SOME AGRONOMIC CHARACTERS OF GRAIN SORGHUM

MALE STERILE LINES AND SINGLE CROSSES

By

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF APPENDIX TABLES

LIST OF FIGURES

INTRODUCTION

Grain sorghums are becoming more important in the agricultural picture. In areas of adaptation, they are grown on increasing acreages and are competing with wheat as a cash crop under both dryland and irrigated conditions.

With this increased interest in grain sorghums, there follows naturally the problem of producing and making sufficient planting seed available to the farmer. If a method can be developed and utilized that is practical in reducing the amount of time, labor and expense needed to produce hybrid seed, another forward step has been taken in the direction of crop improvement.

A recently prepared method of producing hybrid sorghum seed for planting is through the use of a male sterile single cross, utilizing the male sterile line as the female. This type of single cross usually results in an increased seed set per inflorescence and more seed yield on a given area.

The purpose of this study was to determine if a male sterile single cross sorghum hybrid (A x B) was superior in seed production to a male sterile line (A) when both were pollinated from a common source. This superiority should be expressed as greater yield and higher threshing percent. Other factors considered were bushel weight, weight of 1000 seed, days to mid-bloom, days to maturity and plant height.

REVIEW OF LITERATURE

Investigations have shown that grain sorghum hybrids are superior to many of the established varieties in yield, resistance to lodging, combine height and other characteristics (19)[1]. The plant breeders goal then is to produce excellent hybrids that have the desired characteristics.

Any practice that reduces the cost of seed production of any crop without lowering the quality of seed or quality of crops produced from that seed should be an advancement. One of the discoveries which changed methods of seed production was male sterility.

Duvick (8) suggested that it may be possible to find suitable male sterile lines in many of the cultivated crops. He indicated that the use of such male steriles would result in a more efficient process of seed hybridization and production through the elimination of flower emasculation.

Thus far only a few crops have been found to contain a factor for male sterility. A major portion of these crops have factors for at least one of the three known types of male sterility: cytoplasmic, genetic, or cytoplasmic-genetic.

Sorghum

Stephens (28), in 1935, discovered a genetic male sterile plant of Texas Blackhull kafir. Subsequent testing revealed that there was

1/ Refers to Literature Cited.

a progeny segregation of three fertile to one sterile indicating single factor inheritance. In 1937, he proposed that the male sterile character might be used for the production of hybrid sorghum seed. Work concentrated along this line until another genetic male sterile was found by Kuykendall as reported by Stephens et al. (30). After several years work with this male sterile character, even though complete male sterility had not been obtained in the line, they proposed the following method of hybrid production with a three way cross:

> Line A (male sterile) planted beside Line B (male fertile) gives male sterile progeny. These male steriles are then planted beside Line C which will restore fertility to the resulting hybrid. This hybrid would then be released to the public.

Stephens and Holland (29) found a type of male sterility from a cross between Milo and Kafir. They concluded that this male sterility was a result of the interaction of Milo cytoplasm and Kafir nuclear factors. They proposed that this type of sterility could be used in hybridization through a single cross. By using only two lines, (an A line as the female parent and an R line as the pollinator and fertility restorer), less labor, time, and isolation of the stocks would be required for maintainence as compared with a three-way hybrid.

Stephens and Lahr (31) compared the yield of male sterile hybrids and male sterile parental lines when crossed with a common restorer line. They found that the hybrids gave consistently higher yields than the parental lines. Earlier they had observed that individual panicles of the hybrids had a better seed set than the parental lines.

In 1960, Ross[1] compared the yields of single cross and three-way cross hybrids of three grain sorghum varieties when pollinated with each of three restorer lines. He found that yields were somewhat higher in the hybrids than the parental lines.

Ross[2] also compared the yield and bushel weight of similar male sterile and male fertile lines of two varieties of grain sorghum. In both varieties, there was a significant difference in yield in favor of the male fertile lines. Also the bushel weights were about two pounds greater in the male fertile lines than in the male sterile lines.

Corn

Although numerous male sterile characters which behave as simple gene recessives have been reported in corn (2, 3, 9, 26) relatively few have been discovered that are controlled in the cytoplasm. A cytoplasmic male sterile condition was reported by Rhoades (24) in 1933. He concluded that the behavior of this character indicated that it was transmitted through the maternal cytoplasm, and that nuclear factors exerted little or no influence on this transmission. Later findings by Josephson and Jenkins (14) showed that male sterility is also dependent upon at least two genetic factors in combination with the cytoplasm.

Josephson and Kincer (15) made comparisons of height, silking date and yield between male sterile and similar male fertile lines of corn. They found that yield was not materially affected, but shorter plants

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[1]W. M. Ross. Comparison of three-way crosses and single crosses involving the same parentage. Unpublished data. Kans. Agr. Exp. Sta. Ft. Hays, 1960.

[2]W. M. Ross. Summary of yield experiment involving various proportions of A and B seed. Unpublished data. Kans. Agr. Exp. Sta. Ft. Hays, 1960.

and later silking dates were found in the male sterile lines. Duvick (7), however, found there was a difference in grain yield. He also found differences for other characters with these differences being affected to some extent by genotype and physical environment.

Methods of utilization have been suggested for the male sterile character. Rogers and Edwardson (25) concluded that by crossing a suitable male sterile inbred line with the proper restorer line, a high yielding single cross could be obtained. Bagshaw and Rossman (1), however, produced three way hybrids that were higher yielding than the adapted single crosses.

Sugar beet

Owen (23) described male sterility in sugar beets. He concluded that the condition resulted from the interaction of the cytoplasm and certain factors in the nucleus. The cytoplasm carried one factor and the nucleus carried two factors. Male sterility resulted from the combination of sterile cytoplasm and homozygous recessive genes for sterility. Such a combination was obtained by crossing a line heterozygous for male fertility with sterile cytoplasm and a line heterozygous for male fertility with either sterile or fertile cytoplasm. The line with the sterile cytoplasm was used as the female parent.

Onion

According to Jones and Emswaller (13) a male sterile onion plant was found in 1925. They suggested the feasibility of utilizing male sterility in the production of hybrid onions.

Jones and Clark (12) reported male sterility was the result of interaction between a recessive nuclear gene and a cytoplasmic condition. They stated there were two types of cytoplasm, normal and sterile, which interacted with the genetic effect. A male sterile line could be produced by crossing a line with sterile cytoplasm and at least one recessive gene and a line that was homozygous recessive or heterozygous for male sterility.

