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THE INFLUENCE OF POPULATION DENSITY ON THE EMBRYO, SEED SIZE, YIELD AND OTHER AGRONOMIC CHARACTERS IN *SORGHUM BICOLOR* (L.) MOENCH

A Thesis

Submitted to the Faculty

of

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by

Fernando Rodriguez

In Partial Fulfillment of the

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of

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ABSTRACT

Rodriguez, Fernando. M.S., Purdue University, June 1969. The Influence of Population Density on the Embryo, Seed Size, Yield and Other Agronomic Characters in Sorghum bicolor (L.) Moench. Major Professor: Robert C. Pickett.

The influence of population pressure upon 16 characters in sorghum was studied using six genotypes chosen because of their adaptation, relatively high and differing grain protein content. The three population densities used were 86,450, 172,900 and 345,800 plants per hectare and the characters studied were embryo weight, embryo as percen of the whole seed, percent protein in the embryo, lysine as percent of protein in the embryo, percent protein in the embryo free seed, lysine as percent of protein in the embryo free seed, percent protein in the whole seed, lysine as percent of protein in the whole seed, percent oil in the seed, weight of 100 seeds, grain yield, length and width of the flag leaf, panicle length, plant height and head exertion. Significant differences due to population pressures were observed for head exertion, panicle length, length and width of flag leaf, percent protein in the embryo free seed and the whole seed and lysine as percent of protein in the embryo free seed. Mean percent protein in the embryo free seed and whole seed ranged from 9.55 to 13.00 and 10.77 to 13.93 percent respectively, for the low population. For the medium population the range was from 9.55 to 12.20 and 10.57 to 13.53 percent and for the high population 8.95 to 11.85 and 10.45 to 13.10

percent. The range for lysine as percent of protein in the embryo free seed was from 0.88 to 1.30 percent for the low population, 0.99 to 1.30 percent for the medium population and 1.08 to 1.40 percent for the high population. No significant differences with population were observed for percent protein in the embryo, lysine as percent of protein in the embryo and the whole seed, weight of 100 seeds, embryo weight, oil percent in the seed, yield, plant height and embryo as percent of the whole seed.

Significant mean squares among genotypes were found for 15 of the characters studied and the only exception was lysine as percent of protein in the embryo which ranged from 5.50 to 6.47 percent when the genotypes were considered over three populations. The embryo as percent of the whole seed over three populations ranged from 10.52 to 13.88 with a grand mean of 11.69. The percent protein in the embryo over three populations ranged from 18.14 to 24.68 with a grand mean of 22.05. Thes values are very similar to those obtained by other workers. The percent protein in the embryo free seed and whole seed over three populations ranged from 9.35 to 12.36 and 10.60 to 13.52 percent respectively, with grand means of 10.90 and 12.30 percent.

The genotype with the heaviest embryo was found to have the highest proportion of embryo, the highest percent of oil in the seed and the highest percent protein in the embryo. The genotype with the highest percent protein in the embryo free seed was also the highest in percent protein in the whole seed.

A significant population by genotype interaction was observed only for head exertion.

Simple correlation coefficients were calculated to estimate the relationship between the 16 characters. The weight of the embryo was significantly positively correlated with percent oil in the seed ($r = .6720$), percent protein in the embryo free seed and the whole seed, lysine as percent of protein in the embryo free seed, weight of 100 seeds ($r = .7478$), embryo as percent of the whole seed and certain other characters. Grain yield gave significant positive correlation coefficients with plant height, but not significant with flag leaf length and width. Percent lysine in the protein of the embryo and the whole seed was significantly negatively correlated with percent protein. Panicle length was significantly negatively correlated with percent oil in the seed ($r = -.5764$) and with percent protein in the embryo free seed and whole seed. Percent protein in the whole seed was significantly positively correlated with percent protein in the embryo free seed ($r = .8867$).

INTRODUCTION

The effects of different plant densities upon the components of yield as well as upon other agronomic characters in sorghum is today an important area of research in many countries of the world. The objective is to determine those plant characters which are most responsive to high population density and to obtain valuable information on genotypes which are best adapted for particular conditions.

While much attention is now being placed on increasing production using high populations, there is a lack of information concerning the effects of population pressure upon the composition of the individual fractions of the sorghum seed. Since the embryo is the richest portion of the seed in percent oil, percent protein and percent lysine in the protein and since the embryo and endosperm represent about 94 percent of the seed, it is important to consider how these fractions are influenced by population density. If high populations reduce the nutritional quality of these components it may be undesirable to use high populations with the objective of increasing grain yield since this will result in a reduction in the nutritional quality of the whole seed. More information is also needed regarding the inheritance of the protein, oil, and lysine.

This study was conducted primarily to evaluate the effect of different plant densities and genotype on the size and composition of the

embryo, embryo free seed and the whole seed of sorghum, and secondarily, to study the effect of plant densities upon other agronomic characters. The third objective was to study the correlations between these characters.

REVIEW OF LITERATURE

Seed Size and Embryo Size

Rao *et al.* (26) studied the relationship between seed size and seed weight. They found the weight of sorghum seed to be highly correlated with seed size. They also found that seed size was positively correlated with embryo size. Ashby (2) concluded that the basis of hybrid vigor is an increase in embryo size, and that the hybrid vigor he observed in maize was nothing more than the maintenance of an initial advantage in embryo size. He suggested that there is no correlation between embryo weight and grain weight. Sprague (33) found in maize that in general hybrid embryos were heavier than selfed embryos.

The relative importance of embryo size and endosperm size in relation to the effects associated with seed size was studied by Bremmer *et al.* (9) in wheat. They stated that the amount of reserve material, and the amount of meristematic tissue in seeds both increase linearly with seed size. Hatcher (15) found the weight of the embryo to be proportional to seed weight.

