased significantly with increased populations as expected with additional plant competition (Table 22). Plant heights decreased significantly in the later date of planting as expected from a shorter growing period with fewer days to 50% bloom.

The two-way interaction of date x population was highly significant indicating a difference in the amount of height change between dates and among populations for the two hybrids.

The three-way interaction was low and significant only at the .05 level of probability. This interaction probably reflects primarily the interaction of date x population where the two hybrids responded at different

Table 23. Analysis of variance for total plant height (m) for two grain sorghum hybrids grown at three population levels in two dates of planting. Marana, Arizona, 1984.

Source of Variation	df	Mean Square	F Observed
Sorghum hybrid (Hybrid)	1	52.08	2.74
Error 1	3	18.97	-
Date of planting (Date)	1	3,468.00	346.80**
Hybrid x Date	1	1.33	.13
Error 2	3	10.00	-
Plant population	2	885.25	53.29**
Hybrid x Population	2	11.58	.70
Date x Population	2	102.25	6.16**
Population x Hybrid x Date	2	63.58	3.82*
Within + Residual+	24	16.61	-

+ The three-way interaction was tested against a pooled error (Within + Residual).
* Significant at .05 level
** Significant at .01 level

rates of change (Table 22). The height of the plants obtained were within the range that do not cause mechanical harvesting problems. This observation agrees with Casady (1965) who reported that, height of the plant is essential when grain harvesting is done by combine. Hadley, Freeman and Javier (1965) observed that taller sorghum plants of similar genotypes produced higher grain yields.

Tables 24 and 25 present the mean data for head length, peduncle length and plant height to the upper leaf collar for Topaz and Colt, respectively, for both planting dates and all three population levels. The percent of each plant height component of the total heights are also presented.

Head Length

The average head length (cm) of both hybrids and the least significant difference tests (LSD) are given in Table 26. All comparisons of head length between dates of planting within hybrids within populations were non-significant.

The single factor of plant population had a highly significant influence on head length (Table 27). This influence caused a decrease in head lengths from low to high populations within dates of planting and within hybrids. This decrease in head length is as expected from the smaller

Table 24. Mean data for head length, peduncle length and plant height to the upper leaf collar for Topaz sorghum hybrid grown at three plant population levels and two dates of planting. Marana, Arizona, 1984.

Planting Date	Plant Height	Plant population ha^{-1}						
		64,583		129,167		387,501		
22 May		cm	%	cm	%	cm	%	x%
	Head length	26.0	(19.4)	24.5	(16.7)	23.0	(15.4)	(17.2)
	Peduncle length	4.8	(3.6)	9.8	(6.7)	14.8	(10.0)	(6.8)
	Plant height to Upper leaf collar	103.0	(77.0)	112.0	(76.6)	111.0	(74.6)	(76.0)
Total plant height		133.8	(100%)	146.3	(100%)	148.8	(100%)	
10 July		cm	%	cm	%	cm	%	x%
	Head length	25.0	(20.8)	25.8	(21.1)	24.0	(17.5)	(19.8)
	Peduncle length	2.0	(1.7)	7.3	(6.0)	15.3	(11.1)	(6.3)
	Plant height to Upper leaf collar	93.0	(77.5)	89.0	(72.9)	98.0	(71.4)	(73.9)
Total plant height		120.0	(100%)	122.1	(100%)	137.3	(100%)	

Table 25. Mean data for head length, peduncle length and plant height to the upper leaf collar for Colt sorghum hybrid grown at three plant population levels and two dates of planting. Marana, Arizona, 1984.

Planting Date	Plant Height	Plant population ha^{-1}						
		64,583		129,167		387,501		
22 May		cm	%	cm	%	cm	%	x%
	Head length	27.0	(19.7)	25.8	(18.0)	23.5	(16.3)	(18.0)
	Peduncle length	2.0	(1.5)	5.8	(4.0)	11.0	(7.6)	(4.4)
	Plant height to upper leaf collar	108.0	(78.8)	111.0	(78.0)	110.0	(76.1)	(77.6)
Total plant height		137.0	(100%)	142.6	(100%)	144.5	(100%)	
10 July		cm	%	cm	%	cm	%	x%
	Head length	26.5	(23.5)	26.2	(21.0)	23.8	(17.8)	(20.8)
	Peduncle length	2.5	(2.2)	4.5	(3.6)	13.8	(10.3)	(5.4)
	Plant height to upper leaf collar	84.0	(74.3)	94.0	(75.4)	96.0	(71.9)	(73.8)
Total plant height		113.0	(100%)	124.7	(100%)	133.6	(100%)	

Table 26. Average head length of Topaz and Colt sorghum hybrids grown at three plant population levels in two dates of planting. Marana, Arizona, 1984.

Hybrid	Planting date	Plant population ha^{-1}		
		64,583	129,167	387,501
			Head Length cm	
Topaz	22 May	26.0a+	24.5a	23.0a
	10 July	25.0a	25.8a	24.0a
Colt	22 May	27.0a	25.8a	23.5a
	10 July	26.5a	26.2a	23.8a

+Values followed by the same letters between dates of planting within hybrids within populations are not significantly different at the 0.05 level of probability.

plants that resulted from the greater competition within the higher populations.

It could be concluded that head length was influenced more by different plant populations pressures than by differences between planting dates.

Peduncle Length

Mean peduncle lengths (cm) for Topaz and Colt, and least significant difference tests (LSD) are presented in Table 28. Peduncles for Topaz were significantly longer in the May planting than in the July planting by 140.0% in population 1. Differences were not significant between May and July in populations 2 and 3. The peduncle length for

Table 27. Analysis of variance for head length (cm) for two grain sorghum hybrids grown at three population levels in two dates of planting. Marana, Arizona, 1984.

