RELATIONSHIP OF MECHANICAL COMPOSITION AND OIL CONTENT OF UPLAND COTTONSEED

By

Sadek Mourad Ayoub

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Oklahoma Agricultural and Mechanical College

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CONTENT OF UPLAND COTTONSEED

Thesis Approved:

John M. Green
Thesis Adviser

Ralph S. Matlock

[illegible]
Dean of the Graduate School

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I. INTRODUCTION

From earliest days of recorded history down to the present time, the cotton plant has been grown primarily for its fiber. While the seed was for many centuries of little value, it is today one of the more important agricultural commodities. The manufacturing of cottonseed and its products constitutes one of the major industries. Cottonseed has, however, never possessed more than a fraction of the value of the fiber. Consequently, the production of seed, which obviously varies directly with lint production, is not only closely related to but is dominated by the factors determining the production of lint cotton.

Selection and breeding for improvement in cotton has been, at least up to the present, guided by considerations of lint character and relative productivity. The changes made or the differences occurring in varietal capacity for fuzz production, and all other seed characters, have occurred, for the most part, without intent.

The first record of the crushing of cottonseed to obtain oil or cake apparently dates back to the early Hindu writings (18)*. Old medical books of the Hindus are said to have recommended cottonseed oil for external applications and to have described the method of extracting the oil as consisting mainly of first pounding the seed and then boiling the pounded contents.

It has been said that at an early stage of history the Chinese were not only producing oil, but were using methods in the crushing of oilseed somewhat similar to those of oil mills of modern times. The oil

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* Figures in parenthesis refer to "Literature Cited".

content of cottonseed varies with the variety, locality in which the cotton is grown, soil fertility, fertilizers used and climatic conditions. Probably the factor causing the greatest difference is the variety.

This thesis is concerned with the mechanical composition and oil content of seeds of thirteen varieties and certain F_1 hybrids involving those varieties. The purpose of this study was to determine if sufficient variability existed among these varieties to indicate opportunity for effective selection for a higher percentage of oil in their hybrid progenies, and to determine the relationship of mechanical composition to total percent oil in the seed.

II. REVIEW OF LITERATURE

It seems appropriate to include in the review of literature sections on cottonseed development and structure, composition of cottonseed, interrelationships of seed properties, development of the cottonseed oil industry, and current uses of cottonseed products. The section on composition of cottonseed and interrelationships of properties relate directly to the present study; the other sections provide important background information.

Cottonseed Development and Structure

The following is a summary of a discussion by Bailey (3) on cottonseed development and structure. The cottonseed is a product of the cotton plant comprising two principal parts: the hull or spermoderm from which staple cotton and cotton linters arise, and the kernel or embryo from which oil and meal are obtained.

The cottonseed in anatropous, i.e., characterized by an inverted ovule and micropyle bent down toward the funiculus. The ovule of the cottonseed is characterized by two integuments which develop into the hull or seed coat known as the spermoderm. In addition to the two principal elements of the seed, i.e., spermoderm and embryo, there is a third structure, a membrane which completely envelops the embryo. This membrane may be described as a residual tissue of endosperm which supported the embryo development and perisperm, the remnants of the nucellus of the ovule.

An examination of delinted cottonseed will disclose the presence of a single slight ridge, running longitudinally with the long axis of the seed, extending from the hilum to the chalazal cap. This ridge is known as the raphe. It contains the vascular bundles which supply the developing seed with moisture and minerals.

In the tissue of the embryo are stored aleurone, oil, and starch grains which serve as reserve nutritive materials for the germinating plant.

The outer epiderm is composed of cells of irregular shape but characterized by substantially thick cutinized walls enclosing tannin-containing compounds. Fibers are single cells. Parenchyma cells contain sugars and pentosans as principal constituents. The inner epiderm is colorless and has lignified cells, the arrangement of which is irregular in that at frequent intervals two small cells are superimposed and occupy approximately the same area as a single cell.

Close examination of a longitudinal or transverse section of a cottonseed will disclose the presence of a thin skin membrane occurring between the inner wall of the spermoderm and the embryo. It is the membrane which forms the attachment to the cottonseed hull at the chalazal cap. There appears to be no oil here.

Whenever an embryo is carefully extracted from the hull of the cottonseed it will be observed to be completely enveloped in the perisperm-endosperm membrane. The perisperm and endosperm, containing protein, oil, and sugar, constitute nutritive materials for the growing embryo.

The kernel or meat of a cottonseed is an embryo which has consumed the entire reservoir of endosperm nutrients in maturing. In the case of cereal grains, such as wheat or corn, the endosperm is in excess supply to the needs of the embryo and it is the surplus of endosperm, mainly starch, which gives commercial value and importance to such grains. Conversely, cottonseed are valuable by virtue of their high concentration of protein and oil which is produced and concentrated by the embryo at the expense of the endosperm.

The embryo of the cottonseed, comprising two cotyledons and the axial organs, together with the enveloping membrane, constitutes the part of the seed from which oil and meal are obtained.

Composition of Cottonseed

Seeds may be inherently large or small; they may produce a high percentage of short fuzz fibers (linters) or they may be essentially naked. Seeds may also differ quite widely in relative proportions of kernels and hulls.