Composition of the Seed

Hubbard *et al.* (16) separated the seed from five varieties of sorghum into endosperm, germ (embryo) and bran (cuticle, epidermis, hypoderm and major portion of the mesocarp) and the proportion of each was determined. The proportion of endosperm ranged from 80.0 to 84.6 percent, the germ from 7.8 to 12.1 percent and the bran 7.3 to 9.3

percent. All fractions and the whole seed of each variety were analyzed for ash, protein, oil and starch with the following average results: whole seed 1.65, 12.3, 3.6, 73.8 percent; endosperm 0.37, 12.3, 0.6, 82.5 percent; germ 10.36, 18.9, 28.1, 13.4 percent, and bran 2.02, 6.7, 4.9, 34.6 percent, respectively. Bidwell (4) dissected the kafir kernel and found that on the average 6.1 percent by weight of the kernel was bran, 10 percent was germ and 83.9 percent was endosperm. In a similar experiment Bidwell et al. (5) studied the composition and proportion of the component parts of the kafir, milo and corn kernels. They found the corn kernel to contain 7.4 percent bran, 11.5 percent germ and 81.1 percent endosperm. The kafir kernel 6.1 percent bran, 10 percent germ and 83.9 percent endosperm. Milo contains 5.5 percent bran, 11.1 percent germ and 83.4 percent endosperm. The germ of milo was found to contain about 20.8 percent protein. Early et al. (13) working with corn, separated by hand eleven samples of corn seed into fractions representing the endosperm, germ, bran and tip cap. They reported that the endosperm contains about 75 percent of the total protein and 15 percent of the oil. The germ contains about 22 percent of the total protein and 84 percent of the oil. The proportion of endosperm ranged from 79.7 to 83.5 percent, the germ from 10.2 to 14.1 percent and the bran from 4.4 to 6.2 percent. Their data also showed high correlation between the amount of oil in the seed and the amount in the germ.

No reference was found in the literature concerning the effect of plant density upon the composition of the individual fractions of the seed or upon the percentage they represent. However, Lang et al. (18) studied the influence of population and nitrogen levels on yield,

protein and oil content of nine corn hybrids and found that the protein and oil content of the seed tends to decrease with higher population and lower nitrogen levels. Since the embryo contains most of the oil present in the seed, this might suggest that the composition of the embryo tends to change with higher populations. Earley and DeTurk (12) reported from their experiment with corn seed that at each level of soil nitrogen, the percentage of protein in the seed decreased with increasing field stand. Nelson (20) on the contrary, suggested that plant spacing does not affect the protein content of sorghum grain under irrigation.

Rabideau (24) revealed that in his experiment with corn there was as great and in some cases a greater concentration of amino acids per unit dry weight in the embryo than in the endosperm. The endosperm was regularly about eight to ten times the dry weight of the embryo.

The Effects of Plant Density on Yield and Other Characters

The response of individual genotypes to changes in plant density is an important consideration in breeding. Karchi and Rudich (17) studied the effect of row width and seedling spacing on yield and yield components in grain sorghum grown under dryland conditions. He found that superior yield resulted from narrow rows combined with wide intra-row seedling spacing. Yield superiority was due primarily to increased number of heads per unit area, rather than to changes in head weight. Pickett (22) reported that 7-inch row spacing gave significantly higher yields than 14-inch or 21-inch row spacing and that plant population of 360,000 plants per acre were higher yielding than lower population for some hybrid sorghums in Indiana. Wilkins (36) conducted an experiment

at Manhattan, Kansas, and studied the effects of spacing on dwarf grain sorghums. Row width of 10-, 20-, 30- and 40-inch were used and the square inches of soil area each plant occupied was 40-, 60-, 80- and 160- within each row width. As row width and area per plant increased, plant height decreased. With narrower rows and less area per plant, the number of heads produced on tillers decreased. As row width decreased, the size of the kernel was found to decrease. Row width had a greater influence on weight per bushel than did area per plant. The 40-inch rows produced significantly lower yields than any other row width. In the humid north, Robinson et al. (27) made comparisons in sorghum of 10-, 20-, 30- and 40-inch row spacing, each at planting populations of 78,408, 156,816 and 313,632 plants per acre. Planting populations of 78,408, 156,816 and 313,632 did not result in appreciable differences in yield, date of heading or plant height. Increasing the population resulted in a decrease in seed weight. Lodging was also increased with increased populations. Porter et al. (23) reported that planting rates which gave average plant populations of 61,000, 108,000 and 152,000 had little influence on grain yield of irrigated grain sorghum in Texas. Bond et al. (7) in another experiment with irrigated grain sorghum found that under normal dryland farming conditions where there is less than 4 inches of available moisture at seeding, wide rows will produce better grain yields at either a 2 or 4 pound seeding rate than will narrow rows. Also, the 4 pound seeding rate generally produced more lodging than the 2 pound rate. High seeding rates were found to be more important in limiting yield than narrow row spacing. Brown and Shrader (10) found that grain sorghum under a limited moisture supply, higher yields might be expected from row spacing wider than 40 inches.

Stickler et al. (31) in Manhattan, Kansas, reported that on the average, grain yield from 4-inch rows was less than that from 10-, 20-, or 30-inch rows. When row width and plant populations were evaluated, they indicated that the superiority of narrow rows was due to a higher plant population and not to row width effects per se. In general, plant height increased as plant area and row width decreased, but seed weight was not significantly influenced by row width or variety. Nelson (20) studied the effect of spacing and nitrogen application on yield of grain sorghum. Populations varying from 72,000 to 228,000 plants per acre were found to have no significant effect on productivity under irrigation. There was no interaction between varieties and spacing.

The sorghum varieties Plainsman and Martin were found to be the highest yielding varieties in Arkansas trials conducted by Thruman and Staten (34). Row spacings of 20 inches gave higher yields than 40-inch spacings.

The effect of population size on plant characters did not reveal significant differences with respect to plant height, leaf number, or length and thickness of panicle in an experiment made by Rachie and Rao (25) using four sorghum varieties sown in 6-, 12- and 18-inch row spacings with a plant population of 184,000, 155,000 and 123,000 per acre, respectively. Spacings, varieties and their interaction were statistically significant with respect to grain yield. Grain size was not influenced by plant spacing. Stickler and Laude (30) suggested that grain sorghum yields were higher with 78,000 than with 52,000 plants per acre, and that a significant plant population x row spacing interaction was present. They concluded that successful narrow-row culture requires a high plant population. Among other observations they

found that soil temperature, light intensity at the soil surface and water loss from the soil surface decreased as row width decreased. Bowers et al. (8) compared 40- and 20-inch rows and 13,000 and 105,000 populations. They explained that plant populations and not row spacing was significantly influencing the net radiation absorbed by sorghum plants.

A study of the effects of moisture, spacing, fertility and their interaction on grain sorghum production was carried out under irrigation in northeastern New Mexico by Painter and Leamer (21). They used the variety Plainsman planted in 36-inch rows with plants spaced four and nine inches in a row. The highest yield was obtained from a combination of 240 pounds of nitrogen and 80 pounds of P_2O_5, plants spaced 4 inches apart in 36 inch rows and irrigated whenever the soil moisture reached a tension of 0.7 atmospheres at a 9-inch depth. The value of thicker planting was evident only when 120 or more pounds of nitrogen was applied. In this case yields were from 14 to 18 bushels higher.

