A COMPARISON OF THE RELATIVE GRAIN YIELDS OF WAXY AND STARCHY GENOTYPES WITHIN 9 STRAINS OF SORGHUM

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Introduction

Sorghum varieties producing seed with waxy endosperms have been known for a great number of years. In China, the grain of waxy rice and sorghum has been used in the preparation of foods for special occasions, as stated by Cushing (9)[1].

The waxy endosperm is so named because the cut surfaces of kernels which have this character have a uniform waxy, opaque appearance, while the cut surfaces of kernels with the usual type of endosperm either are more lustrous and hard or else white and chalky in appearance. The iodine test quickly identifies the two types of starch.

Comparatively recent studies have shown that the starch of the waxy cereals has many properties similiar to those of tapioca starch. At the present time many producers and plant breeders in the United States are interested in the waxy sorghum grain as a source of tapioca starch and for the manufacture of other special starches. Tapioca starch, consumed largely as a human food, is also used in the preparation of adhesives for postage stamps, envelopes, boxes and packages, and sizings for the textile and paper industries.

The chief source of tapioca starch, prior to World War II, was from the roots of the cassava plant, *Manihot utilissima*, Pohl, which is grown abundantly in the Dutch East Indies. As much as 375,000 tons of this product have been imported into the United States in one year but as a result of the war in the Pacific this source of tapioca starch is no longer available. Consequently, it has been suggested by the

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[1] Figures in parenthesis refer to "Literature Cited". p. 20.

sorghum investigators that the waxy-seede sorghums be utilized as a domestically produced substitute.

Grasses in which there are known to be strains having the waxy endosperm include corn, *Zea mays*, L.; sorghum, *Sorghum vulgare*, Pers.; rice, *Oryza sativa*, L.; barley, *Hordeum vulgare*, L.; proso millet, *Panicum milaceum*, L.

No definite studies with the waxy type cereals have been made to determine the effect of the waxy gene on the yield of grain when the waxy, heterozygous, and starchy genotypes are derived from the same parental stock and compared on a uniform basis.

The primary objectives of these investigations were to determine (1) the effect of the waxy gene on yield, (2) the relative differences in yield of the waxy, heterozygous, and starchy genotypes, and (3) the segregation for the waxy and starchy allels of self-fertilized heterozygous plants.

Review of Literature

Experimental data regarding the effect of the waxy gene on the yield of grain of sorghum and other grass crops such as corn, rice, barley, and proso millet when the parentage of the waxy and starchy genotypes is identical is sparse. However, considerable data are available concerning the inheritance of the waxy and starchy genes and how the two genotypes may be identified.

The second generation hybrids from a waxy crossed with a sweet type corn produced starchy, waxy, and sweet seeds on the same self-fertilized plant according to Collins and Kempton (8). Separate weights of the three classes of seed showed that in nearly every ear the starchy seeds were heavier than the waxy, which in turn were heavier than the sweet. They concluded the differences in weight was due to differences in size since the specific-gravity determinations showed no significant differences.

A similiar study with sorghum was made by Karper and Quinby (12) in 1937. To determine to what extent the waxy gene normally reduces the weight of the seed, the starchy and waxy seeds from 3 segregating heads of sorghum were separated and weighed. The starchy seeds were found to have a relative weight of 104.4% as compared to 100% for the waxy seeds. Increases four times this large were obtained when Hegari or milo was used as one of the parents.

Investigations of the heredity of the waxy gene in sorghum show that when a waxy variety is crossed with a homozygous starchy variety, the F_1 seeds have a starchy endosperm. The starchy endosperm of this F_1 hybrid cannot be distinguished from that of homozygous starchy varieties, although it behaves in an entirely different manner in the following generation. Such F_1 plants produce both waxy and starchy seeds in the F_2 generation. Karper (11) states that the waxy gene in sorghum is inherited as a simple Mendelian recessive. The proportion of starchy to waxy seeds produced from F_2 hybrids fits the monohybrid ratio, 3:1.

Most of the investigators that have worked on the inheritance of the starchy and waxy genes in sorghum used the iodine test as a rapid means of distinguishing the waxy from the starchy genotype. Karper (11) reports that the cross-sectioned surface of the waxy seed stains reddish-brown, whereas, the starchy seeds give a typical blue starch reaction when stained with an aqueous solution of potassium iodide and iodine. He also reports that the reddish staining of the waxy seed is confined to the endosperm starch, the pericarp and embryo staining blue.

Probably more work has been done with corn in studying the waxy character than with any other grass. The waxy character in maize was first described in 1909 by Collins (6), who noted that it involved a new type of endosperm. He states that in inheritance, the waxy gene behaves as a simple recessive to the starchy condition. Collins and Kempton (7) and Kempton (13) have shown that the waxy gene in corn is recessive to the flint, horny, pop, dent, and starchy genes and that only the sugary gene is recessive to waxy. They also state that in the F_2 generation, segregation of the kernels occur in agreement with the simple Mendelian ratio of 3 starchy to 1 waxy and xenia is displayed in the endosperm starch when recessive waxy flowers are fertilized with the starchy type pollen. Segregation is visible in the gametophytic generation of heterozygous plants and the waxy and starchy pollen grains are produced in equal numbers as indicated by the iodine test. Similiar results were obtained by Kiesselbach and Peterson (14) on the segregation of carbohydrates in crosses between waxy and starchy types of corn.

