AGRONOMIC CHARACTERISTICS, PROTEIN, AND CAROTENOID COMPOSITION OF SOME GRAIN SORGHUM VARIETIES, STRAINS, AND HYBRIDS---WITH EMPHASIS ON YELLOW ENDOSPERM TYPES

By

WEI-NING FU

Bachelor of Science

National Honan University

Kaifeng, Honan, China

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Thesis Approved:

Frank F. Davies
Thesis Advisor

Dale E. Weibel

Lester W. Reed

Robert Woodside
Dean of the Graduate School

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INTRODUCTION

Sorghum in the United States is an emigrant crop which became established about 100 years ago. At present, production is centered in the Great Plains from Texas to South Dakota, however, it has spread into the corn belt and the southeast. Grain sorghum production in Oklahoma in 1959 was the largest on record. The crop of 18.8 million bushels averaged 27 bushels per acre compared to the national average of 37.2 bushels per acre. Since Oklahoma grain sorghum yields are below the national average, increasing yield is as important as improving grain quality.

Sorghum hybrids were long recognized as a possibility for increasing yields, and recently the establishment of cytoplasmic male sterility made commercial use of hybrid vigor in sorghum economically feasible. Hybrids were first recommended for production in Oklahoma in 1959.

An important use of sorghum grain in the United States is as feed for poultry and livestock. Since consumers demand a yellow egg yolk and a yellow shank on broilers, and since yellow corn is preferred to white for feeding, the addition of carotenoid pigments to sorghum grain has become an important breeding objective. A yellow endosperm variety of sorghum was found in Nigeria, Africa (29)[1/] by Dr. O. J. Webster.

[1/] Figures in parentheses refer to bibliography.

Crosses with American varieties were made in Africa, and seed from F_1 plants was distributed to breeders in 1952. Yellow endosperm selections from this material were available in the breeding program for evaluation as varieties in 1959. One particular selection from a cross of Redlan X Kaura (the yellow endosperm parent) which was designated as Y-8, was found in early tests to be an excellent pollinator when used on Redlan sterile. Crossing the yellow endosperm male with the non-yellow endosperm female produced a dilute yellow endosperm, which should be superior to the straight non-yellow endosperm grain.

The main objectives of this study were: (1) to evaluate yellow endosperm selections originating from Oklahoma's breeding program as varieties, and (2) to evaluate sorghum hybrids produced with one yellow endosperm parent. The evaluations were to include yield and other agronomic characteristics, and such quality factors as protein and carotenoid content.

REVIEW OF LITERATURE

Interest in the commercial production of hybrid sorghum seed increased greatly after Stephens (38) discovered a genetic male sterile plant in Texas Blackhull Kafir. The techniques for its application were nearly established when a cytoplasmic male sterile was discovered. This method opened the way for commercial production of hybrid sorghum on a wide scale. Hybrid seeds produced by using cytoplasmic male sterility came into farm use for the first time in 1957. By 1959 from 50 to 90 percent of the grain sorghum acreage was sown with hybrids.

As early as 1937, Karper and Quinby (18) reported a large grain yield increase due to hybrid vigor. Quinby, et al. (29) in Texas, concluded from the performance test of grain sorghums in 1957 that the hybrids produced 38 percent more grain than the average of their parents. Data from the Oklahoma grain sorghum performance test at five locations in 1958 (9) showed that the hybrids produced an average of 21 percent more grain than the average of the varieties included in the same test as checks. Similar tests in Kansas in 1957 and 1958 at six locations (7) showed a 23 percent increase in grain yields of hybrids over varieties. Khan (20) studied crosses of Redlan X Plainsman and Combine Kafir-60 X Combine 7078 at Perkins, Oklahoma in 1959 and found that the grain yield per plant of

the hybrids was 12.8 and 50.2 percent, respectively, more than the average of the parents.

The days from planting to blooming vary considerably in different varieties. Quinby, et al. (29) using performance test data from 1957 pointed out that the hybrids were 2.4 days earlier than the average of their parents. Davies (9) reported that the hybrids averaged about three days earlier to bloom than the varieties.

As early as 1931, John B. Sieglinger of the U. S. Department of Agriculture at Woodward, Oklahoma, released the first variety of combine height grain sorghum for commercial production in Kansas and Oklahoma. Since that time numerous dwarf types have been developed. At present, most of the distributed grain sorghum varieties and hybrids are combine types. Conner and Karper (8) in 1927 used three height types including Extra Dwarf, Dwarf and Standard to measure heterosis of plant height in hybrids. The first generation of the crosses between the different varieties showed an average increase of 66 percent in the height of plant over the tall parent. The corresponding second generation gave an increase of 40 percent over the tall parents. Crosses between strains of the same variety showed no hybrid vigor. Bartel (3) using forage sorghum parents found that all of the hybrids showed increases in plant height over the means of the parents, ranging from 6.2 to 113.8 percent. Data from grain sorghum performance tests in 1958 in Oklahoma (9) and in Kansas (7) indicated that the hybrids were 4.7 inches taller in Oklahoma and 5.1 inches

taller in Kansas than the varieties used for comparison. Based on the average of eight hybrids and their parents in the Texas performance test in 1957, Quinby, et al. (29) found that the hybrids were 2.4 inches taller than the average of the parents.

Head length may be related to grain yield, since large heads usually produce more grain. Khan (20) reported that the F_1 hybrid heads averaged 9.56 and 9.68 inches long for Redlan (8.95) X Plainsman (8.95) and Combine Kafir-60 (9.21) X Combine 7078 (8.50), respectively. Head length probably is one of the factors which influenced the grain yield of the hybrid.

Quinby, et al. (29) concluded that the bushel weight of hybrids grown under irrigation in Texas in 1957 was 1.4 pounds per bushel higher than the average of the parents. Walter (40) reported that the test weight of hybrids was lower than that of the standard varieties. Martin (25) pointed out that the number of heads per acre was either negatively or non-significantly correlated with weight per bushel and average size of heads.

Weight of 1,000 seed is an indication of the size of the individual seed and the amount of carbohydrates stored in the seeds. Le Clerc (21) indicated that a grain with low weight of 1,000 seed will be higher in fiber than one with a high seed weight. Bartel (3) found that in kernel weight the hybrids were intermediate between the parents, or were as heavy as or heavier than the larger kernel parents. He indicated that since the kernel consists largely of endosperm, the maximum effect of hybrid vigor on the kernel would be

expressed in the F_1 generation. The same result was obtained by Khan (20).

Varietal differences in tillering have been noted by many agronomists. Ball and Rothgeh (1), Sieglinger (34), Sielinger and Martin (35), Karper, et al. (19) and Quinby, et al. (31) have presented data on the relative tillering of a number of varieties. Sieglinger and Martin (35) found that the six year average (1930-37) number of stalks per plant in 79 varieties was 1.28 where plants were spaced 7 inches apart and 2.39 where plants were spaced 36 inches apart in the row. Some varieties produced no tillers in certain seasons. They also found that differences in tillering appears to account for many of the yield relationships and adaptations that have been observed in sorghum varieties.

In sorghum, most of the hybrids have shown a tendency toward severe lodging particularly in dry seasons (6). Davies (9) in Oklahoma and Clapp (7) in Kansas in 1958 found that lodging of hybrids and varieties was not different. In some locations, the lodging of the hybrids was less than that of varieties. Bartel (3) found more lodging occurred in hybrids than in varieties. In Oklahoma and in other states, charcoal rot has been responsible for much lodging in the grain sorghums (41).

Threshing percentage, the ratio of head weight to grain weight, shows the degree of seed set. Davies (9), reporting data based on six locations from the Oklahoma grain sorghum performance test in 1958, indicated that the average threshing

percentage of hybrids was higher than the average of varieties. The average threshing percentage was 71.9 percent in varieties and 74.5 percent in hybrids. The same conclusion was drawn by Clapp (7) from data from the Kansas grain sorghum performance test in 1957 in which the threshing percentage of hybrids and varieties was 76.3 and 73.6 percent, respectively.

Most of the sorghum grain in this country is used as feed for livestock. Therefore, the feeding value of sorghum grain could play a major role in sorghum production. An important factor influencing the feeding value of sorghum grain is the protein content. Many protein determinations of sorghum grain have been made by various researchers. Heller and Green (14) reported the analysis of 20 Oklahoma sorghum varieties. The protein content ranged from 9.7 to 14.8 percent. Protein content in sorghum grain, as in other crops, is influenced to some degree by such factors, as soil fertility, climatic conditions, irrigation, etc. A complete chemical analysis of 28 varieties of grain sorghum grown at Perkins and Woodward, Oklahoma, was reported by Heller and Sieglinger (13) in 1944. They indicated that there was some variation among varieties. They also found that drouth decreased the yield but increased the protein percentage. Lowe (24) compared seven hybrids with five varieties of grain sorghum for two years in Kansas. He found the protein content of the varieties grown on fallow was 26 percent greater than the varieties grown under irrigation. However, the protein content

of hybrids after fallow was 43 percent greater than that of the hybrids produced with irrigation. Walter (40) in Kansas reported protein contents of 11.65 and 10.79 for varieties and hybrids following a summer fallow, while they were 11.78 and 10.94 for varieties and hybrids with irrigation. Nelson (27) found that the protein content of the sorghum grain from three varieties increased with each increment of nitrogen fertilizer applied with irrigation. He also found that plant spacing did not affect the protein content of the grain.

Compared with their parents, the protein content of hybrids is usually lower. Lowe (24) in Kansas found the average protein content of varieties with irrigation was 16 percent greater than the hybrids. The yield of the hybrids after fallow was 24.4 bushels of grain per acre, which was a 48 percent increase over the varieties. This indicated that the hybrids had higher yield and lower protein content than the varieties. The same conclusion was drawn by Garner (11) Sieglinger (34) and Bartel (3).

Both sorghum and corn are used largely as feed for livestock and poultry. Heller and Green (14) in Oklahoma found grain sorghum could be a substitute for corn in every way unless the fat content is too low. Karper and Quinby (17) indicated that sorghum grain can be substituted for corn in almost all places where corn is used as livestock feeds. Hubbard, et al. (16) from an average of five varieties of sorghum grain found the protein content was about 2 percent higher than corn.

In addition to protein, carotenoid pigments are important to the feeding value of sorghum grains. Carotenoid pigments are made up partly of carotene and partly of xanthophyll pigments. Both of the ingredients impart yellow color to milk and to the skin and eggs of poultry. Moreover, carotene is the precursor of Vitamin A. Ronning, et al. (33) from an experiment of carotene requirements of dairy cattle through 20 years (1937-57) at Oklahoma, pointed out that successful reproduction could be expected from dairy cattle when they receive 75 to 85 mcg. of carotene per pound live weight daily.

Previous tests showed that sorghum grain was deficient in feeding value compared to yellow corn because of a deficiency of carotene. Heller and Green (14) concluded that yellow milo contained more vitamin A than the white-coated varieties. Smith (36) and Karper and Quinby (17) also reported that many of the grain sorghums were inferior to yellow corn as a source of vitamin A. Gross and Heller (12) determined the carotene of 38 varieties of grain sorghums grown at Perkins and at Woodward, Oklahoma. The data showed no great variation among varieties. The average amount of carotene was less than one-half of the percentage found in Oklahoma-grown yellow corn. The same conclusion was drawn by Heller and Sieglinger (13). Gross and Heller (12) suggested that when grain sorghum was used as the base ration, alfalfa meal or some other vitamin A supplement would be required.

In 1952, yellow endosperm sorghum was introduced into this country from Nigeria. Since that date breeders have undertaken the development of yellow endosperm varieties. Blessin, et al. (5) in 1958 analyzed seeds of yellow milo, white kafir and yellow endosperm strains which were selected from crosses of adapted varieties with Kaura. They were produced at the Nebraska Agricultural Experiment Station during the 1956 and 1957 crop years along with yellow corn. The data indicated that grain of common sorghum varieties contained about 1.5 parts per million of total carotenoids, while yellow corn ran as high as 20 to 30 parts per million. Certain environmental conditions affect the amount of carotenoid pigments. Bagging the heads of sorghum seems to conserve the amount. Analysis of grain from bagged and open heads of yellow endosperm selections showed 1.2 and 0.6 parts per million of carotene and 6.5 and 3.9 parts per million of xanthophyll, respectively. The average carotene content of non-yellow endosperm varieties was 0.23 parts per million, while that of the yellow endosperm selections was 0.63 parts per million. The xanthophyll content of non-yellow types was 1.2 parts per million, while that of the yellow types was 3.4 parts per million. Blessin, et al. (5) also found that the major carotenoid pigments present were identified as lutein, zeaxanthin, and beta-carotene. Carotenoids found in yellow corn but not detected in the grain sorghum were cryptoxanthin, hydroxy-alpha-carotene, and alpha-carotene.

From the standpoint of feeding value, one of the important problems in sorghum breeding is to raise the carotenoid content of sorghum from the present level up to that of yellow corn.

MATERIALS AND METHODS

The experimental material consisted of 37 entries of which 13 were hybrids and 24 were varieties. The hybrids consisted of 7 experimental crosses produced in the greenhouse at Stillwater during the winter of 1958-59, 3 experimental crosses produced at Woodward, and 3 commonly grown hybrids to serve as checks. The hybrids and their parents are listed in Table I.

TABLE I

THE PEDIGREES OF THE HYBRIDS TESTED

Hybrid	Female	Male
Oklahoma 5901	Wheatland	Y-8
Oklahoma 5902	Westland	Y-8
Oklahoma 5903	Martin	Y-8
Oklahoma 5904	Combine Kafir-60	Y-8
Oklahoma 5905	Redlan	Y-8
Oklahoma 5906	Dwarf Early Redlan	Y-8
Oklahoma 5907	Redlan-Kaura 5-1-2	Y-8
Woodward 5601	Wheatland	Cody X Dwarf white Feterita
Woodward 5602	Wheatland	Custer
Woodward 5805	Wheatland	Cyto#1-Kaura
RS 610	Combine Kafir-60	Combine 7078
Texas 660	Combine Kafir-60	Caprock
DeKalb E56a	Commercial - - - - closed pedigree	

The varieties consisted of 12 yellow endosperm selections from the Oklahoma breeding program, most of the parents of the

hybrids and four additional promising non-yellow endosperm selections. The 12 yellow endosperm strains and their parentages are listed in Table II.

TABLE II

THE PEDIGREES OF TWELVE YELLOW ENDOSPERM SELECTIONS

Variety	Female	Male
Y - 1	Combine Kafir-60	Kaura
Y - 2	White Martin	Kaura
Y - 3 *	Texioca -63	Kaura
Y - 4 * (white)	Texioca -63	Kaura
Y - 4 * (yellow)	Texioca -63	Kaura
Y - 5	Texioca -63	Kaura
Y - 6 *	Texioca -63	Kaura
Y - 7	Redlan	Kaura
Y - 8	Redlan	Kaura
Y - 9	Redlan	Kaura
Y - 10	Redlan	Kaura
Y - 11	Cyto #12	Kaura

* Waxy endosperm, white or yellow pericap

All 37 entries are shown in Table III along with the origin of each hybrid and variety.