Statistical reports of composition are usually made on what might be considered the industrial basis. When mills buy seed from gins or growers, the transactions are governed by the "Rules" of the National Cottonseed Products Association (3) and the grade determines the price. If "quality" factors are disregarded for the present, the grade becomes dependent upon the percentages of oil and ammonia measured on the "as received" sample of seed, moisture being included in the base weight of the sample. This method of representing composition may be considered the "grade basis". Some investigators have chosen a basis that would facilitate clarification of the problems being studied, or in some cases because they have lacked equipment for carrying out complete analyses.

According to Bailey (3), there are two sound morphological parts of the cottonseed: the embryo, and the seed coat with its epidermal cells elongated to form fibers, both lint and fuzz. He states that percent of kernels in seed cotton becomes the sound morphological measure. Measurement of kernel proportion referred to as but a part of the whole is unlikely to be found exactly associated with any other true biological character of cottonseed.

The term "linters" is used here synonomously with "fuzz" although strictly speaking the two have different meanings. The fuzz hairs are mostly shorter, and are morphologically distinct from the true lint fibers of cottonseed (4). "Linters" usually refers to all fibers left on the seed following ginning that can be removed quantitatively and includes both lint and fuzz fibers.

The seed that are marketed in the United States, however, vary from the types with fuzz only on the tip, through low-fuzz content strains, up to certain selections that develop close to 20 per cent of linters by weight (10).

Lang (16) found that the development of fuzz (and lint) fibers followed a generally consistent course but that position and quantity patterns were dependent upon the variety or species studied. Environment is quite an important factor in conditioning the amount of fuzz that may be produced within a given varietal potential. It is found, however, that varieties tend to hold rank throughout many environmental alterations in respect to comparative development of fuzz (10, 20, 29).

The weight of the hull varies between 40 and 50 per cent of the weight of the whole cottonseed. It varies in thickness from 0.28 to 0.35 mm. Neither is the hull of a single seed uniform in thickness (3). Sheets and Thompson (25) give the following analysis of cottonseed hulls: water, 8.5 per cent; ash, 2.4 per cent; protein, 2.8 per cent;

fiber, 48.6 per cent; nitrogen-free extract, 37.4 per cent; and fat, 0.3 per cent. Cottonseed hull ashes, as given by McBryde (17), contain phosphoric acid, 9.08 per cent; potash, 23.40 per cent; and lime, 8.85 per cent.

Rast (21) in laboratory studies found a difference of 16.5 gallons of oil per ton between different varieties of cotton grown in Georgia. Brown and Anders (5) in laboratory tests found a difference of 12.42 gallons of oil per ton between different varieties grown on the same plots in a variety test at State College, Mississippi, in 1917.

In 1932, Sievers and Lowman (27) investigated the oil content percent for 15 varieties. The highest and the lowest percentages were 38.35 and 34.74 with a mean of 36.74. Tharp, cited by Bailey (3), with 22 varieties obtained a high of 38.22 and a low of 33.13 per cent oil. The mean was 35.37. Brown and Anders (5), 1920, obtained from 25 varieties a high 36.63 and a low 31.91 per cent oil. The mean was 34.67.

Among varieties of cotton there is considerable difference as to the characteristic percentage of kernel in the seed. These differences are larger if referred to the composition of the fuzzy seed (5, 7, 8, 10, 12, 18, 21) but are also considerable when based on delinted seed (26). Bailey (3) stated that W. H. Tharp found that variations in the proportions of hull and kernel do not appear exactly correlated with any other seed character, although high oil content of seed with high kernel content has been recognized as a definite trend (5, 6, 11, 13, 14, 21, 22, 23, 24, 26, 27). Unusually high fuzz content would condition a low percentage kernel content if other characters were comparable, but it is questionable if the percentage kernel content should be based on fuzzy seed.

Interrelationships of Seed Properties

Attempts to improve the oil and/or protein content of cottonseed by selection have shown that a certain amount of segregation occurs in this respect. Fraps (7) found selections from the same parent strain to differ as much as 2.95% in protein in kernels, 5.84% in oil in kernels, and 7.9% in kernels in seed. The highest selection as to percent kernels had the highest oil content and a low (but not the lowest) protein content.

Large seed and high oil content have been reported as associated characters (6), although it has also been reported that small seed produced more oil (5). Other investigators have reported that there is no association at all (8, 12, 20, 26).

High kernel content appears to be associated with high oil content of seed among varieties (5, 6, 21, 22, 23, 26, 27). Tharp, in unpublished data cited by Bailey (3), said due to influences contributing to lack of correlation, the percent oil in seed seems associated with percent kernels in seed in a positive manner, but this relationship will be found nonsignificant in certain series of selections.

Oil and percent lint are reported both as positively (11, 30) and negatively (29) related, with others disclaiming any covariability (11, 20). Percent of fuzz seems to bear no relationship to oil among varieties (20, 29). From still other studies it appears that high oil content may be related to the content of inorganic constituents (11), to large bolls (11), to tensile strength of the lint (30), and to shortness of staple (11), but bears no relationship to lint quality (29) or to quality of the oil (12).