Flax

Gairdner (10) reported evidence stating that male sterility in flax is an interaction of the cytoplasm and the nucleus. Male sterile plants were obtained from certain crosses, however, when the reciprocal crosses were made, no male sterile plants appeared. Further testing revealed that some of the lines contained the cytoplasmic factor and other lines contained the genetic factor. A male sterile line could be produced by crossing a line with the cytoplasmic factor and a line with the nucleus factor, using the line with the cytoplasmic factor as the female.

Potato

Potatoes are reported to have the male sterility factor inherited as a dominant Mendelian character with only one pair of genes accounting for the expression (11).

Tomato

In 1915, Crane (5) reported the presence of male sterility in tomatoes, but did not report the mode of inheritance. Lesley (21) observed a male sterile plant in 1933. He reported that male sterility was caused by genetic factors which depend upon at least two recessive genes.

Barley

Suneson (32) reported a male sterile plant of barley to have occurred in 1936. Using controlled pollination, he found that the F_1 was all fertile and the F_2 segregated three fertiles to one sterile, indicating that the character was controlled by a single recessive gene.

Tobacco

Clayton (4) stated that male sterility in tobacco was controlled in the cytoplasm. He indicated that sterility was caused by an incompatibility of the cytoplasm and the genes. After considerable study, he concluded that no genetic factors affected the sterility.

MATERIALS AND METHODS

This study consisted of evaluating ten single crosses and six lines of male sterile grain sorghum when crossed with a common fertility restorer line. Emphasis was placed on grain yield and threshing percent as previous studies (30, 31) indicated that male sterile single crosses were higher yielders than male sterile lines. Other characters measured were bushel weight, weight of one thousand seed, days to mid-bloom, plant height, and days to maturity.

The three different types of lines with respect to male fertility were:

Line A - male sterile

Line B - male fertile but male sterile producing

Line R - male fertile and male fertile producing

All of the line steriles and single cross steriles were crossed with Y-8 as the common pollinator or the R line. Y-8 is a homozygous yellow endosperm line from a cross of Redlan with Kaura (yellow endosperm type native to Nigeria, Africa).

The line steriles were Wheatland A, Westland A, Martin A, Combine Kafir-60 A, Redlan A, and Dwarf Redlan A. The single cross steriles were Wheatland A, Westland A, Martin A, and Combine Kafir-60 A crossed with Redlan B and Dwarf Redlan B, Redlan A crossed with Dwarf Redlan B, and Dwarf Redlan A crossed with Redlan B. A listing of these lines is given in Table I.

TABLE I

DESIGNATION OF LINE STERILES AND SINGLE CROSS STERILES

Line Steriles

1. Wheatland A
2. Westland A
3. Martin A
4. Combine Kafir-60 A
5. Redlan A
6. Dwarf Redlan A

Single Cross Steriles (Series 1)

1 x 5	Wheatland A x Redlan B
2 x 5	Westland A x Redlan B
3 x 5	Martin A x Redlan B
4 x 5	Combine Kafir-60 A x Redlan B
6 x 5	Dwarf Redlan A x Redlan B

Single Cross Steriles (Series 2)

1 x 6	Wheatland A x Dwarf Redlan B
2 x 6	Westland A x Dwarf Redlan B
3 x 6	Martin A x Dwarf Redlan B
4 x 6	Combine Kafir-60 A x Dwarf Redlan B
5 x 6	Redlan A x Dwarf Redlan B

The genetic constitution and agronomic characteristics of Wheatland (33), Westland (16), Martin 17), Combine Kafir-60 (18), Redlan (6) and Dwarf Redlan[3] have been reviewed and are not presented in this paper.

The materials were planted at the Agronomy Research Station, Perkins, Oklahoma on June 27, 1960 in rows fifty feet long and forty inches apart. The seed were hand dropped at a rate heavy enough to insure a good stand. After emergence the plots were thinned to two plants per foot.

A randomized block design with four replicates was used. Each replicate consisted of single row plots of each of the entries plus sufficient rows of the pollinator to insure maximum seed set.

Cultivation was accomplished with a tractor driven two-row cultivator. Two operations of this type were required during the growing season for control of weeds.

Corn earworms, Heliothis zea (Boddie) and sorghum webworms, Celama sorghiella (Riley), infested the heads at the milk to soft dough stage of maturity. Sevin (1-naphthyl methylcarbamate), a commercial wettable powder spray, was used for the control. The operation was accomplished by the use of a knapsack sprayer with an attached air tank to maintain sufficient nozzle pressure.

Adequate rainfall was received during the growing season, thereby eliminating the need for application of irrigation water. Table II shows the monthly distribution of rainfall during the 1960 growing season and the thirty year average. No excessively heavy rains occurred

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[3]J. B. Sieglinger, D. E. Weibel and F. F. Davies. Unpublished data. Okla. Agr. Exp. Sta., Stillwater, Oklahoma. 1961.

during the growing season, enabling maximum utilization of the precipitation received.

TABLE II

MONTHLY RAINFALL (INCHES), MAY TO SEPTEMBER, INCLUSIVE, AGRONOMY RESEARCH STATION, PERKINS.

Month	1960	Average 1931-60
May	6.06	4.86
June	2.09	4.48
July	5.40	3.15
August	3.14	3.01
September	1.22	3.60

The average temperatures during the critical period of July and August were favorable for grain sorghum production. The average daily temperature for July was 78.6° F. and for August was 79.7° F. These temperatures were considered within the optimal range during these periods. Harper[4] stated that the maximum optimal temperature for grain sorghum production is approximately 82.0° F. and temperatures above this maximum markedly lower grain yields. For favorable production, Martin (22) states that the minimum July temperature should be 75° F.

The grain yields were obtained by harvesting heads from a twenty-six foot segment of each entry row. The heads were placed in burlap bags and stored to facilitate drying. When dry, the heads were threshed and grain weights were obtained.

Statistical analyses (27) were made on grain yield, threshing percent, bushel weight, weight of 1000 seed, days to mid-bloom, days to

[4]H. J. Harper. Unpublished data. Okla. Agr. Exp. Sta., Stillwater, 1961.

maturity and plant height. Simple correlation coefficients for these characters were computed.

RESULTS AND DISCUSSION

For ease of discussion the male sterile varieties will be referred to as line steriles, the single crosses of line steriles x Redlan B as Series 1 and the single crosses of line steriles x Dwarf Redlan B as Series 2. Each line is identified by number as shown in Table I.