In several tests with sorghum, Grimes and Musick (14) evaluated the effects of row width of 7-, 14- and 28-inch rows all with plant populations of 56,000, 112,000 and 224,000 plants per acre under irrigation. They concluded that plant population may vary widely without seriously affecting grain yield and that this tolerance to varying plant populations of grain sorghums was due to their ability to tiller and produce larger heads with low plant populations and smaller heads combined with some plants not producing heads with high population. Data from spacing experiments at Woodward, Oklahoma, covering four years and including Dwarf Milo, Sunrise Kafir and Reed Kafir was collected by Sieglinger (28). He showed that the tillering characteristic

of various sorghum genotypes greatly influence their response to spacing. Stickler and Younis (32) obtained information on the extent to which plant height affected response to row width and stand density in three grain sorghum varieties. They used one short variety and two tall varieties. They found that the interactions of plant height by stand density and plant height by variety were significant in all cases. The short genotype performed better at high stand density but the tall genotypes were superior at lower stand densities. Martin (19) concluded that in sorghum, environmental conditions favorable for greater plant height also favor greater yield per unit area and greater seed size.

The effect of soil fertility and plant competition in sorghum grain was studied by Blum (6). High soil fertility and low plant population increased the seed weight and number of seeds per panicle. Anderson and Webster (1) compared the seed weight of sorghum hybrids and inbred varieties. They observed that seed weight of the hybrid tested was not greater than the inbred varieties when plant population was equal. Douglas (11) using plants of the strains Martin and RS 610 reported that seed weight decreased as distance between plants became greater.

MATERIALS AND METHODS

Field Work

This experiment was initiated at the Purdue University Agronomy Farm, Lafayette, Indiana in the summer of 1968. The laboratory work was conducted during the fall of the same year. Three inbred varieties, 0793 (I.S. No. 0075), 0819 (I.S. No. 2319) and Martin B from the world collection of sorghum and three hybrids, Martin x 0793, Martin x 1884 and RS610 were selected for this study. Two of these strains, RS610 and Martin B, can be considered as short-size sorghum while the other four can be considered as medium types. For the purpose of this work the strains were chosen among a group of sorghum genotypes because of their adaptation, relatively high and differing grain protein content.

The lines were planted on May 1, 1968. The soil type was a Chalmers silty clay loam. This soil is characterized by being almost black, of neutral pH and fairly high in organic matter. The prior summer it was cropped with maize. The field was spring plowed. To eliminate fertility as a limiting factor to plant development, 259 pounds actual nitrogen was applied, half in the form of urea and half in the form of ammonium nitrate, the week prior to planting. Only hours after planting, rain began to fall and continued falling for several days flooding the experimental area. Due to this situation and the contribution of abnormally cool temperatures during the same period, germination was extremely poor and most of the experiment had to be replanted.

The experiment was a two factor factorial. The first factor consisted of three population densities, 86,450, 172,900 and 345,800 plants per hectare and the second factor consisted of six genotypes, Martin x 0793, Martin x 1884, Martin B, RS610, 0793 and 0819. A randomized complete block design with four replications was used. Plant densities and replications were considered fixed and genotypes were random. Each plot consisted of four 12-foot long rows spaced 30 inches apart. The experiment was thinned to approximately the desired population densities when plants were between three to four inches tall.

Atrazine at the rate of 6.2 pounds per hectare and Ramrod at 3.7 pounds per hectare were applied for weed control. Cultivation was practiced by machinery first when the plants were young and by hand later. All counts and measurements were taken from the center 10 feet of the two center rows to eliminate border effects. The experiment was bordered with two rows of RS610 sorghum.

The characters studied in the field, the procedure used to measure them and the units of measurements are given in Table 1.

Laboratory Work

Seed weight was determined by recording the weight of 100 seeds chosen at random for each of the 72 plots involved. To check on uniformity of samples, each seed was inspected to ensure that only whole seeds were included.

Percent oil in the seed was measured by use of the "nuclear magnetic resonance (N.M.R.) spectroscopy method." This method is rapid, accurate and nondestructive.

For the embryo study a sample of 30 seeds was taken from each plot. Each sample contained only whole seeds. Samples were placed in a drier

Table 1. Characters measured in field plots to study effects of population pressure on plant performance in six sorghum genotypes. 1968, Lafayette, Indiana.

Character	Unit of Measurement	Procedure
Plant Height	cm	Recorded at maturity by measuring the main stem from ground level to the top of the panicle.
Head Exertion	cm	Measured from the collar of the flag leaf to the lowermost panicle node.
Panicle Length	cm	Measured from the bottom panicle node to the uppermost floret.
Length of the Flag Leaf	cm	Measured from the ligule to the tip of the leaf.
Width of the Flag Leaf	cm	Measured from the widest portion of the leaf blade.
Grain Yield	Kg/ha	Determined by hand-cutting the panicles from the center 10 feet of the two center rows of each plot, air drying to about 9% moisture, threshing and weighing.

at 180 degrees Fahrenheit for 96 hours to remove all the moisture from the seed. After that they were removed from the drier and weighed. To be sure that 180 degrees was enough to remove all the moisture from the seed, two samples were left in the drier for 48 additional hours after recording their weight at 96 hours. The new weight was then recorded and no significant change in weight occurred. This was taken as indicating that the seeds were moisture free after 96 hours at 180 degrees. Next, seeds were soaked in water for five hours in the cold to facilitate separation of the embryo from the endosperm. Separations were made by hand and each embryo was checked visually for cleanliness of separation. The seeds, now without embryos, were placed back in the drier at the same temperature for the same period of time as before to remove all moisture. The weight was again recorded. By subtracting the weight of the seed without embryo and moisture free, from the weight of the whole seed moisture free, an estimate of the weight of the embryo and the percent embryo of the whole seed was calculated.

To determine the relationship between the characters studied, simple correlation coefficients were calculated.