Development of the Cottonseed Oil Industry

One of the earliest recorded experiments relating to the use of cottonseed for the production of oil in the United States was carried out in 1768. On September 20, 1768, Otto, a Moravian of Bethlehem, Pennsylvania, made some experiments in the extraction of oil. He presented to the American Philosophical Society of Philadelphia samples of cottonseed oil together with a statement that 1.5 bushels of cottonseed yielded 9 pints of oil (19). On March 2, 1799, a Mr. C. Whiting was granted a patent for "a process for extracting oil from cottonseed" (19). In 1801, a planter of Natchez by the name of Sir William Dunbar ordered a press from Philadelphia and said that he expected to use it in making cottonseed oil (19). It is reported that in 1802 Benjamin Waring of Columbia, South Carolina, was operating an oil mill in which he crushed flax seed, sesame seed, and some cottonseed. A statement appearing in the Niles Register of 1829 made a reference to a Col. Clark, who about 1818 conducted some experiments on cottonseed oil for burning in lamps (15). The first patent for a cottonseed hulling machine was granted to J. Lineback of Salem, North Carolina, March 31, 1814 (3). Several years later in January, 1829, Francis Follet of Petersburg, Virginia, is said to have begun rather intensive efforts to develop a machine for hulling cottonseed. Follet and his partner Smith are reported to have advertised the yields of kernel, oil, and oil cake which could be expected from cottonseed. They also claimed that because of cottonseed oil's cheapness and its usefulness it would supersede other oils for many purposes and that the oil cake was a highly nutritious feed for cattle (3). All the above mills were crushing cottonseed which had a tough hull covered by short lint fibers or fuzz.

This made the seeds hard to grind, reduced the quantity of oil extracted, as the lint absorbed some of the oil, and lowered the quality of the cake. Harry Hammond (9) stated that about 1832 a small oil mill was operating on an island off the Georgia coast. The seeds crushed were those of the "naked" Sea Island cotton which is similar to the Egyptian cotton and therefore easier to crush than the seed of Upland cotton. Apparently sizeable quantities of Egyptian cottonseed were being crushed in England and France at about this time.

In the latter part of the 1840's, Messrs. Frederick Good and William Wilbur of New Orleans made renewed efforts but apparently failed, since Mr. Good is reported to have exhibited a small bottle of cottonseed oil which cost him $12,000 (15). About this time Dr. Edward J. Coxe, also of New Orleans, attempted to convince producers of the large amount of waste which resulted from the failure to utilize the seed from the cotton crop (3). In 1852, Mr. A. A. Maginnis of New Orleans, a manufacturer of linseed oil, crushed a small amount of cottonseed experimentally. The oil was intended for medicinal purposes and sold for $1.00 per gallon (15). In this same year Paul Aldige, also of New Orleans, is said to have visited Marseilles for the purpose of studying the process used there. In 1855, Messrs. Bradbury and Nautre of New Orleans are credited with having attempted to extract oil from cottonseed (3). William Fee of Cincinnati invented and patented an improved huller in 1857 which played an important part in the rapid expansion of cottonseed crushing following the Civil War (3). Mr. Fee's patent is only one of about a dozen granted for hulling machines in the United States from 1855 to 1870. During this same period four patents were granted for the process of extracting oil from the seed, five for cleaning seed, and two for delinting. One of the delinting patents was granted to W. F. Pratt of Bridgewater, Massachusetts, June, 1869, and the other to G. W. Grader of Memphis, Tennessee, August, 1869 (3).

Andrews (1) stated that today there are more than 410 mills in the United States. This is due to several factors; (a) improvements in oil refining, (b) hydrogenation of oils which has made such a laudatory contribution to the housewife's cuisine, and (c) Europe's awakening to the value of and demand for American cottonseed cake and meal.

The current uses of cottonseed products are listed in outline form on the following two pages.

Current Uses of Cottonseed Products (2)

- Meats (Kernels)
  - Crude Oil
    - Refined Oil
      - Prime Summer Yellow Oil
        - Shortenings
        - Margarine
        - Salad Dressing
        - Salad Oil
        - Packing Oil (Sardines, Olives, etc.)
        - Medicinal Preparations
        - Cosmetics
      - Off-Grade Summer Yellow Oil
        - Miner's Oil
        - Soap
    - Putty
    - Foots
      - Washing Powder
      - Acidulated Foots ---
        - Glycerine - Nitroglycerine
        - Fatty Acids ----------------------
          - Washing Powder
          - Soap
          - Candles
          - Composition Roofing
          - Linoleum
          - Oilcloth
          - Fullingware
          - Waterproofing
          - Insulating Materials
          - Cotton Rubber
          - Synthetic Leather
          - Phonographic Records
      - Soap
  - Flour
  - Cake and Meal
    - Feed For
      - Cattle (Beef and Dairy)
      - Horses and Mules
      - Sheep
      - Hogs
      - Poultry
    - Fertilizer
- Hulls
  - Livestock Feed
  - Fertilizer
  - Fiber ----------------
    - Stuffing Material
    - Cellulose (See Linters)
    - Paper