The mean values for the characters studied are presented in Table III. Analyses of variance for the characters are presented in Appendix Table I. In all cases the grain yields and threshing percentages of the line steriles were lower than those of Series 1 or Series 2. Series 2 had the highest mean for these characters. Bushel weights were generally higher in Series 1 and Series 2 than in the line steriles. Weights of a thousand seed varied somewhat with no definite trend. The number of days required to reach mid-bloom varied among the lines as did the number of days required to reach maturity. Those varieties which were earlier as line steriles also produced earlier progenies in Series 1 and Series 2. Plant heights varied among the line steriles. Likewise, the heights varied in the single cross steriles according to the male sterile and the B line used.

Bar graphs as illustrated in Figure 1 showed that the line steriles gave the lowest mean grain yield. The single crosses in Series 1 had somewhat higher mean yields than the line steriles but were lower than the single crosses in Series 2. These differences in yield might be

TABLE III

MEAN VALUES OF SEVEN AGRONOMIC CHARACTERS OF LINE STERILES AND SINGLE CROSS STERILES WHEN POLLINATED WITH Y-8

	Grain Yield lbs./A.	Thresh-ing Percent	Bushel Weight pounds	1000 seed Weight grams	Days to Mid-bloom	Days to Matu-rity	Plant Height inches
Wheatland A	2363	69.7	56.1	36.5	73	115	33
Wheatland A x Redlan B	3138	76.5	57.9	34.3	75	116	37
Wheatland A x Dwarf Redlan B	3325	76.0	57.5	35.7	72	115	35
Westland A	1750	66.1	58.3	30.5	75	116	41
Westland A x Redlan B	2900	76.0	59.1	31.1	75	116	41
Westland A x Dwarf Redlan B	3100	77.0	59.0	29.2	73	115	37
Martin A	2513	74.3	59.1	31.6	76	118	39
Martin A x Redlan B	3063	76.0	59.5	30.4	75	115	39
Martin A x Dwarf Redlan B	3038	75.2	58.4	29.8	73	115	38
Combine Kafir 60 A	2188	71.0	57.0	30.8	77	122	40
Combine Kafir 60 A x Redlan B	2338	72.4	57.4	32.6	75	116	37
Combine Kafir 60 A x Dwarf Redlan B	2763	73.4	57.6	32.0	73	115	37
Redlan A	2263	70.3	57.1	32.7	78	122	42
Redlan A x Dwarf Redlan B	2913	73.8	58.6	32.4	74	117	38
Dwarf Redlan A	2238	71.3	56.1	31.3	73	115	35
Dwarf Redlan A x Redlan B	2375	72.0	57.6	32.3	75	116	37
Least Significant Difference (.05 level)	467.7	4.4	1.2	2.4	1.5	1.1	1.4
Least Significant Difference (.01 level)	624.7	5.9	1.7	3.2	2.0	1.5	1.9

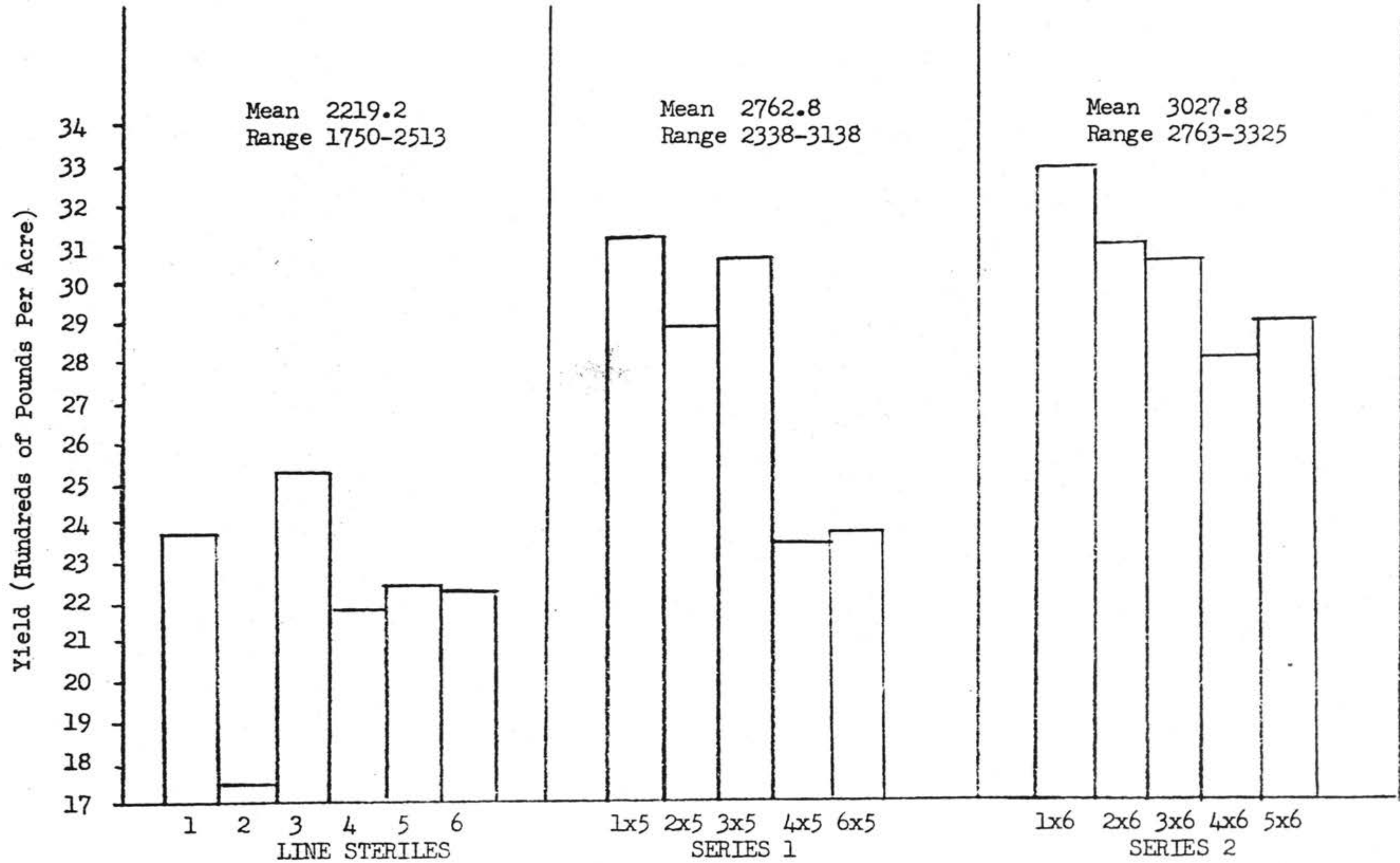

Figure 1. Bar graphs of means of grain yields for line steriles and single cross steriles when pollinated with Y-8.

attributed to the fact that Redlan is somewhat more closely related to the line steriles than is Dwarf Redlan. Therefore, crosses with Dwarf Redlan B as in Series 2 might be expected to exhibit a greater degree of vigor than crosses with Redlan B as in Series 1.