RESULTS AND DISCUSSION

The analysis of seed fractions revealed that the embryo as percent of the whole seed, over three populations in six sorghum genotypes, ranged from 10.52 to 13.88 with a grand mean (over three populations and 6 genotypes) of 11.69. This indicates that the embryo free seed, which is mainly endosperm, ranges from 89.48 to 86.12 percent. The percent protein in the embryo over three populations ranged from 18.14 to 24.68 with a grand mean of 22.05. These values are very similar to those reported by Hubbard et al. (16) in which the proportion of endosperm was found to range from 80.0 to 84.6 percent of whole seeds, and the germ from 7.8 to 12.1 percent. They also found the percent oil in the seed and percent protein in the whole seed and embryo were 3.60, 12.3 and 18.9 percent, respectively, which is quite comparable to grand means of 3.65, 12.3 and 22.05 reported in this work. These results are also very similar to those obtained by Early et al. (13) in corn. They found the germ to range from 10.2 to 14.1 percent and to contain about 22 percent of the protein and about 84 percent of the oil. Tables 2 to 4 give the analysis of variance with mean squares for 16 characters. Highly significant mean squares among genotypes were found for head exertion, panicle length, plant height, length of flag leaf, width of flag leaf, weight of 100 seeds, weight of embryo, embryo as percent of whole seed, percent oil in the seed, yield, percent protein in the embryo free seed and whole seed, lysine as percent of protein in the

Table 2. Analysis of variance for six characters with six genotypes over three population densities in *Sorghum bicolor* (L.) Moench. 1968, Lafayette, Indiana.

Source of variation	df	% protein in embryo free seed	% lysine in embryo free seed††	% protein in whole seed	% lysine in whole seed††	% protein in the embryo	% lysine in the embryo††
				Mean Squares			
Blocks	3	0.376	0.026	1.941**	0.003	52.074	3.433
Population	2	4.014**	0.048**	2.828**	0.051	21.557	1.225
Genotypes	5	17.638**	0.168**	19.929**	0.387**	58.004*	1.497
P x G	10	0.421	0.009	0.229	0.027	8.058	1.396
Error	51	0.584	0.010	0.444	0.023	20.625	2.245

*Significant at the .05 level
**Significant at the .01 level
††Lysine as percent of protein

Table 3. Analysis of variance for five characters with six genotypes over three population densities in *Sorghum bicolor* (L.) Moench. 1968, Lafayette, Indiana.

Source of variation	df	Weight of 100 seeds	Embryo weight	Embryo as % of whole seed	% oil in the seed	Grain yield
				Mean Squares		
Blocks	3	0.076	0.251	0.692	0.066	242297.563
Population	2	0.114	0.082	0.485	0.059	1917450.688
Genotypes	5	3.999**	5.942**	17.391**	7.882**	4664653.759**
P x G	10	0.036	0.048	0.208	0.034	633072.172
Error	51	0.047	0.155	0.591	0.033	450419.950

**Significant at the .01 level

Table 4. Analysis of variance for five characters with six genotypes over three population densities in *Sorghum bicolor* (L.) Moench. 1968, Lafayette, Indiana.

Source of variation	df	Head exertion	Panicle length	Plant height	Length of flag leaf	Width of flag leaf
				Mean Squares		
Blocks	3	13.638	1.155	375.584*	66.557**	0.404
Population	2	290.062**	29.393**	241.127	207.161**	3.559**
Genotype	5	421.945**	417.034**	38937.650**	236.591**	5.424**
P x G	10	25.434*	1.493	94.068	13.354	0.203
Error	51	11.386	2.481	115.932	14.026	0.317

*Significant at the .05 level
**Significant at the .01 level

embryo free seed and whole seed. Significant differences at the .05 level were found for percent protein in the embryo, but not significant for lysine as percent of the protein in the embryo. This suggested that one or more of the genotypes were considerably different in their performance for the characters studied with the exception of lysine as percent of protein in the embryo. Duncan's new multiple range test was used to determine which of the 6 genotype means were significantly different for oil percent in the seed and for yield. The results are shown in Tables 5 and 6 which give the average performance of each genotype over three population densities for each of the 16 characters studied.

The analysis of variance also indicated highly significant differences due to population densities for such characters as head exertion, panicle length, length and width of the flag leaf, percent protein in the embryo free seed, lysine as percent of protein in the embryo free seed and percent protein in the whole seed. No significant differences due to population densities were found for percent protein in the embryo, lysine as percent of protein in the embryo, lysine as percent of protein in the whole seed, plant height, weight of 100 seeds, embryo weight, embryo as percent of the whole seed, percent oil of the seed, or yield.

Of the 16 characters studied, only head exertion showed a significant population by genotype interaction. This might indicate that the response of the genotypes to changes in population density was not the same for this character.

Appendix Table A1 to A16 give the mean performance of each individual genotype for each character at each plant density. To facilitate the comparison of performance the genotypes were ranked

Table 5. Means of six sorghum genotypes for nine characters with three population densities and ranked according to percent oil in the seed with test of significance for percent oil. 1968, Lafayette, Indiana.

Genotype	Weight of embryo (mg)	Embryo as % of the whole seed	% protein in whole seed	% lysine in whole seed††	% protein in embryo free seed	% lysine in embryo free seed††	% protein in the embryo	% lysine in the embryo††	% oil in the seed	Duncan's New Multiple Range Test†
0819	4.71	13.88	13.38	2.12	11.70	1.33	24.68	6.16	5.28	
Martin B	2.88	11.49	13.24	1.82	11.59	0.98	22.52	6.47	3.49	
Martin x 0793	3.98	11.23	12.08	1.86	10.79	1.13	21.31	5.69	3.44	
0793	3.96	10.52	13.52	1.62	12.36	1.08	18.14	5.75	3.33	
RS610	3.13	12.13	10.95	2.00	9.60	1.09	22.79	5.85	3.28	
Martin x 1884	3.12	10.88	10.60	2.03	9.35	1.18	22.86	5.50	3.07	
Mean	3.63	11.69	12.30	1.91	10.90	1.13	22.05	5.90	3.65	

†Any two means not spanned by the same line are significantly different at the .05 level. Any two means spanned by the same line are not significantly different at the .05 level.

Table 6. Means of six sorghum genotypes for seven characters with three population densities and ranked according to yield with test of significance for yield. 1968, Lafayette, Indiana.