- Hulls
  - Packing Material
  - Insulating Material
  - Poultry House Litter
  - Xylose (Saccharine Concentrate)
  - Fuel - Potash
- Linters
  - Stuffing Material
    - Mattresses
    - Upholstery (Automobiles and Furniture)
    - Cushions and Comforts
  - Surgical Dressings
    - Absorbent Cotton
    - Bandages
    - Gauze
  - Low-Grade Yarns
    - Wicks
    - Twine
    - Carpets
  - Cellulose
    - Paper
    - Cellophane
    - Explosives
    - Plastics
      - Automotive Parts
      - Electrical Parts
      - Fountain Pens
      - Toiletware
      - Jewelry
      - Safety Glass
      - Films (Motion Picture and Photographic)
      - Phonographic Records
    - Rayon
    - Lacquers and Enamels

III. EXPERIMENTAL PROCEDURE

On May 27, 1954, 13 varieties and certain F_1 hybrids of cotton were planted at Paradise, Oklahoma. A randomized block field design was used with six replications. The plot size was three rows wide and twenty-five feet long. The rows were spaced 42 inches apart. The previous year corn was grown on this field. Following harvest the field was plowed with a lister type plow and remained without cover until the spring of 1954. At this time one hundred pounds of 15-15-0 fertilizer was applied per acre. A ridge type seedbed was prepared and the seeds were planted by hand. The rows were thinned to approximately one plant every 12 inches during a four day period starting July 11. Plots were cultivated with a two row cultivator and a hand hoe.

During the period from July 20 to 24, the blooms were counted, tagged, and recorded by rows on the two outside rows in each plot. In October, the tagged bolls were counted and hand harvested by rows. Due to the extreme drought and to some physiological factors, many bolls were either dried out or shed before completing maturity. One hundred seed groups of seed cotton for each variety and hybrid from each replication were counted out. Not all the varieties and their hybrids had one hundred seeds or more. Data for these were supplied with the aid of a formula proposed by Allen and Wishart and modified by Yates as demonstrated by Snedecor (28).

$$X = \frac{tT + bB - S}{(t-1)\ (b-1)}$$

where
t = number of treatments
b = number of blocks
T = sum of items with same treatment as missing item

B = sum of items in same block as missing item
S = sum of all observed items.

The one hundred seed groups were ginned on a small saw gin and weights of lint and seed were recorded. Seeds were weighed, then delinted with sulfuric acid, and again weighed to determine the weight of the linters. Seeds were then dissected with a razor blade and the hulls removed. Hulls and kernels were weighed separately. All weights were made on an analytical balance after drying in an electric oven at 100° C. for 15 hours. Kernels were handed over to the Agricultural Chemistry Department for oil analysis. Analyses of variance were used to analyze data obtained. Comparison of pairs of varieties were made using individual degrees of freedom (28).

IV. EXPERIMENTAL RESULTS

Variation in Properties Measured

The mean weight in grams per hundred seed and percentage of kernels, hulls, linters, oil in kernels, and total percentage of oil in seed of thirteen varieties and certain F_1 hybrids are shown in table 1. The means and the range constitute a summary of the information contained in the entire table 1.

Grams Per 100 Seed

Among the extreme parent varieties, Empire had a mean weight of 13.2206 grams per one hundred seed while D & PL Fox had a mean weight of 9.2258 grams per one hundred seed. This difference resulted in a range of 3.9948. Empire times Stoneville 62, with a mean weight of 11.5191 per one hundred seed, produced the highest weight among all hybrids, while Stormmaster times Stormproof No. 1 showed the lowest weight of 9.2709 grams per hundred seed. This difference resulted in a range of 2.2482, and the coefficient of variation was 5.32 per cent. Therefore, the parents had a greater range than the hybrids.

Percentage of Kernels

The percentage of kernels likewise varies less in the hybrids than in the parent varieties. The ranges were 8.128 and 10.944 respectively. Parrott had a kernel percentage of 60.657 and Lankart 57 had a kernel percentage of 49.713. They were the highest and the lowest respectively of the parent varieties. The coefficient of variation was 4.345 per cent.

The cross Parrott times Stormproof No. 1 had a kernel percentage of 62.768. It was the highest percentage of the hybrids, while on the other hand, Lockett 140 times Stoneville 62 had the lowest kernel percentage of the hybrids with 54.640 per cent.

Percentage of Hulls

The mean percentage of hulls listed in the third column of table 1 indicates that Lankart 57 had the highest percentage of hulls among the parent varieties, and Empire had the lowest percentage. Their respective percentages were 36.907 and 30.875. The range among these was 6.032. The highest mean hull percentage was 32.920 from the cross Paymaster 54 times Stoneville 62. Empire times Stoneville 62 had the lowest mean hull percentage with 31.552. The range among the hybrids for mean hull percentage was 1.642. The coefficient of variation was 4.617.

Percentage of Linters

The mean percentage of linters listed in the fourth column of table 1 indicates that Lankart 57 had the highest percentage of linters among the parent varieties and Stormproof No. 1 had the lowest percentage of linters. Their respective percentages were 17.5283 and 9.9350. The range among the varieties for mean percentage of linters was 7.5933.

