INHERITENCE OF SEED SIZE IN SORGHUM HYBRIDS

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By

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TABLE OF CONTENTS

INTRODUCTION

The utilization of grain sorghum as a source of starch for human consumption and for industrial use has occurred during recent years and particularly during and since World War II.

The problem of growing larger sorghum seed by selecting large seed in early hybrid generations is of great concern to the sorghum breeder and producer. Many products such as edible oils, industrial wax, gluten, alcohols, and other feed by-products may be obtained from grain sorghums. The starch from sorghum may be converted into dextrose syrup (19)[1]. Larger sorghum seed containing these industrial qualities might be of great economical concern. These products may be of special value to the principal sorghum producing region in the southern half of the Great Plains.

The production of waxy-seeded sorghums in the United States as a source of waxy starch and other special starches has received considerable interest recently (16). Selection of large hybrid seed during the process of developing waxy-seeded strains offers possibilities to the plant breeder.

During the last 25 years much has been found concerning the inheritance of many of the characters in sorghum. The genetic factors influencing seed colors, endosperm character, seed-coat structure, maturity, height, plant color, juiciness, sweetness, head exertion, panicle shape, male sterility, diseases, and hybrid vigor have been determined (19). No extensive studies, however, have been made to determine the inheritance of seed size in sorghums. Studies in corn (9, 10), beans (4, 9), and flax (7, 14) indicate that the size of seed follows a multiple factor type of inheritance.

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[1] Figures in parenthesis refer to "Literature Cited", p. 30.

The primary objective of this investigation is to supplement information on seed size inheritance by studying weights of seed obtained from segregates in crosses of small- by large-seeded sorghums.

REVIEW OF LITERATURE

In a review of size characters, East (8) concluded that the variation seems to be continuous, but relatively constant graduations may be isolated, each fluctuating around a particular mode.

A method commonly used in studying seed size characters in maize (10) consists of crossing parents that differ rather widely in a given character, such as size of seed. A study is made of the F_1, F_2, and F_3 generations in comparison with the parents. As large a population as can be studied is grown in the F_2, and selected for the character desired. Recovery of the parental types may be obtained, as a rule, by continuing in the F_3 and in later segregation generations.

According to Hayes and Garber (11), Swanson at the Kansas Station found that the F_2 generation of a cross between Red Amber and feterita, produced 337 plants with small seed, 2,025 with intermediate seed and 286 with large seed. Hayes and Garber regarded Swanson's unpublished data as a type of segregation that is rather typical of the size character inheritance that is dependent upon several factors for its expression.

In a study of hybrid vigor in sorghums, Bartel (3) reported that the weight of 100 kernels in all crosses between 6 parents having different seed sizes was intermediate between the parents, or was as large as or larger than the large-seeded parent. The F_1 endosperm generation or the immediate cross gave the maximum effect of hybrid vigor on the kernel. Since many of the hybrids had large kernels in the F_2, he concluded that growth or vigor factors were still operating.

Ayyangar, et al (2) studying a hundred kernels for each of 6 representative sorghum varieties found that the range of variation of seed size in

sorghum varieties is very wide and that seed size (length by breadth by thickness) is highly correlated with seed weight. In correlation studies of a bean hybrid, Belling (4) found the length of seed to be correlated with breadth and to a lesser degree with the thickness of seed.

Heterosis, change in endosperm type, and size inheritance were found by Kiesselbach (13) in Nebraska to be the factors controlling the change in kernel weight of corn. Size inheritance had an effect not to exceed 1%. He concluded that in general the lower the heterozygosity the greater will be the immediate effect of foreign pollen upon kernel weight.

Collins and Kempton (5) found that by mixing pollen of a white-seeded and a colored maize and applying the mixture to the white variety that hybrid and pure kernels may be produced on the same ear. The hybrid kernels were from 3 to 21% heavier than the pure. In a similar study McCleur (15) found that hybrid maize kernels averaged 24.2% heavier than the parent kernels.

In 8 corn variety combinations involving 37 ears, Wolfe (21) found responses ranging from 13.45% decrease to 16.04% increase in kernel weight when mixing pollen from white- and yellow-seeded varieties. The various crosses produced a significant increase in weight in 56.8%, and a slight increase in 13.5% of the kernels, while 29.7% produced a decrease.

In a cross of small-seeded Queen's Golden pop corn with medium-seeded Black Mexican sweet, Emerson (9) reported that the kernels from F_1 ears where intermediate between the parents in size and showed no more variation than did either parent. Some of the F_2 ears had kernels as large as those of Black Mexican, while others were about the size of the F_1, and still others were intermediate between the F_1 and each of the parents.

The weight of F_1 seeds from the cross of Tom Thumb x Black Mexican

sweet was reported by Emerson and East (10) to be a little below the mid-parental weight. The ranges of variation of F_2 well overlapped the ranges of the parents but neither parental type was recovered. Allowance was made for the large Black Mexican seed because of previous mixtures of the strains. Other data (10) indicated that in the crosses of Missouri dent with California pop and with Tom Thumb the breadth of the kernels of both the F_1's were distinctly intermediate between the parents. Over 300 F_2's in each of the above crosses showed a markedly greater variability than the F_1's or the parents. Two F_3 lots of California pop with Tom Thumb, grown from small-seeded F_2 individuals, had seed practically as small as those of the small-seeded parent. Relative to the breadth of seed it was estimated that Missouri dent x Tom Thumb probably differed by not over 5 factors and that Missouri dent x California pop by as many as 6 factors.

Crosses involving all combinations of three varieties of beans differing in size and shape of seed were studied by Emerson (9) in Nebraska. The mean dimensions, mean shapes and weights and the coefficients of variation were calculated for the parents, F_1 and F_2. The mean weight of seed for the F_1 progeny was about the same as the mean of the parents and for the F_2 progeny it was higher than the mean weight of the parents. The coefficient of variation for the F_1 seed weight was only slightly higher than that of the parents, while in the F_2 it was usually twice as great as the parents. He concluded that F_1 hybrids were not breeding true as blends because the coefficients of variation for the F_2 were greater than that of the parents and F_1 hybrids. Also Emerson (9) found that large, round beans crossed with small, round ones produced large, medium and small, round beans in the F_1; whereas, large, long beans crossed with small, round ones produced an F_1 that was intermediate and a variable F_2. He concluded that the length and

breadth are not inherited independently and that the inheritance was quantitative.