TABLE III

THE 37 ENTRIES AND THE ORIGIN OF EACH HYBRID AND VARIETY

Entries	Variety or Hybrid	Origin
Oklahoma 5901	Hybrid	Oklahoma
Oklahoma 5902	Hybrid	Oklahoma
Oklahoma 5903	Hybrid	Oklahoma
Oklahoma 5904	Hybrid	Oklahoma
Oklahoma 5905	Hybrid	Oklahoma
Oklahoma 5906	Hybrid	Oklahoma
Oklahoma 5907	Hybrid	Oklahoma
Wheatland	Variety	Kansas

TABLE III (Cont'd)

Westland	Variety	Kansas
Martin	Variety	Texas
Combine Kafir-60	Variety	Texas
Redlan	Variety	Oklahoma
Dwarf Early Redlan	Variety	Oklahoma
Y - 1	Variety	Oklahoma
Y - 2	Variety	Oklahoma
Y - 3	Variety	Oklahoma
Y - 4 (white)	Variety	Oklahoma
Y - 4 (yellow)	Variety	Oklahoma
Y - 5	Variety	Oklahoma
Y - 6	Variety	Oklahoma
Y - 7	Variety	Oklahoma
Y - 8	Variety	Oklahoma
Y - 9	Variety	Oklahoma
Y - 10	Variety	Oklahoma
Y - 11	Variety	Oklahoma
Woodward 5601	Hybrid	Oklahoma
Woodward 5602	Hybrid	Oklahoma
Woodward 5805	Hybrid	Oklahoma
RS 610	Hybrid	Texas
Texas 660	Hybrid	Texas
DeKalb E56a	Hybrid	DeKalb Seed Co.
Tan Redlan	Variety	Oklahoma
Dwarf Early Red Kafir 4-1-4	Variety	Oklahoma
Dwarf Early Red Kafir 8-2	Variety	Oklahoma
811-Redlan	Variety	Oklahoma
Combine 7078	Variety	Texas
Caprock	Variety	Texas

The experiment was conducted at four locations in Oklahoma, namely Perkins, Mangum, Woodward, and Goodwell. At each location, the 37 entries were planted in a randomized complete block design, using four replications. The planting dates were June 10 for Perkins and Goodwell, and June 18 and 19 for Woodward and Mangum, respectively. Single rows 40 inches apart and approximately 40 feet long served as plots. The seed were treated with Arasan, and the usual cultural practices for each area were followed.

Chinch bugs caused some damage to susceptible varieties in the test at Perkins. Dieldrin was used as a control measure. Also, there was poor emergence of the hybrids whose planting seed was produced in the Stillwater greenhouse. Consequently, a second test was sown June 30. Better stands were obtained but webworm damage was severe and only the first planting was harvested.

The Mangum experiment was not established from the first planting and was replanted on June 19. This was an excellent test with the exception of insect (midge) damage to Y - 10, a late maturing yellow endosperm selection.

At Woodward the experiment was established and carried through, but the results were obtained too late to be included in this study. The Goodwell test was sown on preirrigated land, but extremely dry, windy weather immediately after planting dried out the soil and resulted in stands too erratic for reliable data. The experiment was not harvested.

The data included in this study were obtained from Perkins and Mangum.

The observed characteristics presented in this study are divided into two groups: (1) yield and other agronomic characteristics, including days to bloom, plant height, head length, bushel weight, weight of 1,000 seed, tiller percentage, lodging percentage, and threshing percentage, and (2) chemical characteristics including protein, and carotenoid pigment content. These characteristics were studied at both locations, except for carotenoid pigments, which were determined only on

the Mangum material. The characteristics are described in more detail below.

Grain yield --- The weight of threshed grain in pounds per acre. All the heads were harvested from 26 feet (1/500th acre) of each single row plot. Where plants were missing or skips in the row occured within the 26 feet of row, additional material was harvested from a similar area in the border. The heads were put in sacks and allowed to air dry before threshing.

Days to bloom --- The average number of days from planting to blooming.

Plant height --- The height in inches from the soil surface to the top of the heads. Five plants were chosen at random and measured at harvest in each plot.

Head length --- The length in inches of the main heads from the basal node to the top. This measurements came from the same plants selected for plant height.

Bushel weight --- The weight of grain in pounds per bushel as determined by standard apparatus.

Weight of 1,000 seed --- Ten times the weight in grams of 100 kernels selected at random from the bushel weight sample.

Tiller percentage --- The average percentage of tillering as determined by the ratio of tillers to total plants per plot.

Lodging percentage --- The average percentage of lodging as determined by the ratio of lodged plants to total plants per plot.

Threshing percentage --- The average percentage of threshing as determined by the ratio of threshed grain weight to head weight per plot. The head weight was determined as the weight of the harvested material before threshing.

Protein percentage --- The total nitrogen as determined by the Improved Kjeldahl method (15 p. 12) multiplied by 6.25.

Carotenoid pigments --- The carotene, xanthophyll, and total carotenoid pigments as determined by a combination of methods (4, 5, 15 p. 816-817, 41). These tests were made only on the material from Mangum. The samples for analysis were drawn from a composite of equal amounts of grain from the four replications and ground through 60 mesh screen. In addition to the 37 entries, four possible combinations of the yellow and non-yellow endosperm hybrids were used to study dosage effect. They were non-yellow times non-yellow, non-yellow times yellow, yellow times non-yellow, and yellow times yellow. This hybrid grain was either produced in the greenhouse or in the field and the grain was protected by bagging the head after pollination. Yellow corn was used for comparison in all the determinations.

EXPERIMENTAL RESULTS AND DISCUSSION

For convenience of discussion, the entries have been classified into four groups: (1) eight hybrids seven of which were made up with yellow endosperm pollinators and one of which was made up with both yellow endosperm seed parent and pollinator; (2) twelve yellow endosperm strains which included Y - 1 to Y - 11; (3) five non-yellow endosperm hybrids which included two Woodward hybrids-- 5601 and 5602, RS 610, Texas 660 and one commercial hybrid-- DeKalb E56a; and (4) twelve non-yellow endosperm varieties which included fertile counterparts of the six varieties used as the female parents in the yellow endosperm hybrids, Tan Redlan, Dwarf Early Red Kafir 4-1-4, Dwarf Early Red Kafir 8-2, 811-Redlan, Combine 7078 and Caprock.

The climatic conditions during the growing season were more favorable at Mangum than at Perkins. At Mangum, the crop stood well and developed normally; while at Perkins there was severe lodging due to strong wind accompanied with heavy rain in early September. Excessive rainfall continued through September and October at Perkins. Some of the seed on the heads germinated and severe weathering of grain occurred. Consequently, there was some loss of grain in the field, and some quality characters may have been influenced. Damage was more serious at Perkins than at Mangum from diseases and

insects such as charcoal rot, chinch bug, midge and sorghum webworm. These appeared in the field during different growth periods of the crop. For this reason, the experimental results from Mangum were considered more reliable than those from Perkins.

All of the observed characteristics reported will be discussed in the following order: grain yield, days to bloom, plant height, head length, bushel weight, weight of 1,000 seed, tillering percentage, lodging percentage, threshing percentage, protein content, and carotenoid pigments content. Following the discussion of these observations, some relationships or correlations among the characteristics are presented and discussed.

The results have been grouped in two ways. The first gives a comparison of hybrids with varieties, while the second gives a comparison of yellow endosperm types with non-yellow endosperm types for both hybrids and varieties.

Agronomic Characteristics

The summaries of the data on agronomic characteristics are presented in Tables IV and V for Perkins and Mangum, respectively.

Grain yield:

Grain yields in pounds per acre are given in Tables IV and V, column 1, for Perkins and Mangum, respectively. The entries in the table are listed according to the magnitude

TABLE IV

SUMMARY OF DIFFERENT AGRONOMIC CHARACTERISTICS OF SOME GRAIN SORGHUM VARIETIES AND HYBRIDS AT PERKINS, OKLAHOMA, 1959

Rank In Yield	Variety or Hybrid	1 Grain Yield	2 Multiple* Range Test	3 Days to Bloom	4 Plant Height	5 Head Length	6 Bushel Weight	7 Weight/ 1,000 Seed	8 Tillering	9 Lodging	10 Threshing
		lbs/acre		day	inch	inch	lbs/bu	gram	%	%	%
1	Woodward 5601	4190		60	63.6	12.7	58.1	34.2	5.7	35.4	77.4
2	Oklahoma 5903	3940		58	51.5	13.6	58.8	29.9	19.3	33.2	78.2
3	Oklahoma 5901	3815		59	47.5	13.6	57.6	29.9	41.1	11.0	79.6
4	Oklahoma 5904	3450		60	50.6	13.8	57.1	29.9	37.8	40.0	78.2
5	RS 610	3415		58	46.8	10.2	56.0	30.1	6.8	33.4	78.4
6	Woodward 5602	3400		56	42.3	11.7	58.0	28.6	5.1	8.8	79.5
7	Oklahoma 5905	3390		60	51.0	13.8	57.5	27.6	32.3	24.9	77.2
8	DeKalb E56a	3340		57	49.6	12.4	57.3	28.5	10.7	34.2	76.3
9	Oklahoma 5906	3300		59	48.4	14.3	57.1	28.5	26.3	13.2	77.6
10	Wheatland	3300		61	38.3	10.8	58.0	33.0	11.9	2.0	80.7
11	Oklahoma 5907	3200		57	51.9	15.3	55.8	29.6	18.9	8.4	76.6
12	Oklahoma 5902	3175		57	48.5	13.9	57.1	27.8	31.8	28.0	75.6
13	Texas 660	3140		61	46.9	11.2	57.0	30.7	14.1	18.6	76.5
14	Redlan	3140		62	48.7	9.7	58.0	28.5	4.1	21.6	80.2
15	Y-11	2940		61	52.4	13.0	54.5	32.3	4.6	37.5	69.7
16	Tan-Redlan	2925		61	40.9	10.3	58.5	25.7	8.1	1.0	78.3
17	Combine Kafir-60	2900		61	46.4	9.6	56.9	29.4	7.5	26.5	77.6
18	Martin	2825		61	45.5	11.4	59.3	29.4	6.1	11.5	80.1
19	Y-9	2765		59	51.6	12.1	55.4	33.3	12.3	4.6	76.7
20	Caprock	2740		61	43.3	11.2	57.7	28.3	5.0	5.0	76.8
21	Westland	2725		61	39.6	9.8	56.4	28.2	9.9	17.5	78.9
22	Dwarf Early Red Kafir 4-1-4	2665		59	40.3	11.5	59.7	26.1	7.9	3.5	78.9
23	Dwarf Early Redlan	2600		59	40.0	11.2	55.0	27.6	6.4	16.5	77.9
24	Woodward 5805	2565		52	38.8	11.5	56.9	39.0	7.8	7.5	73.7
25	Y-8	2475		58	47.5	13.5	53.8	26.8	23.7	10.0	75.9
26	811-Redlan	2465		62	39.6	8.8	56.6	30.0	3.5	3.5	75.5
27	Y-7	2440		58	39.7	11.5	53.9	30.9	10.4	14.4	73.9
28	Y-1	2290		60	35.5	9.2	56.7	33.1	12.3	1.9	72.3
29	Y-5	2150		60	40.2	9.8	56.4	34.8	6.2	2.8	73.2
30	Dwarf Early Red Kafir 8-2	2025		57	40.3	10.6	57.0	32.0	8.6	7.8	73.3
31	Y-4 (white)	1990		59	42.6	12.8	53.9	30.2	12.7	6.3	72.6
32	Y-6	1865		60	41.8	10.2	54.2	28.1	9.2	2.2	69.3
33	Combine 7078	1790		63	37.8	9.4	54.4	30.1	105.9	0.6	74.1
34	Y-3	1790		58	39.4	10.7	53.0	35.6	14.3	2.9	73.0
35	Y-2	1740		61	39.4	9.6	54.7	21.9	21.2	5.3	67.2
36	Y-4 (yellow)	1690		59	41.7	12.1	54.7	31.3	12.8	3.1	70.3
37	Y-10	1400		65	45.8	10.4	54.7	32.0	2.2	6.5	61.9
	Average	2755.5		59.6	44.8	11.6	56.4	30.1	15.8	13.8	75.5
	Variety	2401.5		60.4	42.4	10.9	56.0	29.9	13.6	8.9	74.5
	Hybrid	3409.2		58.1	49.1	12.9	57.3	30.3	19.8	22.8	77.3
	L.S.D. 5%	471		1.61	1.8	---	1.27	2.19	---	---	---
	1%	625		2.14	2.4	---	1.68	2.91	---	---	---
	C.V.	12.2		1.93	2.9	---	1.13	5.21	---	---	---

* Any two means not underscored by the same line are significantly different at 5 percent level.
Any two means underscored by the same line are not significantly different at 5 percent level.

TABLE V

SUMMARY OF DIFFERENT AGRONOMIC CHARACTERISTICS OF SOME GRAIN SORGHUM VARIETIES AND HYBRIDS AT MANGUM, OKLAHOMA, 1959

Rank In Yield	Variety or Hybrid	1 Grain Yield	2 Multiple* Range Test	3 Days to Bloom	4 Plant Height	5 Head Length	6 Bushel Weight	7 Weight/ 1,000 Seed	8 Tillering	9 Lodging**	10 Threshing
		lbs/acre		day	inch	inch	lbs/bu	gram	%	%	%
1	Woodward 5601	6800		55	50.4	12.4	59.2	32.4	29.0		79.9
2	Texas 660	5075		57	41.5	11.1	59.3	28.1	19.3		77.3
3	Oklahoma 5905	5000		60	45.7	12.7	59.0	26.0	32.8		77.5
4	RS 610	4875		55	40.8	9.7	58.6	28.2	31.9		82.6
5	Oklahoma 5901	4840		56	42.8	12.0	59.0	27.8	36.1		79.0
6	Woodward 5602	4825		56	39.3	10.9	59.8	28.5	27.8		81.8
7	Oklahoma 5906	4750		57	43.2	13.0	58.6	24.9	32.7		79.7
8	Westland	4600		57	35.6	9.4	59.3	28.9	57.1		79.7
9	Oklahoma 5904	4550		57	45.6	12.9	58.2	26.6	52.7		77.6
10	Tan Redlan	4365		61	34.9	10.3	60.6	25.8	30.8		80.6
11	Redlan	4325		63	40.5	9.5	59.9	28.7	25.5		81.6
12	Oklahoma 5903	4315		56	45.3	12.5	60.0	26.5	35.8		80.4
13	Oklahoma 5907	4100		54	43.5	14.0	58.2	24.9	23.1		78.5
14	Wheatland	4075		59	32.0	9.3	59.3	33.9	28.4		81.5
15	Oklahoma 5902	4065		55	43.1	12.5	58.9	26.5	21.9		77.8
16	DeKalb E56a	3975		56	43.2	11.9	59.2	28.4	25.5		81.1
17	Caprock	3940		59	37.9	10.5	59.0	29.1	24.8		79.6
18	Woodward 5805	3890		51	33.8	10.9	58.1	31.6	17.2		80.4
19	Combine Kafir-60	3740		60	38.8	9.8	58.9	27.9	21.4		78.5
20	Combine 7078	3665		59	32.6	8.7	57.6	30.7	28.6		80.5
21	Martin	3600		58	39.4	10.7	60.0	27.3	22.0		79.8
22	Y-9	3490		57	43.4	11.4	58.2	33.5	18.5		79.3
23	811-Redlan	3400		63	37.0	8.7	58.7	32.8	17.9		77.5
24	Dwarf Early Red Kafir 8-2	3300		55	35.8	9.8	59.2	26.1	25.6		80.7
25	Y-7	3290		57	38.5	10.9	57.3	31.6	28.3		80.2
26	Y-2	3275		59	34.4	9.1	57.6	25.4	29.5		77.5
27	Y-11	3240		59	43.0	13.2	58.5	32.0	21.4		70.8
28	Dwarf Early Redlan	3165		60	36.7	10.7	57.8	26.5	52.7		83.2
29	Y-3	3075		54	34.5	9.6	57.8	30.7	26.2		79.6
30	Y-8	3050		58	40.8	12.5	56.4	26.6	20.1		80.8
31	Y-4 (white)	2990		55	39.3	11.7	57.3	27.9	29.3		79.7
32	Y-1	2940		59	31.2	8.2	58.1	28.1	33.2		74.8
33	Dwarf Early Red Kafir 4-1-4	2900		58	35.8	10.3	60.8	24.5	24.4		82.6
34	Y-4 (yellow)	2725		57	38.7	11.9	58.5	28.3	17.6		77.3
35	Y-5	2515		59	36.4	9.0	58.6	31.5	24.5		81.0
36	Y-6	2424		57	38.8	10.0	57.1	26.2	28.8		71.6
37	Y-10	740		62	39.2	10.2	55.5	28.3	29.4		45.7
	Average	3780.8		57.5	39.3	10.9	58.6	28.5	28.4		78.3
	Variety	3284.6		58.5	37.3	10.2	58.4	28.8	27.8		77.7
	Hybrid	4696.9		55.8	42.9	12.0	58.9	27.8	29.7		79.5
	L.S.D. 5%	686		1.8	2.1	---	0.65	2.00	---		---
	1%	912		2.4	2.8	---	0.86	2.66	---		---
	C.V.	13.0		2.3	3.8	---	0.79	5.04	---		---