Investigations with corn by Demeric (10), Brink and MacGillivray (4), Kiesselbach and Peterson (14), Longley (15), and Brink (2) also demonstrate the presence of the waxy gene in the pollen. They show the presence of the waxy and starchy allelomorphs in the male gametophyte of segregating plants in which the waxy and starchy pollen grains are produced in equal proportion. The waxy pollen stained a reddish-brown color and the starchy pollen stained blue when treated with an iodine-potassium iodide solution.

Similiar observations with rice in which the starchy gene is completely dominant over the waxy gene were reported by Parnell (16) and Chao (5). The two kinds of kernels and the three classes of pollen were differentiated by their coloration with an iodine solution. The pollen grains from homozygous starchy plants stain blue, those from waxy plants reddish-brown, and the pollen from heterozygous plants 50% blue and 50% reddish-brown.

Experimental results with corn show an average shortage of 0.8% for the waxy kernels according to Kempton (13). Data reported by Bregger (1) in connection with linkage studies in corn show a 1% shortage from the expected number of waxy kernels. Brink (2) and Collins and Kempton (7) report shortages of 1.7% and 1.1%, respectively, of waxy kernels from selfed F_2 heterozygous corn plants. Kiesselbach and Peterson (14) obtained additional data and summarized all the available corn data which show a waxy kernel deficiency of 1.1% from the expected 25% when the heterozygote is selfed and 0.7% deficiency from the expected 50% when the heterozygote is backcrossed to the recessive. They conclude, however, that the evidence at hand seems insufficient to definitely establish the causes or significance of these deviations. In a study of 6,879 rice kernels, Parnell (16) reports a waxy kernel deficiency of 1.9%.

Several explanations have been offered to account for the deficiency of waxy kernels by Brink and Burnham (3), Brink and MacGillivray (4), Kiesselbach and Peterson (14), and Kempton (13). The following causes have been proposed: (1) Lack of vigor of the pollen carrying the waxy gene causing slower growth of the pollen tube;

(2) differential selection of sperm by female gametes; (3) greater death rate of zygotes homozygous for waxy; (4) differential death rate of the gametes during their formation so that equal numbers do not function.

Materials and Methods

This study was conducted in 1946 on the Oklahoma Agricultural Experiment Station Agronomy Farm on level Miller clay loam soil. The 9 sorghum strains investigated were furnished by Mr. J. B. Sieglinger, Agronomist, in charge of sorghum investigation at the Oklahoma Agricultural Experiment Station.

The seed of each strain was produced by selfing F_4 generation heterozygous plants and the pedigree of each is as follows: (1) 71 x Leoti x Bonar; (2) Cody x Dwarf White feterita; (3) 71 x Leoti x Dwarf White feterita; (4) 71 x Leoti x Yellow darso; (5) 71 x Leoti x 85; (6) 71 x Leoti x 695-2-1; (7) 71 x Leoti x Dwarf White feterita; (8) 71 x Leoti x Dwarf kafir; (9) Cody x Yellow darso. The plantings were made May 15, 1946, in 2-row plots with 42-inch row spacing. Two border rows were planted adjacent to the outside strain on each side and 3 feet at the end of each row was allowed for border. A job planter was used to plant the seed so the spacing in the row could be controlled, having 1 plant per 12 inches within the row. To insure a uniform stand, 3 to 5 seeds were planted per hill and after the plants were well established they were thinned to 1 plant. General cultural methods, common to this region, were practiced during the growing season. All suckers or tillers were spudded out so only 1 head per plant was produced.

Frequent observations were made as the plants approached the blossoming period and all the plants within 1 row of each of the 9 strains were self-pollinated by bagging before pollen shedding started. Maturity dates were variable among the strains with the 3 dwarf types maturing during the early part of August and the 6 standard types maturing in late August.

During the pollination period a small amount of pollen was collected from each plant in both the bagged and unbagged rows. The pollen was placed on a microscope slide and stained with a solution containing 1.5 cc of potassium iodide and iodine (stock solution-3g. of KI, 2g. of I., and 50 cc of H_2O), 50 cc of water, and 15 drops of glacial acetic acid. The plant genotypes of waxy, heterozygous, and starchy were determined by studying the pollen under the low-power lens (450x) of a microscope. Previous work showed that the waxy pollen stained reddish-brown, the starchy blue, and the heterozygous 50% reddish-brown and 50% blue (Fig. 1). As the pollen from each plant was identified, the plant was tagged and labeled according to genotype.

The pollination period for each strain ranged from 5 to 15 days depending upon the weather conditions. After pollination had ceased on the unbagged rows, each head was bagged and remained bagged until harvest to prevent damage by birds.

After maturity the sorghum heads were allowed to thoroughly dry in the field before harvesting, September 15. All heads were harvested except those next to hills that produced no plants in the rows which might show border effect. A count of all the heads, before discarding those showing border effect, was made for each of the

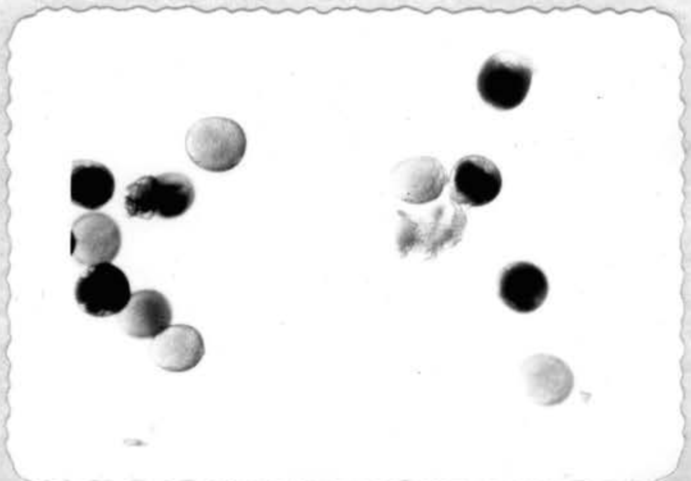

Figure 1.--Representative pollen grains from a heterozygous plant showing segregation into equal numbers of waxy and starchy grains which stain red and blue respectively, with iodine. The starchy grains are dark and the waxy light in this photograph.