The highest mean percentage of linters was 14.9233, resulting from the cross Lockett 140 times Stoneville 62. The lowest mean percentage of linters was 10.3550, resulting from the cross Stormmaster times Stormproof No. 1. The coefficient of variation was 12.34.

Percentage of Oil

The mean oil percentage in the fifth column shows that Stormmaster had the highest mean percentage with 34.58 and Lankart 57 had the lowest mean percentage with 32.05. The range was 2.53. Among the hybrids

Table 1. Grams/100 seed and percentage of kernels, hulls, linters, oil in kernels, and total % of oil in seed of thirteen varieties and certain F_1 hybrids grown at Paradise, Oklahoma in 1954.

Varieties and Hybrids	Grams/100 Seed	Percentage				Total % of Oil in Seed
		Kernels	Hulls	Linters	Oil	
Paymaster 54	10.9984	55.912	33.017	13.7767	33.40	18.67
Lankart 57	11.7533	49.713	36.907	17.5283	32.05	15.93
Empire	13.2206	58.367	30.875	15.4083	33.71	19.68
Stormmaster	10.5087	56.892	32.453	13.5683	34.58	19.67
Hi-Bred	10.5198	55.885	32.270	14.0333	33.40	18.67
Parrott	10.5281	60.657	31.180	10.8683	34.14	20.71
CR-2	9.8649	57.438	30.928	14.7850	33.66	19.33
Deltapine 15	10.1291	54.158	34.472	12.8333	32.89	17.81
Lockett 140	10.4301	52.460	31.648	15.6983	33.04	17.33
D & PL Fox	9.2258	52.882	32.085	16.1067	33.40	17.66
Lankart 611	12.0888	52.647	32.972	14.3517	32.56	17.14
Stoneville 62	10.6714	57.340	32.613	10.4583	33.74	19.35
Stormproof No. 1	10.3655	59.805	32.900	9.9350	34.22	20.47

Table 1 Continued.

Varieties and Hybrids	Grams/100 Seed	Percentage				Total % of Oil in Seed
		Kernels	Hulls	Linters	Oil	
Paymaster 54 x Stoneville 62	10.1215	56.682	32.920	12.0667	35.02	19.85
Lankart 57 x Stormproof No. 1	10.7361	58.702	32.603	10.3867	34.96	20.52
Empire x Stoneville 62	11.5191	57.870	31.552	12.8783	34.40	19.91
Mebane 6801 x Stoneville 62	10.0118	56.157	32.027	14.9000	34.77	19.53
Stormmaster x Stormproof No. 1	9.2709	58.222	32.570	10.3550	35.26	20.53
Hi-Bred x Stoneville 62	10.0630	56.122	31.508	13.9150	35.20	19.75
Parrott x Stormproof No. 1	9.5823	62.768	32.228	10.5800	35.63	22.36
CR-2 x Stoneville 62	9.6614	57.068	31.895	13.2233	34.30	19.57
Deltapine 15 x Stoneville 62	10.7800	56.698	31.278	13.9783	34.03	19.29
Lockett 140 x Stoneville 62	10.5297	54.640	32.153	14.9233	33.98	18.57
D & PL Fox x Stoneville 62	9.4462	57.527	31.765	13.0817	33.81	19.45
Lankart 611 x Stormproof No. 1	10.8664	58.060	32.300	11.9583	34.91	20.27

Parrott times Stormproof No. 1 had the highest mean oil percentage with 35.63. The lowest mean oil percentage was from the cross D & PL Fox times Stoneville 62 with 33.81. The range was 1.82.

In regard to total percentage of oil in seed, Parrott variety had the highest with 20.71, while Lankart 57 was the lowest with 15.93. The range between them was 4.78. Of the hybrids, Parrott times Stormproof No. 1 had the highest with 22.36, while Lockett 140 times Stoneville 62 had the lowest with 18.57. They had a range of 3.79.

Results of Analysis

Mean squares for grams/100 seed, percentage kernels, percentage hulls, and percentage linters for the thirteen varieties and certain F_1 hybrids are presented in table 2. As stated previously in the experimental procedure, the missing items were calculated with the aid of a formula. Footnotes (table 2) show the number of missing values which had to be computed.

The F test showed differences among varieties and hybrids in all properties measured. Coefficient of variation was calculated for grams /100 seed, percentage kernels, percentage hulls, and percentage linters. They were 5.32, 4.35, 4.62, and 12.34 respectively.

Comparison of F_1 Hybrids and Their Parents

Grams Per 100 Seed

Table 3 contains the mean seed weight (grams/100 seed) of parents and F_1 hybrids of crosses in which the parents differed significantly.

Results from these data indicate that all the F_1 hybrids deviated negatively from mid-parent, suggesting the possibility of dominance for low seed weight. The cross between Stormproof No. 1 times Lankart 57

Table 2. Mean squares and coefficient of variation of grams/100 seed and percentage of kernels, hulls, and linters.