* Any two means not underscored by the same line are significantly different at 5 percent level.
Any two means underscored by the same line are not significantly different at 5 percent level.

**No lodging occurred in this test.

of the grain yield.

The analyses of variance of grain yield are listed in Table VI (Perkins) and VII (Mangum). To test the significance of differences for grain yield among the entries, both the least significant difference method (37) and the new multiple range test (22) were used. The former has been a popular method and is more commonly used than the latter. But in an experiment with a large number of entries, the latter is more appropriately used. The least significant differences are indicated at the bottom of Table IV and V. The grain yield of the yellow endosperm entries and non-yellow endosperm entries showed highly significant differences in both varieties and hybrids for both locations. The non-yellow endosperm entries produced more grain than the yellow endosperm entries. The new multiple range test for the grain yield is shown in column 2 of Table IV and V.

Among the 37 entries, Woodward 5601 was the leading one in grain yield, and Y-10 was the lowest at both locations. According to previous observations Y-10 should have performed better, perhaps equal to Y-8 in grain yield among the yellow endosperm strains. Y-10, however, was rather late in maturity and was more subject to attack by the sorghum midge. The midge population built up during the season. At Mangum Y-10 was almost completely destroyed by this insect while other varieties which bloomed only a few days earlier escaped noticeable damage. Among the yellow endosperm varieties, Y-9 produced the highest yield, and Y-10 the lowest yield, while Y-8

TABLE VI

ANALYSIS OF VARIANCE FOR GRAIN YIELD (POUNDS PER PLOT) AT PERKINS, 1959

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Total	147	324.04	
Replication	3	7.90	
Entry	36	267.37	7.427**
Variety vs. hybrid	1	137.01	137.010**
Among Variety	23	99.07	4.307**
Yellow vs. non-yellow	1	28.82	28.820**
Among Yellow	11	38.12	3.466**
Among non-Yellow	11	32.12	2.920**
Among Hybrid	12	31.30	2.608**
Yellow vs. non-yellow	1	0.82	0.820*
Among yellow	6	8.52	1.418**
Among non-yellow	5	21.96	4.392**
Error	108	48.77	0.452

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

TABLE VII

ANALYSIS OF VARIANCE FOR GRAIN YIELD (POUNDS PER PLOT) AT MANGUM, 1959

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Total	147	716.32	
Replication	3	7.85	
Entry	36	604.82	16.801**
Variety vs. hybrid	1	269.30	269.300**
Among variety	23	226.19	9.834**
Yellow vs. non-yellow	1	85.50	85.500**
Among yellow	11	92.82	8.438**
Among non-yellow	11	47.87	4.352**
Among hybrid	12	109.33	9.111**
Yellow vs. non-yellow	1	7.86	7.860**
Among yellow	6	13.03	2.172**
Among non-yellow	5	88.44	17.688**
Error	108	103.65	0.960

**Significant difference at 1 percent level.

ranged almost halfway between the two at both locations. Among the non-yellow varieties, Wheatland produced the highest yield at Perkins and Westland at Mangum. Due to the chinch bug, Combine 7078 gave a low yield at Perkins, but yielded well at Mangum. Among the yellow endosperm hybrids, Oklahoma 5903 and 5901 were promising at Perkins, and Oklahoma 5905 and 5901 at Mangum. Among the non-yellow hybrids, Woodward 5601 was the highest yielder at both locations, however, it is too tall for combine harvest.

A comparison of the average yield of the 24 varieties and strains with the average yield of 13 hybrids, revealed that the hybrids yielded 1,000 pounds per acre or more (over 40 percent) than the varieties. See Table VIII.

Since both parents of eight of the hybrids were included in the test, comparisons could be made between the hybrids and their parents. Six of the hybrids had a common yellow endosperm pollen parent. Two of the hybrids did not involve yellow endosperm, but they are commonly grown and are well adapted hybrids. The yields of the hybrids and their parents are given in Table IX for both Perkins and Mangum. Compared to an average of the standard hybrids (RS 610 and Texas 660), Oklahoma 5903 and 5901 produced significantly more grain at Perkins. At Mangum, the two highest yielding yellow endosperm hybrids, Oklahoma 5905 and 5901 did not yield significantly different from the checks. The lowest yielding hybrid, Oklahoma 5902, produced significantly less grain than the checks. The commercial hybrid, DeKalb E56a, yielded 3340 and 3975

TABLE VIII

COMPARISON OF GRAIN YIELD OF VARIETIES VS. HYBRIDS AND YELLOW VS. NON-YELLOW ENDOSPERM VARIETIES AND HYBRIDS AT PERKINS AND MANGUM, 1959

Unit: Pounds per acre

Variety or Hybrid	Yellow or non-yellow		Perkins	Mangum	Average
Varieties (24)*	Yellow(12)*	Average	2126	2812	2469
		Range	1400-2940	740-3490	
	Non-yellow (12)	Average	2674	3755	3215
		Range	1790-3300	2900-4600	
	Average		2402	3284	2842
	Range		1400-3300	740-4600	
Hybrids (13)	Yellow (8)	Average	3354	4438	3896
		Range	2565-3940	3890-5000	
	Non-yellow (5)	Average	3551	5110	4331
		Range	3140-4190	3975-6800	
	Average		3429	4697	4053
	Range		2565-4190	3890-6800	
Hybrid increase above the average of varieties			1027 43%	1413 43%	1220 43%

* The arabic number in the parathesis show the number of varieties or hybrids.

TABLE IX

GRAIN YIELD OF EIGHT HYBRIDS COMPARED WITH THEIR PARENTS, 1959

Female Parent		Hybrid		Male Parent	
Variety	Pounds/acre	F_1	Pounds/acre	Variety	Pounds/acre
		PERKINS			
Wheatland	3300	Oklahoma 5901	3815	Y-8	2475
Wheatland	2725	Oklahoma 5902	3175	Y-8	2475
Martin	2825	Oklahoma 5903	3940	Y-8	2475
Combine Kafir-60	2900	Oklahoma 5904	3450	Y-8	2475
Redlan	3140	Oklahoma 5905	3390	Y-8	2475
Dwarf Early Redlan	2600	Oklahoma 5906	3300	Y-8	2475
Combine Kafir-60	2900	RS 610	3415	Combine 7078	1790
Combine Kafir-60	2900	Texas 660	3140	Caprock	2740
Average	2911		3453		2423
Hybrid increase above average of parents			29.5%		

L.S.D. -- 471 and 625 pounds per acre at 5 percent and 1 percent level, respectively.

TABLE IX (Continued)

Female Parent		Hybrid		Male Parent	
Variety	Pounds/acre	F_1	Pounds/acre	Variety	Pounds/acre
		MANGUM			
Wheatland	4075	Oklahoma 5901	4840	Y-8	3050
Westland	4600	Oklahoma 5902	4065	Y-8	3050
Martin	3600	Oklahoma 5903	4315	Y-8	3050
Combine Kafir-60	3740	Oklahoma 5904	4550	Y-8	3050
Redlan	4325	Oklahoma 5905	5000	Y-8	3050
Dwarf Early Redlan	3165	Oklahoma 5906	4750	Y-8	3050
Combine Kafir-60	3740	RS 610	4875	Combine 7078	3665
Combine Kafir-60	3740	Texas 660	5075	Caprock	3940
Average	3873		4684		3238
Hybrid increase above average of parents			31.7%		

L.S.D. -- 686 and 912 pounds per acre at 5 percent and 1 percent level, respectively.

pounds per acre at Perkins and Mangum, respectively. It ranged between RS 610 and Texas 660 at Perkins and lower than both at Mangum.

The average yields from the two locations showed rather small differences between the yellow endosperm hybrids and the standards.

When all eight hybrids in Table IX are compared with their parental lines, the hybrids produced about 30 percent more grain than the average of both parents.

Days to Bloom:

The data for days to bloom are given in column 3 of Tables IV and V for Perkins and Mangum, respectively. The days to bloom at Perkins were about 2 days later than at Mangum. This was not expected since the planting dates were June 10 at Perkins and June 19 at Mangum.

The analyses of variance of days to bloom are given in Tables X and XI for Perkins and Mangum, respectively. Among the 37 entries, Y-10, Redlan, and 811-Redlan were relatively late to bloom. They required about 63 days at Perkins, and about 61 days at Mangum. Woodward 5805 bloomed in less than 52 days, and was the earliest entry at both locations. Compared to the varieties, the hybrids bloomed 3 days earlier at both locations (Table XII). The eight hybrids, compared with their parents, bloomed 1 day earlier at Perkins and 2.4 days earlier at Mangum (Table XIII). In general, it appeared that the hybrids were earlier in blooming than the average of

TABLE X

ANALYSIS OF VARIANCE FOR DAYS TO BLOOM AT PERKINS, 1959

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Total	147	1043	
Replication	3	162	
Entry	36	737	20.47**
Error	108	144	1.33

**Significant difference at 1 percent level.

TABLE XI

ANALYSIS OF VARIANCE FOR DAYS TO BLOOM AT MANGUM, 1959

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Total	147	1103	
Replications	3	10	
Entry	36	910	25.28**
Error	108	183	1.69

**Significant difference at 1 percent level.

TABLE XII

COMPARISON OF DAYS TO BLOOM OF VARIETIES VS. HYBRIDS AND YELLOW VS. NON-YELLOW ENDOSPERM VARIETIES AND HYBRIDS AT PERKINS AND MANGUM, 1959

Unit: day

Variety or Hybrid	Yellow or non-yellow		Perkins	Mangum	Average
Varieties (24)*	Yellow (12)*	Average	59.9	57.7	58.8
		Range	58.0-64.8	54.0-62.0	
	Non-yellow (12)	Average	60.9	59.2	60.1
		Range	57.5-63.3	55.0-63.0	
	Average		60.4	58.5	59.5
	Range		57.5-64.8	54.0-63.0	
Hybrids (13)	Yellow (8)	Average	57.9	55.6	56.8
		Range	52.3-60.5	51.3-59.8	
	Non-yellow (5)	Average	58.4	55.7	57.1
		Range	55.8-61.0	55.3-56.5	
	Average		58.1	55.8	57.0
	Range		52.3-61.0	51.3-59.8	
Hybrid decrease below the average of varieties			2.3	2.7	2.5

* The arabic number in the parathesis shows the number of varieties or hybrids.

TABLE XIII

DAYS TO BLOOM OF EIGHT HYBRIDS COMPARED WITH THEIR PARENTS, 1959

Female Parent		Hybrid		Male Parent	
Variety	Days	F_1	Days	Variety	Days
		PERKINS			
Wheatland	61	Oklahoma 5901	59	Y-8	58
Westland	61	Oklahoma 5902	57	Y-8	58
Martin	61	Oklahoma 5903	58	Y-8	58
Combine Kafir-60	61	Oklahoma 5904	60	Y-8	58
Redlan	62	Oklahoma 5905	60	Y-8	58
Dwarf Early Redlan	59	Oklahoma 5906	59	Y-8	58
Combine Kafir-60	61	RS 610	58	Combine 7078	63
Combine Kafir-60	61	Texas 660	61	Caprock	61
Average	60.9		59.0		59.0
Hybrid increase above average of parents			1.0 day		

L.S.D. -- 1.61 and 2.14 days at 5 percent and 1 percent level, respectively.

TABLE XIII (Continued)

Female Parent		Hybrid		Male Parent	
Variety	Days	F_1	Days	Variety	Days
		MANGUM			
Wheatland	59	Oklahoma 5901	56	Y-8	58
Westland	57	Oklahoma 5902	55	Y-8	58
Martin	58	Oklahoma 5903	56	Y-8	58
Combine Kafir-60	60	Oklahoma 5904	57	Y-8	58
Redlan	63	Oklahoma 5905	60	Y-8	58
Dwarf Early Redlan	60	Oklahoma 5906	57	Y-8	58
Combine Kafir-60	60	RS 610	55	Combine 7078	59
Combine Kafir-60	60	Texas 660	57	Caprock	59
Average	59.6		56.6		58.3
Hybrid increase above average of parents			2.4 days		

L.S.D. -- 1.82 and 2.42 days at 5 percent and 1 percent level, respectively.

parents. The same conclusion was reported by Quinby, et al. (29) and Davies (9).

Among the varieties, the days to bloom ranged from 58 to 65 days at Perkins and from 54 to 63 days at Mangum (Table XII). Dwarf Early Red Kafir 8-2 and Y-3 were early; Redlan and Y-10 were late at both locations; and Y-8 ranged in between. Combine 7078 bloomed 5 days earlier at Mangum than at Perkins. The chinch bug infestation during the seedling stage at Perkins delayed its blooming date.

Plant height:

The plant height data are presented in column 4 of Tables IV and V for Perkins and Mangum, respectively. The average height of the plants at Perkins was about 5 inches taller than at Mangum. Seasonal conditions and geographic location are probably responsible for the difference. Woodward 5601 was the tallest entry at both locations, measuring 64 inches at Perkins and 50 inches at Mangum. The shortest entry was Y-1, being only 35 inches in height at Perkins and 31 inches at Mangum. Y-9 and Y-11 approached being too tall for combine harvesting. The hybrids produced with Y-8 as the pollen parent were taller than desired. Woodward 5602 was only 42 inches in height at Perkins and 39 inches at Mangum.