9 strains and the number in each genotype was recorded in order to determine the ratio of segregation for the 3 genotypes. Each head was threshed individually and the foreign material was removed from the seed by using a small desk fan.

A torsion balance with a capacity of 125 grams was used in making the weight determination for each head sample. All weights are recorded in grams.

A separate analysis of variance was calculated for the waxy and starchy genotypes within each of the 9 strains to determine any significant yield differences. The bagged and unbagged conditions of pollination were compared by the use of the t test.

Results and Discussion

The analyses of variance of the experimental data are presented in table 1. A separate analysis of variance was calculated for the waxy and starchy genotypes within each of the 9 strains. According to the required F values in 5 of 18 plots (bagged and unbagged plots for each of the 9 strains), the yield of the starchy genotypes shows a significant increase over the waxy genotype at the 5% level and with one plot at the 1% level. The analyses of variance for the remaining 12 plots indicate no significant differences in yield for the two genotypes.

Four of the sorghum strains including 5 bagged and unbagged rows, namely, the unbagged row of 71 x Leoti x Yellow darso, unbagged row of 71 x Leoti x 695-2-1, bagged row of 71 x Leoti x Dwarf kafir, and both the bagged and unbagged rows of Cody x Yellow darso showed significant increases in yield of starchy over the waxy genotypes at the

Table 1.--Analyses of variance of grain yield of bagged and unbagged plants in waxy and starchy genotypes within 9 sorghum strains.

Strain	Source	D.F.	Sum of squares	Mean square	F values Actual	F values Required
71 x Leoti x Bonar						
Bagged	Total	40	4653.04			
	Genotype	1	344.69	344.69	3.12	4.09
	Error	39	4308.35	110.47		
Unbagged	Total	29	5673.84			
	Genotype	1	179.14	179.14	0.91	4.20
	Error	28	5494.70	196.24		
Cody x Dwarf White feterita						
Bagged	Total	30	1143.40			
	Genotype	1	19.19	19.19	0.49	4.18
	Error	29	1124.21	38.77		
Unbagged	Total	12	478.11			
	Genotype	1	21.40	21.40	0.52	4.84
	Error	11	456.71	41.52		
71 x Leoti x Dwarf White feterita						
Bagged	Total	43	3742.93			
	Genotype	1	61.53	61.53	0.70	4.07
	Error	42	3681.40	87.65		
Unbagged	Total	22	798.58			
	Genotype	1	103.27	103.27	3.12	4.32
	Error	21	695.31	33.11		
71 x Leoti x Yellow darso						
Bagged	Total	41	9196.58			
	Genotype	1	817.53	817.53	3.90	4.08
	Error	40	8379.05	209.48		
Unbagged	Total	40	12817.86			
	Genotype	1	1237.68	1237.68	4.17*	4.09
	Error	39	11580.18	296.93		
71 x Leoti x 85						
Bagged	Total	34	7089.96			
	Genotype	1	151.08	151.08	0.72	4.14
	Error	33	6938.88	210.27		
Unbagged	Total	30	3451.28			
	Genotype	1	14.01	14.01	0.12	4.18
	Error	29	3437.27	118.53		

Table 1.—Continued

Strain	Source	D.F.	Sum of squares	Mean square	F values Actual	F values Required
71 x Leoti x 695-2-1						
Bagged	Total	38	3488.16			
	Genotype	1	611.26	611.26	7.86**	4.11
	Error	37	2876.90	77.75		
Unbagged	Total	29	5348.49			
	Genotype	1	759.98	759.98	4.63*	4.20
	Error	28	4588.51	163.88		
71 x Leoti x Dwarf White feterita						
Bagged	Total	37	8891.77			
	Genotype	1	667.25	667.25	2.92	4.11
	Error	36	8224.52	228.46		
Unbagged	Total	30	7214.87			
	Genotype	1	177.67	177.67	0.73	4.18
	Error	29	7037.20	242.66		
71 x Leoti x Dwarf kafir						
Bagged	Total	32	2504.65			
	Genotype	1	403.07	403.07	5.95*	4.16
	Error	31	2101.58	67.79		
Unbagged	Total	37	6403.45			
	Genotype	1	136.02	136.02	0.78	4.11
	Error	36	6267.43	174.10		
Cody x Yellow darso						
Bagged	Total	36	6193.14			
	Genotype	1	764.31	764.31	4.93*	4.12
	Error	35	5428.83	155.11		
Unbagged	Total	36	5636.24			
	Genotype	1	764.06	764.06	5.49*	4.12
	Error	35	4872.18	139.21		

* Indicates that the F values exceed the values required for significance at the 5% level.

** Indicates that the F value exceeds the value of 7.37 required for significance at the 1% level.

5% level. The calculated F values were 4.17, 4.63, 5.95, 4.93, and 5.49 respectively, while the required F values to show significant differences in yield at the 5% level were 4.09, 4.20, 4.16, 4.12, and 4.12 respectively.