Genotype	Head exertion (cm)	Plant height (cm)	Panicle length (cm)	Weight of 100 seeds (gm)	Length of flag leaf (cm)	Width of flag leaf (cm)	Grain yield Kg/ha	Duncan's New Multiple Range Test†
Martin x 0793	14.58	235.08	23.72	3.72	42.05	6.53	8962.99	
0819	1.70	265.55	13.36	3.55	33.47	6.28	7195.33	
RS610	15.45	128.83	21.34	2.72	32.13	4.84	6396.43	
Martin x 1884	17.83	186.53	29.73	2.95	43.19	5.66	6384.79	
0793	12.55	214.12	16.20	4.02	38.20	6.60	6189.31	
Martin B	17.03	125.28	24.12	2.63	37.12	5.66	4919.74	
Mean	13.19	192.57	21.41	3.26	37.69	5.93	6674.76	

†Any two means not spanned by the same line are significantly different at the .05 level. Any two means spanned by the same line are not significantly different at the .05 level.

based on their mean performance over three populations. For most characters studied, the genotypes with the highest mean values over three populations were also the highest for each individual population. The mean values for those characters which required fractioning of the seed and/or chemical analysis are shown in Appendix Tables A3 to A11. The weight of the embryo, measured in milligrams and the embryo as percent of the whole seed, gave mean values for the low population which ranged from 2.90 to 4.63 mg and 10.60 to 13.50 percent, respectively. At the medium population the range was from 2.82 to 4.82 mg and 10.40 to 13.98 percent, and for the highest population 2.90 to 4.67 mg and 10.55 to 14.15 percent. Percent oil in the seed ranged from 3.00 to 5.22 percent for the low populations, from 3.07 to 5.47 for the medium and 3.13 to 5.12 for the high population. Mean percent protein in the embryo free seed, embryo and whole seed ranged from 9.55 to 13.00 percent, 16.30 to 23.45 percent and 10.77 to 13.93 percent, respectively, for the low population. For the medium population the range was from 9.55 to 12.20, 19.13 to 25.13 and 10.57 to 13.53 percent, and the range for the high population was from 8.95 to 11.85, 19.00 to 25.47 and 10.45 to 13.10 percent. The differences due to populations were found to be highly significant for percent protein in the embryo free seed and whole seed but not for percent protein in the embryo. These observations suggested that the endosperm is probably the fraction of the seed which is most affected by high plant densities in production of protein while the embryo or the proportion of embryo are not appreciably affected. Also, the reduction in percent protein in the endosperm for each increase in population seems to be large enough to result in significant differences in the whole seed. The data for lysine as percent of protein

in the embryo free seed, embryo and whole seed showed that the effect of increasing the population was to increase significantly the lysine percent in the embryo free seed, but to have no significant effect in the embryo and whole seed. The range for each population was from 0.88 to 1.30 percent, 5.66 to 6.60 percent and 1.62 to 1.92 percent for the embryo free seed, embryo and whole seed, respectively, for the low population. For the medium population the range was 0.99 to 1.30, 5.23 to 6.87 and 1.66 to 2.19 percent and for the high population 1.08 to 1.40, 5.62 to 5.95 and 1.57 to 2.24 percent.

At 86,450 plants per hectare the range in grain yield was from 4,764.94 to 7,945.86 kilograms per hectare; at 172,900 from 4,548.33 to 10,150.15 and at 345,800 plants per hectare the range was from 5,445.95 to 8,792.96. Yields were always higher at 345,800 plants per hectare than at 86,450. However, the differences due to population densities were not significant. One explanation for this could be that the high populations used to test the genotypes were not high enough to produce significant differences. The weight of 100 seeds range from 2.73 to 4.20 gm for the low population, 2.59 to 4.01 gm for the medium and 2.56 to 3.86 gm for the high. Plant height increased with higher plant densities and the range was from 122.15 to 270.75, 123.95 to 262.45 and 129.75 to 263.45 cm for the low, medium and high populations, respectively. The mean head exertion for the low, medium and high populations ranged from 0.15 to 13.80 cm, 2.10 to 14.65 cm and 2.85 to 25.05. The mean panicle length ranged from 14.13 to 30.55 cm, 13.03 to 30.52 cm and 12.92 to 28.10 cm. The mean length of the flag leaf as well as the width seemed to be reduced by each increase in plant density. The mean length ranged from 35.90 to 45.65 cm for the low population, 30.27 to 44.17 cm for the medium and 30.22 to 39.75

for the highest. The width ranged from 5.45 to 7.22 cm, 4.60 to 6.30 cm and 4.47 to 6.27 cm for the low, medium and high population, respectively.

The genotype with the heaviest embryo was found to have the highest percent oil in the seed, the highest percent protein in the embryo, the second highest lysine as percent protein in the embryo, the second highest percent protein in the whole seed and embryo free seed, the highest lysine as percent of protein in the embryo free seed and the highest proportion of embryo. Also, it was the second highest in yield.

To determine the type of relationships that exist between the 16 characters studied simple correlation coefficients were calculated (Table 7). The weight of the embryo was significantly positively correlated with percent oil in the seed ($r = .6720$), percent protein in the embryo free seed and the whole seed, lysine as percent of protein in the embryo free seed, flag leaf width, yield, plant height, weight of 100 seeds ($r = .7478$) and embryo percentage of the whole seed. It was significantly negatively correlated with panicle length and head exertion. This suggests that breeding and selection for larger embryos might be effective in improving the quality of the grain for oil and protein. Percent protein in the embryo showed a significant positive association with lysine as percent of protein in the embryo free seed and embryo as percent of the whole seed, and a significant negative relationship with lysine as percent of protein in the embryo, percent protein in the embryo free seed and length of flag leaf. The relationship for lysine as percent of protein in the embryo was significantly positive with percent protein in the embryo free seed and lysine as percent of protein in the whole

Table 7. Simple correlation coefficients among 16 characters of six sorghum genotypes over three population densities. 1968, Lafayette, Indiana.

	Head exertion	Plant height	Wt. of 100 seeds	Yield	Length of flag leaf	Width of flag leaf	Embryo weight	Embryo % of whole seed	% oil in the seed	% protein in embryo free seed	% lysine in embryo free seed††	% protein in whole seed	% lysine in whole seed††	% protein in embryo	% lysine in embryo††
Panicle length	.5086**	-.4845**	-.4693**	-.0918	.5391**	-.1804	-.6466**	-.4653**	-.6764**	-.4821**	-.3275*	-.5309**	.0289	-.0523	-.0162
Head exertion		-.5006**	-.3959**	-.0383	.0089	-.4276**	-.5871**	-.4901**	-.6946**	-.4371**	-.2845*	-.4516**	-.2079	-.0480	-.2205
Plant height			.7533**	.4446**	.1025	.5602**	.8023**	.2404	.5818**	.3021*	.5397**	.2703	.0773	-.0354	-.0432
Weight of 100 seeds				.3496*	.2064	.6444**	.7478**	-.0671	.2572	.5028**	.1729	.4548**	-.2951*	-.2235	-.0271
Yield					.0490	.1699	.3100*	.0534	.1484	-.1914	.3286*	-.1776	.2094	.0671	-.0915
Length of flag leaf						.6378**	-.1123	-.4390**	-.2950*	.0715	-.3163*	-.0445	-.1668	-.2814*	.1595
Width of flag leaf							.4180**	-.1509	.2221	.5179**	-.1302	.4551**	-.2680	-.2379	.1597
Embryo weight								.5579**	.6720**	.3435*	.4678**	.3859**	.1191	.1121	-.0239
Embryo % of whole seed									.7487**	-.0309	.4804**	.1058	.5075**	.4515**	-.0099
% oil in seed										.3345*	.5330*	.4436**	.3476*	.2653	.0783
% protein in embryo free seed											-.2121	.8867**	-.4744**	-.4723**	.3914**
% lysine in embryo free seed††												-.1275	.4243**	.3435*	-.3433*
% protein in whole seed													-.4483**	-.0533	.1261
% lysine in whole seed††														.2611	.3265*
% protein in embryo															-.6262**