The analyses of variance for plant height are given in Tables XIV and XV for Perkins and Mangum, respectively. Highly significant differences are indicated for entries.

TABLE XIV

ANALYSIS OF VARIANCE FOR PLANT HEIGHT AT PERKINS, 1959

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Total	147	5003.78	
Replication	3	12.11	
Entry	36	4807.38	133.538**
Error	108	184.29	1.706

**Significant difference at 1 percent level.

TABLE XV

ANALYSIS OF VARIANCE FOR PLANT HEIGHT AT MANGUM, 1959

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Total	147	2923.42	
Replication	3	21.87	
Entry	36	2666.03	74.056**
Error	108	235.52	2.181

**Significant difference at 1 percent level.

A comparison of the average height of all varieties with the average height of all hybrids (Table XVI) showed that the hybrids were 6.7 inches (Perkins) and 5.6 inches (Mangum) taller than the varieties. Table XVII presents data on the eight hybrids studied as a group, and again the hybrids averaged 4 inches (Perkins) and 5 inches (Mangum) taller than the parent varieties.

These data are in agreement with observations of Davies (9) in Oklahoma and Clapp (7) in Kansas who found the hybrids were 4.7 and 5.1 inches taller than check varieties.

Head length:

The data for head length may be found in column 5 of Table IV and V. These data indicated that the average head length at Perkins (11.6 inches) was about one inch longer than at Mangum (10.9 inches). Among the 37 entries, head length ranged from 8.8 to 15.4 inches in length at Perkins and from 8.2 to 14.0 inches at Mangum (Table XVIII). The hybrid, Oklahoma 5907, had the longest heads, and the variety, Y-1, had the shortest heads at both locations. All the hybrids produced with Y-8 as a pollen parent as well as Y-8 itself had long heads. The average head length of all varieties was 10.9 and of all hybrids was 12.9 inches at Perkins, while similar data for Mangum were 10.2 and 12.0 inches. This represented a difference of about 2 inches between varieties and hybrids which is in agreement with results obtained by Khan (20).

TABLE XVI

COMPARISON OF PLANT HEIGHT OF VARIETIES VS. HYBRIDS AND YELLOW VS. NON-YELLOW ENDOSPERM VARIETIES AND HYBRIDS AT PERKINS AND MANGUM, 1959

Unit: Inches

Variety or Hybrid	Yellow or non-yellow		Perkins	Mangum	Average
Varieties (24)*	Yellow (12)*	Average	43.1	38.2	40.7
		Range	35.6-52.4	31.2-43.4	
	Non-yellow (12)	Average	41.7	36.4	39.1
		Range	37.8-48.7	32.0-40.5	
	Average		42.4	37.3	39.9
	Range		35.6-52.4	31.2-43.4	
Hybrids (13)	Yellow (8)	Average	48.5	42.9	45.7
		Range	38.9-51.9	33.8-45.7	
	Non-yellow (5)	Average	49.9	43.0	46.5
		Range	42.3-63.7	39.3-43.2	
	Average		49.1	42.9	46.0
	Range		38.9-63.7	33.8-45.7	
Hybrid increase above the average of varieties			6.7	5.6	6.2

* The arabic number in the parathesis shows the number of varieties or hybrids.

TABLE XVII

PLANT HEIGHT OF EIGHT HYBRIDS COMPARED WITH THEIR PARENTS, 1959

Female Parent		Hybrid		Male Parent	
Variety	Inches	F_1	Inches	Variety	Inches
		PERKINS			
Wheatland	38.3	Oklahoma 5901	47.5	Y-8	47.5
Westland	39.6	Oklahoma 5902	48.5	Y-8	47.5
Martin	45.5	Oklahoma 5903	51.5	Y-8	47.5
Combine Kafir-60	46.4	Oklahoma 5904	50.6	Y-8	47.5
Redlan	48.7	Oklahoma 5905	51.0	Y-8	47.5
Dwarf Early Redlan	40.0	Oklahoma 5906	48.4	Y-8	47.5
Combine Kafir-60	46.4	RS 610	46.8	Combine 7078	37.8
Combine Kafir-60	46.4	Texas 660	46.9	Caprock	43.3
Average	43.9		48.9		45.8
Hybrid increase above average of parents			4.0 inches		

L.S.D. -- 1.83 and 2.43 inches at 5 percent and 1 percent level, respectively.

TABLE XVII (Continued)

Female Parent		Hybrid		Male Parent	
Variety	Inches	F_1	Inches	Variety	Inches
		MANGUM			
Wheatland	32.0	Oklahoma 5901	42.8	Y-8	40.8
Westland	35.6	Oklahoma 5902	43.1	Y-8	40.8
Martin	39.4	Oklahoma 5903	45.3	Y-8	40.8
Combine Kafir-60	38.8	Oklahoma 5904	45.6	Y-8	40.8
Redlan	40.5	Oklahoma 5905	45.7	Y-8	40.8
Dwarf Early Redlan	36.7	Oklahoma 5906	43.2	Y-8	40.8
Combine Kafir-60	38.8	RS 610	40.8	Combine 7078	32.6
Combine Kafir-60	38.8	Texas 660	41.5	Caprock	37.9
Average	37.6		43.5		39.4
Hybrid increase above average of parents			5.0 inches		

L.S.D. -- 2.07 and 2.75 inches at 5 percent and 1 percent level, respectively.

TABLE XVIII

COMPARISON OF HEAD LENGTH OF VARIETIES VS. HYBRIDS AND YELLOW VS. NON-YELLOW ENDOSPERM VARIETIES AND HYBRIDS AT PERKINS AND MANGUM, 1959

Unit: Inches

Variety or Hybrid	Yellow or non-yellow		Perkins	Mangum	Average
Varieties (24)*	Yellow (12)*	Average	11.4	10.7	11.1
		Range	9.2-13.0	8.2-13.2	
	Non-yellow (12)	Average	10.4	9.8	10.1
		Range	8.8-11.5	8.7-10.7	
	Average		10.9	10.2	10.6
	Range		8.8-13.0	8.2-13.2	
Hybrids (13)	Yellow (8)	Average	13.8	12.6	13.2
		Range	11.5-15.4	12.0-14.0	
	Non-yellow (5)	Average	11.6	11.2	11.4
		Range	10.2-12.7	9.7-12.4	
	Average		12.9	12.0	12.5
	Range		10.2-15.4	9.7-14.0	
Hybrid increase above the average of varieties			2.0	1.8	1.9

* The arabic number in the parathesis shows the number of varieties or hybrids.

The head length data on the eight hybrids and their parents may be found in Table XIX. The head length of all eight hybrids were longer than the average of their parents. The head types and length of the eight hybrids with their parents are shown in Figures 1 and 2. Among the varieties Y-8 had the longest heads and Combine 7078 the shortest. Among the hybrids, Oklahoma 5906 had the longest and RS 610 had the shortest heads in both tests.

Bushel Weight:

The bushel weight data are given in column 6 of Table IV and V. The average bushel weight of all entries was more than two pounds per bushel heavier at Mangum than at Perkins. Lodging, excessive rainfall, and the accompanying weathering of the grain and germination of seeds in the head probably accounted for the lower bushel weight at Perkins. Bushel weight ranged from 53 to 60 pounds per bushel at Perkins and from 56 to 61 pounds per bushel at Mangum. Dwarf Early Red Kafir 4-1-4, Tan Redlan, Martin, and Oklahoma 5903 were among the heaviest at both Perkins and Mangum. The 12 yellow endosperm selections were among the lowest for bushel weight. The analyses of variance for bushel weight are given in Table XX (Perkins) and Table XXI (Mangum). Highly significant differences were found among entries.

In Table XXII may be found bushel weight comparisons among varieties and hybrids with and without yellow endosperm. Within the varieties, the yellow endosperm selections averaged 54.7

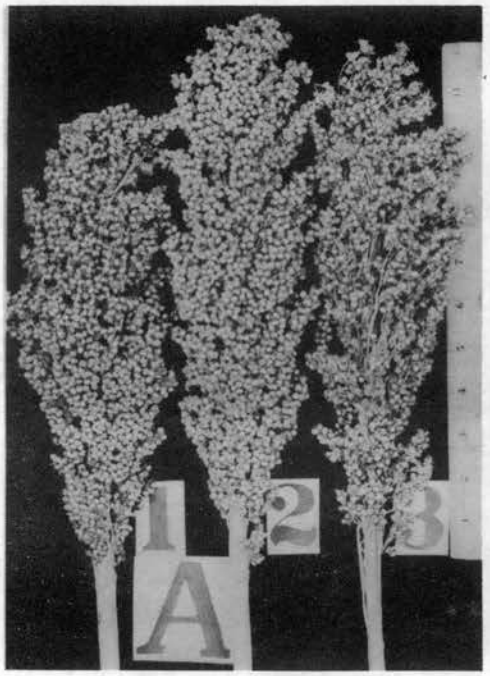
TABLE XIX

HEAD LENGTH OF EIGHT HYBRIDS COMPARED WITH THEIR PARENTS, 1959

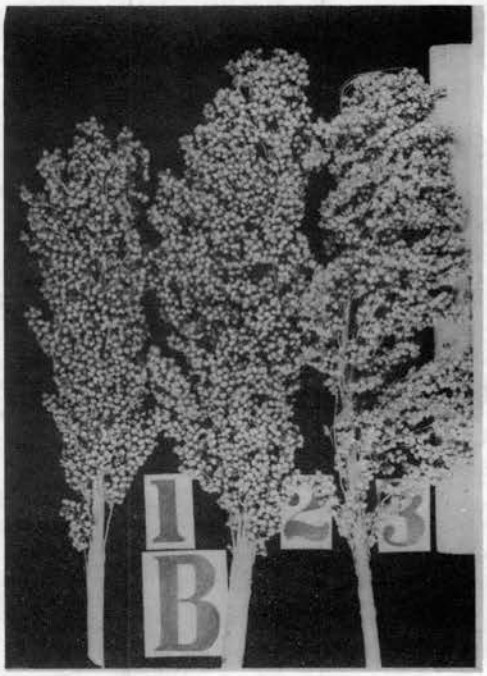
Female Parent		Hybrid		Male Parent	
Variety	Inches	F_1	Inches	Variety	Inches
		PERKINS			
Wheatland	10.8	Oklahoma 5901	13.6	Y-8	13.5
Westland	9.8	Oklahoma 5902	13.9	Y-8	13.5
Martin	11.4	Oklahoma 5903	13.6	Y-8	13.5
Combine Kafir-60	9.6	Oklahoma 5904	13.8	Y-8	13.5
Redlan	9.7	Oklahoma 5905	13.8	Y-8	13.5
Dwarf Early Redlan	11.2	Oklahoma 5906	14.3	Y-8	13.5
Combine Kafir-60	9.6	RS 610	10.2	Combine 7078	9.4
Combine Kafir-60	9.6	Texas 660	11.2	Caprock	11.2
Average	10.2		13.1		12.7
Hybrid increase above average of parents			1.6 inches		

TABLE XIX (Continued)

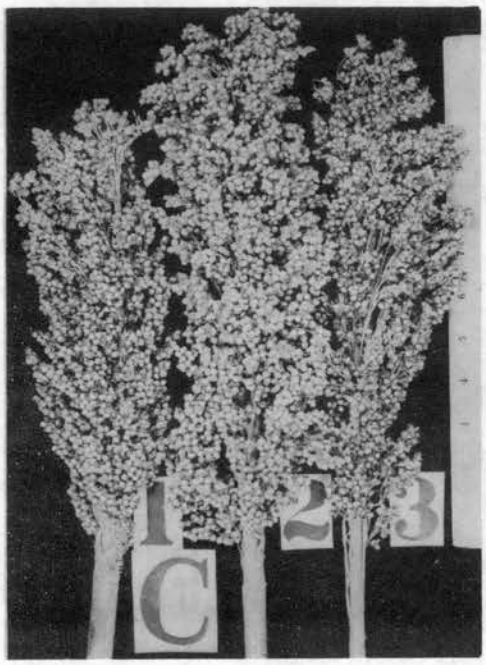
Female Parent		Hybrid		Male Parent	
Variety	Inches	F_1	Inches	Variety	Inches
		MANGUM			
Wheatland	9.3	Oklahoma 5901	12.0	Y-8	12.9
Westland	9.4	Oklahoma 5902	12.5	Y-8	12.9
Martin	10.7	Oklahoma 5903	12.5	Y-8	12.9
Combine Kafir-60	9.8	Oklahoma 5904	12.9	Y-8	12.9
Redlan	9.5	Oklahoma 5905	12.7	Y-8	12.9
Dwarf Early Redlan	10.7	Oklahoma 5906	13.0	Y-8	12.9
Combine Kafir-60	9.8	RS 610	9.7	Combine 7078	8.7
Combine Kafir-60	9.8	Texas 660	11.1	Caprock	10.5
Average	9.9		12.1		12.1
Hybrid increase above average of parents			1.1 inches		



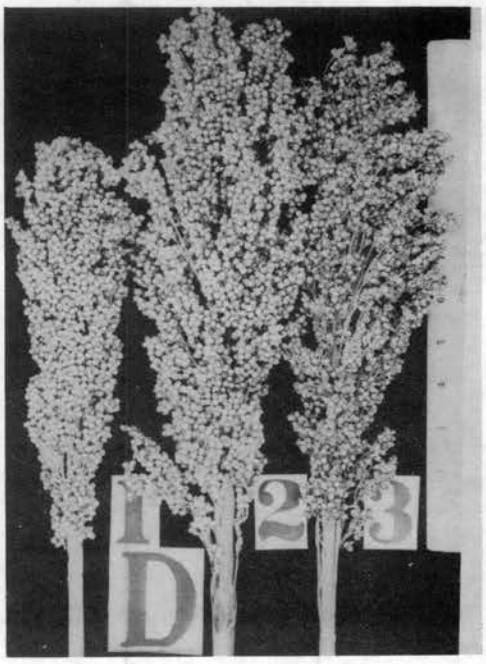
A - 1. Wheatland
2. Oklahoma 5901
3. Y - 8