According to Snyder (18), Johannsen reported that the first generation of selecting large and small seed from a mixed population of Princess beans produced large- and small-seeded progeny, respectively. These investigations on the variation of seed size when selecting the largest and the smallest beans to plant were found to produce progeny after the first generation with the same average seed size. Conklin (6) stated that Johannsen found strains of beans in which the average weight of the individual seed differed by 0.02 to 0.03 grams, yet these minute differences in weight were characteristic of each strain and were inherited.

In a cross between the Velvet and the Lyon beans, Belling (4) reported that the weights of F_2 seed were in accordance with what would be expected in a multiple factor interpretation. Other studies in beans (17) revealed that the factor differences for seed weight was linked with the eye factors, the eye pattern factors, and the factors influencing the color of pigment. In all crosses of large pigmented beans with small white beans the pigmented F_2 segregates had a mean seed weight greater than the white segregates.

Studies of the length of flax seed by Tammes were reported by Dillman (7) and Myers (14) to be dependent upon multiple (polymeric) factors. In the crosses of Linum angustifolium, which averaged 2.4 mm. in length, with Egyptian, averaging 6.1 mm., and with common flax, averaging 4.1 mm., the F_1 was nearly intermediate in every case. The F_2 population had a wider range in length of seed. Width of seed was also inherited on the basis of multiple factors. According to Myers (14), Tammes estimated in 1930 that probably 2, 3, or 4 factors were involved in the inheritance of length and width of flax seed.

Army and Garber (1) studied the relation between the weight of seed planted and the resultant yield in Marquis wheat. These investigators found that the average weight of kernels was substantially and fairly consistently correlated with yield of kernels, but that it was subject to radical changes due to environment.

Studies concerning the relation of size and weight of kernel to yield in the red winter wheat variety, Velvet Chaff, were made by Williams and Welton (20) in Ohio. The seed were separated mechanically by use of sieves and wind blast into heavy, medium and light seed. Seven years data indicated there was no appreciable advantage in rejecting the medium to small kernels of seed wheat provided the seed were free from disease. However, when the seed were hand-sorted and hand-planted in rows 1 foot apart in the field the results indicated that the large kernels had a tendency to produce large kernels.

MATERIALS AND METHODS

The study of seed size inheritance in sorghums was conducted at the Oklahoma Agricultural Experiment Station Farm at Perkins in 1948. The large- and small-seeded parents and F_1 heads used were furnished by Mr. J. B. Sieglinger, Agronomist, in charge of sorghum investigation at the Oklahoma Agricultural Experiment Station.

Cross no. 1, (Early Juicy x 692-1-3) X (Brown Kaoliang x Shattering Sudan-2), was made in the greenhouse in 1946. The large-sseded parent was selected from a cross between Early Juicy and 692-1-3 in the F_6 generation. Its average weight per 100 seed planted in 1948 was 3.80 grams. The small-seeded parent was selected from a cross between Brown Kaoliang and Shattering Sudan-2 in the F_4 generation, and its average weight per 100 seed was 1.43 grams.

Two F_1 heads (A and B) obtained from cross no. 1 were used to produce the F_2 generation. The seed of heads A and B averaged 2.80 and 2.82 grams per 100 seed respectively. A study was made of each parent and an F_1 head to determine the coefficient of variation within each head and the position of the largest and smallest seed in the head. Each of the heads was divided into 3 parts from the tip to the base and each individual branch was divided similarly into 3 sections. Sieve determinations and weights in grams per 100 seed were recorded for each portion of the head.

Circular sieves ranging from 11/64- to 7/64-inch were used to obtain the various size groups to be planted. Since Klages (12) had found that replicated single-row plots gave as reliable results with sorghums at the Oklahoma Agricultural Experiment Station as several rows replicated less frequently, the 2 parents and 5 size groups were each planted in single-

row plots at the rate of 100 seed in 25 feet.[12] All plots were planted in duplicate, except the size group 10-11/64-inch which had 4 plots, because of the large quantity of seed available in this size group.

Cross no. 2, Kaferita no. 811 x Witchweed Resistant kafir, was made in 1945 and the F_1 was produced at Perkins in 1946. A study was made of the F_1 head to determine the number of seed, percentage in each size group and the weight of seed in grams. The large-seeded parent was Kaferita no. 811. The small-seeded parent was Witchweed Resistant kafir, an introduction from Africa. Single-row plots 33 feet long were planted to the parents and to the 11+/64-, 10-11/64-, 9-10/64-, and the 8-9/64-inch size groups. The weights for the 100 seed planted in each plot were 3.47, 3.08, 4.08, 3.55, 2.83, and 1.98 grams respectively.

All plantings were made on May 15th in 42-inch rows. General cultural methods common to this region were practiced during the growing season. All plants were thinned to approximately 8 inches apart by June 30.

All parents and F_2 heads in cross no. 1 were self-pollinated by bagging before pollen shedding started. Each head was tagged, numbered, and date of bagging recorded. At the time of maturity the number of branch stalks produced by each main plant were recorded. Paper bags were left on the heads from the flowering period to maturity.

A total of 996 heads were bagged, but only 604 were harvested because of rain and wind damage during the growing season. The average coefficients of variation for all F_2 branch heads, all F_2 heads and the F_2 main heads from main stalks were 16.98, 15.03, and 14.96% respectively. On this basis only the 361 F_2 main heads and the 89 main heads from the 2 parents were used

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[12] Only 44 seed from head A and 89 from head B were available for planting in the 11+/64-inch size group.

in the calculations.

The parents and F_2 heads in cross no. 2 were bagged after fertilization. From each plot 20 heads were bagged to protect the heads from insect and bird damage.

Precipitation at Perkins Farm in 1948 for the months May, June, July, and August was 4.11, 6.93, 2.91 and 3.10 inches respectively. The 18-year average (1931-1948) for the same months was 4.20, 4.51, 2.21, and 3.58 inches respectively.