The threshing percentages of the line steriles varied among the varieties as shown in Figure 2. By comparison of the means, it can be seen that the threshing percentages were higher in Series 1 and 2 than in the line steriles. The threshing percentages obtained in Series 1 and 2 more nearly approached 75 percent, a figure considered average threshing percentage for grain sorghum. This factor, being closely related to grain yield (r = 0.888, Table IV), would be expected to vary as does yield. By comparison of Figure 1 and Figure 2, it can be seen that those lines with the lowest yield also have the lowest threshing percentage. These differences in threshing percentages are possibly due to a greater expression of vigor in Series 2 since Dwarf Redlan is more distantly related to the other line steriles.

Bushel weights were somewhat higher for Series 1 and Series 2 than for the line steriles. Figure 3 shows that those lines with lower bushel weights as line steriles resulted in the greatest increase in the single crosses. Since a close relationship exists with grain yield (r = 0.442) and with threshing percentage (r = 0.506) bushel weight would then be expected to vary with these factors.

Gram weights of seed are shown in Figure 4. There was a tendency for those lines having high weights as line steriles to express high weights in the single crosses. No marked increase or decrease occurred in the weights whether expressed in the line steriles or single crosses. Bushel weight was negatively correlated (r = -0.374) to this factor.

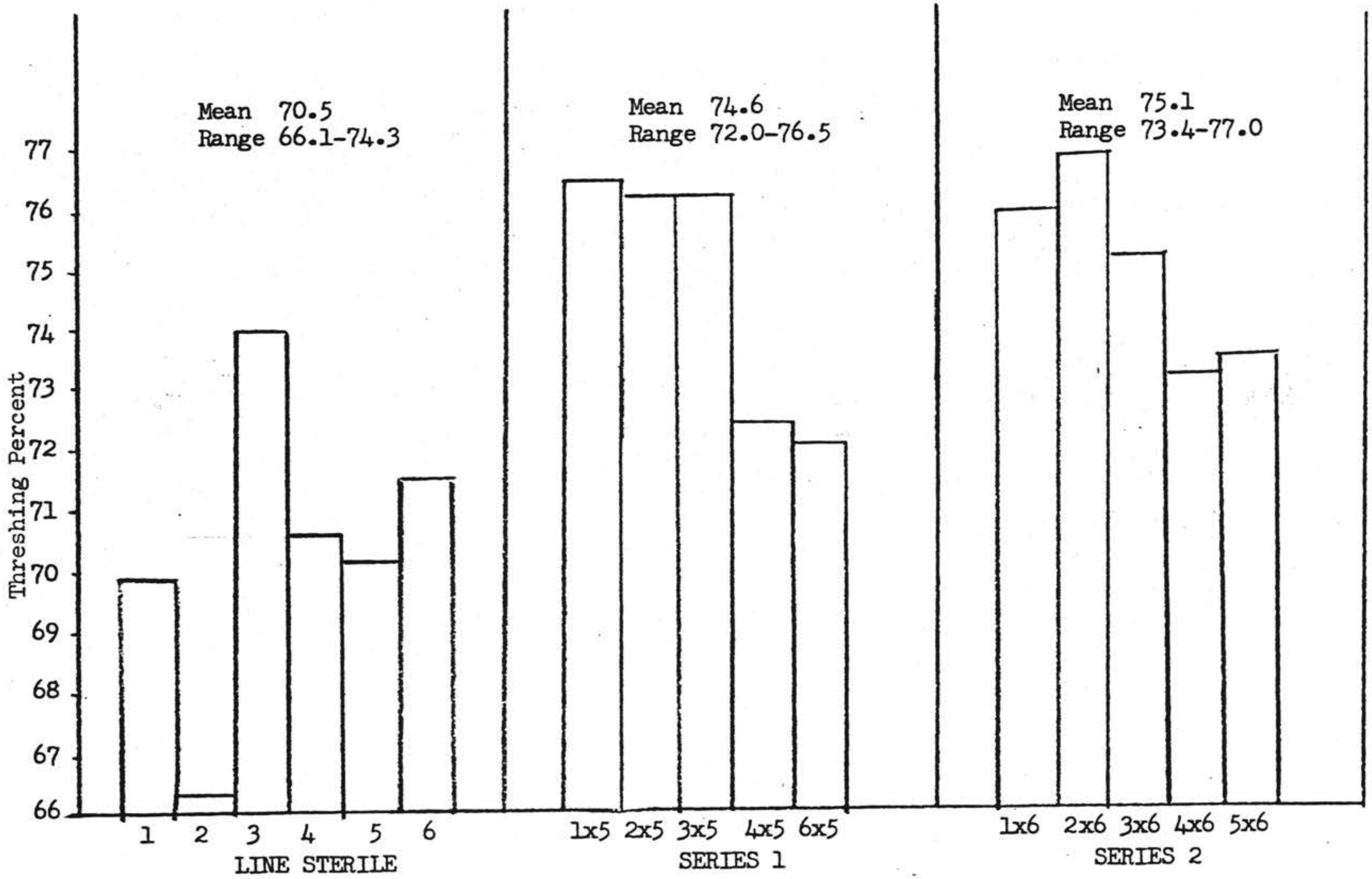

Figure 2. Bar graphs of means of threshing percent ages for line steriles and single cross steriles when pollinated with Y-8.