B - 1. Westland
2. Oklahoma 5902
3. Y - 8

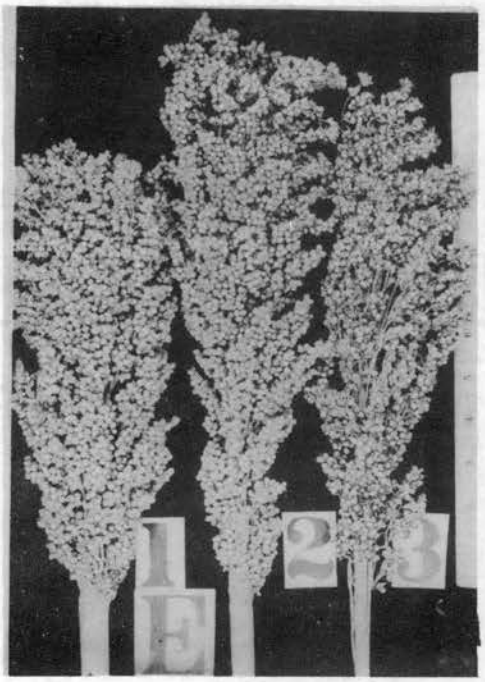


C - 1. Martin
2. Oklahoma 5903
3. Y - 8

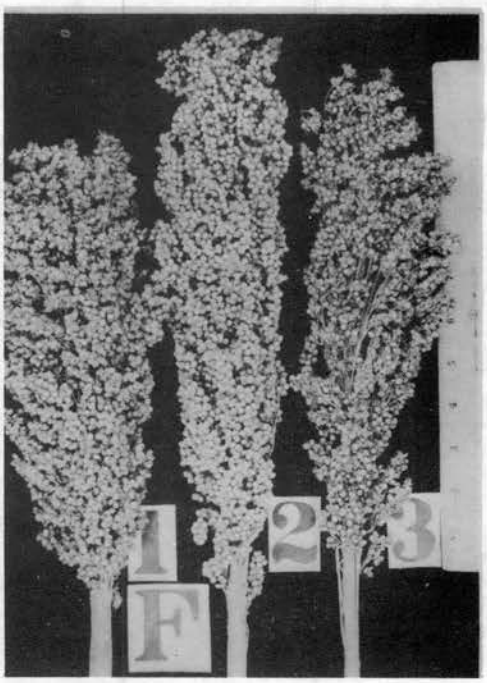


D - 1. Combine Kafir - 60
2. Oklahoma 5904
3. Y - 8

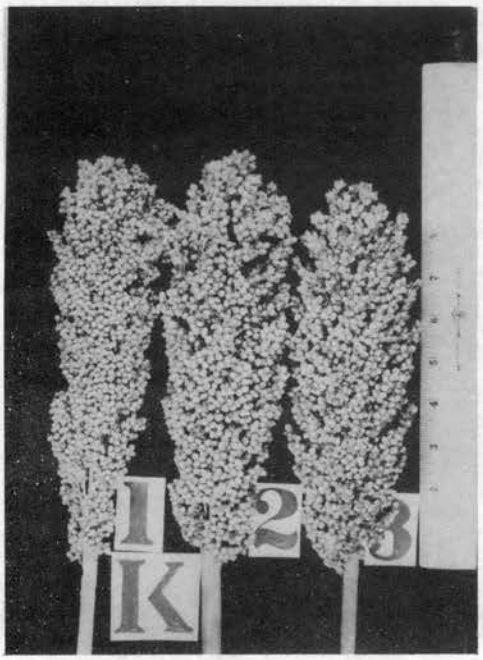
Figure 1. The Head Shape of Four Hybrids (center) with their Female (left) and Male (right) Parents.



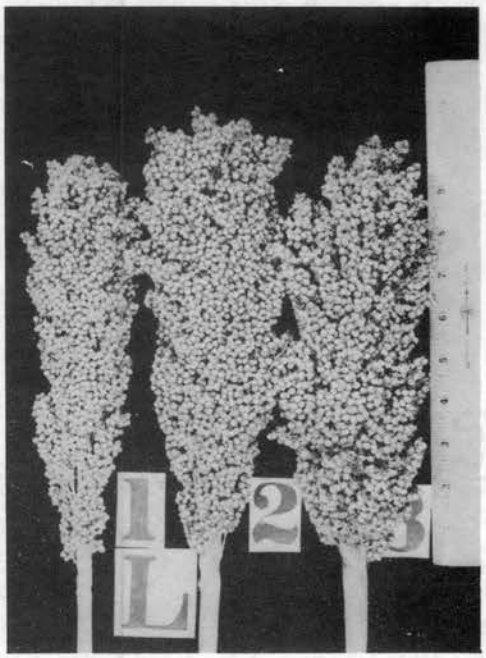
E - 1. Redlan
2. Oklahoma 5905
3. Y - 8



F - 1. Dwarf Early Redlan
2. Oklahoma 5906
3. Y - 8



K - 1. Combine Kafir - 60
2. RS 610
3. Combine 7078



L - 1. Combine Kafir - 60
2. Texas 660
3. Caprock

Figure 2. The Head Shape of Four Hybrids (center) with their Female (left) and Male (right) Parents.

TABLE XX

ANALYSIS OF VARIANCE FOR BUSHEL WEIGHT AT PERKINS, 1959

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Total	147	461.06	
Replication	3	0.76	
Entry	36	416.22	11.562**
Error	108	44.08	0.408

**Significant difference at 1 percent level.

TABLE XXI

ANALYSIS OF VARIANCE FOR BUSHEL WEIGHT AT MANGUM, 1959

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Total	147	196.07	
Replication	3	0.53	
Entry	36	172.57	4.794**
Error	108	22.97	0.213

**Significant difference at 1 percent level.

TABLE XXII

COMPARISON OF BUSHEL WEIGHT OF VARIETIES VS. HYBRIDS AND YELLOW VS. NON-YELLOW ENDOSPERM VARIETIES AND HYBRIDS AT PERKINS AND MANGUM, 1959

Unit: Pounds per Bushel

Variety or Hybrid	Yellow or non-yellow		Perkins	Mangum	Average
Varieties (24)*	Yellow (12)*	Average	54.7	57.6	56.2
		Range	53.0-56.7	55.5-58.6	
	Non-yellow (12)	Average	57.3	59.3	58.3
		Range	54.4-59.7	57.6-60.8	
	Average		56.0	58.4	57.2
	Range		53.0-59.7	55.5-60.8	
Hybrids (13)	Yellow (8)	Average	57.2	58.8	58.0
		Range	55.8-58.8	58.1-60.0	
	Non-yellow (5)	Average	57.3	59.2	58.1
		Range	56.0-58.0	58.6-59.8	
	Average		57.3	58.9	58.1
	Range		55.8-58.0	58.1-60.0	
Hybrid increase above the average of varieties			1.3	0.5	0.9

* The arabic number in the parathesis shows the number of varieties or hybrids.

pounds compared to 57.3 pounds per bushel for non-yellow endosperm varieties at Perkins. Similar values from Mangum were 57.6 and 59.3 pounds per bushel. Among the hybrids the yellow and non-yellow endosperm crosses had almost identical bushel weight at both locations. Averaged over all, the hybrids had 1.3 and 0.5 pounds per bushel higher bushel weight than the varieties, at Perkins and Mangum, respectively.

Comparisons among the eight hybrids and their parents for bushel weight are shown in Table XXIII. The hybrids averaged 1.5 pounds and 1.0 pounds per bushel heavier than the average of the parents at Perkins and Mangum, respectively. A few of the hybrids had bushel weights in excess of the heavier parent, but only in the case of Oklahoma 5906 was the hybrid significantly heavier at both locations. Martin and its hybrid had the highest bushel weights in both tests. Y-8 was rather low in bushel weight, but hybrids produced from it were approximately equal to the heavier parent. It would appear that high bushel weight was dominant in the F_1.

These findings may not be in complete agreement with previous results. Quinby, et al. (29) indicated that bushel weight of hybrids was 1.4 pounds higher than that of their parents under irrigation. Conversely, Walter (40) reported that the bushel weight of hybrids was slightly lower than the standard varieties.

Weight of 1,000 seed:

The data on weight of 1,000 seed are given in Table IV

TABLE XXIII

BUSHEL WEIGHT OF EIGHT HYBRIDS COMPARED WITH THEIR PARENTS, 1959

Unit: Pounds per Bushel

Female Parent		Hybrid		Male Parent	
Variety	Pounds/bushel	F_1	Pounds/bushel	Variety	Pounds/bushel
		PERKINS			
Wheatland	58.0	Oklahoma 5901	57.6	Y-8	53.8
Westland	56.4	Oklahoma 5902	57.1	Y-8	53.8
Martin	59.3	Oklahoma 5903	58.8	Y-8	53.8
Combine Kafir-60	56.9	Oklahoma 5904	57.1	Y-8	53.8
Redlan	58.0	Oklahoma 5905	57.5	Y-8	53.8
Dwarf Early Redlan	55.0	Oklahoma 5906	57.1	Y-8	53.8
Combine Kafir-60	56.9	RS 610	56.0	Combine 7078	54.4
Combine Kafir-60	56.9	Texas 660	57.0	Caprock	57.7
Average	57.2		57.3		54.4
Hybrid increase above average of parents			1.5 pounds per bushel		

L.S.D. -- 1.27 and 1.68 pounds per bushel at 5 percent and 1 percent level, respectively.

TABLE XXIII (Continued)

Female Parent		Hybrid		Male Parent	
Variety	Pounds/bushel	F_1	Pounds/bushel	Variety	Pounds/bushel
		MANGUM			
Wheatland	59.3	Oklahoma 5901	59.0	Y-8	56.4
Westland	59.3	Oklahoma 5902	58.9	Y-8	56.4
Martin	60.0	Oklahoma 5903	60.0	Y-8	56.4
Combine Kafir-60	58.9	Oklahoma 5904	58.2	Y-8	56.4
Redlan	59.9	Oklahoma 5905	59.0	Y-8	56.4
Dwarf Early Redlan	57.8	Oklahoma 5906	58.6	Y-8	56.4
Combine Kafir-60	58.9	RS 610	58.6	Combine 7078	57.6
Combine Kafir-60	58.9	Texas 660	59.3	Caprock	59.0
Average	59.1		59.0		56.9
Hybrid increase above average of parents			1.0 pounds per bushel		

L.S.D. -- 0.65 and 0.86 pounds per bushel at 5 percent and 1 percent level, respectively.

and V, column 7, for Perkins and Mangum, respectively. Seed weights at Perkins averaged 1.6 grams per 1,000 heavier than at Mangum. Apparently the individual kernels produced at Mangum were smaller than those produced at Perkins, but they were not lighter in weight by volume since bushel weights averaged heavier at Mangum than at Perkins.

The weights of 1,000 seed ranged from 21.9 to 39.0 grams at Perkins and from 24.5 to 33.9 grams at Mangum. Entries in the high weight group at Perkins were Woodward 5805 (39.0 grams), Y-3 (35.6 grams), Woodward 5601 (34.2 grams), and Wheatland (33.0 grams). Y-2 (21.9 grams), and Tan Redlan (25.7 grams) were among the low ones. Those in the high weight group at Mangum were Wheatland (33.9 grams), Y-9 (33.5 grams), 811-Redlan (32.8 grams), and Woodward 5601 (32.4 grams). Dwarf Early Red Kafir 4-1-4 (24.5 grams) had the low weight.

Significant differences among entries were indicated in the analyses of variance, Table XXIV and XXV, at both locations.

In the comparisons of the yellow vs. non-yellow varieties and hybrids, Table XXVI, the average weight of 1,000 seed of the yellow endosperm varieties was 1.9 grams more than that of the non-yellow endosperm varieties at Perkins and 0.7 grams more at Mangum. The average weight of the non-yellow hybrids was approximately the same as the yellow endosperm hybrids at Perkins, but at Mangum the non-yellow hybrids were 2.2 grams heavier.

In Table XXVII, the weight of 1,000 seed for the eight hybrids and their parents revealed that the average of the

TABLE XXIV

ANALYSIS OF VARIANCE FOR WEIGHT OF 1,000 SEED AT PERKINS, 1959

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Total	147	1592.81	
Replication	3	9.77	
Entry	36	1318.82	36.634**
Error	108	264.22	2.446

**Significant difference at 1 percent level.

TABLE XXV

ANALYSIS OF VARIANCE FOR WEIGHT OF 1,000 SEED AT MANGUM, 1959

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Total	147	1188.76	
Replication	3	13.51	
Entry	36	954.59	26.516**
Error	108	220.66	2.043

**Significant difference at 1 percent level.

TABLE XXVI

COMPARISON OF WEIGHT OF 1,000 SEED OF VARIETIES VS. HYBRIDS AND YELLOW VS. NON-YELLOW ENDOSPERM VARIETIES AND HYBRIDS AT PERKINS AND MANGUM, 1959

Unit: Gram

Variety or Hybrid	Yellow or non-yellow		Perkins	Mangum	Average
Varieties (24)*	Yellow (12)*	Average	30.9	29.2	30.1
		Range	21.9-34.8	25.4-33.5	
	Non-yellow (12)	Average	29.0	28.5	28.8
		Range	25.7-33.0	24.1-33.9	
	Average		29.9	28.8	29.4
	Range		21.9-34.8	24.1-33.9	
Hybrids (13)	Yellow (8)	Average	30.3	26.9	28.6
		Range	27.6-39.0	24.9-27.8	
	Non-yellow (5)	Average	30.4	29.1	29.8
		Range	28.5-34.2	28.1-32.4	
	Average		30.3	27.8	29.1
	Range		27.6-39.0	24.9-32.4	
Hybrid increase above the average of varieties			0.4	-1.0	-0.3

* The arabic number in the parathesis shows the number of varieties or hybrids.

TABLE XXVII

WEIGHT OF 1,000 SEED OF EIGHT HYBRIDS COMPARED WITH THEIR PARENTS, 1959

Female Parent		Hybrid		Male Parent	
Variety	Grams	F_1	Grams	Variety	Grams
		PERKINS			
Wheatland	33.0	Oklahoma 5901	29.9	Y-8	26.8
Westland	28.2	Oklahoma 5902	27.8	Y-8	26.8
Martin	29.4	Oklahoma 5903	29.9	Y-8	26.8
Combine Kafir-60	29.4	Oklahoma 5904	29.9	Y-8	26.8
Redlan	28.5	Oklahoma 5905	27.6	Y-8	26.8
Dwarf Early Redlan	27.6	Oklahoma 5906	28.5	Y-8	26.8
Combine Kafir-60	29.4	RS 610	30.1	Combine 7078	30.1
Combine Kafir-60	29.4	Texas 660	30.7	Caprock	28.3
Average	29.4		29.3		27.4
Hybrid increase above average of parents			0.9		

L.S.D. -- 2.19 and 2.91 grams at 5 percent and 1 percent level, respectively.

TABLE XXVII (Continued)

Female Parent		Hybrid		Male Parent	
Variety	Grams	F_1	Grams	Variety	Grams
		MANGUM			
Wheatland	33.9	Oklahoma 5901	27.8	Y-8	26.6
Westland	28.9	Oklahoma 5902	26.5	Y-8	26.6
Martin	27.3	Oklahoma 5903	26.5	Y-8	26.6
Combine Kafir-60	27.9	Oklahoma 5904	26.6	Y-8	26.6
Redlan	28.7	Oklahoma 5905	26.0	Y-8	26.6
Dwarf Early Redlan	26.5	Oklahoma 5906	24.9	Y-8	26.6
Combine Kafir-60	27.9	RS 610	28.2	Combine 7078	30.7
Combine Kafir-60	27.9	Texas 660	28.1	Caprock	29.1
Average	28.6		26.8		27.4
Hybrid increase above average of parents			-1.2		

L.S.D. -- 2.0 and 2.7 grams at 5 percent and 1 percent level, respectively.

hybrids was 0.9 gram heavier than the average of the parents at Perkins, but 1.2 grams lighter at Mangum. The 1,000 seed weights of most of the yellow endosperm hybrids were heavier than the male parent (Y-8), but lighter than their female parents. Bartel (3) also reported that the 1,000 seed weights of hybrids were intermediated between parents. The non-yellow endosperm hybrids had 1,000 seed weights heavier than the yellow endosperm hybrids. This probably was due to the heavier seed weight of the pollen parents of the non-yellow hybrids.