Harvesting and threshing were done by hand. Two-100 seed samples were taken at random from each threshed head and weighed. All weights were recorded in grams per 100 seed. The mean, standard deviation, and coefficient of variation were calculated for each of the parents and F_2 size groups. A separate analysis of variance was calculated on the F_2 data from heads A and B in cross no. 1 because the variances were not homogeneous. An anlysis of variance was also calculated for F_2 data obtained in cross no. 2.

EXPERIMENTAL RESULTS AND DISCUSSION

Seed Size Studies of Each Parent and F_1 in Cross No. 1 (Early Juicy x 692-1-3) X (Shattering Sudan-2)

Data obtained from a head of each parent and the F_1 (head A) grown in 1947 from cross no. 1 are presented in Table 1. The largest seed were found in the upper one-third of the heads and the smallest in the lower one-third. In the lower one-third of each head, the tips of the individual branches contained the largest seed, and the bottoms contained the smallest. In the middle one-third of each head, the centers contained the largest seed, but the portion containing the smallest seed varied from the tips of the individual branches in the parents to the bottoms in the F_1 head. The upper one-third varied as to the position of the largest and smallest seed in the individual branches.

The coefficients of variation for the seed within the heads of the large- and small-seeded parents and the F_1 (head A) were 6.85, 3.64, and 9.62% respectively. This indicates a higher degree of uniformity in size of seed between sections of the individual branches within the small-seeded parent than within the large-seeded parent and that the F_1 head varied more than either parent.

Sieve determinations from 11/64- to 7/64-inch were made of the F_1 heads, A and B. The average weights for head A were 3.87, 3.32, 2.81, 2.22, and 1.53 grams in each of the size groups. The corresponding weights for head B were 4.11, 3.48, 2.95, 2.32, and 1.57 grams. The average weights for head B were larger in each size group.

Head A had 39.31% and B had 34.89% or the largest percentage of their seed in the 9-10/64-inch size group. The 11/64-inch size group contained

Table 1.--A study of sections of the head and individual branches of each parent and F_1 in the cross, (Early Juicy x 692-1-3) X (Brown Kaoliang x Shattering Sudan-2) in 1947.

Division of individual branches	Section of head from top to base (average grams per 100 seeds)			Coefficient of variation within head
	Upper	Middle	Lower	
Large parent				
Tips	3.58	3.60	3.84	
Centers	3.82	3.95	3.56	
Bottoms	4.34	3.90	3.54	6.85%
Average	3.94	3.82	3.63	
Small parent				
Tips	1.42	1.37	1.41	
Centers	1.49	1.51	1.39	
Bottoms	1.45	1.46	1.36	3.64%
Average	1.47	1.46	1.38	
F_1 head A				
Tips	3.07	2.88	2.67	
Centers	3.13	2.90	2.52	
Bottoms	2.99	2.76	2.30	9.62%
Average	3.06	2.83	2.46	

the smallest number of seed with 1.12 and 2.20% respectively for heads A and B.

Seed Size Inheritance of F_2 in Cross No. 1

The number of heads, mean weight of two-100 seed samples, standard deviation, and coefficients of variation for the parents and the F_2 size groups from heads A and B in cross no. 1 are shown in Table 2. Basic data for these calculations are given in Tables 8, 9 and 10 (Appendix). The range for the average weights between the large- and small-seeded parent was 2.08 grams, while the range for the size groups within the F_2 progeny from heads A and B was only 0.43 and 0.17 gram respectively. Thus the ranges within the F_2 were considerably smaller than between the parents or within the F_1 seed planted. This tendency probably indicates a great number of factors for seed size or a great environmental influence or both in the F_2 progeny. All the mean weights in the F_2 size groups were greater than 2.49 grams or the mid-parental weight. Since the lowest average weight was 2.60 grams for head A and 2.89 grams for head B, a partial dominance of large seed is indicated.

The coefficients of variation for the parents in 1948 were about the same as those for the F_2 size groups in heads A and B. The greatest variation (16.60%) was found in the progeny from head B in the 11/64-inch size group. The variation in the corresponding size group from head A was 12.65%, which was the lowest for head A. The 7-8/64-inch size group of head A produced F_2 progeny with the greatest variation (15.68%). The corresponding size group for head B was 15.80%, but it ranked second. The lowest variation (12.32%) for head B was obtained from 10-11/64-inch size group. The variation for all F_2 from head A was 1.03% less than that from head B. The coefficients of vari-

Table 2.--Number of heads, mean weight of two-100 seed samples, standard deviation of the sample, and coefficients of variation for the parents and F_2 from heads A and B from the cross, (Early Juicy x 692-1-3(X (Brown Kaoliang x Shattering Sudan-2), grown at Perkins, Oklahoma in 1948.

Designation (size groups)	Number of heads	Mean weight (grams)[3]	Standard deviation of sample	Coefficient of variation (%)
Parents				
Large-seeded	24	3.53	0.5030	14.25
Small-seeded	65	1.45	0.2124	14.65
F_2 from head A				
11/64-inch	20	3.03	0.3834	12.65
10-11/64-inch	94	2.73	0.3937	14.42
9-10/64-inch	36	2.60	0.3421	13.16
8-9/64-inch	40	2.78	0.3755	13.51
7-8/64-inch	22	2.81	0.4405	15.68
Total	212	2.75	0.3975	14.00
F_2 from head B				
11/64-inch	34	3.06	0.5079	16.60
10-11/64-inch	34	2.95	0.3633	12.32
9-10/64-inch	34	2.89	0.3962	15.47
8-9/64-inch	21	3.06	0.4370	14.28
7-8/64-inch	26	2.90	0.4583	15.80
Total	149	2.96	0.4450	15.03

[3]Least significant difference of 0.17 and 0.26 gram at the 5 and 1% levels respectively for the F_2 from head A.

ation for the parents and F_2 are about the same as those obtained by Emerson and East (10) for hybrid weights of 25 corn seed.