Source of Variation	df	Mean Square	F Observed
Sorghum hybrid (Hybrid)	1	6.75	4.12
Error 1	3	1.64	-
Date of planting (Date)	1	0.75	0.18
Hybrid x Date	1	0.33	0.08
Error 2	3	4.22	-
Plant population	2	29.02	29.02**
Hybrid x Population	2	1.31	1.31
Date x Population	2	3.06	3.06
Population x Hybrid x Date	2	0.52	0.52
Within + Residual+	24	1.00	-

+ The three-way interaction was tested against a pooled error (Within + Residual).
** Significant at .01 level

Colt increased with increased plant populations with no significant differences between dates of planting.

Peduncle elongation in sorghum is one of the major morphological plant characteristics most influenced by variation in environmental stresses. The single factor of plant population was highly significant for peduncle elongation (Table 29). The peduncles of both hybrids increased in length with increases in plant population within both dates of planting (Table 28) due to the increased plant competition stresses within the higher populations.

The two-way interaction of hybrid x date was highly significant (Table 29) indicating the unequal amounts of peduncle increase for hybrids across dates (Table 28). This could indicate some difference between hybrids for stress response for peduncle elongation.

The two-way interaction of date x population was significant at the .05 level of probability (Table 29). The hybrids increased their peduncle lengths from low to high population at unequal rate within dates (Table 28).

Plant Height to Upper Leaf Collar

The plant heights to the upper leaf collar were significantly greater in the May planting than in the July planting for both hybrids at all plant populations. The greater heights of Topaz in the May planting over the July

Table 28. Average peduncle length of Topaz and Colt sorghum hybrids grown at three plant population levels in two dates of planting. Marana, Arizona, 1984.

Hybrid	Planting date	Plant population ha^{-1}		
		64,583	129,167	387,501
		peduncle length cm		
Topaz	22 May	4.8[a+]	9.8[a]	14.8[a]
	10 July	2.0[b]	7.2[a]	15.2[a]
Colt	22 May	2.0[a]	5.8[a]	11.0[a]
	10 July	2.5[a]	4.5[a]	13.8[a]

[+]Values followed by the same letters between dates of planting within hybrids within populations are not significantly different at the 0.05 level of probability.

planting were 11.9, 25.8 and 13.2% in populations 1, 2 and 3, respectively. For Colt the greater heights in the May planting over the July planting were 28.6, 17.0 and 14.6% in population 1, 2 and 3, respectively.

The single factor effect of date of planting for plant height to the upper leaf collar was highly significant (Table 31). The differences in height to the upper leaf collar are very evident between dates within hybrids and populations (Table 30). The single factor effect of plant population for height to the upper leaf collar was also highly significant but the mean square value was less than for date of planting (Table 31). The heights to the upper leaf collar across populations but within dates and hybrids

Table 29. Analysis of variance for peduncle length (cm) for two grain sorghum hybrids grown at three population levels in two dates of planting. Marana, Arizona, 1984.

Source of Variation	df	Mean Square	F Observed
Sorghum hybrid (Hybrid)	1	67.68	6.83
Error 1	3	9.90	-
Date of planting (Date)	1	2.52	6.30
Hybrid x Date	1	15.18	37.95**
Error 2	3	0.40	-
Plant population	2	484.08	150.33**
Hybrid x Population	2	5.25	1.63
Date x Population	2	13.58	4.22*
Population x Hybrid x Date	2	1.00	.31
Within + Residual+	24	3.22	-

\+ The three-way interaction was tested against a pooled error (Within + Residual).
* Significant at .05 level
** Significant at .01 level

Table 30. Average plant height to upper leaf collar of Topaz and Colt sorghum hybrids grown at three plant population levels in two dates of planting. Marana, Arizona, 1984.

Hybrid	Planting date	Plant population ha^{-1}		
		64,583	129,167	387,501
		plant height to upper leaf collar m		
Topaz	22 May	1.03^{a+}	1.12^{a}	1.11^{a}
	10 July	$.92^{b}$	$.89^{b}$	$.98^{b}$
Colt	22 May	1.08^{a}	1.10a	1.10^{a}
	10 July	$.84^{b}$	$.94^{b}$	$.96^{b}$

+Values followed by the same letter between dates of planting within hybrids within populations are not significantly different at the 0.05 level of probability.

were not uniform in increases in height with increases in population (Table 30). For example the height to the upper leaf collar for Topaz in the May planting increased from population 1 to 2 but decreased slightly in population 3 compared to population 2. Topaz also had a similar type of variation in the July planting across populations.

The three-way interaction of plant population x hybrid x date of planting (Table 31) was highly significant at the 0.01 level of probability. The mean square value for this three-way interaction was relatively small but reflect the non-uniformity of height increases across populations between dates and hybrids.

Table 31. Analysis of variance for plant height to upper leaf collar (m) for two grain sorghum hybrids grown at three population levels in two dates of planting. Marana, Arizona, 1984.

Source of Variation	df	Mean Square	F Observed
Sorghum hybrid (Hybrid)	1	2.52	0.10
Error 1	3	24.80	-
Date of planting (Date)	1	3,383.52	748.56**
Hybrid x Date	1	20.02	4.42
Error 2	3	4.52	-
Plant population	2	176.64	10.98**
Hybrid x Population	2	14.64	0.91
Date x Population	2	39.40	2.44
Population x Hybrid x Date	2	92.89	5.77**
Within + Residual+	24	16.09	-

+ The three-way interaction was tested against a pooled error (Within + Residual).
** Significant at .01 level

This highly significant three-way interaction for height to the upper leaf collar probably contributed to the significant three-way interaction for total plant height (Table 23). The other two characteristics of head length and peduncle length which make up the rest of the total height had no significant three-way interaction or significance for date of planting (Table 27 and Table 29). The high significance of the influence of date of planting on height to the upper leaf collar apparently was the main source of high significance for date for total plant height.