The bagged plants of 71 x Leoti x 695-2-1 showed a significantly higher yield for the starchy genotype at the 1% level. The calculated F value was 7.86, while the required F value to show significance at this level was 7.37.

The bagged row of 71 x Leoti x Bonar, unbagged row of 71 x Leoti x Dwarf White feterita, bagged row of 71 x Leoti x Yellow darso, and the bagged row of 71 x Leoti x Dwarf White feterita show no significant difference in yield for the waxy and starchy genotypes but have relatively high F values. The calculated F values for the above mentioned strains are 3.12, 3.12, 3.90, and 2.92 respectively, while the required F values to show significant differences in yield at the 5% level for these plots are 4.09, 4.32, 4.08, and 4.11 respectively. The genotypes in 8 additional plots have very low F values, ranging from 0.12 for the unbagged row of 71 x Leoti x 85 to 0.91 for the unbagged row of 71 x Leoti x Bonar, and show no indication that significant differences in yield might occur if similiar tests were repeated. All the required F values to show significance at the 5% level for these 8 plots exceed 4.0.

Of the 9 sorghum strains tested only two showed a significant increase in yield of the starchy over the waxy genotype for both the bagged and unbagged plants, which might indicate that there is a strain difference in yield for the two genotypes. The waxy never yielded more than the starchy genotype in any of the plots.

The required F values to show significant differences in yield of genotypes for each of the 9 strains are relatively large, which is probably due to a greater variation in the weights of the heads within a genotype than between the waxy and starchy genotypes.

Analyses of variance were also calculated in which the heterozygous genotype was included with the waxy and starchy genotypes. The heterozygous genotype, being intermediate in yield, had a tendency to narrow the yield margin between the waxy and starchy genotypes thus allowing the starchy genotype to yield significantly more than the waxy genotype at the 5% level for only 1 of the 18 plots. On the basis of odds of 19:1 this difference may be due to chance variation. The bagged row of the strain 71 x Leoti x 695-2-1 showed the significant difference, having an actual F value of 4.01 and a required F value of 3.12.

The yield of seed from the bagged and unbagged plants for each of the 9 strains were compared by the use of the *t* test. Three of the strains showed no significant difference in yield, while the unbagged plants of two strains showed significantly higher yields at the 5% level and 4 strains at the 1% level. Since considerable worm and mold damage occurred on the bagged heads, it is difficult to accurately measure the effect of cross pollination on yield.

The percent yield (based on waxy as 100%), the average, range, and relative yields for the waxy, heterozygous, and starchy genotypes within the 9 strains of sorghum are shown in table 2. These weights represent an average of the bagged and unbagged plants of each strain. Considering the average weight of the waxy heads for all strains as 100%, relative weights of 104.3% and 111.4% were found for the heterozygous and starchy genotypes, respectively. These data indicate that the heterozygous genotype is intermediate in yield. Although the range in head weights for the 3 genotypes within each of the 9 strains is quite variable, the starchy genotype is consistently the highest yielder. Considering each strain separately, even though the yield among the 9 sorghum strains was quite variable, the starchy genotype yielded more than the heterozygous and waxy genotypes. The heterozygous genotype also yielded more than the waxy genotype in each of the strains with the exception of Cody x Dwarf White feterita, which yielded 99.4% that of the waxy. The highest percent increase in yield for the starchy over the waxy genotype was 17% in two strains, 71 x Leoti x 695-2-1 and Cody x Yellow darso, while the starchy genotype of Cody x Dwarf White feterita yielded only 5% more than the waxy genotype. According to the data presented in table 2 the starchy genotype yielded 11.4% and 7.1% more than the waxy and heterozygous genotypes respectively, which shows a definite trend for the starchy to give higher yields than the waxy and heterozygous genotypes.

Counts of waxy, heterozygous, and starchy plants from the 9 segregating sorghum strains were made and compared with the Mendelian expectation. The number of waxy, heterozygous, and starchy plants in 9 progenies of self-fertilized, heterozygous plants compared with the number expected in accordance with the 1:2:1 hypothesis is shown in table 3. The observed numbers for each strain closely fit the Mendelian ratio of 1:2:1 except for the strain, 71 x Leoti x Dwarf White feterita, which showed a significant difference at the 5% level.

Table 2.--Average, range, and relative yields (based on waxy as 100%) of waxy, heterozygous, and starchy genotypes within 9 sorghum strains.

Strain	Waxy			Heterozygous			Starchy		
	Av. wt.	Range	Yield	Av. wt.	Range	Yield	Av. wt.	Range	Yield
	gms.	gms.	%	gms.	gms.	%	gms.	gms.	%
<u>71 x Leoti</u> x Bonar	63.4*	44--90	100.0	66.7	47-104	105.0	68.8	49-104	108.0
Cody x Dwarf White feterita	33.8	23--48	100.0	33.6	22--52	99.4	35.6	23--55	105.0
<u>71 x Leoti</u> x Dwarf White feterita	32.7	18--56	100.0	36.0	15--56	110.0	36.5	20--59	111.0
<u>71 x Leoti</u> x Yellow darso	66.5	45-102	100.0	68.9	42-112	103.0	76.4	47-115	114.0
<u>71 x Leoti</u> x 85	53.7	32--82	100.0	54.0	35--83	100.5	57.1	40--88	106.0
<u>71 x Leoti</u> x 695-2-1	52.0	34--92	100.0	55.1	31--87	105.9	61.2	36--88	117.0
<u>71 x Leoti</u> x Dwarf White feterita	50.6	36--69	100.0	51.1	27--82	101.0	57.2	26--88	113.0
<u>71 x Leoti</u> x Dwarf kafir	45.0	23--68	100.0	46.6	28--67	103.6	50.4	23--67	112.0
Cody x Yellow darso	54.1	40--74	100.0	59.9	36--93	110.0	63.6	40-104	117.0
Average	50.2		100.0	52.4		104.3	56.3		111.4

*Average weight of bagged and unbagged heads.