Tiller percentage:

The data for tiller percentage are given in column 8 of Table IV and V. There was considerable variation in tillering, especially at Perkins where the average tillering of all entries was 15.8 percent. Combine 7078 had the most tillering (106 percent). This was probably a result of chinch bug injury at an early stage in the life of the plants. The average tillering for all entries at Mangum was 28.4 percent.

The comparison in Table XXVIII indicated the hybrids and varieties tillered alike at Mangum, but the hybrids tillered more at Perkins. Within varieties the yellow endosperm selections tillered less than non-yellow endosperm selections, but the opposite was true within hybrids.

The data from the eight hybrids and their parents are presented in Table XXIX. It was found that the hybrids produced 6.6 percent more tillers at Perkins and 6.4 percent more tillers at Mangum than the average of the parents. This

TABLE XXVIII

COMPARISON OF TILLER PERCENTAGE OF VARIETIES VS. HYBRIDS AND YELLOW VS. NON-YELLOW ENDOSPERM VARIETIES AND HYBRIDS AT PERKINS AND MANGUM, 1959

Variety or Hybrid	Yellow or non-yellow		Perkins	Mangum	Average
Varieties (24)*	Yellow (12)*	Average	11.8	25.6	18.7
		Range	2.2-23.7	17.6-33.2	
	Non-yellow (12)	Average	15.4	29.9	22.7
		Range	3.5-105.9**	17.9-57.1	
	Average		13.6	27.8	20.7
	Range		2.2-105.9	17.6-57.1	
Hybrids (13)	Yellow (8)	Average	26.9	31.5	29.2
		Range	7.8-41.1	21.9-52.7	
	Non-yellow (5)	Average	8.5	26.7	17.6
		Range	5.1-14.1	17.2-31.9	
	Average		19.8	29.7	24.8
	Range		5.1-41.1	17.2-52.7	
Hybrid increase above the average of varieties			6.2	1.9	4.1

* The arabic number in the parathesis shows the number of varieties or hybrids.
**Combine 7078 due to chinch bug damage.

TABLE XXIX

TILLER PERCENTAGE OF EIGHT HYBRIDS COMPARED WITH THEIR PARENTS, 1959

Female Parent		Hybrid		Male Parent	
Variety	Percentage	F_1	Percentage	Variety	Percentage
		PERKINS			
Wheatland	11.9	Oklahoma 5901	41.1	Y-8	23.7
Westland	9.9	Oklahoma 5902	31.8	Y-8	23.7
Martin	6.1	Oklahoma 5903	19.3	Y-8	23.7
Combine Kafir-60	7.5	Oklahoma 5904	37.8	Y-8	23.7
Redlan	4.1	Oklahoma 5905	32.3	Y-8	23.7
Dwarf Early Redlan	6.4	Oklahoma 5906	26.3	Y-8	23.7
Combine Kafir-60	7.5	RS 610	6.8	Combine 7078	105.9
Combine Kafir-60	7.5	Texas 660	14.1	Caprock	5.0
Average	7.6		26.2		31.6
Hybrid increase above average of parents			6.6%		

TABLE XXIX (Continued)

Female Parent		Hybrid		Male Parent	
Variety	Percentage	F_1	Percentage	Variety	Percentage
		MANGUM			
Wheatland	28.4	Oklahoma 5901	36.1	Y-8	20.1
Westland	57.1	Oklahoma 5902	21.9	Y-8	20.1
Martin	22.0	Oklahoma 5903	35.8	Y-8	20.1
Combine Kafir-60	21.4	Oklahoma 5904	52.7	Y-8	20.1
Redlan	25.5	Oklahoma 5905	32.8	Y-8	20.1
Dwarf Early Redlan	52.7	Oklahoma 5906	32.7	Y-8	20.1
Combine Kafir-60	21.4	RS 610	31.9	Combine 7078	28.6
Combine Kafir-60	21.4	Texas 660	19.3	Caprock	24.8
Average	31.2		32.9		21.8
Hybrid increase above average of parents			6.4%		

may be due in part to an apparent tendency of the Y-8 variety to produce tillering in hybrid combination.

Lodging Percentage:

Lodging occured only at Perkins due to the storms and heavy rains in early September. Another important factor influencing the lodging percentage at Perkins was the disease--charcoal rot. In general, factors such as plant height, length of peduncle, and size of heads also influence lodging.

The data on lodging percentage at Perkins are given in Table IV, column 9. Lodging percentage varied among the 37 entries, ranging from 0.6 to 40.0 percent. Generally, the hybrids lodged considerably more than varieties as is indicated by the data in Table XXX. These comparisons showed that hybrids lodged approximately 14 percent more than the varieties. Within the varieties, the yellow endosperm selections lodged less than non-yellow ones, and the same was true within the hybrids. It appeared that the standing ability of the yellow selections has been slightly improved over the non-yellow varieties. A much greater improvement was evident where the yellow endosperm pollen parent was used in hybrid combination.

In Table XXXI the data on the eight hybrids showed that the hybrids lodged 12 percent more than the average of the parents. Wheatland had very little lodging, and its hybrid with Y-8 had less lodging than any other hybrid in this comparison.

TABLE XXX

COMPARISON OF LODGING PERCENTAGE OF VARIETIES VS. HYBRIDS AND YELLOW VS. NON-YELLOW ENDOSPERM VARIETIES AND HYBRIDS AT PERKINS, 1959

Variety or Hybrid	Yellow or non-yellow		Perkins
Varieties (24)*	Yellow (12)*	Average	8.1
		Range	1.9-37.5
	Non-yellow (12)	Average	9.8
		Range	0.6-26.5
	Average		8.9
	Range		0.6-37.5
Hybrids (13)	Yellow (8)	Average	20.8
		Range	7.5-40.0
	Non-yellow (5)	Average	26.0
		Range	8.8-35.4
	Average		23.8
	Range		7.5-40.0
Hybrid increase above the average of varieties			13.9

* The arabic number in the parathesis shows the number of varieties or hybrids.

TABLE XXXI

LODGING PERCENTAGE OF EIGHT HYBRIDS COMPARED WITH THEIR PARENTS, 1959

Female Parent		Hybrid		Male Parent	
Variety	Percentage	F_1	Percentage	Variety	Percentage
		PERKINS			
Wheatland	2.0	Oklahoma 5901	11.0	Y-8	10.0
Westland	17.5	Oklahoma 5902	28.0	Y-8	10.0
Martin	11.5	Oklahoma 5903	33.2	Y-8	10.0
Combine Kafir-60	26.5	Oklahoma 5904	40.0	Y-8	10.0
Redlan	21.6	Oklahoma 5905	24.9	Y-8	10.0
Dwarf Early Redlan	16.5	Oklahoma 5906	13.2	Y-8	10.0
Combine Kafir-60	26.5	RS 610	33.4	Combine 7078	0.6
Combine Kafir-60	26.5	Texas 660	18.6	Caprock	5.0
Average	18.6		25.3		8.2
Hybrid increase above average of parents			12%		

In previous experiments, workers found that the lodging of hybrids was more than that of their parents (3). However, in other experiments (7, 9), the opposite was reported.

Threshing Percentage:

The data for threshing percentage are given in Table IV and V, column 10, for Perkins and Mangum, respectively. There was little difference between the two locations, with the average threshing percentage at Perkins being 75.5 compared to 78.3 at Mangum. Germination of the seeds on the head during rainy weather and the subsequent shattering out of seeds at Perkins explains in part the reduction in threshing percentage.

In Table XXXII a comparison of yellow with non-yellow endosperm varieties and hybrids showed that the non-yellow endosperm varieties and hybrids had higher threshing percentage at both locations although there was very little difference among the hybrids. In the comparisons of varieties and hybrids, the hybrids had a slight advantage at both locations of approximately 2 percent. This same conclusion was drawn by Davies (9) and Clapp (7).

Table XXXIII gives a comparison of the eight hybrids and their parents. In this case there was probably no real difference in the threshing percentage of the hybrids compared to an average of their parents. Compared to the female parents only, however, the hybrids had a lower threshing percentage at both locations. This characteristic does not seem to help explain the increased yield of hybrids over varieties.

TABLE XXXII

COMPARISON OF THRESHING PERCENTAGE OF VARIETIES VS. HYBRIDS AND YELLOW VS. NON-YELLOW ENDOSPERM VARIETIES AND HYBRIDS AT PERKINS AND MANGUM, 1959

Variety or Hybrid	Yellow or non-yellow		Perkins	Mangum	Average
Varieties (24)*	Yellow (12)*	Average	71.3	74.8	73.1
		Range	61.9-76.7	45.7-81.0	
	Non-yellow (12)	Average	77.7	80.5	79.1
		Range	73.3-80.7	77.5-83.2	
	Average		74.5	77.7	76.1
	Range		61.9-80.7	45.7-83.2	
Hybrids (13)	Yellow (8)	Average	77.1	78.9	78.0
		Range	73.7-79.6	77.6-80.4	
	Non-yellow (5)	Average	77.6	80.5	79.2
		Range	76.3-79.5	77.3-82.6	
	Average		77.3	79.5	78.4
	Range		73.1-79.6	77.3-82.6	
Hybrid increase above the average of varieties			2.8	1.8	2.3

* The arabic number in the parathesis shows the number of varieties or hybrids.

TABLE XXXIII

THRESHING PERCENTAGE OF EIGHT HYBRIDS COMPARED WITH THEIR PARENTS, 1959

Female Parent		Hybrid		Male Parent	
Variety	Percent	F_1	Percent	Variety	Percent
		PERKINS			
Wheatland	80.7	Oklahoma 5901	79.6	Y-8	75.9
Westland	78.9	Oklahoma 5902	75.6	Y-8	75.9
Martin	80.1	Oklahoma 5903	78.2	Y-8	75.9
Combine Kafir-60	77.6	Oklahoma 5904	78.2	Y-8	75.9
Redlan	80.2	Oklahoma 5905	77.2	Y-8	75.9
Dwarf Early Redlan	77.9	Oklahoma 5906	77.6	Y-8	75.9
Combine Kafir-60	77.6	RS 610	78.4	Combine 7078	74.1
Combine Kafir-60	77.6	Texas 660	76.5	Caprock	76.8
Average	78.8		77.7		75.8
Hybrid increase above average of parents			0.4%		

TABLE XXXIII (Continued)

Female Parent		Hybrid		Male Parent	
Variety	Percent	F_1	Percent	Variety	Percent
		MANGUM			
Wheatland	81.5	Oklahoma 5901	79.0	Y-8	80.3
Westland	79.7	Oklahoma 5902	77.8	Y-8	80.3
Martin	79.8	Oklahoma 5903	80.4	Y-8	80.3
Combine Kafir-60	78.5	Oklahoma 5904	77.6	Y-8	80.3
Redlan	81.6	Oklahoma 5905	77.5	Y-8	80.3
Dwarf Early Redlan	83.2	Oklahoma 5906	79.7	Y-8	80.3
Combine Kafir-60	78.5	RS 610	82.6	Combine 7078	80.5
Combine Kafir-60	78.5	Texas 660	77.3	Caprock	79.6
Average	80.2		79.0		80.2
Hybrid increase above average of parents			-1.2%		

The Relationship Between Grain Yield and Other Agronomic Characteristics:

The fact that grain sorghum hybrids produce more grain than the varieties or their parents has been recognized by sorghum workers for a long time. Many sorghum workers have been interested in the interpretation of heterosis of sorghum grain yield, especially after the establishment of male sterility for producing hybrid seeds. In this study, information assembled on several agronomic characteristics discussed above may be used to help explain hybrid vigor.

Three agronomic characteristics might be related to grain yield. The hybrids could (1) produce more heads (tillers) per plant; (2) produce more seeds per head or per plant; and (3) produce larger and/or heavier seeds. Any one or combination of the three possibilities may be considered capable of increasing grain weight. Tiller percentage has been discussed in this study, and it was found that the hybrids produced about 6 percent more tillers than the average of the parents. The same was true at both locations. Compared with the female parents, the eight hybrids produced about 19 percent more tillers at Perkins.

Seed number per plant has been observed by Khan (20) at Perkins, Oklahoma in 1959. He studied the F_1 of two crosses and their parents. The crosses were Redlan X Plainsman and Combine Kafir-60 X Combine 7078. The F_1 hybrid of the first cross produced 3346 seeds per plant while the parents produced 2955 seeds (Redlan 2912 and Plainsman 3000). The F_1 hybrid

produced about 13 percent more seed per plant. In the second cross the F_1 hybrid produced about 31 percent more seeds than the average of the parents. The analysis of variance showed a significant difference in both the crosses.

Whether the hybrids produce larger or heavier seeds may be determined from the present data on weight of 1,000 seed and bushel weight. The results on bushel weight in this test showed that the hybrids were 1.0 to 1.5 pounds per bushel heavier than the average of the parents. Other workers such as Quinby, et al. (29) and Khan (20) obtained similar results. But Walter (40) found that the hybrids were less than the average of the parents in bushel weight. As to the 1,000 seed weight, it was found in the present study that the hybrids were slightly heavier than the average of their parents. They usually ranged between the two parents, if the parents were different in 1,000 seed weight. Similar conclusions were drawn by Bartel (3) and Khan (20).

From the three agronomic characteristics, two of them, number of tillers and seed number per plant, were found to be higher in the hybrid than in the average of the parents. Bushel weight and weight of 1,000 seed were not consistently higher in the hybrids. From the data available, the increase yield of hybrids over varieties may be best explained on the basis of increased tillering and increased number of seed per plant.

Chemical Characteristics

Protein Content:

Determinations of protein content were made for both

locations. The summary of the data are given in Table XXXIV. It was found that the grain from Perkins contained less protein than that from Mangum.

Among the 37 entries, Y-6 and 811-Redlan were high in protein content, whereas Oklahoma 5906 and Woodward 5601 were low at both locations. The difference between the highest and the lowest was about 3.5 percent protein for both locations. These averages ranged from 9.53 to 13.24 percent protein.

Among the yellow endosperm selections, Y-6 and Y-10 were high in protein content in the average of both locations, while Y-3 and Y-9 were low. Among the non-yellow varieties, 811-Redlan and Martin were high in protein content and Wheatland was low.

The analyses of variance of protein percentage are given in Table XXXV and XXXVI for Perkins and Mangum, respectively. Highly significant differences were indicated for virtually every comparison.

In Table XXXVII, the average of 24 varieties was compared to the average of 13 hybrids. The hybrids were about 1 percent lower in protein content at both locations. In the average of both locations the hybrids showed a decrease of 10.4 percent in protein content. This substantiated previous findings by Bartel (3), Garner (11), Lowe (24), and Sieglinger (34).