A graphic presentation of the percentage of the total number of heads in each class for each of the parents and the F_2 progeny from heads A and B are shown in Figure 1. The small-seeded parent approximated a normal distribution with a range of 1.0 gram. The large-seeded parent had a lower mode and a wider range (2.0 grams) than the small-seede parent, but it approximated a normal distribution. The weights of the F_2 progeny from head A had a mode to the right of the mean with a range of 2.8 grams. The weights from head B gave a bimodal distribution with a narrower range (2.6 grams) than the progeny from head A. The extreme parental types were not recovered in 361 F_2 heads, but using 3.1 as the breaking point in the curve for the F_2 progeny from head A, 24.52% was like the large-seeded parent, while only 0.47% was like the small-seeded parent. With 3.3 as the breaking point in the curve for the F_2 progeny from head B, 27.51% was like the large-seeded parent, while none was recovered like the small-seeded parent. These data showing definite modes and a high percentage of recovery of the large-seeded parent would indicate that 1 major factor pair and possible several minor factor pairs influence the size of seed and again that there is a partial dominance of large seed in cross no. 1.

A frequency distribution of the average weights in grams for two-100 seed samples from each head is presented in Table 3. The large-seeded parent had the greatest number of progeny in the class centers 3.3 and 3.5, while the small-seeded parent had the greatest concentration in the class centers 1.3 and 1.5, indicating a wide difference in the size of seed of the two parents. The 11/64-inch size group from head A had the greatest concentration in the class centers 2.9 and 3.1, which was closer to the mean of the

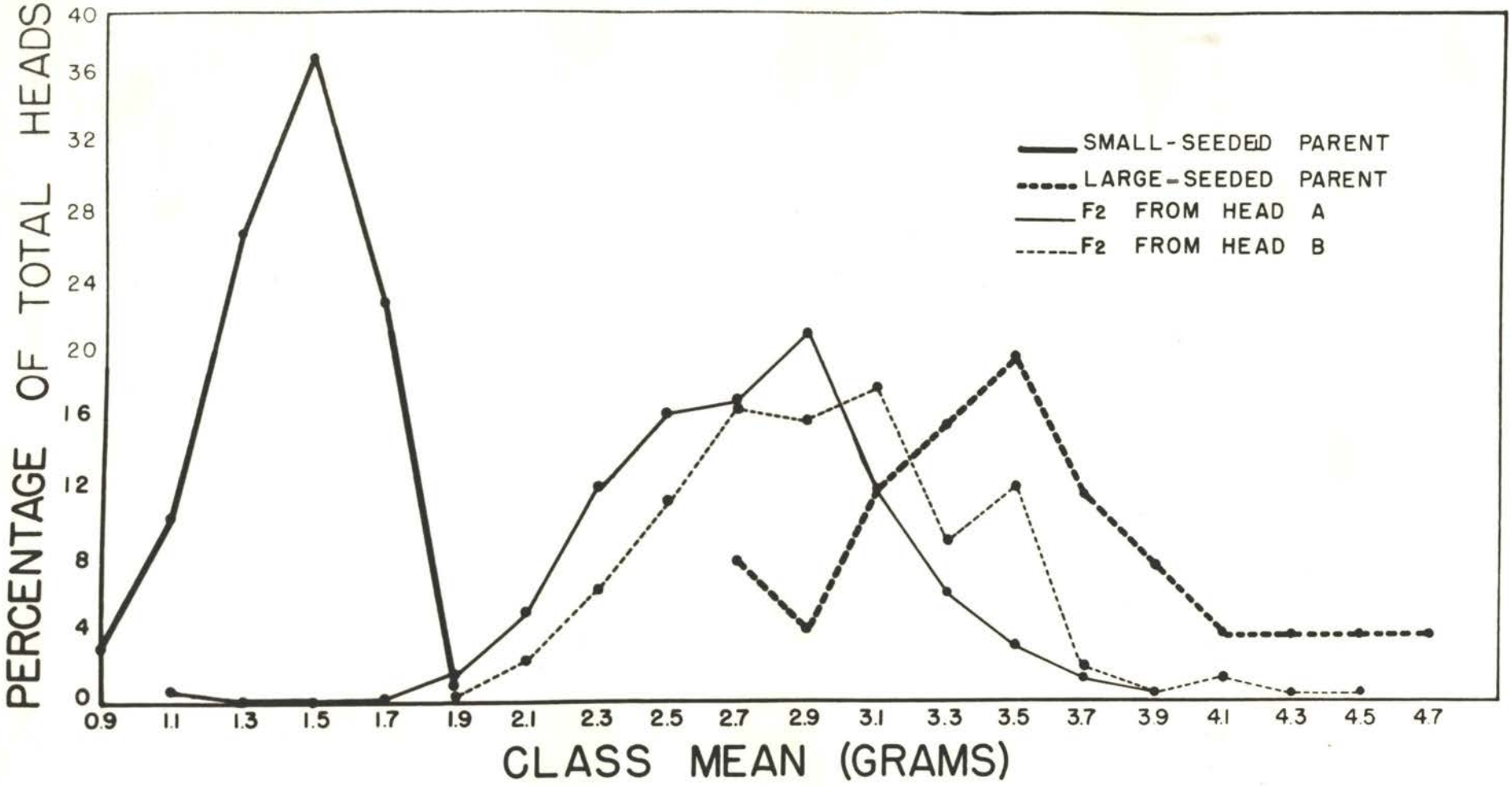

Figure 1.--Graphic presentation of the percentage of total heads of the parents and F_2 from heads A and B in the cross, (Early Juicy x 692-1-3) X (Brown Kaoliang x Shattering Sudan-2), in each class based on the weights of two-100 seed samples from each head. Grown at Perkins, Oklahoma in 1948.

Table 3.--Frequency distribution of average weight in grams of two-100 seed samples from individual heads of the parents and the F_2 in the cross of (Early Juicy x 692-1-3) X (Brown Kaoliang x Shattering Sudan-2) grown at Perkins, Oklahoma in 1948.