Days to 50% Bloom

The days to 50% bloom (Table 32) indicates that Topaz (a medium maturing hybrid) and Colt (a medium-late maturing hybrid) both took significantly more days to flowering in the May planting (68 to 74 days), than the July planting (56 to 58 days) over all three plant populations. Colt showed a greater response to differences in planting date relative to days to flowering (Table 32). The difference between Topaz and Colt indicates that hybrids genetically different for days to flowering are available for planting at specific times with flowering to occur at specified times.

Table 32. Average days to 50% bloom of Topaz and Colt sorghum hybrids grown at three plant population levels in two dates of planting. Marana, Arizona, 1984.

Hybrid	Planting date	Plant population ha^{-1}		
		64,583	129,167	387,501
		Days to 50% Bloom	Days	
Topaz	22 May	68[a+]	66[a]	66[a]
	10 July	56[b]	54[b]	52[b]
Colt	22 May	74[a]	73[a]	73[a]
	10 July	58[b]	56[b]	56[b]

+Values followed by the same letter between dates of planting within hybrids within populations are not significantly different at the 0.05 level of probability.

The single factor effect of hybrid on days to 50% bloom was highly significant. This indicates the basic genetic difference between the two hybirds for days to 50% bloom (Table 33). The single factor effect of date of planting on days to bloom was also highly significant (Table 33). This indicates the strong effect of the environmental differences between dates of planting such as temperatures (heat units), on the rate of plant growth and development of the hybrids. The variation in amount of environmental influence of date of planting between hybrids (Table 32) resulted in a highly significant hybrid x date two-way interaction (Table 33). The single factor effect of plant

Table 33. Analysis of variance for days to 50% bloom (days) for two grain sorghum hybrids grown at three population levels in two dates of planting. Marana, Arizona, 1984.

Source of Variation	df	Mean Square	F Observed
Sorghum hybrid (Hybrid)	1	266.02	182.20**
Error 1	3	1.46	-
Date of planting (Date)	1	2,479.68	19,074.46**
Hybrid x Date	1	50.02	384.76**
Error 2	3	0.13	-
Plant population	2	15.89	66.20**
Hybrid x Population	2	3.52	14.66**
Date x Population	2	2.31	9.62**
Population x Hybrid x Date	2	1.02	4.25*
Within + Residual+	24	0.24	-

\+ The three-way interaction was tested against a pooled error (Within + Residual).
* Significant at .05 level
** Significant at .01 level

population on days to 50% bloom of the hybrids was highly significant (Table 33) indicating variability in days to bloom among populations across hybrids and dates (Table 32). There was not a uniform response for date of bloom for the hybrids across the three populations. The mean square for this response was quite small relative to the other two single factors.

The two-way interactions of hybrid x population and date x population were both highly significant with fairly low mean squares. Neither hybrids nor dates had a uniform reaction across populations. The three-way interaction of population x hybrid x date of planting was significant at the .05 level of probability reflecting the degree of non-uniformity of response for date of bloom among these three factors.

Main Plant Leaf Area

Mean leaf area (cm^2/main plant) for Topaz and Colt, and the least significant difference tests (LSD) are presented in Table 34. Topaz and Colt leaf areas were significantly lower in the July planting within each plant population. The greater leaf areas per main plant for Topaz in the May planting over the July planting were 25.6, 35.8 and 37.4% in populations 1, 2 and 3, respectively. For Colt the leaf area increases were 75.8, 88.4 and 72.0% of May

Table 34. Average leaf area of Topaz and Colt sorghum hybrids grown at three plant population levels in two dates of planting. Marana, Arizona, 1984.

Hybrid	Planting date	Plant population ha^{-1}		
		64,583	129,167	387,501
		Leaf area cm^2/main plant		
Topaz	22 May	4,695.64[a+]	4,296.88[a]	2,558.62[a]
	10 July	3,738.38[b]	3,163.38[b]	1,861.50[b]
Colt	22 May	4,810.60[a]	4,268.22[a]	2,537.00[a]
	10 July	2,735.00[b]	2,265.88[b]	1,475.38[b]

+Values followed by the same letters between dates of planting within hybrids within populations are not significantly different at the 0.05 level of probability.

over the July planting in populations 1, 2 and 3, respectively.

The single factor effect of hybrid on main plant leaf area was statistically significant at the .05 level of probability (Table 35). This indicates that the two hybrids differed in their main plant leaf area development between dates of planting and across populations (Table 34). It is well known that sorghum genotypes differ in leaf morphology such as leaf length and width and leaf numbers.

The single factor effect of date of planting on main plant leaf area of the hybrids was highly significant (Table 35). The different growth environment of the second date of planting caused both hybrids to have less leaf area than the first date of planting (Table 34). This response for less

Table 35. Analysis of variance for leaf area (cm^2/main plant) for two grain sorghum hybrids grown at three population levels in two dates of planting. Marana, Arizona, 1984.