Table 3.—Numbers of waxy, heterozygous, and starchy sorghum plants in 9 progenies of self-fertilized, heterozygous plants with numbers expected under the 1:2:1 hypothesis, and values of Chi-square.

Strain	Total No. Plants	Observed			Expected			Chi-square
		Waxy	Hetero-zygous	Starchy	Waxy	Hetero-zygous	Starchy	
71 x Leoti x Bonar	123	27	62	34	31	62	31	0.81
Cody x Dwarf White feterita	105	22	50	33	26	52	26	2.58
71 x Leoti x Dwarf White feterita	110	21	54	35	27	54	27	3.70
71 x Leoti x Yellow darso	107	26	48	33	27	54	27	2.04
71 x Leoti x 85	87	23	42	22	22	44	22	0.14
71 x Leoti x 695-2-1	119	28	57	34	30	60	30	0.82
71 x Leoti x Dwarf White feterita	93	16	44	33	23	46	23	6.57*
71 x Leoti x Dwarf kafir	103	20	56	27	26	52	26	1.73
Cody x Yellow darso	96	24	44	28	24	48	24	1.00
Total	943	207	457	279	236	472	236	
Total for all strains. . . . . . df = 18; P = 37.84								

* Indicates that the value for Chi-square exceeds the value of 5.99 required for significance at the 5% level.

This difference may be due to chance variation since a relatively small number of individuals were used. The Chi-square values ranged from 0.14 for the strain 71 x Leoti x 85 to 6.57 for 71 x Leoti x Dwarf White feterita. The probability when the 9 strains are totaled is 37.84%, which indicates that similiar tests may be expected to give approximately the same observed numbers between 35% and 40% of the time which is considered to be a good fit for a 1:2:1 ratio.

A further study was made to determine the percent waxy plants produced from the entire population of bagged heads within the 9 strains. In this test 943 selfed F_2 heterozygous plants were observed, 207 were waxy, 457 heterozygous, and 279 starchy as determined by the iodine test. The expected numbers are 236, 472, and 236 respectively, on the basis of a 1:2:1 ratio. According to these observations 21.99% of the plants were of the waxy genotype or a deficiency of 3.01% from the expected 25%. Following is the percentage of waxy plants produced within each of the 9 heterozygous selfed strains: 71 x Leoti x Bonar, 21.95%; Cody x Dwarf White feterita, 20.95%; 71 x Leoti x Yellow darso, 24.29%; 71 x Leoti x 85, 26.44%; 71 x Leoti x 695-2-1, 23.53%; 71 x Leoti x Dwarf White feterita, 17.20%; 71 x Leoti x Dwarf kafir, 19.42%; Cody x Yellow darso, 25.00%; 71 x Leoti x Dwarf White feterita, 19.09%. The percent range of waxy plants produced within the 9 strains was from 17.20% to 26.44%. These data are in agreement with those of Sieglinger[2], who recently examined 24 hybrid strains and found an average of 23.15% plants of the waxy genotype produced when the heterozygous plants were

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[2] Unpublished. Courtesy of Mr. J. B. Sieglinger, in charge of sorghum investigations, Oklahoma Agricultural Experiment Station, Stillwater, Oklahoma.

selfed or a deficiency of 1.85% from the expected 25%. The percent waxy type plants produced within the 24 hybrid strains ranged from 17.18% to 26.37%. Similiar experimental results tabulated by Kiesselbach and Peterson (14) and Collins and Kempton (7), working with corn, show a deficiency of waxy kernels ranging from 0.7% to 1.7%, respectively from the expected 25% when the F_2 heterozygote is selfed. Parnell (16), working with rice, reports a 1.9% deficiency of waxy kernels from the expected 25%.

Summary

An experiment to determine the effect of the waxy gene on yield, the relative differences in yield of the waxy, heterozygous, and starchy genotypes, and the segregation of the waxy and starchy allels from self-fertilized heterozygous plants within 9 sorghum strains was conducted on the Oklahoma Agricultural Experiment Station Agronomy Farm in 1946.

Since the data presented in this paper represent the results obtained during only 1 year, no definite conclusions can be drawn. The conclusions made at this time may be altered by results obtained in the future. The 1 year's data, however, show the following:

1. The yield of the starchy genotype was significantly higher than the waxy at the 5% level for 5 of the 18 plots including the unbagged row of <u>71 x Leoti</u> x Yellow darso, unbagged row of <u>71 x Leoti</u> x 695-2-1, bagged row of <u>71 x Leoti</u> x Dwarf kafir, and both the bagged and unbagged rows of Cody x Yellow darso.
2. The yield of the starchy genotype was significantly higher than the waxy genotype at the 1% level for the bagged plants of <u>71 x Leoti</u> x 695-2-1.