Designation	Class centers for average weights in grams per 100 seed																			No.	Av. Wt. (gms.)
	0.9	1.1	1.3	1.5	1.7	1.9	2.1	2.3	2.5	2.7	2.9	3.1	3.3	3.5	3.7	3.9	4.1	4.3	4.5	4.7	
Parents																					
Large-seeded										2	1	3	4	5	3	2	1	1	1	1	24	3.53
Small-seeded	2	7	17	23	15	1															65	1.45
F_2 head A (inches)																						
11/64-							1	2	2	6	4	1	1	3							20	3.03
10-11/64		1	0	0	0	1	4	13	15	19	19	12	5	5							94	2.73
9-10/64						1	5	4	10	6	7	2	0	1							36	2.60
8-9/64							1	7	6	7	10	4	4	0	0	1					40	2.78
7-8/64						1	1	2	3	3	3	4	4	1							22	2.81
Total		1	0	0	0	3	11	27	36	37	45	26	14	8	3	1					212	2.75
F_2 head B (inches)																						
11/64-							1	1	5	4	6	5	3	6	1	0	0	1	1		34	3.06
10-11/64-							1	3	2	5	7	7	6	3							34	2.95
9-10/64-						1	1	2	5	7	3	8	3	3	0	0	1				34	2.89
8-9/64-								1	2	3	6	2	0	4	2	1					21	3.06
7-8/64-							1	3	3	6	2	5	2	3	0	0	1				26	2.90
Total						1	4	10	17	25	24	27	14	19	3	1	2	1	1		149	2.96

large-seeded parent than that of the small-seeded parent. The 10-11/64-inch size group of head A had the greatest number of progeny in the class centers 2.7 and 2.9, while the class center 2.5 contained the greatest number of progeny for the 9-10/64-inch size group. The one head in the 1.1 class center is an extreme variation in the size group 10-11/64-inch and probably was caused by environmental influences, genes for small seed and/or chance variation. In the first 3 size groups from head A there was a tendency for the mode to be near the small-seeded parent as the size of the seed planted decreased. This was not the case, however, when size groups 8-9/64- and 7-8/64-inch were considered. Thus it would seem that the smallest seed planted were small because of environmental influences rather than genetical.

The F_2 progeny from head B exhibited considerable variation when the number in each class center was considered. Except for the tendency to resemble the large parent more closely, head B produced progeny with about the same class center limits as head A. Each size group in head A and B produced more progeny above the class center 2.5 or the mid-parental class than below.

The analyses of variance for the F_2 data obtained from heads A and B are presented in Table 4. Basic data for these calculations are given in Tables 8 and 9 (Appendix). The F_2 progeny from head A showed a highly significant difference between the weights obtained from the various size groups. Progeny from head B, however, did not show a significant difference between weights in the various size groups. A separate analysis of variance was calculated for the F_2 progeny obtained from heads A and B in cross no. 1, because the variances were not homogeneous. Since head B contained larger seed than head A in the F_1 and produced larger seed in the F_2, it would seem that head B contained a factor or factors for larger seed and consequently

Table 4.—Analyses of variance of the data obtained from 5 different seed size groups from heads A and B of the F_2 progeny in the cross, (Early Juicy x 692-1-3) X (Brown Kaoliang x Shattering Sudan-2), grown at Perkins, Oklahoma in 1948.

Source of variation	D. F.	Sum of squares	Mean square	F value
Head A				
Total	211	33.3966		
Size groups	4	2.5467	0.6367	4.27**
Within groups (error)	207	30.8499	0.1490	
Head B				
Total	148	29.3101		
Size groups	4	0.7772	0.1943	0.98
Within groups (error)	144	28.5329	0.1981	

**Significant at the 1% level.

the population consists of a larger number of different genotypes than the F_2 population from head A.

A least significant difference of 0.17 and 0.26 gram at the 5 and 1% levels respectively for the F_2 from head A was calculated using 42 as the average number of samples in each size group. The mean weight of the 11/64-inch size group was significantly larger than the 10-11/64- and 9-10/64-inch size groups at the 1% level and significantly larger than the 4 smaller size groups at the 5% level. The 9-10/64-inch size groups was significantly smaller than the 8-9/64- or 7-8/64-inch size groups at the 5% level. These results indicate that the largest seed planted produced the largest seed, but that the smallest seed planted did not produce the smallest seed. The size groups 8-9/64- and 7-8/64-inch undoubtedly contained genes for large seed but environmental influences seem to prevent maximum expression.

Seed Size Inheritance of F_2 in Cross No. 2 (Kaferita No. 811 x Witchweed Resistant Kafir)

The number of heads, mean weight of two-100 seed samples, standard deviation, and coefficients of variation for the parents and the F_2 size groups in cross no. 2 are presented in Table 5. Basic data for these calculations are given in Table 10 and 11 (Appendix). The range of the mean weights between the large- and small-seeded parents in 1948 was 0.81 gram, indicating a small difference in the size of seed. The mean weights for the F_2 size groups were all lower than 3.35 grams or the mean weight of the mid-parent. The largest seed planted produced F_2 seed with the highest mean weight, while the smallest seed planted produced F_2 seed with the lowest mean weight.

The low coefficients of variation of 4.38% for the large-seeded parent

Table 5.--Number of heads, mean weight of two-100 seed samples, and coefficients of variation for the parents and the F_2 from the cross, Kaferita no. 811 x Witchweed Resistant kafir, grown at Perkins, Oklahoma in 1948.

Designation (size groups)	Number of heads	Mean Weight (grams)[14]	Standard deviation of sample	Coefficient of variation
Parents				
Kaferita no. 811	20	3.76	0.1646	4.38
Witchweed Resistant kafir	20	2.95	0.0851	2.88
F_2 Size groups				
11/64-inch	20	3.15	0.3240	10.28
10-11/64-inch	20	3.13	0.3271	10.45
9-10/64-inch	20	3.11	0.2644	8.50
8-9/64-inch	20	2.89	0.2439	8.44
Total	80	3.07	0.3028	9.86

[14] Least significant difference of 0.18 gram at the 5% level for the F_2.

and 2.88% for the small-seeded parent indicate a high degree of homozygosity in the parents. The 10-11/64-inch size group produced the highest coefficient of variation, but only slightly higher than the 11/64-inch size group. There was only 2.01% less variation in the smallest size group than in the largest. Since the F_1 head was threshed in bulk no coefficient of variation could be calculated; hence the variation of the parents and the F_2 progeny give only a comparison of the material grown in the same season.