Source of Variation	df	Mean Square	F Observed
Sorghum hybrid (Hybrid)	1	1,646,205.76	22.72*
Error 1	3	72,427.38	-
Date of planting (Date)	1	20,948,154.50	87.38**
Hybrid x Date	1	1,843,497.63	7.69
Error 2	3	239,722.00	-
Plant population	2	15,305,685.23	190.69**
Hybrid x Population	2	83,531.34	1.04
Date x Population	2	588,390.70	7.33**
Population x Hybrid x Date	2	147,484.83	1.84
Within + Residual+	24	80,261.14	-

\+ The three-way interaction was tested against a pooled error (Within + Residual).
* Significant at .05 level
** Significant at .01 level

leaf area from the later date of planting was the same as for total plant height, height to the upper leaf collar, peduncle elongation, total main plant dry matter and dry matter for the main plant leaf, stem and head. A totally smaller sorghum plant is developed from later dates of planting with some genetic variation between hybrids in the amount of decrease. The two-way interaction of hybrid x date was nonsignificant indicating that both hybrids responded similarly to date of planting across populations; however, this response differed between hybrids (Table 34).

The single factor effect of plant population on main plant leaf area was highly significant (Table 35). Leaf areas decreased within increased populations for both hybrids in both dates of planting (Table 34). This indicates the influence of plant competition of the higher populations on total plant size. The two-way interaction of hybrid x population was nonsignificant indicating that the two hybrids decreased their main plant leaf areas similarly with increased populations across dates (Table 34).

The two-way interaction of date x population for main plant leaf area was highly significant (Table 35). This indicates that the leaf area of the two hybrids did not change in a similar manner to both date and population (Table 34).

CHAPTER 5

SUMMARY AND CONCLUSIONS

Two hybrid grain sorghums (Sorghum bicolor (L.) Moench), Topaz of medium maturity and Colt of medium late maturity, were evaluated for their responses to three plant populations in two dates of planting. The full season planting was made in moisture in 22 May, and the double crop planting was made on 10 July to simulate a local practice of planting grain sorghum after harvest of barley or wheat in June.

Fertilizers were applied at the rate of 72 kg (N), and 90 kg (P_2O_5) per ha during seed bed preparation. Weed control was obtained through the post emergence application of Atrazine at the rate of 1.68 kg. of active ingredient per hectare. The experimental plots were seeded heavily and all rows were hand-thinned to obtain plant populations of 2, 4 and 12 plants per 30.5 cm (1 ft.). For the research data only the two middle rows in each plot were evaluated and harvested. Two typical main plants from border rows were used to evaluate leaf, stem and head dry matter and leaf area per main plant.

Research results suggested that for Topaz earlier planting dates and lower plant populations in the range of

65,000 to 130,000 plants per hectare produce optimum yields. Higher plant populations of nearly 390,000 plants per hectare and earlier planting dates may be required for Colt to produce optimum grain yield. The diversity of grain yield reaction of these two hybrids to plant population and date of planting points out the probable necessity of tailoring cultural practices to the genotypes being grown or vice-versa.

The weight of 1000 seed of Topaz was significantly higher in populations 1 and 2 while Colt's seed weight was significantly higher in populations 2 and 3. Date of planting had a significant effect on both hybrids with the late date of planting generally significantly reducing the seed weight (size). These seed size differences may have an influence on quality due to unequal changes in chemical composition associated with differing seed size. Variation in plant population had no apparent effect on seed weight (size) in this experiment.

A significant genetic difference was evident between the two hybrids (Topaz and Colt) for grain volume-weight. Different planting dates also produced significantly different grain volume-weight with the later planting date producing greater volume-weight (test weight). This is as expected from the smaller seed sizes (weight per 1000 seed) of the later planting date. Variation in plant populations did not produce any significant differences in grain volume-weights.

Increased plant populations for both hybrids produced significantly greater numbers of heads, but total head numbers were not directly proportional to the increased population. Average numbers of tillers per main plant for populations 1, 2 and 3 were 2, 1.1 and .4, respectively. The greater total number of heads in the higher plant populations consisted of shorter (smaller) heads that produced less seed per head. There was a significant genetic difference for tillering between the two hybrids as evidenced by the differences in numbers of heads produced. Date of planting had no significant influence on tillering (number of heads) between hybrids or among plant populations.

Total main plant dry matter was determined as the sum of the dry matter of leaf, stem and head of a typical main plant without tillers. Total main plant dry matter per main plant of both hybrids showed progressive decreases with increases in plant populations. The later date of planting produced a significant decrease in total plant dry matter for Topaz at the higher population and for Colt at all three population levels. There was a significant genetic difference between the two hybrids for total main plant dry matter in response to date of planting and population.

Dry matter of the leaf, stem and head make up the total main plant dry matter. The hybrids differed significantly only for stem dry matter and were similar for leaf and head dry matter across dates and populations. Main plant leaf, stem and head dry matter all decreased significantly with increases in populations. Main plant leaf and stem dry matter generally decreased in the later planting date which had no significant effect on head dry matter.

Total plant height (height to the upper leaf collar, peduncle length and head length) of both hybrids was greater in the May planting than the July planting. Differences in both dates of planting and plant populations had highly significant effects on total plant height. Total plant heights of both hybrids decreased in the later (July) planting and increased with the increased plant competition of the higher plant populations. There was no significant difference between hybrids for total plant height under different dates of planting or different plant populations.

Head length, peduncle length and height to the upper leaf collar together make up the total plant height. All three components of plant height increased significantly with increases in plant populations. The late date of planting caused highly significant decreases in height to the upper leaf collar but had no influence on head or peduncle lengths. The two hybrids used in this research did not differ significantly for head or peduncle length or height to the upper leaf collar across dates and populations.

Both hybrids bloomed significantly earlier by a range of 12 to 17 days under the higher growing temperatures of the late (July) planting compared to the early (May) planting. Each hybrid flowered 1 or 2 days earlier in high plant populations. The two hybrids were genetically different in maturity and, as expected, they were highly significantly different under dates of planting and different plant populations.