Source of Variation	Degrees of Freedom	Mean Squares			
		Grams/100 Seed	Percent Kernels	Percent Hulls	Percent Linters
Total	149	1.0562	15.3637	4.5364	8.3937
Replicates	5	0.2742	96.3710	40.7562	70.8699
Varieties	24	5.0010**	46.5873**	9.0622**	24.9377**
Error	115 a/	0.3129	6.0460 b/	2.2338 b/	2.6830 c/
Coefficient of Variation		5.32	4.35	4.62	12.34

a/ 5 missing values computed.

b/ d.f. 114, 6 missing values computed.

c/ d.f., 111, 9 missing values computed.

Table 3. Mean seed weight (grams per 100 seed) of parents and F_1 hybrids of crosses in which the parents differed significantly.

	P_1	F_1	P_2	Deviation of F_1 from Mid-Parent
Stormproof #1 x Lankart 57	10.3655	10.7361	11.7533	-0.3233
Stormproof #1 x Lankart 611	10.3655	10.8664	12.0888	-0.3608
Stoneville 62 x Empire	10.6714	11.5191	13.2206	-1.2746
Stoneville 62 x D & PL Fox	10.6714	9.4462	9.2258	-0.7228

had the smallest deviation of -0.3233 from the mid-parent. The cross between Stoneville 62 times Empire had the greatest deviation of -1.2746 from the mid-parent.

Percentage of Kernels

Mean percentage kernels of parents and F_1 hybrids of crosses in which the parents differed significantly are presented in table 4.

The mean of the two parents minus the mean of the F_1 hybrid indicated both positive and negative deviations of the F_1 from the mid-parent. The greatest positive difference was 0.0491 between Stoneville 62 times Hi-Bred. The greatest negative difference was 0.5056 between Stoneville 62 times Paymaster 54. The above deviations had a range of 0.5547.

Two of the crosses, Stormproof No. 1 times Lankart 57 and Lankart 611, were both negative being 0.3943 and 0.1834 respectively. The one positive difference of 0.0127 indicated little difference from the mid-parent. The range between these crosses was 0.4070.

Percentage of Hulls

Data on percentage hulls (table 5) indicate that the F_1 of Stoneville 62 times Paymaster, CR-2, or Deltapine 15 deviated negatively from the mid-parent. Stoneville 62 times Deltapine 15 had a deviation from the mid-parent of 2.265 which was the highest, while Stoneville 62 times Paymaster 54 had a deviation from mid-parent of 0.105. This was the lowest.

The crosses Stoneville 62 times Empire, Lockett 140, D & PL Fox, and Hi-Bred had positive deviations from mid-parent of 0.192, 0.366, 0.584, and 0.934. The hybrids of Stoneville 62 times Empire and

Table 4. Mean percentage kernels of parents and F_1 hybrids of crosses in which the parents differed significantly.

Hybrid	P_1	F_1 Mean	F_1 Deviation From Mean	P_2
Stoneville 62 x Paymaster 54	57.340	56.682	-.5056	55.912
" x Empire	57.340	57.870	-.0016	58.367
" x Hi-Bred	57.340	56.122	.0491	55.885
" x CR-2	57.340	57.068	.0321	57.438
" x Deltapine 15	57.340	56.698	-.0949	54.158
" x Lockett 140	57.340	54.640	.0260	52.460
" x D & PL Fox	57.340	57.527	-.2416	52.882
Stormproof #1 x Lankart 57	59.805	58.702	-.3943	49.713
" x Stormmaster	59.805	58.222	.0127	56.892
" x Lankart 611	59.805	58.060	-.1834	52.647

Stoneville 62 times Hi-Bred were the lowest and the highest deviations from mid-parent.

The cross Stormproof No. 1 times Stormmaster, Lankart 611, or Lankart 57 had a positive deviation from mid-parent which were 0.107, 0.636, and 2.301 respectively. The hybrids of Stormproof No. 1 times Stormmaster and Stormproof No. 1 times Lankart 57 were the lowest and the highest deviations from the mid-parent.

Among all the hybrids from table 5, the highest deviation from mid-parent was from the cross Stormproof No. 1 times Lankart 57 with 2.301. The lowest deviation from mid-parent was from the cross Stoneville 62 times Deltapine 15 with -2.265. The range between these two extreme hybrids 4.566.

Percentage of Linters

Table 6 contains data on the mean percentage of linters of parents and F_1 hybrids of crosses in which the parents differed significantly.

These data indicate that the F_1 hybrids of all the crosses listed deviated negatively from mid-parent with the exception of Stoneville 62 times D & PL Fox. This cross had a deviation from mid-parent of 0.2008. The greatest and the smallest deviation from mid-parent was from the crosses Stoneville 62 times Deltapine 15 and Stoneville 62 times Paymaster 54. The range was 2.2817.

The hybrids of Stormproof No. 1 times Lankart 57, Stormmaster, and Lankart 611 all had negative deviations from mid-parent. They were 3.3450, 1.3967, and 0.1851 respectively. Among the hybrids which had Stormproof No. 1 as a parent, the highest and the lowest deviations from mid-parent were from the crosses Stormproof No. 1 times Lankart 57 and Stormproof No. 1 times Lankart 611 respectively. The range was

3.1599. Dominance of low percentage of linters is suggested by the data on the crosses studied.

Interrelationships of Properties Measured

Correlation coefficients were run to measure the mutual relationship between measurements. These correlations were between total percentage of oil in seed and grams/100 seed, percent kernels, percent hulls, percent linters, and percent oil in kernels.