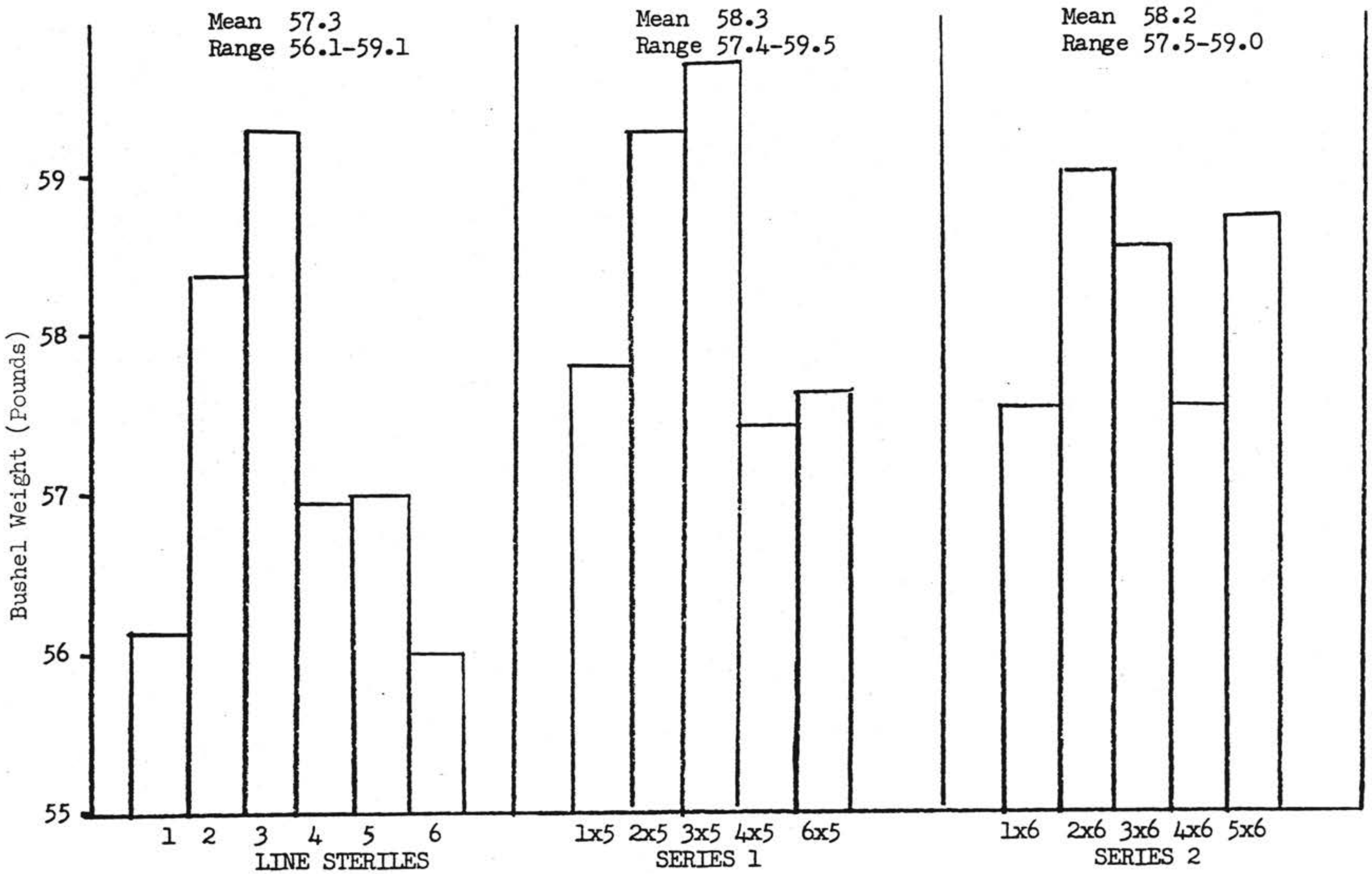

Figure 3. Bar graphs of means of bushel weights for line steriles and single cross steriles when pollinated with Y-8.