Total leaf area per main plant without tillers decreased significantly with increases in plant populations. The late (July) date of planting caused significant decreases in total leaf area per main plant of both hybrids. There was a significant difference in leaf area between the two hybrids across dates of planting and plant populations.

APPENDIX A

DATA COLLECTED ON INDIVIDUAL PLOTS

Table 36. Data collected on each individual plot during the growing seasons of May and July. Marana, Arizona, 1984.

#	PD	HY	PUP	BLK	BL	PIC	PL	HL	TPH
1	1.	1.	1.	1.	67.	109.	5.	25.	134.
2	1.	1.	1.	2.	68.	100.	4.	24.	128.
3	1.	1.	1.	3.	68.	102.	3.	27.	134.
4	1.	1.	1.	4.	67.	101.	3.	28.	134.
5	1.	1.	2.	1.	66.	113.	14.	24.	151.
6	1.	1.	2.	2.	67.	110.	5.	24.	139.
7	1.	1.	2.	3.	67.	114.	10.	25.	149.
8	1.	1.	2.	4.	67.	109.	10.	25.	144.
9	1.	1.	3.	1.	65.	114.	15.	23.	152.
10	1.	1.	3.	2.	66.	112.	17.	20.	149.
11	1.	1.	3.	3.	65.	107.	14.	24.	145.
12	1.	1.	3.	4.	66.	111.	13.	25.	149.
13	1.	2.	1.	1.	73.	110.	1.	27.	138.
14	1.	2.	1.	2.	74.	107.	3.	27.	137.
15	1.	2.	1.	3.	73.	110.	3.	27.	139.
16	1.	2.	1.	4.	75.	105.	2.	27.	134.
17	1.	2.	2.	1.	72.	118.	6.	28.	152.
18	1.	2.	2.	2.	72.	114.	6.	25.	145.
19	1.	2.	2.	3.	73.	108.	8.	25.	139.
20	1.	2.	2.	4.	75.	102.	5.	25.	132.
21	1.	2.	3.	1.	73.	118.	10.	23.	151.
22	1.	2.	3.	2.	73.	109.	10.	25.	144.
23	1.	2.	3.	3.	73.	101.	14.	23.	138.
24	1.	2.	3.	4.	74.	110.	10.	23.	143.
25	2.	1.	1.	1.	56.	90.	2.	26.	118.
26	2.	1.	1.	2.	57.	90.	2.	25.	117.
27	2.	1.	1.	3.	57.	90.	2.	26.	118.
28	2.	1.	1.	4.	56.	100.	2.	23.	125.
29	2.	1.	2.	1.	53.	85.	10.	26.	121.
30	2.	1.	2.	2.	54.	86.	4.	25.	119.
31	2.	1.	2.	3.	53.	95.	9.	25.	129.
32	2.	1.	2.	4.	54.	90.	6.	27.	123.
33	2.	1.	3.	1.	52.	86.	18.	25.	129.
34	2.	1.	3.	2.	53.	104.	13.	25.	142.
35	2.	1.	3.	3.	53.	100.	16.	23.	139.
36	2.	1.	3.	4.	53.	100.	14.	23.	137.
37	2.	2.	1.	1.	57.	86.	3.	27.	116.
38	2.	2.	1.	2.	58.	80.	3.	26.	109.
39	2.	2.	1.	3.	58.	85.	2.	27.	114.
40	2.	2.	1.	4.	58.	86.	2.	26.	114.
41	2.	2.	2.	1.	56.	93.	3.	27.	123.
42	2.	2.	2.	2.	56.	95.	3.	25.	123.
43	2.	2.	2.	3.	57.	95.	7.	27.	128.
44	2.	2.	2.	4.	58.	92.	5.	26.	123.
45	2.	2.	3.	1.	56.	93.	11.	24.	128.
46	2.	2.	3.	2.	56.	96.	14.	24.	134.
47	2.	2.	3.	3.	56.	95.	17.	25.	130.
48	2.	2.	3.	4.	57.	100.	13.	23.	136.

Table 36. (Continued).