Among the varieties, the protein content of yellow and of non-yellow endosperm kinds showed very little difference, with the average of all varieties being 11.4 percent protein. Among

TABLE XXXIV

SUMMARY OF PROTEIN CONTENT OF SOME GRAIN SORGHUM VARIETIES AND HYBRIDS AT PERKINS AND MANGUM, 1959

Entries	Perkins	Mangum	Mean
Oklahoma 5901	9.11	10.17	9.64
Oklahoma 5902	10.03	10.79	10.41
Oklahoma 5903	10.99	10.76	10.88
Oklahoma 5904	10.37	10.69	10.53
Oklahoma 5905	9.42	10.69	10.06
Oklahoma 5906	9.17	9.89	9.53
Oklahoma 5907	9.30	10.88	10.99
Wheatland	9.63	11.22	10.43
Westland	10.58	10.90	11.24
Martin	12.20	12.93	12.57
Combine Kafir-60	11.36	11.97	11.68
Redlan	10.24	12.26	11.25
Dwarf Early Redlan	10.78	11.53	11.16
Y-1	10.75	11.84	11.30
Y-2	10.41	12.07	11.74
Y-3	10.77	9.79	10.28
Y-4 (white)	10.25	10.90	11.08
Y-4 (yellow)	10.92	10.67	11.30
Y-5	10.91	11.71	11.31
Y-6	13.08	13.39	13.24
Y-7	10.92	11.42	11.17
Y-8	9.96	11.20	10.58
Y-9	10.13	10.93	10.53
Y-10	12.31	13.24	12.78
Y-11	10.02	10.74	10.88
Woodward 5601	9.24	10.51	9.88
Woodward 5602	9.68	10.93	10.31
Woodward 5805	9.75	10.05	9.90
RS 610	11.06	10.76	10.91
Texas 660	10.83	10.60	10.72
DeKalb E56a	10.60	11.60	11.60
Tan Redlan	10.14	11.18	10.66
Dwarf Early Red Kafir 4-1-4	10.94	11.74	11.34
Dwarf Early Red Kafir 8-2	12.25	11.16	11.71
811-Redlan	12.21	14.10	13.16
Combine 7078	10.70	11.67	11.19
Caprock	10.80	12.19	11.50
Average	10.73	11.35	11.04

TABLE XXXV

ANALYSIS OF VARIANCE FOR PROTEIN CONTENT AT PERKINS, 1959

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Total	147	276.35	
Replication	3	46.96	
Entry	36	139.60	3.878**
Variety vs. hybrid	1	24.05	24.050**
Among variety	23	81.57	3.547**
Yellow vs. non-yellow	1	14.42	14.420**
Among yellow	11	34.47	3.143**
Among non-yellow	11	32.68	2.971**
Among hybrid	12	33.98	2.832**
Yellow vs. non-yellow	1	4.47	4.470**
Among yellow	6	12.13	2.022**
Among non-yellow	5	17.38	3.476**
Error	108	89.79	0.831

**Significant difference at 1 percent level.

TABLE XXXVI

ANALYSIS OF VARIANCE FOR PROTEIN CONTENT AT MANGUM, 1959

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square
Total	147	186.71	
Replication	3	20.56	
Entry	36	135.08	3.752**
Variety vs. hybrid	1	40.70	40.700**
Among variety	23	85.29	3.708**
Yellow vs. non-yellow	1	5.94	5.940**
Among yellow	11	48.29	4.390**
Among non-yellow	11	31.06	2.824**
Among hybrid	12	9.10	0.758**
Yellow vs. non-yellow	1	0.46	0.460*
Among yellow	6	3.31	0.552**
Among non-yellow	5	5.34	1.068**
Error	108	31.07	0.288

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

TABLE XXXVII

COMPARISON OF PROTEIN CONTENT OF VARIETIES VS. HYBRIDS AND YELLOW VS. NON-YELLOW ENDOSPERM VARIETIES AND HYBRIDS AT PERKINS AND MANGUM, 1959

Variety or Hybrid	Yellow or non-yellow		Perkins	Mangum	Average
Varieties (24)*	Yellow (12)*	Average	11.20	11.49	11.35
		Range	9.96-13.08	9.79-13.24	
	Non-yellow (12)	Average	10.99	11.99	11.49
		Range	9.63-12.25	11.16-14.10	
	Average		11.09	11.74	11.42
	Range		9.63-13.08	9.79-14.10	
Hybrid (13)	Yellow (8)	Average	9.77	10.55	10.16
		Range	9.11-10.99	9.89-10.88	
	Non-yellow (5)	Average	10.36	10.74	10.55
		Range	9.24-11.06	10.05-11.60	
	Average		10.04	10.64	10.34
	Range		9.11-11.06	9.89-11.60	
Hybrid decrease below the average of varieties			1.05 10.46%	1.10 10.34%	1.08 10.40%

* The arabic number in the parathesis shows the number of varieties or hybrids.

the hybrids, the non-yellow endosperm kinds showed slightly more protein at both locations. The average protein percentage for all hybrids was 10.3, or 1.1 percent less than the varieties.

In Table XXXVIII, the hybrids were compared with their parental lines and showed that the average of eight hybrids was 0.5 percent lower in protein than the average of both parental lines at Perkins and 1.1 percent lower in protein at Mangum. Compared with their female parents, the hybrids were 1 percent lower at Perkins and 1.5 percent lower at Mangum. The male parent, Y-8, was as low as the hybrids at Perkins, but slightly higher at Mangum. Of the hybrids, Oklahoma 5903 and RS 610 were higher than the others in protein content at both locations.

The Relationship Between Protein and Grain Yield of Grain Sorghum:

The correlation of protein content with grain yield has been recognized by Garner (11), Sieglinger (34), Bartel (3), and Lowe (24). In this experiment a correlation was obtained also. The correlation coefficients calculated for both locations were -0.727 for Perkins and -0.476 for Mangum. The regression lines were drawn in Figures 3 and 4 for Perkins and Mangum, respectively.

The protein content of sorghum grain is determined in part by the total nitrogen available to the plant from the soil. Nelson (27) indicated that the protein content of

TABLE XXXVIII

PROTEIN CONTENT OF EIGHT HYBRIDS COMPARED WITH THEIR PARENTS, 1959

Female Parent		Hybrid		Male Parent	
Variety	Percent	F_1	Percent	Variety	Percent
		PERKINS			
Wheatland	9.6	Oklahoma 5901	9.1	Y-8	10.0
Westland	10.6	Oklahoma 5902	10.0	Y-8	10.0
Martin	12.2	Oklahoma 5903	11.0	Y-8	10.0
Combine Kafir-60	11.4	Oklahoma 5904	10.4	Y-8	10.0
Redlan	10.2	Oklahoma 5905	9.4	Y-8	10.0
Dwarf Early Redlan	10.8	Oklahoma 5906	9.2	Y-8	10.0
Combine Kafir-60	11.4	RS 610	11.1	Combine 7078	10.7
Combine Kafir-60	11.4	Texas 660	10.8	Caprock	10.8
Average	11.0		10.1		10.2
Hybrid decrease below average of parents			0.5 4.7%		

L.S.D. -- 1.25 and 1.70 percent at 5 percent and 1 percent level, respectively.

TABLE XXXVIII (Continued)

Female Parent		Hybrid		Male Parent	
Variety	Percent	F_1	Percent	Variety	Percent
		MANGUM			
Wheatland	11.2	Oklahoma 5901	10.2	Y-8	11.2
Westland	11.9	Oklahoma 5902	10.8	Y-8	11.2
Martin	12.9	Oklahoma 5903	10.8	Y-8	11.2
Combine Kafir-60	12.0	Oklahoma 5904	10.7	Y-8	11.2
Redlan	12.3	Oklahoma 5905	10.7	Y-8	11.2
Dwarf Early Redlan	11.5	Oklahoma 5906	9.9	Y-8	11.2
Combine Kafir-60	12.0	RS 610	10.8	Combine 7078	11.7
Combine Kafir-60	12.0	Texas 660	10.6	Caprock	12.2
Average	12.0		10.6		11.4
Hybrid decrease below average of parents			1.1 9.4%		

L.S.D. -- 0.75 and 1.00 percent at 5 percent and 1 percent level, respectively.

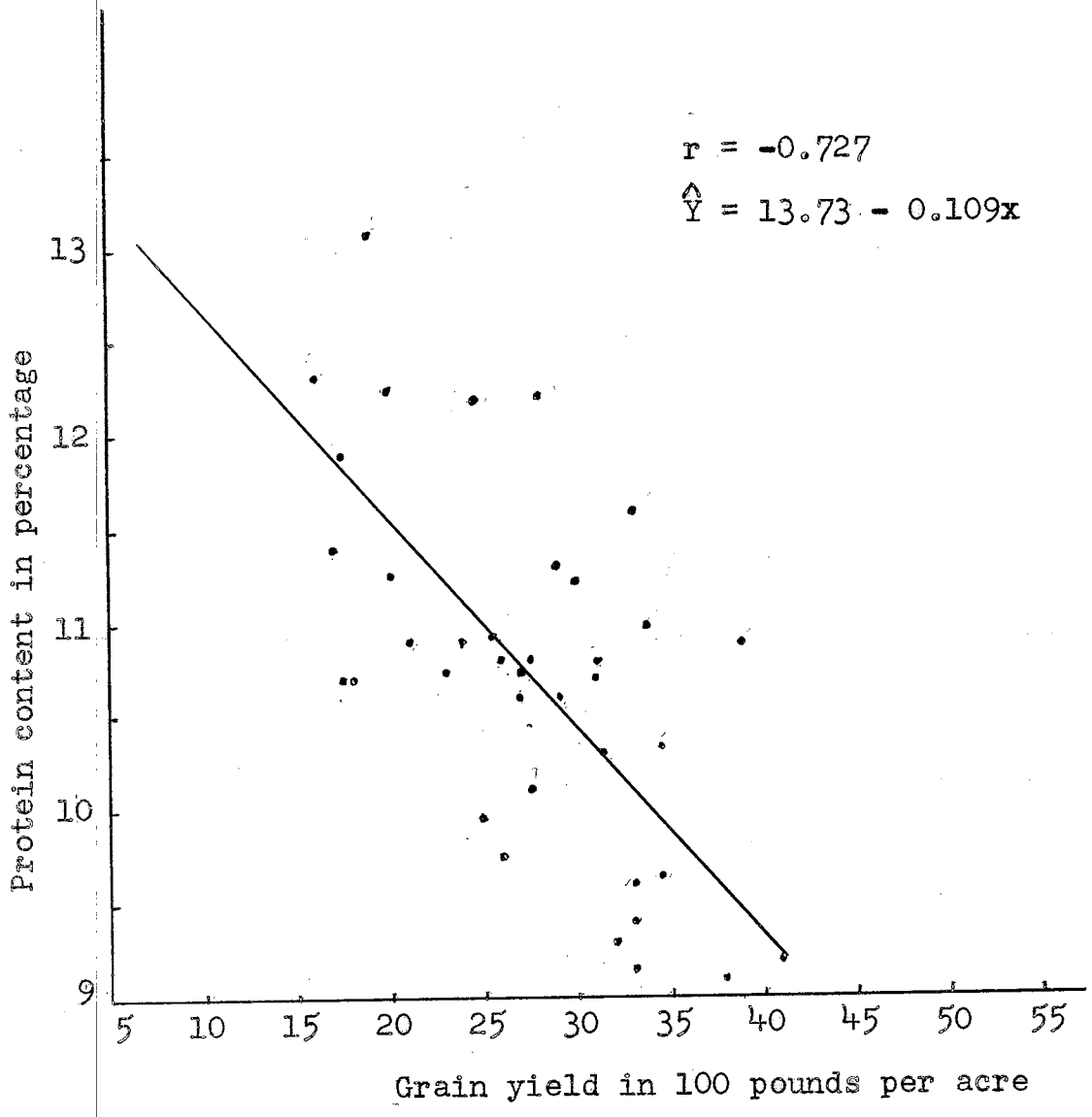


Figure 3. The Regression Line of Percentage of Protein Content on Grain Yield of Sorghum at Perkins, 1959

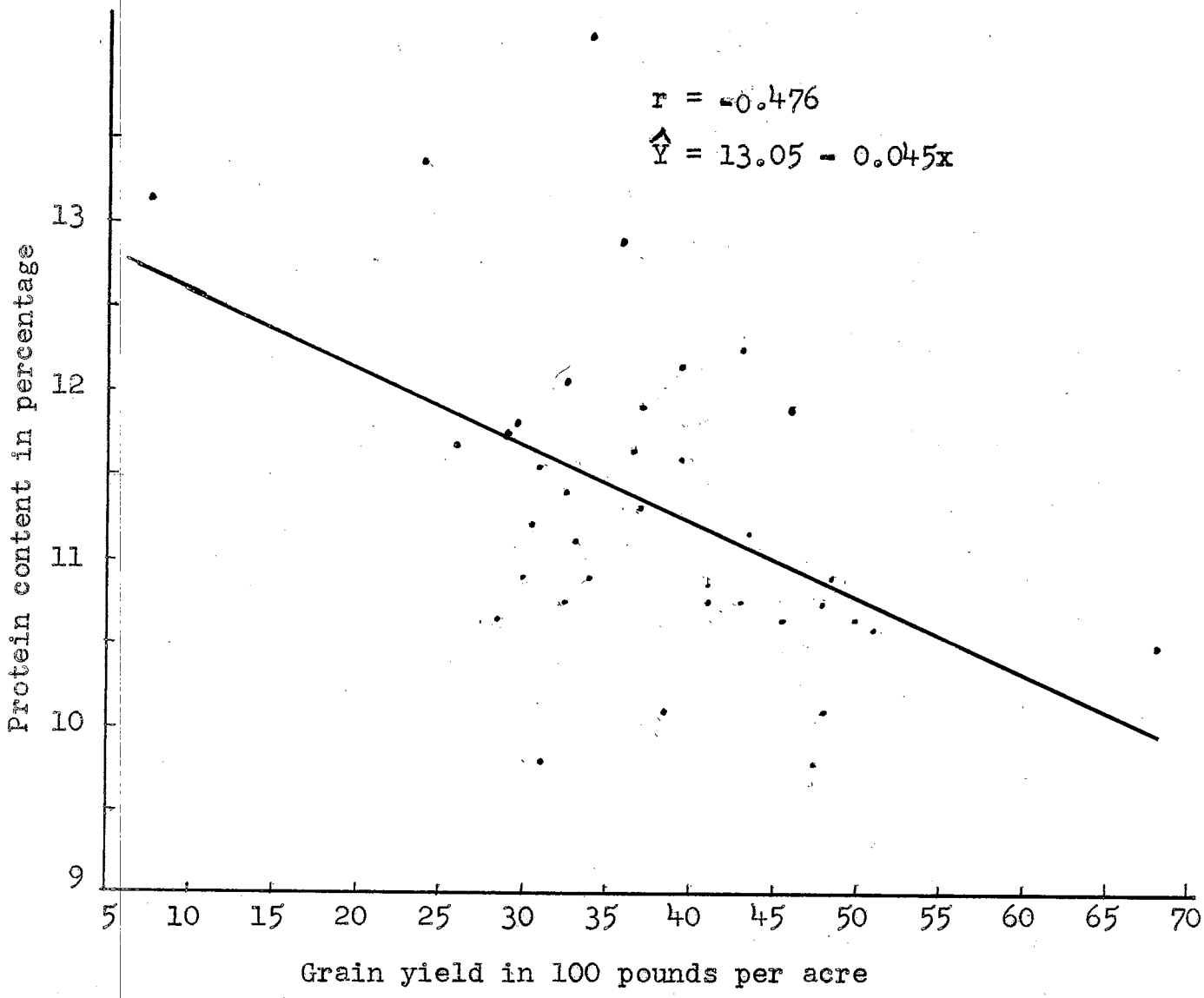


Figure 4. The Regression Line of Percentage of Protein Content on Grain Yield of Sorghum at Mangum, 1959

sorghum grain for three varieties increased with each increment of nitrogen fertilizer applied. If a soil is uniform with a uniform nitrogen level, the amount of nitrogen taken up from the soil by individual plant of the same crop should, theoretically, be equal. Thus, it might follow that the more grain produced in a unit area, the less nitrogen contained in the grain. Conversely, the less grain produced in a unit area, the more nitrogen contained in the grain. This is illustrated in Figures 3 and 4.