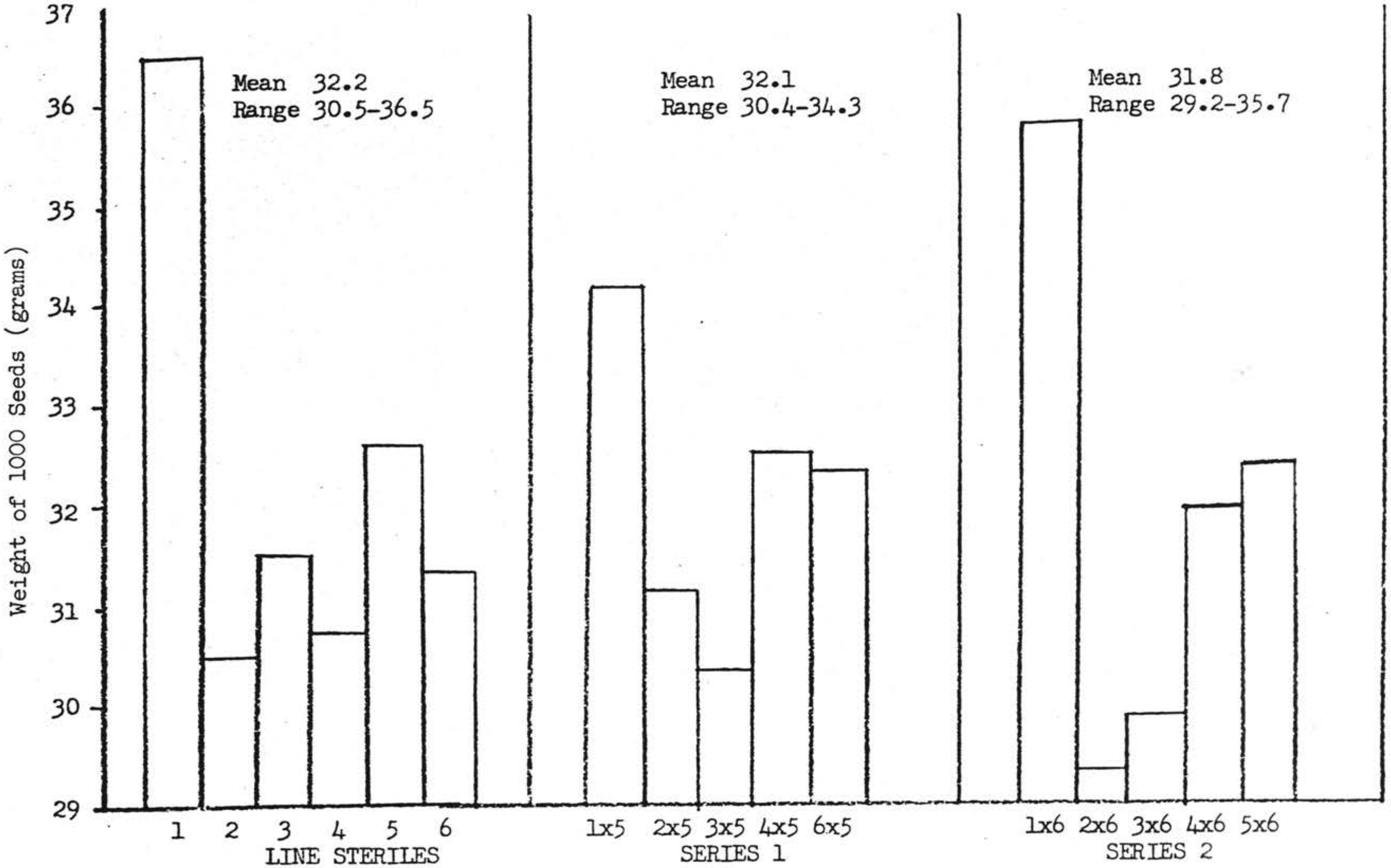

Figure 4. Bar graphs of means of 1000 seed weights for line steriles and single cross steriles when pollinated with Y-8.

This indicates that as bushel weight increased one thousand seed weight decreased.

Bar graphs for days to mid-bloom are presented in Figure 5. The earliest average bloom dates occurred in Series 2. Dwarf Redlan B, being earlier in blooming, than Redlan B, tended to produce earlier blooming progeny. The bloom date of the single crosses approached the bloom date of the early parent. No single cross was as late in blooming as the late parent.

Days required to reach maturity are presented in Figure 6. This factor was closely correlated with days to mid-bloom ($r = 0.803$) and performed somewhat like it. Greatest mean days to maturity were in the line steriles. The earliest mean days to maturity were in Series 2. The maturity dates of the single crosses approach the maturity date of the early parent.

No single cross was as late in maturity as the late maturing parent.

Mean plant heights of the lines are shown in Figure 7. The single crosses in Series 2 had the shortest mean heights. This was expected since Dwarf Redlan B is a short variety. These heights were comparable to the height desired for grain sorghum. Series 1 single crosses were slightly taller than the Series 2 single crosses and line steriles. The mean heights of the line steriles varied with the variety. Simple correlation coefficients of the seven characters were calculated. These values are presented in Table IV.

Grain yield was found to have a highly significant positive correlation with threshing percent and bushel weight, which coincides with the findings of Khan (20). Also a highly significant positive correlation was found between threshing percent and bushel weight.

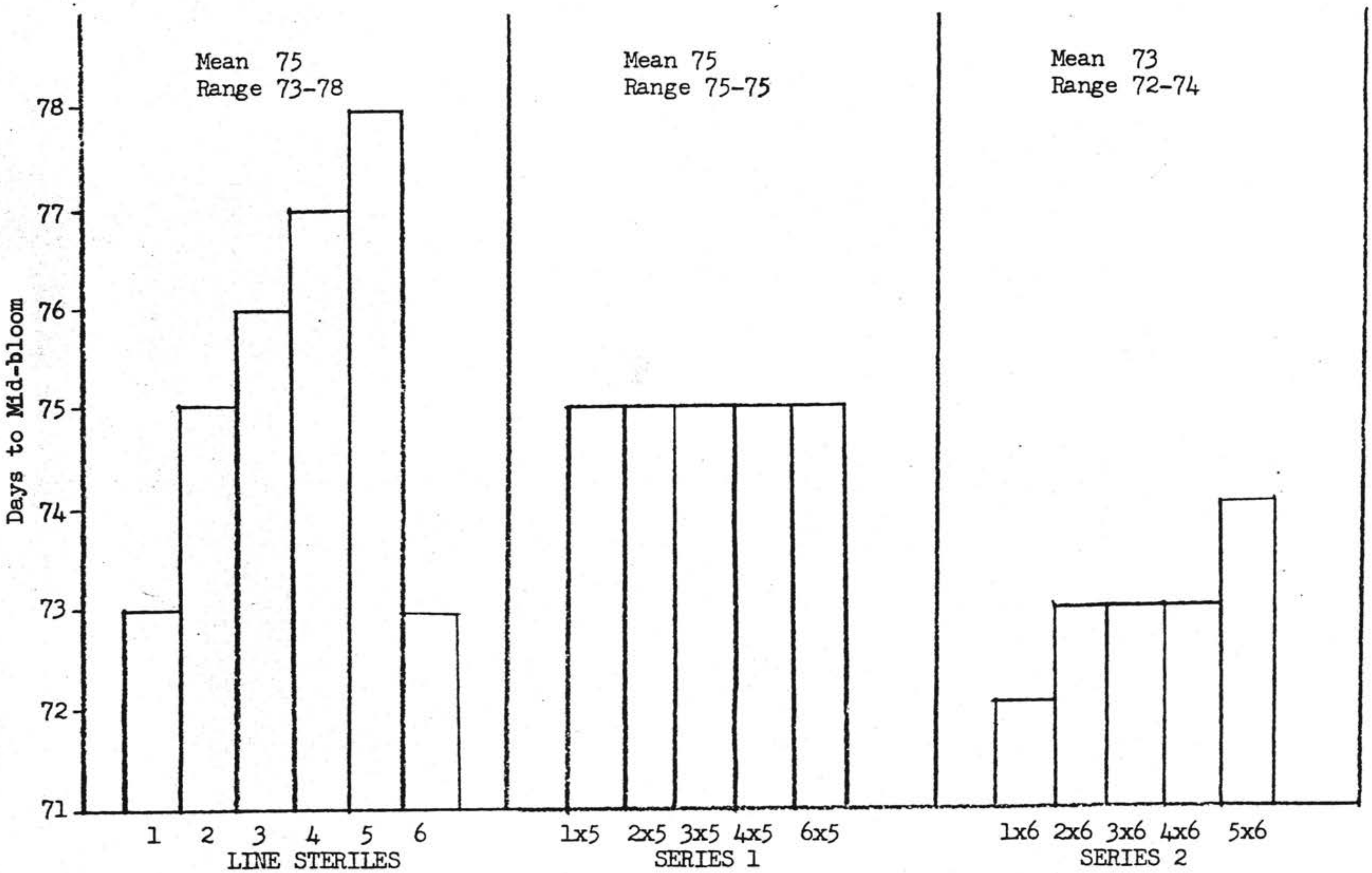

Figure 5. Bar graphs of means of days to mid-bloom for line steriles and single cross steriles when pollinated with Y-8.