A graphic presentation of the number of heads of the parents and the F_2 progeny in each class from cross no. 2 is shown in Figure 2. The small-seeded parent had a range of 0.2 gram because of the low number of heads and/or a high degree of homozygosity. The large-seeded parent had a range of 0.6 gram and approximated a normal curve. The curve for the 80 F_2 progeny had a range that overlapped the large-seeded parent and extended below the lesser extreme of the small-seeded parent. Since 48.75% of the progeny was within the range of the small-seeded parent, it would seem, though the population is small, that possibly 2 or more factor pairs influence size of seed.

The frequency distribution of the average weights in grams for two-100 seed samples from each head is presented in Table 6. The large-seeded parent had the greatest number of progeny in the class center 3.7 with about equal distribution on either side. The small-seeded parent having only two class centers was extremely homozygous as 80% of the individuals fell in the class center 2.9. The size groups 11/64- and 10-11/64-inch produced F_2 progeny within the same class centers. Thus it would seem that selecting for seed size by mechanical methods does not necessarily mean that one was selecting genes influencing the size of seed. Considering the progeny from the 9-10/64-inch group, however, the mode changes toward the small-seeded

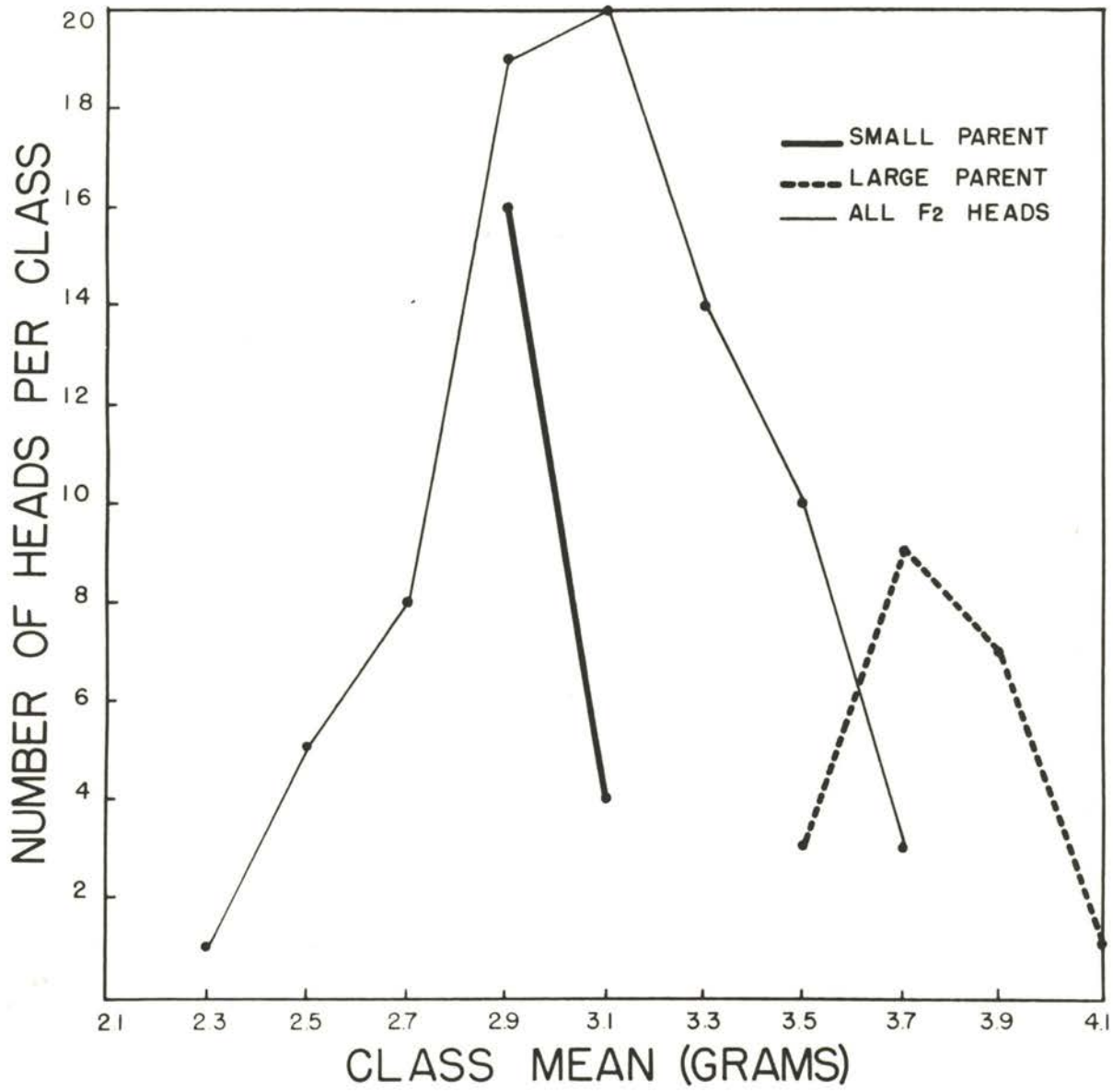

Figure 2.—Graphic presentation of the number of heads of the parents and F_2 progeny from the cross, Kaferita no. 811 x Witchweed Resistant kafir, in each class based on the weights of two-100 seed samples from each head.

Table 6.--Frequency distribution of average weight in grams of two-100 seed samples from individual heads of parents and F_2 in the cross of Kaferita no. 811 x Witchweed Resistant kafir, grown at Perkins, Oklahoma in 1948.

Designation	Class centers for av. wts. of two-100 seed samples										No. of heads	Av. Wt. (gms.)
	2.3	2.5	2.7	2.9	3.1	3.3	3.5	3.7	3.9	4.1		
Parents												
Large-seeded							3	9	7	1	20	3.76
Small-seeded				16	4						20	2.95
F_2 Size groups												
11/64-inch		1	2	3	6	3	4	1			20	3.15
10-11/64-inch		1	2	4	3	6	2	2			20	3.13
9-10/64-inch			2	6	4	4	4				20	3.11
8-9/64-inch	1	3	2	6	7	1					20	2.89
Total	1	5	8	19	20	14	10	3			80	3.07

parent. In the 8-9/64-inch group there was a marked shift in range toward the small-seeded parent. It would seem here that some selection of genes for smaller size had taken place. For a summary of the F_2 progeny, the smallest class center for the small-seeded parent was recovered 19 times, while the largest class center for the large-seeded parent was not recovered. Although the number of F_2 progeny was small, the data show a transgressive segregation beyond the small-seeded parent in cross no. 2.