#	FD	HY	PUP	DIR	YLD	GTW	WG	LDM	SDM
1	1.	1.	1.	1.	7745.	780.0	26.48	28.48	44.15
2	1.	1.	1.	2.	6848.	778.4	25.64	26.10	38.25
3	1.	1.	1.	3.	6868.	771.8	25.36	26.55	43.30
4	1.	1.	1.	4.	6802.	772.2	27.08	14.58	29.40
5	1.	1.	2.	1.	7436.	771.0	26.24	26.29	42.20
6	1.	1.	2.	2.	7326.	770.6	24.94	21.29	34.20
7	1.	1.	2.	3.	6600.	782.1	27.08	20.12	32.10
8	1.	1.	2.	4.	7404.	771.8	21.36	17.97	26.85
9	1.	1.	3.	1.	6248.	769.7	25.46	12.41	24.30
10	1.	1.	3.	2.	6038.	762.6	24.96	11.04	23.25
11	1.	1.	3.	3.	6471.	769.3	22.40	12.61	23.10
12	1.	1.	3.	4.	6054.	773.8	25.12	11.20	16.85
13	1.	2.	1.	1.	4498.	747.9	23.02	33.16	59.75
14	1.	2.	1.	2.	4810.	744.2	22.46	26.08	50.10
15	1.	2.	1.	3.	5463.	757.8	23.68	37.56	57.40
16	1.	2.	1.	4.	5240.	754.1	23.20	36.29	56.95
17	1.	2.	2.	1.	6393.	745.8	23.50	25.76	43.30
18	1.	2.	2.	2.	6480.	755.3	23.10	27.43	56.35
19	1.	2.	2.	3.	6512.	750.4	23.34	25.81	49.50
20	1.	2.	2.	4.	6409.	756.1	24.54	26.08	34.35
21	1.	2.	3.	1.	6611.	743.5	25.80	15.29	28.40
22	1.	2.	3.	2.	6458.	747.7	24.98	12.00	23.15
23	1.	2.	3.	3.	6593.	739.3	25.08	12.66	22.85
24	1.	2.	3.	4.	6674.	755.7	23.70	13.36	24.95
25	2.	1.	1.	1.	5928.	780.8	23.20	20.72	26.70
26	2.	1.	1.	2.	6030.	781.7	23.28	18.57	28.15
27	2.	1.	1.	3.	5660.	783.3	22.92	20.76	29.95
28	2.	1.	1.	4.	5897.	785.0	23.26	23.98	30.85
29	2.	1.	2.	1.	6104.	780.4	22.78	17.88	28.65
30	2.	1.	2.	2.	6300.	806.4	22.52	17.50	24.90
31	2.	1.	2.	3.	5868.	785.4	20.94	12.20	20.15
32	2.	1.	2.	4.	5755.	788.8	22.82	16.68	24.30
33	2.	1.	3.	1.	6692.	799.4	22.96	8.64	13.70
34	2.	1.	3.	2.	6014.	790.3	22.98	7.62	14.70
35	2.	1.	3.	3.	6105.	783.3	23.70	8.75	13.00
36	2.	1.	3.	4.	6762.	786.6	25.06	8.82	15.90
37	2.	2.	1.	1.	4896.	773.8	22.40	19.02	39.72
38	2.	2.	1.	2.	5513.	780.0	22.78	15.65	31.28
39	2.	2.	1.	3.	5792.	775.1	21.78	19.35	35.32
40	2.	2.	1.	4.	5068.	776.1	24.08	21.06	36.40
41	2.	2.	2.	1.	4626.	769.3	20.86	12.19	25.90
42	2.	2.	2.	2.	4223.	772.6	21.48	14.74	28.95
43	2.	2.	2.	3.	4350.	771.5	21.92	17.27	29.30
44	2.	2.	2.	4.	4736.	774.5	22.38	12.82	24.05
45	2.	2.	3.	1.	4897.	770.1	21.90	8.43	18.13
46	2.	2.	3.	2.	5216.	776.3	22.92	8.82	20.32
47	2.	2.	3.	3.	4885.	776.3	21.64	8.36	12.62
48	2.	2.	3.	4.	5342.	776.7	24.48	8.26	17.20

Table 36. (Continued).

#	PD	HY	PUP	BLK.	HDM	TDM	NH	LA
1	1.	1.	1.	1.	17.75	90.38	234580.	5016.0
2	1.	1.	1.	2.	14.65	79.00	200131.	4634.0
3	1.	1.	1.	3.	13.75	85.60	224659.	5001.5
4	1.	1.	1.	4.	10.35	59.73	216535.	4131.0
5	1.	1.	2.	1.	14.10	82.59	290354.	5074.5
6	1.	1.	2.	2.	9.90	65.35	267389.	4097.5
7	1.	1.	2.	3.	9.50	62.12	262152.	4119.0
8	1.	1.	2.	4.	8.30	53.12	280512.	3896.5
9	1.	1.	3.	1.	7.20	43.91	579060.	2602.5
10	1.	1.	3.	2.	5.85	42.14	600394.	2282.5
11	1.	1.	3.	3.	7.50	43.21	551181.	2900.0
12	1.	1.	3.	4.	4.20	32.25	502249.	2449.5
13	1.	2.	1.	1.	19.15	112.00	198491.	4952.0
14	1.	2.	1.	2.	15.20	91.36	191929.	4272.2
15	1.	2.	1.	3.	14.95	100.71	166640.	4531.6
16	1.	2.	1.	4.	19.70	122.94	178806.	5406.6
17	1.	2.	2.	1.	15.55	83.61	273950.	4238.1
18	1.	2.	2.	2.	13.00	90.90	267389.	4361.9
19	1.	2.	2.	3.	12.40	87.71	270669.	4301.5
20	1.	2.	2.	4.	13.05	95.48	272310.	4151.4
21	1.	2.	3.	1.	7.35	51.24	495407.	2842.9
22	1.	2.	3.	2.	5.95	41.10	518373.	2305.0
23	1.	2.	3.	3.	5.55	41.00	497047.	2570.7
24	1.	2.	3.	4.	6.40	44.71	521654.	2529.4
25	2.	1.	1.	1.	13.15	60.57	244423.	3772.0
26	2.	1.	1.	2.	13.25	61.21	229659.	3775.0
27	2.	1.	1.	3.	15.60	66.31	219616.	3566.0
28	2.	1.	1.	4.	15.80	70.63	201772.	4241.5
29	2.	1.	2.	1.	12.95	59.48	273950.	3297.5
30	2.	1.	2.	2.	12.20	53.60	267389.	3351.5
31	2.	1.	2.	3.	9.85	42.20	263793.	2020.5
32	2.	1.	2.	4.	11.85	52.83	264108.	3164.0
33	2.	1.	3.	1.	3.90	26.25	546260.	1881.0
34	2.	1.	3.	2.	5.45	27.77	546260.	1621.5
35	2.	1.	3.	3.	3.55	25.29	573151.	2054.5
36	2.	1.	3.	4.	5.20	29.92	603675.	1889.5
37	2.	2.	1.	1.	15.92	74.66	219816.	2713.0
38	2.	2.	1.	2.	12.40	59.32	193570.	2440.0
39	2.	2.	1.	3.	10.64	63.31	160963.	2998.0
40	2.	2.	1.	4.	14.00	71.46	182087.	2789.0
41	2.	2.	2.	1.	9.75	47.84	216535.	1977.5
42	2.	2.	2.	2.	10.65	50.34	202152.	2349.0
43	2.	2.	2.	3.	11.65	58.22	244423.	2644.5
44	2.	2.	2.	4.	9.75	44.62	252625.	2092.5
45	2.	2.	3.	1.	7.05	38.61	561024.	1403.0
46	2.	2.	3.	2.	6.20	35.34	592192.	1491.0
47	2.	2.	3.	3.	4.60	30.56	581270.	1327.0
48	2.	2.	3.	4.	4.22	29.70	583990.	1480.5