Carotenes, Xanthophylls, and Total Carotenoid Content in Sorghum Grain:

The determinations of carotenes, xanthophylls, and total carotenoid pigments were made on the grain from Mangum. In addition to the 37 entries in this test, hybrid seeds from four different possible combinations of yellow and non-yellow varieties were determined. Yellow corn was used for comparison in all determinations. The results of the chemical analyses are given in Table XXXIX.

In contrast with yellow corn, the carotene, xanthophyll and carotenoid pigments in yellow endosperm sorghum grain were relatively low, especially in carotene content. The yellow corn contained about 19.4 parts per million in total carotenoids, but the yellow endosperm sorghum varieties contained only 4.6 parts per million. The same results were indicated by Blessin, et al. (5).

There was considerable variation among the yellow endosperm varieties, Y-1 to Y-11, for carotene, xanthophyll, and

TABLE XXXIX

CAROTENE, XANTHOPHYLL, AND TOTAL CAROTENOID IN SORGHUM GRAINS AT MANGUM, 1959*

Unit: Parts Per Million

Entries	Carotene	Xanthophyll	Total Carotenoids
Oklahoma 5901	0.000	1.550	2.800
Oklahoma 5902	0.025	1.550	2.675
Oklahoma 5903	0.005	1.725	2.775
Oklahoma 5904	0.025	1.700	2.650
Oklahoma 5905	0.025	2.200	3.250
Oklahoma 5906	0.000	2.475	3.200
Oklahoma 5907	0.163	1.875	3.088
Wheatland	0.125	0.900	1.525
Westland	0.125	1.025	1.550
Martin	0.063	0.850	1.450
Combine Kafir-60	0.150	1.138	1.850
Redlan	0.156	1.500	2.200
Dwarf Early Redlan	0.275	1.500	2.550
Y-1	0.313	2.550	3.800
Y-2	0.125	2.575	3.575
Y-3	0.197	2.744	4.038
Y-4 (white)	0.200	2.825	4.300
Y-4 (yellow)	0.150	2.625	4.075
Y-5	0.171	3.450	4.792
Y-6	0.150	2.750	4.450
Y-7	0.063	2.725	3.875
Y-8	0.150	2.925	4.813
Y-9	0.200	3.350	4.725
Y-10	0.328	4.750	6.225
Y-11	0.075	5.650	7.250
Woodward 5601	0.005	0.675	1.750
Woodward 5602	0.125	1.430	2.225
Woodward 5805	0.175	2.200	3.450
RS 610	0.150	1.060	1.800
DeKalb E56a	0.063	1.350	2.150
Texas 660	0.025	1.325	2.050
Tan Redlan	0.105	1.378	2.150
Dwarf Early Red Kafir 4-1-4	0.100	1.193	1.775
Dwarf Early Red Kafir 8-2	0.063	0.900	1.575
811-Redlan	0.060	1.253	2.125
Combine 7078	0.163	1.003	1.675
Caprock	0.232	1.572	2.400
Non-yellow X Non-yellow	0.200	1.643	2.550
Yellow X Non-yellow	0.163	2.200	3.175
Non-yellow X Yellow	0.168	2.413	3.450
Yellow X Yellow	0.188	4.763	6.050
Corn	1.200	17.620	19.400

* Analysis from biochemistry by Dr. J. E. Webster.

total carotenoids content. Y-10 and Y-11 had substantially more xanthophyll and total carotenoids than any of the other varieties in this series. They were not higher in carotene, however. It was noted that the non-yellow endosperm varieties and hybrids showed as much carotene and in some cases as much xanthophyll, as the yellow endosperm types. Woodward 5805, having a yellow endosperm male parent, developed nearly as much carotene, xanthophyll and total carotenoids as the yellow varieties.

Theoretically, the hybrid seed from a cross from two yellow endosperm varieties should have more carotenoid pigments than any of the other three combinations (bottom of Table XXXIX). In this test it appeared to be true. The yellow times yellow was the highest one in all carotenoid pigments. In contrast to yellow corn, it had about one sixth as much carotene, one fourth as much xanthophyll and one third as much total carotenoids.

Variation in carotenoid pigments due to bagging was pointed out by Blessin, et al. (5). He found that the bagged seeds contained about twice as much carotene and xanthophyll as open seeds. The hybrid seeds from non-yellow times non-yellow contained about one half of the xanthophyll and total carotenoids in the hybrid seeds as from the yellow times yellow, but it was higher in carotene than the other non-yellow times non-yellow hybrids such as RS 610, Texas 660, Woodward 5601 and 5602 and DeKalb E56a. This probably was also due to the fact that the seeds were produced under bags. Hybrid seeds from

non-yellow times yellow and yellow times non-yellow contained approximately the same amount in carotene, xanthophyll and total carotenoids and they ranked between the yellow times yellow and non-yellow times non-yellow hybrids. These results indicated that the amount of yellow pigments in the hybrids came from both or either of the parents in equal amount depending on the yellow endosperm type.

Comparison of yellow and non-yellow endosperm kinds may be found in Table XXXX. Among the varieties, the yellow endosperm type had more carotene, xanthophyll and total carotenoids than the non-yellow types. In the hybrids, the non-yellow hybrids actually had more carotene than the yellow hybrids, but the yellow ones had more xanthophyll and total carotenoids. The differences were not as great among the hybrids as among the varieties. The yellow varieties showed more carotene, xanthophyll and total carotenoids than the yellow hybrids. This might have been expected since only two of the eight hybrids, indicated as yellow, had both yellow male and female parents. The other six had only a yellow male parent.

In Table XXXXI the eight hybrids were compared with their parents. The hybrids had less carotene than the yellow parent, but also less than the non-yellow parent. This can not be readily explained. The hybrids had 0.123 parts per million less carotene than the average of the parents.

In xanthophyll (Table XXXXII), the hybrids exceeded the non-yellow parents, but showed 0.160 parts per million less

TABLE XXXX

COMPARISON OF CAROTENE, XANTHOPHYLL AND TOTAL CAROTENOIDS OF VARIETIES VS. HYBRIDS AND YELLOW VS. NON-YELLOW ENDOSPERM VARIETIES AND HYBRIDS AT MANGUM, 1959

Variety or Hybrid	Yellow or non-yellow		Carotene	Xanthophyll	Total Carotenoid
Varieties (24)*	Yellow(12)*	Average	0.169	2.815	4.660
		Range	0.063-0.313	2.500-5.650	3.575-7.250
	Non-yellow (12)	Average	0.135	1.184	1.902
		Range	0.063-0.275	0.850-1.572	1.450-2.550
	Average		0.152	2.000	3.281
	Range		0.063-0.313	0.850-5.650	1.450-7.250
Hybrids (13)	Yellow (8)	Average	0.052	1.885	2.986
		Range	0.000-0.163	1.550-2.475	2.650-3.450
	Non-yellow (5)	Average	0.074	1.168	1.626
		Range	0.005-0.150	0.675-1.430	1.750-3.450
	Average		0.061	1.609	2.463
	Range		0.000-0.163	0.675-2.475	1.750-3.450
Yellow Corn			1.200	17.620	19.400

* The arabic number in the parathesis shows the number of varieties or hybrids.

TABLE XXXXI

CAROTENE CONTENT OF EIGHT HYBRIDS COMPARED WITH THEIR PARENTS AT MANGUM, 1959

Unit: Parts per Million

Female Parent		Hybrid		Male Parent	
Wheatland	0.125	Oklahoma 5901	0.000	Y-8	0.150
Westland	0.125	Oklahoma 5902	0.025	Y-8	0.150
Martin	0.063	Oklahoma 5903	0.005	Y-8	0.150
Combine Kafir-60	0.150	Oklahoma 5904	0.025	Y-8	0.150
Redlan	0.156	Oklahoma 5905	0.025	Y-8	0.150
Dwarf Early Redlan	0.275	Oklahoma 5906	0.000	Y-8	0.150
Combine Kafir-60	0.150	RS 610	0.150	Combine 7078	0.163
Combine Kafir-60	0.150	Texas 660	0.025	Caprock	0.232
Average	0.149		0.032		0.162
Hybrid decrease below average of parents			0.123 p.p.m.		

TABLE XXXXII

XANTHOPHYLL CONTENT OF EIGHT HYBRIDS COMPARED WITH THEIR PARENTS AT MANGUM, 1959

Unit: Parts per Million

Female Parent		Hybrid			Male Parent
Wheatland	0.900	Oklahoma 5901	1.550	Y-8	2.925
Westland	1.025	Oklahoma 5902	1.550	Y-8	2.925
Martin	0.850	Oklahoma 5903	1.725	Y-8	2.925
Combine Kafir-60	1.138	Oklahoma 5904	1.700	Y-8	2.925
Redlan	1.500	Oklahoma 5905	2.000	Y-8	2.925
Dwarf Early Redlan	1.500	Oklahoma 5906	2.475	Y-8	2.925
Combine Kafir-60	1.138	RS 610	1.060	Combine 7078	1.003
Combine Kafir-60	1.138	Texas 660	1.325	Caprock	1.572
Average	1.149		1.673		2.516
Hybrid decrease below average of parents			0.160 p.p.m.		

than the average of the parents. The highest reading for a hybrid was 2.475 parts per million for Oklahoma 5906.

The hybrids had about 0.3 parts per million less total carotenoids than the average of the parents (Table XXXXIII). For this determination the hybrids clearly had more carotenoids than the female (non-yellow) parents.

TABLE XXXXIII

TOTAL CAROTENOIDS OF EIGHT HYBRIDS COMPARED WITH THEIR PARENTS AT MANGUM, 1959

Unit: Parts per Million

Female Parent		Hybrid			Male Parent
Wheatland	1.525	Oklahoma 5901	2.800	Y-8	4.813
Westland	1.550	Oklahoma 5902	2.675	Y-8	4.813
Martin	1.450	Oklahoma 5903	2.775	Y-8	4.813
Combine Kafir-60	1.850	Oklahoma 5904	2.650	Y-8	4.813
Redlan	2.200	Oklahoma 5905	3.250	Y-8	4.813
Dwarf Early Redlan	2.550	Oklahoma 5906	3.200	Y-8	4.813
Combine Kafir-60	1.850	RS 610	1.800	Combine 7078	1.675
Combine Kafir-60	1.850	Texas 660	2.050	Caprock	2.400
Average	1.853		2.650		4.119
Hybrid decrease below average of parents			0.336 p.p.m.		

SUMMARY

The experiment was conducted at four locations in Oklahoma. They were Perkins, Mangum, Woodward, and Goodwell. The results from the Woodward test were received too late to be included in this study. The Goodwell test was not harvested due to poor seedling establishment. Thus the data presented in this study came from Perkins and Mangum.

Thirty-seven grain sorghum varieties and hybrids were in this test. Thirteen hybrids consisted of seven experimental crosses with a yellow endosperm pollinator from Stillwater, three experimental crosses from Woodward, and three standard hybrids to serve as check. Twenty-four varieties consisted of twelve yellow endosperm selections from the Oklahoma breeding program, six non-yellow varieties as parents of the hybrids and six other selections in the early stages of testing.

The test was sown in a randomized complete block design, using four replications. Single rows 40 inches apart and 40 feet long served as plots.

All the observed characteristics in this study were divided into two groups: (1) yield and other agronomic characteristics, including days to bloom, plant height, head length, bushel weight, weight of 1,000 seed, tiller percentage, lodging percentage, and threshing percentage; and (2) chemical characteristics including protein and carotenoid pigment content.

The hybrids produced from 30 to 40 percent more grain, were from 1 to 2 days earlier in blooming, were from 4 to 5 inches taller in plant height, were from 1 to 2 inches longer in head length, had from 6 to 14 percent more tillers and lodged 12 percent more than the average of parents.

Compared with the check hybrids, some of the yellow endosperm hybrids were higher and some were lower in grain yield, bushel weight and threshing percentage. Other characteristics varied, but these difference were not great.

Woodward hybrid 5601 was highest in grain yield, but was also the tallest and had the highest lodging percentage.

Compared with other varieties, in most cases, the yellow endosperm varieties were slightly lower in grain yield, in bushel weight and in lodging percentage.

It was concluded that hybrids produced more grain than varieties due to increased tillers and increased number of seed per plant, and that there was no consistant relationship with weight of 1,000 seed and bushel weight.

Hybrids had about 1 percent less protein than the average of the parents. The 811-Redlan strain was the highest with 14 percent. In the yellow endosperm strains, Y-11 and Y-6 were higher than other yellow endosperm strains. Grain yield was negatively correlated with protein content. The correlation coefficients (r) were -0.7 and -0.4 for Perkins and Mangum, respectively.

Yellow endosperm varieties had one seventh as much carotene, one sixth as much xanthophyll, and one fdurth as much

total carotenoid pigments as yellow corn. Hybrids with only one yellow endosperm parent had about one-third as much carotene, one-half as much xanthophyll, and three-fifths as much total carotenoid pigments as the yellow endosperm varieties.

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VITA

Wei-ning Fu

Candidate for the Degree of

Master of Science

Thesis: AGRONOMIC CHARACTERISTICS, PROTEIN, AND CAROTENOID COMPOSITION OF SOME GRAIN SORGHUM VARIETIES, STRAINS AND HYBRIDS --- WITH EMPHASIS ON YELLOW ENDOSPERM TYPES

Major Field: Agronomy (Field Crops)

Biographical:

Personal Data: Born at Shantung, China, February 24, 1925, the son of T. C. Fu and Shih Yu.

Education: Attended primary school and high school in Shangtung, China. Graduated from high school in 1945; received the Bachelor of Science degree from National Honan University, with a major in Agronomy, in 1949; completed the requirements for the Master of Science degree in May, 1960.

Professional experience: Served as teacher in high school at Taipei, Taiwan, China, 1949-1952; entered Taiwan Tobacco Research Institute as assistant agronomist at Taichung, Taiwan, China 1952-1957.

Professional Organizations: Member of Agricultural Association of China and the American Society of Agronomy.

Date of Final Examination: May 1960