3. Two strains, 71 x Leoti x 695-2-1 and Cody x Yellow darso, gave significantly higher yields for the starchy genotype for both the bagged and unbagged plots when the analyses of variance were computed, which might indicate that there is a strain difference in yield for the two genotypes.
4. The heterozygous genotype, being intermediate in yield, had a tendency to narrow the yield margin between the waxy and starchy genotypes when analyses of variance were calculated including the waxy, heterozygous, and starchy genotypes. According to the calculations only the bagged row of the strain 71 x Leoti x 695-2-1 showed a significantly higher yield for the starchy genotype at the 5% level which may be due to chance variation, since only 1 plot in 18 showed a significant difference.
5. According to the average head weights and relative yields of waxy, heterozygous, and starchy genotypes within the 9 sorghum strains, the starchy genotype was consistently the highest yielder. Considering the weight of the waxy seed as 100%, the heterozygous and starchy seed were found to have relative weights of 104.3% and 111.4% respectively.
6. The proportion in which the waxy, heterozygous, and starchy types occurred from selfed heterozygous plants approximates the Mendelian ratio of 1:2:1.
7. The data presented show a deficiency of 3.01% waxy plants from the expected 25% when the hybrid strains were selfed. Of the various explanations that have been offered to account for this deficiency the most plausible one would seem to be, unequal fertilization resulting from differential pollen tube growth dependent upon the waxy factor or a linked factor.

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A P P E N D I X

Table 4.--Grain yield in grams of bagged and unbagged plants in waxy, heterozygous, and starchy genotypes within 9 sorghum strains.

	Bagged				Unbagged			
	Waxy	Heterozygous		Starchy	Waxy	Heterozygous		Starchy
	gms.	gms.		gms.	gms.	gms.		gms.
				71 x Leoti x Bonar				
	55.4	66.2	76.8	76.4	55.6	68.4	81.4	61.2
	48.2	60.6	54.2	62.8	72.3	92.3	77.6	78.5
	73.5	56.2	60.1	74.2	82.7	71.9	65.2	60.1
	80.0	72.0	54.0	55.2	72.9	47.0	104.1	103.6
	52.1	62.1	79.1	66.3	68.5	60.1	61.7	69.5
	55.2	59.5	69.0	75.6	55.1	74.1	65.8	56.8
	54.4	61.2	67.3	86.1	71.2	61.7	72.6	67.5
	59.8	83.3	61.2	66.8	68.8	62.1	65.8	63.5
	78.8	63.8	74.6	52.8	43.7	66.1	60.6	62.7
	56.6	71.4	80.0	58.5	72.7	70.1	48.2	80.4
	47.5	48.9	62.1	49.4	72.5	60.6	84.3	52.5
	56.6	64.6	53.4	58.8	90.4	71.1	69.6	83.9
	73.7	65.1	67.3	76.7	45.2	56.5	87.1	60.8
	62.9	57.1	65.4	70.5	56.8	69.5	80.1	72.4
	51.9	56.7	65.6	55.9		47.2	64.4	98.8
	57.4	80.2	70.1	77.3				67.2
	69.0	56.7	71.7	53.2				
	72.7	55.1	61.2	77.5				
	59.5	67.5	67.9	78.5				
				74.2				
				75.8				
				54.6				
Av.	61.3	65.0		67.1	66.3	68.9		71.2

Table 4.--Continued.

Bagged				Unbagged			
Waxy	Heterozygous		Starchy	Waxy	Heterozygous		Starchy
gms.	gms.		gms.	gms.	gms.		gms.
Cody x Dwarf White feterita							
28.2	35.1	40.6	38.9	41.0	52.2	46.7	32.2
33.7	25.5	24.4	22.9	38.4	37.7	41.8	45.8
36.9	31.1	30.5	24.8	47.6	45.5	33.7	38.0
42.7	23.9	37.6	25.9	37.2	36.7	36.1	54.7
26.2	31.2	34.5	30.6	38.9	42.8	40.4	44.9
23.1	45.2	26.0	47.8	36.8	28.6	43.1	34.8
25.1	27.3	21.7	34.8				47.5
33.4	32.9	27.0	39.2				
32.5	28.6	30.8	31.8				
29.1	29.8	28.9	32.1				
26.0	30.1	31.7	41.1				
34.5	34.8	25.9	33.8				
36.1	32.3	25.8	27.1				
29.4			33.4				
			31.5				
			38.1				
			23.6				
Av. 31.2	30.5		32.8	40.0	40.4		42.6

Table 4.— Continued.

Bagged				Unbagged			
Waxy	Heterozygous		Starchy	Waxy	Heterozygous		Starchy
gms.	gms.		gms.	gms.	gms.		gms.
			71 x Leoti x Dwarf White feterita				
46.7	33.7	21.4	35.7	32.2	46.0	37.7	24.4
44.8	48.4	54.6	33.8	36.3	42.5	19.2	31.5
23.3	28.3	35.1	30.7	18.4	30.4	26.2	26.5
57.6	18.1	34.6	32.6	32.4	31.4	32.8	36.8
18.1	25.2	53.8	40.7	26.1	26.9	34.9	32.6
26.8	50.5	26.3	36.1	25.3	38.8	44.8	36.2
41.2	31.3	49.0	30.3	23.8	50.7	28.0	41.2
25.6	42.8	39.6	41.4	34.8	32.4	29.3	38.4
22.1	50.2	45.2	34.9	32.2	31.6	14.9	27.9
44.5	25.0	49.8	37.0	26.6	34.5	25.1	38.4
55.8	25.1	47.9	55.6		15.5	39.6	27.4
26.8	41.5	29.8	28.5		38.3	21.6	40.7
32.6	32.3	34.1	44.8		32.4	31.7	28.1
31.7	41.4	38.5	33.7		46.4	34.4	
	41.5	24.6	28.8		23.9		
	39.2	40.1	51.6				
	46.8	32.0	51.3				
	43.8	29.2	59.3				
	47.8	52.9	35.0				
	27.9	55.7	38.2				
	24.5	44.8	29.4				
	30.2	44.6	43.1				
	29.7	50.2	31.6				
			56.8				
			29.0				
			20.1				
			43.9				
			27.4				
			38.6				
			37.8				
Av. 35.5	38.2		37.9	28.8	32.5		33.1

Table 4.--Continued.