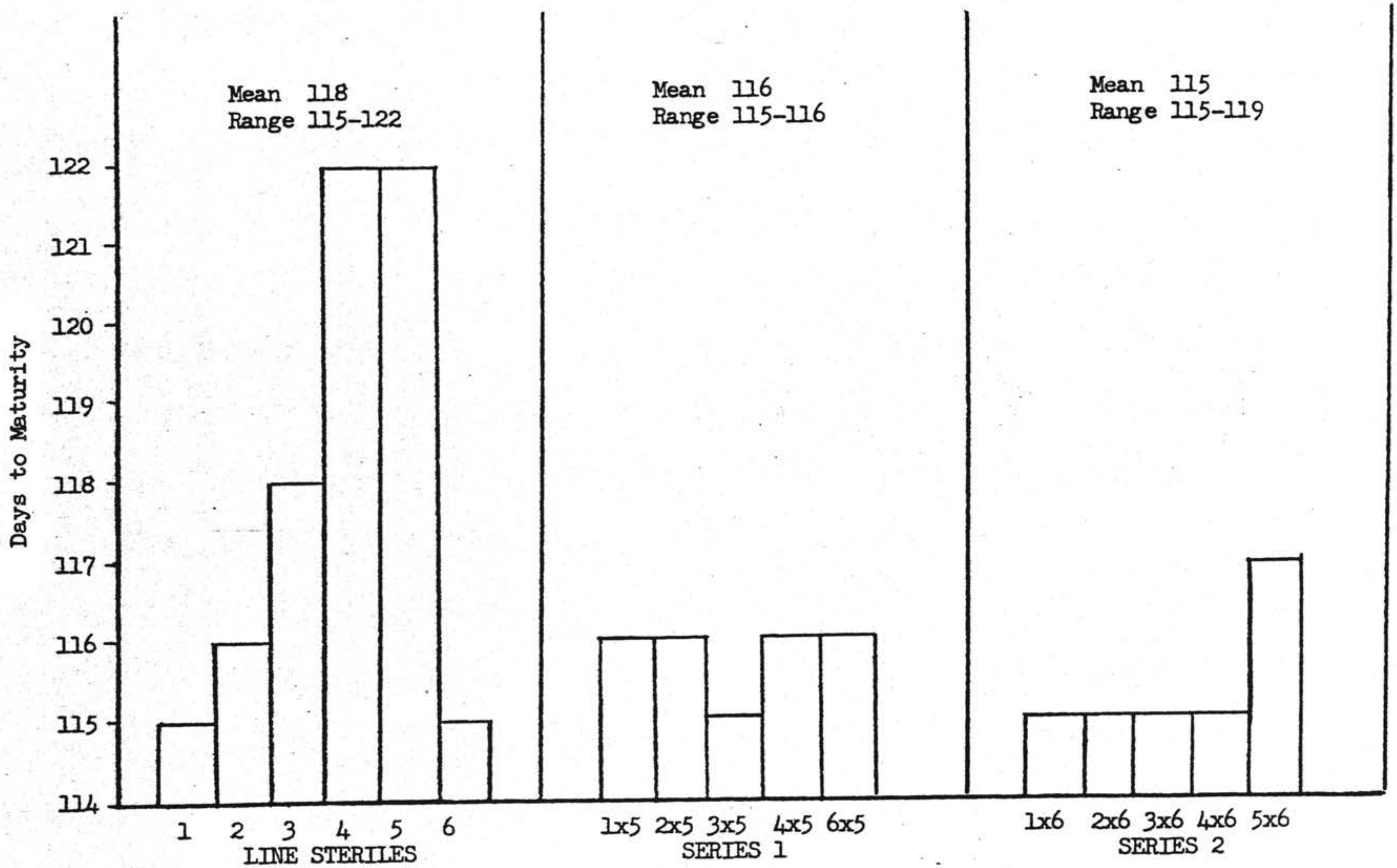

Figure 6. Bar graphs of means of days to maturity for line steriles and single cross steriles when pollinated with Y-8.