Abbreviations for preceding table.

# = Number of cases
PD = Planting date (22 May; 10 July)
HY = Hybrid (1 = Topaz; 2 = Colt)
POP = Plant population (1 = Low, 2 = Med, 3 = High)
BLK = Block (4 Blocks)
BL = Days to 50% bloom (Days)
PLC = Plant height to upper leaf collar (m)
PL = Peduncle length (cm)
HL = Head length (cm)
TPH = Total plant height (m)
YLD = Grain yield (Mg ha^{-1})
GTW = Grain volume-weight (Kg m^3)
WG = Weight of 1000 seed (g)
LDM = Leaf dry matter (g/main plant)
SDM = Stem dry matter (g/main plant)
HDM = Head dry matter (g/main plant)
TDM = Total plant dry matter (g/main plant)
NH = Number of heads (ha^{-1})
LA = Leaf area (cm^2/main plant)

APPENDIX B

PEARSON CORRELATION COEFFICIENTS OF THE AGRONOMIC PARAMETERS FOR TOPAZ AND COLT SORGHUM HYBRIDS

Table 37. Pearson correlation coefficients of the agronomic parameters for Topaz sorghum hybrid planted 22 May and 10 July. Marana, Arizona, 1984.

	Plant Population	Days to 50% Bloom (Days)	Plant Height to Upper Leaf collar (m)	Peduncle Length (cm)	Head Length (m)	Total Plant Height (cm)	Grain Yield Mg ha-1	Grain Volume Weight Kg/m3	Weight of 1000 Seed (g)	Leaf Dry Matter g/plt	Stem Dry Matter g/plt	Head Dry Matter g/plt	Total Dry Plant Matter g/plt	Number of Head ha-1	Leaf Area of Main Plant cm2/plt
Plant population	--														
Days to 50% bloom	-.8661**	--													
Plant height to upper leaf collar	.6822**	-.6114*	--												
Peduncle length	.8640**	-.8466**	.6667**	--											
Head length	-.6470**	.4846	-.6610*	-.8803**	--										
Total plant height	.8167**	-.7827**	.9218**	.8864**	-.6016*	--									
Grain yield	-.6496**	.4880	-.1481	-.6731*	.3486	-.3682	--								
Grain volume-weight	-.6322*	.6111*	-.1068	-.6314*	.3864	-.2900	.3206	--							
Weight of 1000 seed	-.6016*	.3086*	-.0613	-.2963	.6126*	-.1022	.3000	.6167*	--						
Leaf dry matter	-.8636**	.7247**	-.4034	-.7364**	.4611	-.6016*	.7960**	.5368*	.4266	--					
Stem dry matter	-.7868**	.6236*	-.2963	-.6000*	.2690	-.4682	.7360**	.3837	.3469	.9883**	--				
Head dry matter	-.8600**	.6278**	-.4271	-.6728**	.3854	-.6843*	.7292**	.4904	.4063	.9636**	.9647**	--			
Total dry matter	-.8429**	.6664**	-.3640	-.6681**	.3693	-.5486*	.7648**	.4676	.3807	.9866**	.9808**	.9841**	--		
Number of heads	.9262**	-.8660**	.6166*	.8678**	-.6609**	-.6898**	-.7587**	-.6636*	-.4976*	-.8832**	-.7461**	-.7633**	-.8082**	--	
Leaf area	-.6764**	.7086**	-.3072	-.7184**	.5384*	-.5652*	.8244**	.6136*	.4823	.9827**	.9251**	.9861**	.9660**	-.9136**	--

	Plant Population	Days to 50% Bloom (Days)	Plant Height to Upper Leaf collar (m)	Peduncle Length (cm)	Head Length (cm)	Total Plant Height (m)	Grain Yield Mg ha-1	Grain Volume Weight Kg/m3	Weight of 1000 Seed (g)	Leaf Dry Matter g/plt	Stem Dry Matter g/plt	Head Dry Matter g/plt	Total Plant Dry Matter g/plt	Number of Head ha-1	Leaf Area of Main Plant cm2/plt
Plant population	--														
Days to 50% bloom	-.9062**	--													
Plant height to upper leaf collar	.3262	-.1182	--												
Peduncle length	.9446**	-.8827**	.2676	--											
Head length	-.3262	.1670	-.6676**	-.3467	--										
Total plant height	.8004**	-.6348**	.7916**	.7818**	-.6601*	--									
Grain yield	.6437**	-.5736*	-.0268	.6482**	-.4842	.3368	--								
Grain volume-weight	.3086	-.3864	-.2431	.2220	-.0099	-.0292	.4763	--							
Weight of 1000 seed	.1943	.0667	.2223	.2286	-.4680	.2416	.4108	-.3133	--						
Leaf dry matter	-.9632**	.7862**	-.3746	-.9204**	.3086	-.8214**	-.6139*	-.2936	-.2407	--					
Stem dry matter	-.9234**	.7791**	-.4262	-.9022**	.3806	-.8362**	-.5706*	-.3182	-.1432	.9686**	--				
Head dry matter	-.9480**	.8106**	-.3929	-.9433**	.4006	-.8364**	-.6396**	-.2936	-.2328	.9706**	.9884**	--			
Total dry matter	-.9478**	.7963**	-.4034	-.9271**	.3656	-.8364**	-.6120*	-.3069	-.2018	.9866**	.9940**	.9944**	--		
Number of heads	.9180**	-.7092**	.4768	.9101**	-.4943	.8611**	.6866**	.2228	.4198	-.9673**	-.9362**	-.9631**	-.9664**	--	
Leaf area	-.9337**	.7597**	-.3662	-.9084**	.2876	-.8264**	.8918*	-.2679	-.2131	.9948**	.9603**	.9618**	.9734**	-.9431**	--