The results obtained in table 7 indicate that at 1 per cent and 5 per cent levels the correlation coefficient was significant in total percent oil in seed with percent kernels, percent linters, and percent oil in kernels. Their correlation coefficients, $r = 0.9693$, -0.7665, and 0.8857 respectively, were highly significant at both levels. This indicates that total percent oil in seed is dependent upon percent kernels, percent linters, and percent oil in kernels. Percent hulls and weight of seed were not significantly correlated with percent oil in seed.

The correlation coefficient at the 5 per cent and 1 per cent levels of significance are from table 7.3 in Snedecor (28).

Table 5. Mean percentage hulls of parents and F_1 hybrids of crosses in which the parents differed significantly.

Hybrid	P_1	F_1 Mean	F_1 Deviation From Mid-Parent	P_2
Stoneville 62 x Paymaster 54	32.613	32.920	-0.105	33.017
" x Empire	32.613	31.552	0.192	30.875
" x Hi-Bred	32.613	31.508	0.934	32.270
" x CR-2	32.613	31.895	-0.124	30.928
" x Deltapine 15	32.613	31.278	-2.265	34.472
" x Lockett 140	32.613	32.153	0.366	31.648
" x D & PL Fox	32.613	31.765	0.584	32.085
Stormproof #1 x Lankart 57	32.900	32.603	2.301	36.907
" x Stormmaster	32.900	32.570	0.107	32.453
" x Lankart 611	32.900	32.300	0.636	32.972

Table 6. Mean percentage linters of parents and F_1 hybrids of crosses in which the parents differed significantly.

Hybrid	P_1	F_1 Mean	F_1 Deviation From Mid-Parent	P_2
Stoneville 62 x Paymaster 54	10.4583	12.0667	-0.0508	13.7767
" x Empire	10.4583	12.8783	-0.7608	15.4083
" x Hi-Bred	10.4583	13.9150	-1.6692	14.0333
" x CR-2	10.4583	13.2233	-0.6016	14.7850
" x Deltapine 15	10.4583	13.9783	-2.3325	12.8333
" x Lockett 140	10.4583	14.9233	-1.8450	15.6983
" x D & PL Fox	10.4583	13.0817	0.2008	16.1067
Stormproof #1 x Lankart 57	9.9350	10.3867	-3.3450	17.5283
" x Stormmaster	9.9350	10.3550	-1.3967	13.5683
" x Lankart 611	9.9350	11.9583	-0.1851	14.3517

Table 7. Correlation coefficient between total percent of oil in seed and grams/100 seed, percent kernels, percent hulls, percent linters, and percent oil.

		r
Total percent oil in seed with		
Grams per 100 seed		-0.2647
Percent kernels		0.9693
Percent hulls		-0.3388
Percent linters		-0.7665
Percent oil in kernels		0.8857
Significant values of r with 23 degrees of freedom		
	5% level	0.396
	1% level	0.505

V. DISCUSSION

Variability in Properties

In general in the arid southwest (Texas, Oklahoma, and some of Western Arkansas) the seeds are often poorly filled with kernels, and have a low oil content in comparison to some other regions.

Pope and Ware (20) investigated in 1933 through 1937 the oil percentage in the southwest region according to geographical source. They found 20.24 per cent oil. Tharp, cited by Bailey (3), in 1942 through 1944, found 18.11 per cent oil for the same region. In the present study the average total percentage of oil in seed was 19.28, which agrees more closely with Pope and Ware than with Tharp. From this investigation the range for total percentage of oil in hybrid seeds was 3.79 and among the 13 varieties was 4.78. Pope and Ware (20), in 1935 and 1936, found a range of 3.33 among 16 varieties of cotton grown at 16 locations.

The results obtained in this investigation for percent oil in kernels were 35.63 and 32.05 for the highest and the lowest respectively. The highest percent oil in kernels obtained from this investigation is very close to the high of 36.63 obtained by Brown and Anders (5). The lowest percent oil in kernels was closer to the one obtained by Brown and Anders (5), 31.91, than the low of 33.13 reported by Tharp (3).

The mean of the thirteen varieties and certain F_1 hybrids, 34.04, was very similar to the mean of 34.67 found by Brown and Anders (5) for 25 varieties.

Comparison of F_1 Hybrids and Their Parents

The mean seed weight (grams/100 seed) of parents and F_1 hybrids of crosses indicated that all the F_1 hybrids deviated negatively from the mid-parents. This suggests the possibility of dominant genes for low seed weight. The mean percentage of linters of parents and some F_1 hybrids indicate definitely that there is gene action which is dominant for low percentage of linters with one exception. Pope and Ware (20) obtained ranges of 3.32 and 7.61 for grams/100 seed and percent linters respectively. The ranges of this investigation were 3.99 and 7.59 for grams/100 seed and percent linters respectively. These results indicate close similarity.