*Significant at the .05 level
**Significant at the .01 level
††Lysine as percent of the protein

seed, and significantly negative with lysine as percent of protein in the embryo free seed and percent of protein in the embryo. Percent protein in the seed showed significant negative relationships with lysine as percent of protein in the seed, head exertion and panicle length, but significantly positive with percent protein in the embryo free seed (r = .8867), percent oil in the seed, embryo weight, weight of 100 seeds and width of flag leaf. Lysine as percent of protein in the seed gave correlation coefficient values significantly positive with percent oil in the seed, lysine as percent of protein in the embryo and embryo free seed and embryo as percent of the whole seed; and significantly negative with percent protein in the whole seed and embryo free seed and weight of 100 seeds. Yield gave highly significant positive correlation coefficients with plant height, but no significant association seemed to exist between yield and flag leaf length and width. Panicle length was significantly negatively correlated with percent oil in the seed (r = -.6764) and with percent protein in the embryo free seed and whole seed.

SUMMARY

The effects of increasing plant density from 86,450 to 172,900 plants per hectare and from 172,900 to 345,800 was to significantly increase the percent lysine in the protein of the embryo free seed and head exertion; and to significantly reduce the percent protein in the embryo free seed and whole seed, panicle length and flag leaf length and width. No significant differences due to populations were observed for percent protein in the embryo, percent lysine in the protein of the embry and whole seed, weight of 100 seeds, embryo weight, percent oil in the seed, yield, plant height and embryo as percent of the whole seed. Yields were always higher at 345,800 plants per hectare than at 86,450. However, the differences due to population densities were not significant One explanation for this could be that the high populations used were not high enough to produce a significant response. Yield was significantly positively correlated with plant height but no significant association was shown with flag leaf length and width. The weight of the embryo was significantly positively correlated with percent oil in the seed ($r = .6720$), percent protein in the embryo free seed and the whole seed, weight of 100 seeds ($r = .7478$) and with certain other characters. Panicle length was significantly negatively correlated with percent oil in the seed ($r = -.6764$) and with percent protein in the embryo free seed and whole seed. Percent lysine in the protein of the embryo and the whole seed was significantly negatively correlated with percent protein. In general, increasing the population resulted in an

increase in plant height. A significant population by genotype interaction was observed only for head exertion.

Significant differences among genotypes were found for 15 out of 16 characters studied. The only exception was lysine as percent of protein in the embryo.

The embryo as percent of the whole seed over three populations ranged from 10.52 to 13.88 with a grand mean of 11.69.

The mean percent protein in the embryo, embryo free seed and whole seed over three populations ranged from 18.14 to 24.68, 9.35 to 12.36 and 10.60 to 13.52 percent, respectively, with grand means of 22.05, 10.90 and 12.30 percent. Mean lysine as percent of protein in the embryo, embryo free seed and whole seed over three populations ranged from 5.50 to 6.47, 0.98 to 1.33 and 1.62 to 2.12 percent, respectively, with grand means of 5.90, 1.13 and 1.91 percent. Percent protein in the whole seed was significantly positively correlated with percent protein in the embryo free seed ($r = .8867$).

LIST OF REFERENCES

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1. Anderson, R. E., and Webster, O. J. 1959. Factors contributing to yield in sorghum hybrids. Am. Soc. Agron. - Abstract 51st Annual Meeting, p. 53.

2. Ashby, Eric. 1932. Studies in the inheritance of physiological characters. Annals of Botany 46:1008-1032.

3. Bauman, L. F., Conway, T. F., and Watson, S. A. 1965. Inheritance of variation in oil content of individual corn (Zea mays) kernels. Crop Science 5:137-138.

4. Bidwell, G. L. 1918. A physical and chemical study of the kafir kernel. U. S. Dept. Agr. Bull. 634:1-6.

5. Bidwell, G. L., Bopst, L. E., and Bowling, J. D. 1922. A physical and chemical study of Milo and feterita kernels. U. S. Dept. Agr. Bull. 1129:1-8.

6. Blum, A. 1967. Effect of soil fertility and plant competition on grain sorghum panicle morphology and panicle weight components. Agron. J. 59:400-403.

7. Bond, J. J., Army, J. J., and Lehman, O. R. 1964. Row spacing, plant populations and moisture supply as factors in dryland grain sorghum production. Agron. J. 56(1):3-6.

8. Bowers, S. A., Hanks, R. J., and Stickler, F. C. 1963. Distribution of net radiation within sorghum plants. Agron. J. 55(2):204-205.

9. Bremner, P. M., Eckersall, R. N., and Scott, R. K. 1963. The relative importance of embryo size and endosperm size in causing the effects associated with seed size in wheat. J. Agric. Sci. 61:139-145.

10. Brown, P. L., and Shrader, W. D. 1959. Grain yields, evapotranspiration, and water use efficiency of grain sorghum under different cultural practices. Agron. J. 51:339-343.

11. Douglas, C. F. 1958. Effect of nitrogen, variety type, and plant spacing on grain sorghum. Unpublished M.S. Thesis, University of Illinois.

12. Earley, E. B., and De Turk, E. E. 1948. Corn protein and soil fertility. Amer. Seed Trade Assoc. Third Hybrid Seed Corn Industrial Research Conf. 84-93.

13. Earley, F. R., Curtis, J. J., and Hubbard, J. E. 1946. Composition of the component parts of the corn kernel. Cereal Chem. 23:504-511.

14. Grimes, D. W., and Musick, J. T. 1960. Effect of plant spacing, fertility, and irrigation managements on grain sorghum production. Agron. J. 52:647-650.

15. Hatcher, E. S., and Purvis, O. N. 1945. On the behaviour in the field of small grain obtained by premature harvesting. J. Agric. Sci. 35:177-183.

16. Hubbard, J. E., Hall, H. H., and Earley, F. R. 1950. Composition of the component parts of the sorghum kernel. Cereal Chem. 27(5): 415-420.