Table 38. Pearson correlation coefficients of the agronomic parameters for Colt sorghum hybrid planted 22 May and 10 July. Marana, Arizona, 1984.

	Plant Population	Days to 50% Bloom (Days)	Plant Height to Upper Leaf collar (m)	Peduncle Length (cm)	Head Length (cm)	Total Plant Height (m)	Grain Yield Mg ha^{-1}	Grain Volume Weight Kg/m^3	Weight of 1000 seed (g)	Leaf Dry Matter g/plt	Stem Dry Matter g/plt	Head Dry Matter g/plt	Total Plant Dry Matter g/plt	Number of Head ha^{-1}	Leaf Area of Main Plant cm^2/plt
Plant population	—														
Days to 50% bloom	-.2166	—													
Plant height to upper leaf collar	.1181	-.6534**	—												
Peduncle length	.9633**	-.2293	-.0208	—											
Head length	-.8377**	-.0345	.1256	-.8271**	—										
Total plant height	.4819	-.7303**	.8970**	.3938	-.1400	—									
Grain yield	.8614**	-.2522	.1571	.7946**	-.6019**	.4547	—								
Grain volume-weight	-.3166	.3079	-.0684	-.4664	.1667	-.3062	-.0236	—							
Weight of 1000 seed	.7541**	-.2130	.1959	.6676**	-.7864**	.3784	.6696**	.1022	—						
Leaf dry matter	-.9139**	.1927	-.0409	-.9207**	.7742**	-.4116	-.6644**	.4049	-.6834**	—					
Stem dry matter	-.9074**	.2238	-.0943	-.9210**	.7161**	-.4763	-.6399**	.8181*	-.6078*	.9789**	—				
Head dry matter	-.9217**	.2026	-.0248	-.9365**	.8068**	-.3986	-.7209**	.3822	-.6669**	.9891**	.9673**	—			
Total dry matter	-.9179**	.2130	-.0678	-.9299**	.7525**	-.4472	-.6707**	.4646	-.6476**	.9834**	.9963**	.9868**	—		
Number of heads	.9608**	-.1417	.0743	.9325**	-.8317**	.4318	.7089**	-.3602	.7804**	-.9627**	-.9668**	-.9630**	-.9611**	—	
Leaf area	-.9168**	.1720	-.0218	-.9171**	.7823**	-.3900	-.6636**	.3967	-.7006**	.9967**	.9773**	.9810**	.9902**	-.9638**	—

	Plant Population	Days to 50% Bloom (Days)	Plant Height to upper Leaf collar (m)	Peduncle Length (cm)	Head Length (cm)	Total Plant Height (m)	Grain Yield Mg ha^{-1}	Grain Volume Weight Kg/m^3	Weight of 1000 seed (g)	Leaf Dry Matter g/plt	Stem Dry Matter g/plt	Head Dry Matter g/plt	Total Dry Matter g/plt	Number of Head ha^{-1}	Leaf Area of Main Plant cm^2/plt
Plant population	—														
Days to 50% bloom	-.7104**	—													
Plant height to upper leaf collar	.8731**	-.6642**	—												
Peduncle length	.9909**	-.5454*	.8774**	—											
Head length	-.8109**	.4639	-.6299**	-.8115**	—										
Total plant height	.9490**	-.6695**	.9318**	.8901**	-.7186**	—									
Grain yield	.0197	.3040	-.2701	.2703	-.3854	-.0716	—								
Grain volume-weight	-.2168	.5562*	-.2888	.1186	-.0712	-.1233	.6141*	—							
Weight of 1000 seed	-.0601	.4407	-.0354	.1206	-.3437	-.0066	.6766**	.5843*	—						
Leaf dry matter	-.9316**	.6462**	-.7166**	-.8293**	.8007**	-.8164**	-.2116	.2136	.0865	—					
Stem dry matter	-.9512**	.5672*	-.7567**	-.8626**	.8069**	-.8596**	-.1481	.1243	.0720	.9638**	—				
Head dry matter	-.8948**	.4420	-.7416**	-.8308**	.7921**	-.8335**	-.1729	.0638	.0221	.9072**	.9644**	—			
Total dry matter	-.9482**	.5710*	-.7539**	-.8598**	.8145**	-.8549**	-.1732	.1306	.0660	.9776**	.9968**	.9667**	—		
Number of heads	.9211**	-.6161*	.7074**	.9536**	-.9134**	.8663**	.3010	-.0370	.1684	-.8792**	-.8710**	-.8382**	-.8809**	—	
Leaf area	-.9294**	.6519**	-.7067**	-.8378**	.8326**	-.8086**	-.2712	.2257	-.0166	.9874**	.9439**	.8649**	.9526**	-.9038**	—

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