Bagged				Unbagged			
Waxy	Heterozygous		Starchy	Waxy	Heterozygous		Starchy
gms.	gms.		gms.	gms.	gms.		gms.
			71 x Leoti x Yellow darso				
53.8	61.3	60.2	95.6	69.4	93.1	43.1	83.8
63.9	52.3	48.9	58.5	57.2	69.7	79.3	46.6
101.8	67.9	74.9	78.8	79.1	68.9	69.0	78.8
71.7	51.4	77.8	84.4	57.3	75.5	65.8	72.4
79.5	90.6	56.3	82.5	91.8	54.2	98.3	68.8
80.7	66.1	78.3	76.7	79.3	88.5	45.9	81.0
50.2	78.7	65.2	77.8	97.5	77.6	97.2	115.0
75.3	55.9	63.2	77.6	60.4	60.3	48.2	99.2
52.5	78.1	64.5	69.5	71.2	76.1	112.2	73.5
49.6	71.9	79.2	73.1	83.4	41.9	85.1	66.5
35.4	49.4	62.9	85.4	100.9	74.7	48.9	65.1
51.5	65.0	52.2	97.2	47.5	62.1	68.2	110.3
52.6	71.1	66.3	73.1	66.9	89.2	71.9	79.3
78.8	45.5	58.1	54.3	45.3	54.8	45.6	88.1
87.8			66.8	65.7	87.3	67.8	75.3
47.9			83.4	64.1	103.0	71.0	98.5
50.4			64.2	63.5	97.9		76.3
63.0			59.8	46.4			75.8
			58.7				50.6
			62.0				87.7
			72.3				94.8
			73.6				102.4
			56.7				58.1
			60.5				
Av. 63.7	64.8		72.6	69.3	72.5		80.3

Table 4.--Continued.

Bagged				Unbagged			
Waxy	Heterozygous		Starchy	Waxy	Heterozygous		Starchy
gms.	gms.		gms.	gms.	gms.		gms.
			<u>71 x Leoti x 85</u>				
82.0	48.3	83.1	82.6	64.7	64.4	37.9	56.0
69.4	59.2	39.6	75.5	49.7	72.3	71.1	53.1
59.4	55.7	47.0	49.9	45.5	82.9	53.8	58.4
67.0	48.6	49.9	47.9	53.4	70.4	47.5	41.2
43.5	72.4	48.1	47.6	45.1	47.3	62.2	69.7
46.5	46.3	41.5	49.1	53.3	42.5	56.2	50.5
32.0	43.1	61.7	47.9	52.1	54.7	45.3	40.1
80.2	50.0	65.5	53.5	36.7	47.5	50.3	42.1
59.8	43.0	48.9	80.9	39.0	59.5	48.6	60.1
37.2	41.6	60.7	50.0	63.1	58.9	44.2	51.0
52.4	58.2		61.6	70.1	34.8	65.4	44.5
58.6			55.1	67.3	41.6	40.8	71.7
62.8			57.7	50.3	57.5	70.2	64.7
37.0			48.3	46.5	53.5		
35.8			56.6	55.3			
			70.3	56.6			
			88.2	31.7			
			59.7	68.6			
			43.2				
			56.5				
Av. 54.9	53.0		59.1	52.7	54.9		54.1

Table 4.--Continued.

Bagged				Unbagged			
Waxy	Heterozygous		Starchy	Waxy	Heterozygous		Starchy
gms.	gms.		gms.	gms.	gms.		gms.
			71 x Leoti x 695-2-1				
55.0	46.7	48.8	53.6	61.6	51.6	58.3	52.4
49.5	59.1	57.0	60.1	49.1	63.9	66.4	54.9
54.4	49.0	59.5	79.0	91.9	70.8	58.6	76.1
50.6	59.8	38.9	63.8	48.5	87.0	53.1	78.3
40.3	38.8	43.7	62.3	42.7	56.6	49.8	66.0
35.3	48.6	51.0	49.5	58.8	44.6	53.5	62.2
44.8	47.5	46.6	35.9	42.6	57.5	70.5	71.5
50.6	58.7	30.7	69.4	58.3	86.4	52.4	87.9
51.6	43.4	72.5	54.4	33.6	52.2	52.1	64.5
48.6	52.6	37.5	52.2	48.6	44.8	38.9	61.6
56.9	51.9	74.3	48.6	54.6	60.0	50.7	47.3
46.7	60.5	53.2	56.6	62.1	59.1	61.4	56.1
67.4	68.9	47.6	42.4	65.3	55.3	80.8	56.7
41.5	57.2	48.1	69.8		72.1	48.8	76.2
52.7	58.1	49.1	62.6		59.1		64.5
55.3	50.1	42.4	60.7				53.8
40.4	57.1	38.1	63.5				81.2
56.3	51.7	64.8	54.3				
48.1	54.8		64.4				
			51.1				
Av. 49.8	51.8		57.7	55.2	59.2		65.4

Table 4.—Continued.