For the percentage of kernels, the mean of the two parents minus the mean of the F_1 hybrid indicated both positive and negative deviations of the F_1 from mid-parent. This indicates that there is no definite trend toward either side.

From the results obtained in the mean percentage of hulls, there are no dominant genes controlling either high or low percentage of hulls in F_1 which have been found.

Interrelationships of Properties Measured

Total percentage of oil in seed was not significantly correlated with grams/100 seed. This is not in agreement with Cook's statement (6) that large seeds and high oil content are associated characters, or with Brown and Anders (5) who said small seeds produce more oil. This lack of correlation is in agreement with several workers (8, 12, 20, 26) who reported that there is no association at all among seed properties. Percent hulls was not significantly correlated with oil content.

However, other properties measured were significantly correlated with oil content. The highest correlation coefficient, 0.9693, was between total percent of oil in seed and percent kernels. This correlation is in agreement with Tharp's statement (3): "Percent kernels in seed seems associated positively with percent oil in seed." Some previous investigators (5, 6, 21, 22, 23, 26, 27) found that high kernel content is associated with high oil content. The correlation coefficient, 0.8857, between total percent oil in seed and percent oil in kernels was highly significant. It seems that there is a strong relationship between total percent oil in seed, percent kernels, and percent oil. The correlation coefficient, -0.7665, for percent linters with total percent oil in seed is significant. It is assumed that this correlation is associated with the percentage of kernels. The results of the present study is not in agreement with some previous workers (20, 29) who said that there is no relationship between percent linters and oil among varieties.

From the results obtained in the present study, it is the author's belief that to breed or to select for high percent kernels is to breed or to select too for high percent oil.

VI. SUMMARY AND CONCLUSIONS

Thirteen varieties and certain F_1 hybrids of cotton were planted near the Paradise Community, 19 miles southwest of Stillwater, Oklahoma, to determine if sufficient variability existed among these varieties to indicate opportunity for effective selection for a higher percentage of oil in their hybrid progenies, and to determine the relationship of mechanical composition to total percent oil in seed.

Varieties and hybrids were planted in plots three rows wide and twenty-five feet long. The rows were spaced 42 inches apart. One hundred pounds of 15-15-0 fertilizer were applied per acre. A ridge type seedbed was prepared and the seeds were planted by hand. The rows were thinned to approximately one plant every 12 inches.

The F test showed highly significant differences among varieties and hybrids in all properties measured.

Results from the mean seed weight (grams/100 seed) indicate that all the F_1 hybrids deviated negatively from mid-parent, suggesting the possibility of dominance for low seed weight.

The mean percentage kernels of the two parents minus the mean of the F_1 hybrid indicated both positive and negative deviations of the F_1 from the mid-parent. This indicates that there is no definite trend toward either side.

Data on percentage hulls indicate that the F_1 of Stoneville 62 times Paymaster, DR-2, or Deltapine 15 deviated negatively from mid-parent, while the crosses Stoneville 62 times Empire, Lockett 140, D & PL Fox, and Hi-Bred deviated positively from mid-parent. This shows that there are no dominant genes controlling either high or low percentage of hulls in F_1 which have been found.

Data on the mean percentage linters indicate that the F_1 hybrids of crosses deviated negatively from mid-parent. This indicates definitely that there is gene action which is dominant for low percentage of linters with one exception. The greatest variability as measured by the coefficient of variation was in the percentage linters. This variability will help the plant breeder to breed varieties for high or low linters percentage.

The highest correlation coefficient was between total percent of oil in seed and percent kernels. The correlation coefficient between total percent oil in seed and percent oil in kernels was highly significant. This indicates a strong relationship between total percent oil in seed, percent kernels, and percent oil. The correlation coefficient for percent linters and total percent oil in seed is significant. This correlation is assumed to be associated with the percentage of kernels.

The results of the present study indicate that to breed or to select for high percent kernels is to breed or to select for high percent oil.

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VITA

Sadek Mourad Ayoub
Candidate for the degree of
Master of Science

Thesis: RELATIONSHIP OF MECHANICAL COMPOSITION AND OIL CONTENT OF UPLAND COTTONSEED

Major: Field Crops

Biographical and Other Items:

Born: November 2, 1922 at Cairo, Egypt

Undergraduate Study: Hastings College, Hastings, Nebraska, 1950-1951; O. A. M. C., 1951-54

Graduate Study: O. A. M. C., 1954-55

Experiences: Employed by State Bank of Ethiopia, Addis-Abeba, Ethiopia, 1949; Employed by Ethiopian Air Lines, Addis-Abeba, Ethiopia, 1949-50; Employed as Undergraduate and Graduate Assistant in Cotton Breeding, 1953-55.

Member of Phi Sigma, The American Society of Agronomy, and Aggie Society.

Date of Final Examination: July, 1955

THESIS TITLE: RELATIONSHIP OF MECHANICAL COMPOSITION AND OIL CONTENT OF UPLAND COTTONSEED

AUTHOR: Sadek Mourad Ayoub

THESIS ADVISER: Dr. John M. Green

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TYPIST: Patricia A. Tennille