17. Karchi, Z., and Rudich, Y. 1966. Effect of row width and seedling spacing on yield and its components in grain sorghum under dryland conditions. Agron. J. 58:602-604.

18. Lang, A. J., Pendleton, J. W., and Shaw, R. H. 1956. Influence of population and nitrogen levels on yield and protein and oil content of nine corn hybrids. Agron. J. 48:284-289.

19. Martin, J. H. 1928. Plant characters and yield in grain sorghums. J. Amer. Soc. Agron. 20:1177-1182.

20. Nelson, C. E. 1952. Effects of spacing and nitrogen application on yield of grain sorghum under irrigation. Agron. J. 44:303-305.

21. Painter, G. G., and Leamer, Ross W. 1953. The effects of moisture, spacing, fertility, and their interrelationship on grain sorghum production. Agron. J. 45:261-264.

22. Pickett, R. C. 1959. 1958 sorghum research in Indiana. Sorghum Newsletter 2:21-22.

23. Porter, K. B., Jensen, M. E., and Sletten, W. H. 1960. The effect of row spacing, fertilizer, and planting rate on the yield and water use of irrigated grain sorghum. Agron. J. 52(8):431-434.

24. Rabideau, G. S. 1954. Amino acids in the embryo and endosperm of the grain of different varieties of corn. Bot. Gaz. 115:391-394.

25. Rachie, K. O., and Rao, D. V. 1963. Influence of population density on yield and plant characters in sorghums. Andhra Agr. J. 10(5): 185-193.

26. Rao, V. P., Ayyangar, G. N., and Rajabhoosharram, D. S. 1938. Sorghum - size relationship of seed, embryo, seedling, and the first seedling leaves. Proc. Indian Acad. Sci. Sect. B 8(3):151-156.

27. Robinson, R. G., Bernat, L. A., Nelson, W. W., Thompson, R. L., and Thompson, J. R. 1964. Row spacing and plant population for grain sorghum in the humid north. Agron. J. 56(2):189-191.

28. Sieglinger, John B. 1926. Spacing of grain sorghum. J. Amer. Soc. Agron. 18:525-528.

29. Steel, R.G.D., and Torrie, J. H. 1960. Principles and procedures of statistics. McGraw-Hill Book Company, New York.

30. Stickler, F. C., and Laude, H. H. 1960. Effect of row spacing and plant population of performance of corn, grain sorghum, and forage sorghum. Agron. J. 52(5):275-277.

31. Stickler, F. C., Pauli, A. W., Laude, H. D., Wilkings, and Mings, J. L. 1961. Row width and plant population studies with grain sorghum at Manhattan, Kansas. Crop Sci. 1(4):297-300.

32. Stickler, F. C., and Younis, M. A. 1966. Plant height as a factor affecting responses of sorghum to row width and stand density. Agron. J. 58:371-373.

33. Sprague, G. F. 1936. Hybrid vigour and growth rates in maize cross and its reciprocal. J. Agric. Research 53:819-829.

34. Thurman, R. L., and Staten, R. D. 1955. Sorghum yield experiments. Rep. Serv., 46. Arkansas Agric. Expt. Sta. 19. Field Crop Abst. 1956.9.no. 1144.

35. Vaugham, C. E. 1961. Seed color and size related to viability, vigour. Miss. Fm. Res. 24, no. 5:3-4.

36. Wilkings, H. D. 1953. Study of the effect of row spacings on dwarf grain sorghums. Unpublished M.S. Thesis, Kansas State College.

APPENDIX

APPENDIX

Table A1. Mean grain yield of six sorghum genotypes for three population densities (Kg/ha). 1968, Lafayette, Indiana.

Genotype	Population (Plants/Hectare)			
	86,450	172,900	345,800	Mean
Martin x 0793	7,945.86	10,150.15	8,792.96	8,962.99
0819	7,154.66	6,870.33	7,561.01	7,195.33
RS610	6,224.79	6,286.06	6,678.44	6,396.43
Martin x 1884	4,300.00	6,549.98	8,304.38	6,384.79
0793	5,834.03	6,030.75	6,703.16	6,189.31
Martin B	4,764.94	4,548.33	5,445.95	4,919.74
Grand Mean	6,037.38	6,739.26	7,247.65	6,674.76

Table A2. Mean 100 seed weight of six sorghum genotypes for three population densities (gm). 1968, Lafayette, Indiana.

Genotype	Population (Plants/Hectare)			
	86,450	172,900	345.800	Mean
0793	4.20	4.01	3.86	4.02
Martin x 0793	3.79	3.72	3.65	3.72
0819	3.59	3.65	3.42	3.55
Martin x 1884	2.83	3.09	2.93	2.95
RS610	2.71	2.76	2.70	2.72
Martin B	2.73	2.59	2.56	2.63
Grand Mean	3.31	3.30	3.19	3.26

Table A3. Mean percent oil in the seed of six sorghum genotypes for three population densities. 1968, Lafayette, Indiana.

Genotype	Population (Plants/Hectare)			
	86,450	172,900	345,800	Mean
0819	5.22	5.47	5.12	5.28
Martin B	3.53	3.52	3.42	3.49
Martin x 0793	3.40	3.50	3.42	3.44
0793	3.25	3.42	3.32	3.33
RS610	3.25	3.22	3.38	3.28
Martin x 1884	3.00	3.07	3.13	3.07
Grand Mean	3.61	3.70	3.63	3.65

Table A4. Mean embryo as percent of the whole seed of six sorghum genotypes for three population densities. 1968, Lafayette Indiana.

Genotype	Population (Plants/Hectare)			
	86,450	172,900	345,800	Mean
0819	13.50	13.98	14.15	13.88
RS610	12.05	12.30	12.05	12.13
Martin B	11.25	11.45	11.77	11.49
Martin x 0793	10.85	11.35	11.50	11.23
Martin x 1884	10.90	11.10	10.65	10.88
0793	10.60	10.40	10.55	10.52
Grand Mean	11.53	11.76	11.78	11.69

Table A5. Mean weight of the embryo of six sorghum genotypes for three population densities (mg). 1968, Lafayette, Indiana.

Genotype	Population (Plants/Hectare)			
	86,450	172,900	345,800	Mean
0819	4.63	4.82	4.67	4.71
Martin x 0793	3.95	3.97	4.02	3.98
0793	4.00	4.00	3.87	3.96
RS610	2.92	3.22	3.28	3.13
Martin x 1884	3.05	3.28	3.02	3.12
Martin B	2.90	2.82	2.90	2.88
Grand Mean	3.57	3.69	3.63	3.63

Table A6. Mean percent protein in the embryo free seed of six sorghum genotypes for three population densities. 1968, Lafayette, Indiana.