Bagged				Unbagged			
Waxy	Heterozygous		Starchy	Waxy	Heterozygous		Starchy
gms.	gms.		gms.	gms.	gms.		gms.
			71 x Leoti x Dwarf White feterita				
65.2	44.2	44.4	67.5	65.1	55.4	63.7	64.7
52.3	51.3	41.1	86.9	68.6	30.8	50.3	66.0
39.2	31.3	64.3	48.1	59.6	75.4	47.0	65.3
36.2	46.2	34.8	28.0	47.7	70.2	57.5	75.1
38.6	47.6	34.9	64.5	47.1	53.4	32.4	73.3
42.3	68.1	37.9	81.8	51.3	63.9	47.2	64.2
39.0	45.2	49.5	66.8	55.1	67.1	65.8	26.5
58.3	41.0	41.3	44.4	48.6	46.9	55.4	58.8
55.3	39.7	44.9	76.0	51.1	82.0	32.3	69.2
54.8	29.7	45.5	44.0	36.5	37.3	50.9	38.1
52.0	64.5	42.6	60.1	52.7	49.8	66.0	79.6
63.0	40.2	69.2	59.8		40.4	54.6	40.5
49.8	46.7	79.4	40.3		65.4	68.2	33.1
36.1	58.6	64.5	77.2		36.7		43.9
	63.2		32.5		27.1		44.5
			52.9		62.1		49.8
			47.7				64.1
			25.6				33.4
			58.6				82.4
			73.1				88.3
			64.1				
			58.5				
			39.6				
			79.8				
Av. 48.7	48.7		57.4	53.0	53.6		58.0

Table 4.--Continued.

	Bagged				Unbagged			
	Waxy	Heterozygous		Starchy	Waxy	Heterozygous		Starchy
	gms.	gms.		gms.	gms.	gms.		gms.
				71 x Leoti x Dwarf kafir				
	53.1	29.6	48.4	39.1	41.6	55.1	41.2	55.3
	45.9	42.1	48.3	57.6	32.5	35.6	55.9	52.8
	44.2	33.7	50.1	61.0	40.5	43.0	47.7	64.5
	48.7	33.8	49.8	33.1	65.3	47.2	55.3	56.4
	52.2	36.8	39.8	53.2	22.8	54.7	31.7	39.8
	31.7	39.3	42.3	52.9	28.8	48.9	42.4	30.6
	30.8	45.4	40.5	44.8	50.1	61.3	37.1	23.3
	43.9	50.9	45.8	54.7	47.4	58.0	51.2	68.2
	37.2	40.7	40.9	64.2	67.8	64.2	40.9	54.5
	45.1	57.9	66.4	49.6	57.9	44.2	39.3	40.9
	49.4	40.0	50.3	59.2	47.8	47.8	32.9	25.1
	50.1	53.9	34.2	57.9	49.0	42.5	45.6	43.6
	52.2	55.6	57.5	56.2	45.2	38.1	59.5	60.5
	34.6	62.8	49.1	45.4		42.8	46.4	55.5
	43.2	61.8	62.4	57.4		37.3	49.4	52.8
		56.4	57.6	54.2		44.8	44.6	58.9
		34.1		44.5		38.4	46.4	24.6
				36.1		46.3	55.0	42.3
						51.2	67.3	59.1
						28.1	31.5	67.2
						44.2	42.6	42.7
								58.8
								57.1
								60.4
								52.3
Av.	44.1	47.2		51.2	45.9	46.1		49.9

Table 4.--Continued.

	Bagged				Unbagged			
	Waxy	Heterozygous		Starchy	Waxy	Heterozygous		Starchy
	gms.	gms.		gms.	gms.	gms.		gms.
				Cody x Yellow darso				
	50.4	46.5	36.4	50.7	53.1	56.9	62.5	65.6
	44.5	60.7	84.6	47.8	67.6	38.3	45.6	67.5
	50.2	63.3	48.6	103.8	52.0	54.4	57.2	74.6
	66.7	53.1	52.4	40.1	74.0	76.2	59.9	65.8
	55.1	63.2	58.7	37.9	55.4	51.9	58.4	82.9
	49.9	59.6	78.9	75.4	47.2	58.5	54.1	72.7
	59.7	62.9	54.1	62.7	57.8	55.9	72.8	40.3
	55.8	42.5	51.6	72.3	52.8	53.2	54.9	91.6
	39.6	45.5	53.4	64.2	55.7	82.9	88.8	62.2
	55.1	73.6	60.0	44.0	48.8	52.5	50.6	62.8
	54.2	67.1	65.7	66.8	59.0	80.2	42.2	65.1
	64.2	41.3	78.9	48.7	66.0	79.1	55.3	60.9
	43.1	58.3	69.3	74.1	57.8	75.9	69.6	73.8
	50.0	53.0		67.4	61.8	59.3	53.4	49.6
	41.4			68.8	51.4	52.9	43.5	62.9
	60.5			57.3	49.6	92.8		58.3
	42.6			48.0				90.7
	46.1			63.3				58.2
	53.3							86.8
								41.1
								53.6
Av.	51.7	58.6		60.7	56.9	61.0		66.0

Typist: Mary Wallace Spohn