An analysis of variance of the F_2 progeny is presented in Table 7. Basic data for this calculation are given in Table 11 (Appendix). The analysis of variance for the F_2 in cross no. 2 indicates a significant difference between size groups.

The least significant difference at the 5% level was 0.18 gram. The mean weights of size groups 11+/64-, 10-11/64-, and 9-10/64-inch are significantly larger than the mean weight of the size groups 8-9/64-inch, but the 11+/64-inch group was not significantly larger than the 10-11/64- or the 9-10/64-inch size groups. There was a tendency for the 3 largest size groups to produce significantly larger seed than the smallest size group. Although there was a slight tendency for the 3 larger size groups to produce smaller seed as the size of seed planted decreased the least significant difference at the 5% level indicated that the differences in the mean weights were not significant.

Table 7.—Analysis of variance of the data obtained from 4 different seed size groups of the F_2 progeny in the cross, Kaferita no. 811 x Witchweed Resistant Kafir, grown at Perkins, Oklahoma in 1948.

Source of variation	D. F.	Sum of squares	Mean square	F value
Total	79	7.3337		
Size groups	3	0.8477	0.2826	3.33*
Within groups (error)	76	6.4860	0.0853	

*Indicates significance at the 5% level.

SUMMARY AND CONCLUSIONS

A study of the mode of inheritance of seed size in sorghum hybrids was conducted at the Oklahoma Agricultural Experiment Station Farm at Perkins in 1948. Definite conclusions concerning inheritance cannot be made without more information about the F_1 and additional observations of several sorghum hybrids in later generations. From one year's data, however, the following conclusions concerning the cross of (Early Juicy X 692-1-3) X (Brown Kaoliang x Shattering Sudan-2) were drawn:

1. The largest seed were found in the upper one-third of the head and the smallest in the lower one-third. It was in the lower one-third that the tips of the individual branches contained the largest seed and the bottoms contained the smallest. In the middle and upper one-third, however, the position of the largest and smallest seeds varied in the individual branches.
2. The coefficient of variation was less for the main heads from the main stalks than for the branch heads.
3. The homogeneity of variance test indicated that the two F_1 heads used for seed had significantly different variances. Head B contained larger seed than head A in the F_1 and produced larger seed in the F_2, thus head B probably contained a factor or factors for larger seed and consequently the population consists of a larger number of different genotypes than the F_2 population from head A.
4. The mean weights of the F_2 progeny size groups were greater in all cases than that of the mid-parent. Since the lowest average weights for heads A and B were 2.60 and 2.89 grams respectively,

and the mid-parental weight was 2.49 grams there would appear to be partial dominance of large seed.

5. The parents showed about as much variation as the progeny from the F_2 size groups in 1948.
6. A partial dominance of large seed was indicated because the modes of the F_2 progeny from heads A and B definitely approached that of the large-seeded parent. The definite modes and high percentage of recovery of the large-seeded parent in the F_2 indicated that 1 major factor and possible several minor factor pairs influence the size of seed.
7. In the first 3 size groups from head A there was a tendency for the mode to be near the small-seeded parent as the size of seed planted decreased. Since this was not the case when the two smaller size groups were considered, it would seem that the smallest seed planted were small because of environmental influence rather than genetical.
8. A separate analysis of variance indicated a highly significant difference between the size groups from head A, but not between the size groups from head B. A least significant difference of 0.17 and 0.26 gram at the 5 and 1% levels for head A indicated that the progeny from the 11/64-inch size group was significantly larger than the mean of all size groups and for each of the other 4 size groups at the 1% level.

From one years data in the cross, Kaferita no. 811 x Witchweed Resistant kafir, the following conclusions were made:

1. The largest seed planted produced F_2 progeny with the largest seed and there were corresponding decreases through the size groups to

the smallest seed planted which produced the smallest seed, but the differences in seed weights were not so pronounced as the seed planted.

2. Low variances for the parents indicated a high degree of homozygosity.

3. In view of comparatively small numbers of the parents and F_2 progeny, it is possible to have chance deviates, but with 17.50% of the F_2 individuals beyond the extreme of the small-seeded parent transgressive segregation was indicated.

4. Possibly 2 or more factor pairs influenced size of seed in cross no. 2 since 17.50% of the F_2 were transgressing, 48.75% were like the small-seeded parent, 17.50% were intermediate, and 16.33% were like the large-seeded parent.

5. A least significant difference of 0.18 gram at the 5% level indicated that the progeny from the 8-9/64-inch size group was significantly smaller than each of the 3 larger size groups, but that the differences in the mean weights among the 3 largest size groups were not significant.

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A P P E N D I X

Table 8.--Average weights in grams of two-100 seed samples obtained from each F_2 head in the cross, (Early Juicy x 692-1-3) X (Brown Kaoliang x Shattering Sudan-2), grown from head A at Perkins, Oklahoma in 1948.