Genotype	Population (Plants/Hectare)			
	86,450	172,900	345,800	Mean
0793	13.00	12.20	11.85	12.36
0819	12.28	11.80	11.03	11.70
Martin B	11.80	12.13	10.85	11.59
Martin x 0793	11.17	10.43	10.78	10.79
RS610	9.80	9.70	9.30	9.60
Martin x 1884	9.55	9.55	8.95	9.35
Grand Mean	11.27	10.97	10.47	10.90

Table A7. Mean lysine as percent of protein in the embryo free seed of six sorghum genotypes for three population densities. 1968, Lafayette, Indiana.

Genotype	Population (Plants/Hectare)			
	86,450	172,900	345,800	Mean
0819	1.30	1.30	1.40	1.33
Martin x 1884	1.12	1.24	1.19	1.18
Martin x 0793	1.15	1.12	1.13	1.13
RS610	1.02	1.13	1.12	1.09
0793	1.02	1.11	1.10	1.08
Martin B	0.88	0.99	1.08	0.98
Grand Mean	1.08	1.15	1.17	1.13

Table A8. Mean percent protein in the embryo of six sorghum genotypes for three population densities. 1968, Lafayette, Indiana.

Genotype	Population (Plants/Hectare)			
	86,450	172,900	345,800	Mean
0819	23.45	25.13	25.47	24.68
Martin x 1884	20.98	21.75	25.85	22.86
RS610	22.28	22.73	23.35	22.78
Martin B	23.32	20.48	23.75	22.52
Martin x 0793	20.50	22.68	20.75	21.31
0793	16.30	19.13	19.00	18.14
Grand Mean	21.14	21.98	23.03	22.05

Table A9. Mean lysine as percent of protein in the embryo of six sorghum genotypes for three population densities. 1968, Lafayette, Indiana.

Genotype	Population (Plants/Hectare)			
	86,450	172,900	345,800	Mean
Martin B	6.60	6.87	5.95	6.47
0819	5.50	6.75	6.22	6.16
RS610	6.51	5.55	5.49	5.85
0793	6.74	5.60	4.90	5.75
Martin x 0793	5.85	5.20	6.01	5.69
Martin x 1884	5.66	5.23	5.62	5.50
Grand Mean	6.14	5.87	5.70	5.90

Table A10. Mean percent protein in the whole seed of six sorghum genotypes for three population densities. 1968, Lafayette, Indiana.

Genotype	Population (Plants/Hectare)			
	86,450	172,900	345,800	Mean
0793	13.93	13.53	13.10	13.52
0819	13.87	13.55	12.73	13.38
Martin B	13.68	13.50	12.55	13.24
Martin x 0793	12.28	11.95	12.00	12.08
RS610	11.05	11.10	10.70	10.95
Martin x 1884	10.77	10.57	10.45	10.60
Grand Mean	12.60	12.37	11.92	12.30

Table A11. Mean lysine as percent of protein in the whole seed of six sorghum genotypes for three population densities. 1968, Lafayette, Indiana.

Genotype	Population (Plants/Hectare)			
	86,450	172,900	345,800	Mean
0819	1.92	2.19	2.24	2.12
Martin x 1884	1.98	2.03	2.08	2.03
RS610	2.02	1.98	2.03	2.00
Martin x 0793	1.89	1.81	1.89	1.86
Martin B	1.77	1.78	1.94	1.82
0793	1.62	1.66	1.57	1.62
Grand Mean	1.87	1.91	1.96	1.91

Table A12. Mean plant height of six sorghum genotypes for three population densities (cm). 1968, Lafayette, Indiana.

Genotype	Population (Plants/Hectare)			
	86,450	172,900	345,800	Mean
0819	270.75	262.45	263.45	265.55
Martin x 0793	230.70	233.55	241.00	235.08
0793	213.45	217.30	211.60	214.12
Martin x 1884	180.95	185.20	193.45	186.53
RS610	120.90	128.65	136.95	128.83
Martin B	122.15	123.95	129.75	125.28
Grand Mean	189.82	191.85	196.03	192.57

Table A13. Mean head exertion of six sorghum genotypes for three population densities (cm). 1968, Lafayette, Indiana.

Genotype	Population (Plants/Hectare)			
	86,450	172,900	345,800	Mean
Martin x 1884	13.80	14.65	25.05	17.83
Martin B	13.40	20.00	17.70	17.03
RS610	9.95	17.15	19.25	15.45
Martin x 0793	9.35	15.50	18.90	14.58
0793	10.15	13.15	14.35	12.55
0819	0.15	2.10	2.85	1.70
Grand Mean	9.46	13.76	16.35	13.19

Table A14. Mean panicle length of six sorghum genotypes for three population densities (cm). 1968, Lafayette, Indiana.

Genotype	Population (Plants/Hectare)			
	86,450	172,900	345,800	Mean
Martin x 1884	30.55	30.52	28.10	29.73
Martin B	25.27	24.72	22.35	24.12
Martin x 0793	25.25	23.30	22.60	23.72
RS610	22.88	20.85	20.30	21.34
0793	17.13	15.82	15.65	16.20
0819	14.13	13.03	12.92	13.36
Grand Mean	22.52	21.38	20.32	21.41

Table A15. Mean length of flag leaf of six sorghum genotypes for three population densities (cm). 1968, Lafayette, Indiana.

Genotype	Population (Plants/Hectare)			
	86,450	172,900	345,800	Mean
Martin x 1884	45.65	44.17	39.75	43.19
Martin x 0793	43.00	42.25	40.90	42.05
0793	42.42	36.32	35.85	38.20
Martin B	41.03	38.95	31.38	37.12
0819	35.60	34.55	30.25	33.47
RS610	35.90	30.27	30.22	32.13
Grand Mean	40.60	37.75	30.73	37.69

Table A16. Mean width of flag leaf of six sorghum genotypes for three population densities (cm). 1968, Lafayette, Indiana.

Genotype	Population (Plants/Hectare)			
	86,450	172,900	345,800	Mean
0793	7.22	6.30	6.27	6.60
Martin x 0793	6.65	6.60	6.32	6.52
0819	6.60	6.35	5.90	6.28
Martin B	6.30	5.60	5.07	5.66
Martin x 1884	5.85	5.65	5.47	5.66
RS610	5.45	4.60	4.47	4.84
Grand Mean	6.35	5.85	5.59	5.93