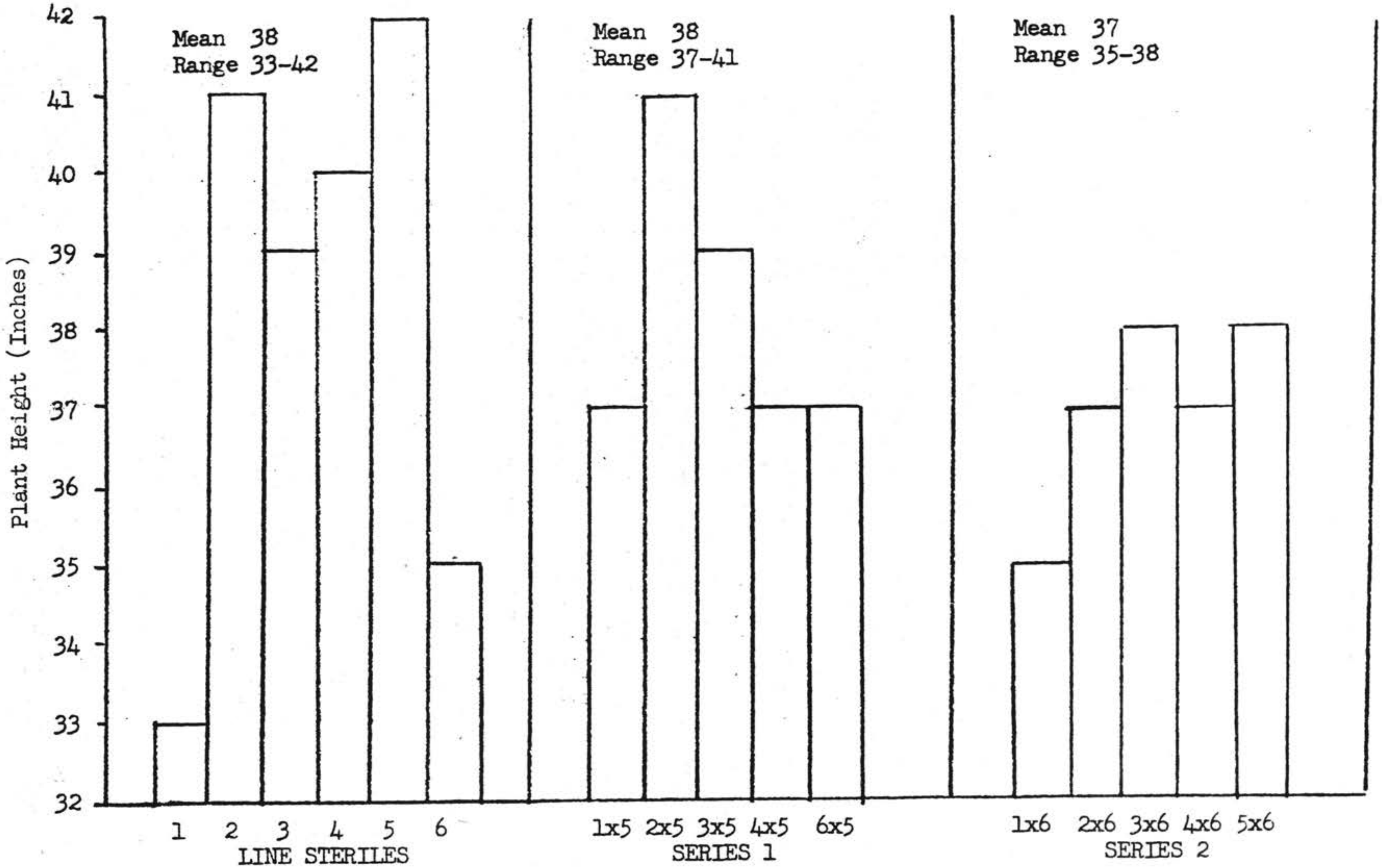

Figure 7. Bar graphs of means of plant heights of line steriles and single cross steriles when pollinated with Y-8.

TABLE IV

SIMPLE CORRELATION COEFFICIENTS FOR SEVEN AGRONOMIC CHARACTERS OF LINE STERILES AND SINGLE CROSS STERILES

	Grain Yield	Threshing Percent	Bushel Weight	1000 Seed Weight	Days to Mid-bloom	Days to Maturity
Threshing Percent	0.888**					
Bushel Weight	0.442**	0.506**				
1000 seed weight	-0.002	-0.058	-0.374**			
Days to Mid-bloom	-0.385**	-0.188	0.021	0.029		
Days to Maturity	-0.313*	-0.195	-0.113	0.028	0.803**	
Plant height	-0.222	-0.138	0.317*	-0.422**	0.608**	0.543**

*Significant at the 5 percent level
**Significant at the 1 percent level

These correlations indicated that as grain yield increased, threshing percent and bushel weight increased. Grain yield and days to mid-bloom were highly negatively correlated indicating that earlier blooming lines yield more. This is not always true (20). Days to maturity had a highly significant positive correlation in days to mid-bloom and a negative correlation with grain yield. This indicates that early blooming lines mature early and give a high yield.

Weights of 1000 seed had a high negative correlation with both bushel weight and plant height. Therefore, it appears that as height increased bushel weight increased and individual seed weight decreased. Highly significant positive correlations were found between plant height and days to mid-bloom as well as days to maturity. For this test indications were that as plant height increased days required to reach maturity and mid-bloom were increased.

SUMMARY AND CONCLUSIONS

A study of six line steriles and ten single cross steriles of grain sorghum was conducted during the 1960 growing season. The seven characters studied were: (1) Grain yield; (2) Threshing percent; (3) Bushel weight; (4) Weight of 1000 seed; (5) Days to mid-bloom; (6) Days to maturity; and (7) Plant height. These lines were grown in a randomized block design. Analyses of variance and correlation coefficients were calculated by appropriate methods.

The line steriles were lower in yield and threshing percent than the single crosses. Series 2 single crosses had a higher grain yield and threshing percent than the Series 1 single crosses. This was possibly the expression of vigor resulting from crossing distantly related lines.

In both Series 1 and 2 the greatest increase in yield resulted from those crosses (Wheatland A, Westland A, and Martin A) that were distantly related to Redlan B and Dwarf Redlan B. The remaining crosses resulted in less increase in yield.

Bushel weights were not increased markedly in the single crosses. Mean bushel weights for the single crosses were only about 1.0 pounds greater than the weights for line steriles. None of the lines had bushel weights that were below the accepted standard weight (56 pounds per bushel).

Weights of a thousand seed did not vary significantly from the line steriles to the single crosses. Those line steriles with high seed weights tended to produce single crosses that were also high. Those line steriles with low weights produced single crosses with low weights.

Days required to reach mid-bloom varied with the individual lines in the line steriles. The average bloom dates of the single crosses tended to approach the bloom date of the early parent. Series 2 single crosses bloomed approximately two days earlier than the Series 1 single crosses and line steriles.

The number of days required to reach maturity was greatest in the line steriles. The single crosses averaged 2 to 3 days earlier in maturity than the line steriles. The earliest maturing lines were those in Series 2 with the lines in Series 1 maturing about a day later.

Mean plant heights were lowest in the Series 2 single crosses. Mean plant heights of the Series 1 single crosses and the line steriles were an inch shorter. There was a tendency for the single crosses to approach the height of the shorter parent.

From data obtained in this study, there are indications that an increase in grain yield per unit area could be obtained from a male sterile single cross. However, before procedures could be outlined in detail, more extensive information should be obtained within this geographical area.

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APPENDIX

APPENDIX TABLE I

ANALYSES OF VARIANCE FOR SEVEN AGRONOMIC CHARACTERS OF LINE STERILES AND SINGLE CROSS STERILES

Source of Variation	Degrees of Freedom	Mean Squares						
		Grain Yield	Threshing Percent	Bushel Weight	Weight of 1000 seeds	Days to Mid-bloom	Days to Maturity	Plant Height
Replications	3	342122.38*	28.53*	1.68	28.62**	0.36	0.56	5.06**
Entries	15	794143.23**	35.96**	4.25**	15.22**	10.53**	17.95**	21.30**
Series 1 and 2 vs. Lines	1	6859710.93*	283.08**	14.14**	5.30	30.10**	69.88**	7.53**
Series 1 vs. Series 2	1	702250.00*	2.55	0.06	1.81	27.23**	2.03	21.03**
Within Series 1	4	580312.50**	19.04	36.13**	8.58*	0.43	0.33	10.25**
Within Series 2	4	177312.50	8.99	1.67	20.08**	2.30	1.55	5.20**
Within Line	5	263937.50*	28.33*	5.69**	21.31**	17.94**	37.97**	45.87**
Error	45	107872.40	9.62	0.76	2.88	1.08	0.65	0.98

*Significant at the 5 percent level.
**Significant at the 1 percent level.

VITA

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