11/64-inch	10-11/64-inch			9-10/64-inch	8-9/64-inch	7-8/64-inch
2.30	1.19	2.38	2.53	2.00	2.12	1.89
2.45	1.95	2.38	2.53	2.08	2.21	2.10
2.51	2.22	2.48	2.54	2.11	2.22	2.24
2.62	2.26	2.49	2.58	2.13	2.28	2.29
2.80	2.32	2.52	2.59	2.18	2.32	2.52
2.88	2.38	2.55	2.62	2.20	2.33	2.52
2.94	2.42	2.62	2.62	2.22	2.34	2.60
2.95	2.45	2.72	2.72	2.33	2.34	2.62
2.97	2.47	2.73	2.74	2.36	2.44	2.65
2.99	2.62	2.73	2.81	2.38	2.45	2.67
3.00	2.62	2.74	2.83	2.45	2.57	2.84
3.10	2.66	2.75	2.84	2.46	2.57	2.85
3.12	2.67	2.79	2.85	2.48	2.59	2.91
3.16	2.69	2.82	2.85	2.49	2.60	3.02
3.17	2.69	2.83	2.85	2.52	2.63	3.10
3.25	2.76	2.88	2.87	2.51	2.69	3.14
3.45	2.77	2.95	2.93	2.53	2.70	3.19
3.61	2.86	2.96	3.04	2.54	2.73	3.25
3.61	2.87	3.00	3.09	2.57	2.74	3.29
3.70	2.91	3.01	3.11	2.58	2.76	3.34
	2.91	3.07	3.12	2.65	2.77	3.39
	2.93	3.09	3.13	2.66	2.86	3.44
	3.07	3.40	3.15	2.66	2.86	
	3.09	3.44	3.15	2.70	2.87	
	3.22	3.48	3.24	2.75	2.88	
	2.14	2.11	3.33	2.79	2.88	
	2.15	2.15	3.39	2.81	2.90	
	2.26	2.33	3.47	2.85	2.92	
	2.30	2.34	3.57	2.86	2.94	
	2.31	2.41	3.58	2.87	2.95	
	2.34	2.43		2.92	2.98	
	2.37	2.50		2.96	3.05	
				2.99	3.11	
				3.18	3.18	
				3.19	3.19	
				3.53	3.22	
					3.23	
					3.35	
					3.40	
					3.86	
Av. wt. 3.03		2.73		2.60	2.78	2.81
No. heads 20		94		36	40	22

Table 9.--Average weights in grams of two-100 seed samples obtained from each F_2 head in the cross, (Early Juicy x 692-1-3) X (Brown Kaoliang x Shattering Sudan-2), grown from head B at Perkins, Oklahoma in 1948.

11/64-inch	10-11/64-inch	9-10/64-inch	8-9/64-inch	7-8/64-inch
2.15	2.08	2.00	2.35	2.12
2.40	2.36	2.20	2.43	2.28
2.45	2.37	2.23	2.57	2.29
2.47	2.39	2.27	2.64	2.35
2.52	2.53	2.52	2.76	2.50
2.54	2.58	2.52	2.79	2.55
2.55	2.64	2.56	2.81	2.58
2.66	2.65	2.57	2.82	2.66
2.73	2.66	2.57	2.84	2.67
2.78	2.72	2.62	2.90	2.68
2.78	2.78	2.64	2.98	2.78
2.81	2.81	2.65	2.99	2.78
2.83	2.83	2.68	3.04	2.80
2.83	2.90	2.70	3.08	2.85
2.93	2.90	2.73	3.42	2.89
2.98	2.94	2.76	3.46	3.07
3.00	2.95	2.81	3.52	3.08
3.01	2.97	2.86	3.53	3.08
3.04	3.02	2.92	3.70	3.08
3.09	3.03	3.01	3.71	3.20
3.14	3.05	3.02	3.82	3.27
3.18	3.12	3.07		3.36
3.24	3.15	3.10		3.42
3.27	3.16	3.12		3.49
3.38	3.20	3.12		3.50
3.41	3.26	3.13		4.11
3.42	3.31	3.17		
3.42	3.32	3.27		
3.44	3.31	3.35		
3.48	3.39	3.40		
3.48	3.40	3.43		
3.71	3.44	3.49		
4.27	3.48	3.49		
4.51	3.50	4.16		
Av. Wt. 3.06	2.95	2.89	3.06	2.90
No. heads 34	34	34	21	26

Table 10.--Average weights of two-100 seed samples from each head of the 4 parents grown at Perkins, Oklahoma in 1948.

Early Juicy x 692-1-3	Brown Kaoliang x Shattering Sudan-2		Kaferita no. 811	Witchweed Resistant kafir
2.74	1.06	1.00	3.74	2.85
2.78	1.06	1.00	3.77	2.85
2.97	1.17	1.06	3.85	2.86
3.06	1.23	1.16	3.48	2.87
3.08	1.29	1.20	3.49	2.88
3.16	1.29	1.20	3.54	2.88
3.36	1.30	1.24	3.64	2.88
3.73	1.31	1.26	3.66	2.90
3.84	1.37	1.28	3.68	2.91
4.16	1.38	1.30	3.69	2.91
4.42	1.39	1.30	3.71	2.95
3.22	1.41	1.32	3.72	2.95
3.26	1.42	1.35	3.77	2.96
3.41	1.44	1.35	3.81	2.97
3.43	1.45	1.37	3.83	2.99
3.46	1.45	1.42	3.88	2.99
3.53	1.46	1.43	3.96	3.07
3.54	1.50	1.43	4.00	3.09
3.64	1.50	1.52	4.00	3.09
3.70	1.51	1.54	4.06	3.11
3.96	1.53	1.56		
4.36	1.54	1.59		
4.65	1.55	1.59		
	1.57	1.65		
	1.58	1.65		
	1.59	1.68		
	1.62	1.69		
	1.70	1.71		
	1.70	1.75		
	1.72	1.77		
	1.75	1.78		
	1.77	1.82		
	1.79			
Av. Wt. 3.53		1.45	3.76	2.95
No. 24 heads		65	20	20

Table 11.--Average weights of two-100 seed samples for 20 heads in each F_2 size group in the cross between Kaferita no. 811 x Witchweed Resistant kafir grown at Perkins, Oklahoma in 1948.

11+/64-inch	10-11/64-inch	9-10/64-inch	8-9/64-inch
2.57	2.41	2.63	2.38
2.72	2.67	2.68	2.53
2.73	2.70	2.85	2.56
2.82	2.82	2.87	2.60
2.85	2.86	2.88	2.64
2.89	2.91	2.93	2.80
3.02	2.97	2.97	2.84
3.05	3.06	3.00	2.87
3.06	3.12	3.07	2.88
3.15	3.16	3.06	2.91
3.16	3.24	3.09	2.92
3.19	3.24	3.14	3.00
3.28	3.27	3.24	3.04
3.29	3.29	3.30	3.05
3.37	3.30	3.31	3.06
3.49	3.32	3.32	3.08
3.52	3.41	3.41	3.09
3.58	3.49	3.44	3.15
3.58	3.62	3.44	3.20
3.68	3.67	3.58	3.27
Av. Wt. 3.15	3.13	3.11	2.89

Typist: Mary Wallace Spohn