INHERITANCE AND ASSOCIATION OF OIL AND PROTEIN CONTENT AND SEED COAT TYPE IN SESAME, *SESAMUM INDICUM* L.¹

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SINCE considerable progress has been made in the development of disease-resistant indehiscent sesame varieties adapted to mechanized harvesting, breeders will probably concentrate more effort on other agronomic and chemical characteristics of this plant. A knowledge of the genetic behavior of oil content, protein content and seed coat type should be helpful in the selection of high oil and protein lines.

The purpose of this paper is to report inheritance studies of oil content, protein content and rough and smooth seed coat type along with the associations which exist among these characters.

Information pertaining to the inheritance of oil content, protein content and seed coat type in sesame is limited. KINMAN and STARK (1954) reported oil and protein content of the seed of 24 varieties grown at College Station, Texas, in 1950. The range in oil and protein content for varieties was 45.29 to 63.38 and 16.69 to 27.25 percent, respectively, indicating the presence of a rather high degree of variability in the expression of these two characters. The oil and protein content of eight varieties grown at ten locations were given. The mean oil content for varieties exhibited a range of 47.34 to 55.45 percent and for locations a range of 50.63 to 56.58 percent. The mean protein for varieties exhibited a range of 25.09 to 28.21 percent and for locations a range of 22.24 to 29.49 percent. These data indicated that oil and, to a lesser extent, protein content of sesame seed are markedly influenced by both genotype and environment. They suggest that the genetic and environmental influences affecting protein content inversely affect oil content and that protein synthesis is favored over oil synthesis as the nitrogen supply to the seed increases.

CULP (1953), in a preliminary study of the inheritance of oil content and seed coat type in sesame, found that seed coat type was simply inherited, being conditioned by one pair of genes, and that two to seven polygenes were involved in the inheritance of oil content. Rough seed was found to possess lower oil content than smooth seeded segregates. This is due to the fact that the rough seed coat makes up a larger part of the total seed weight than the smooth seed coat. (It

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should be noted that rough seed coat has no economic importance in sesame breeding at the present time but was used as a genetic marker in these inheritance studies.) The F_1 generation was found to be intermediate in oil content. There was some evidence for partial dominance of low oil content; however, this may have been due to the influence of the rough seed coat type. These data indicated that at least two different types of factors were responsible for the segregation of oil content in sesame. These two factors were the single pair of genes conditioning seed-coat type which influenced the amount of oil-bearing tissue and the polygenic complex conditioning the inheritance of oil in the oil-bearing tissues of the seed.

MATERIALS AND METHODS

Parental material selected for this study consisted of two lines of sesame, K8-4-5-1-2 and N124-9-3-6-2-3-5-2, hereafter referred to as K8 and N124. K8 was chosen for its high oil content, lower protein content and smooth seed coat type. N124 was chosen for its low oil content, higher protein content and rough seed coat type. These two parents were considered to be in a homozygous condition for the characters under study, since they had been selfed for a number of generations.

During the fall and winter of 1951-52, seed of the F_1 , F_2 , both backcross generations and selfed seed of the respective parents were obtained in the greenhouse. These progenies and parents were grown in a randomized block design of three replications on a Norwood clay soil at College Station, Texas, in 1952. The planting was made in rows 17 feet long and 40 inches apart with six inches between adjacent plants within the rows. Each plant was harvested as an individual selection, and seed-coat type, percentage germ (decorticated or hulled seed), oil content and protein content of the whole seed and calculated oil and protein content of the germ were determined.

In order to produce a representative sample of the F_3 generation, seed from 180 F_2 plants (135 rough seeded and 45 smooth seeded segregates) were planted at College Station, Texas, in 1953. No statistical design was used for this study. The planting was made in three ranges of 60 rows each, 17 feet long with 40 inches between rows. The F_3 lines were classified according to segregation for seed coat type, and 10 to 15 plants were harvested as a representative bulk sample of each F_3 line. Percentage germ, oil content and protein content of the whole seed and calculated oil and protein content of the germ were determined for each sample.

Seed from plants of the F_1 , F_2 , F_3 , backcross generations and respective parents were decorticated and the percentage germ of the whole seed was determined. The term "percentage germ" refers to the percentage of decorticated or hulled seed obtained from a sample of whole seed. (No attempt was made to remove the small amount of endosperm present in these samples.) A one gram sample of seed was soaked in about 40 mls of 1.0 N NaOH solution for one to two minutes. The NaOH solution was then decanted and replaced with approximately the same amount of water. This solution was made slightly acid by the addition of 1.0 N HCl solution,

using phenolphthalein as an indicator. The seed coats were rubbed from the seeds by using a Sargent wet mill which had been modified by placing a rubber tube over the central grinding wheel to reduce seed breakage and crushing. The seed coats were removed from the seeds in about three minutes. As much of the seed coat as possible was washed from the sample before it was placed on a filter paper in an oven and dried at 100°C. After the sample was dry, fragments of the seed coat were removed by hand, and the sample was weighed. Percentage germ was then calculated as the proportion of decorticated seed obtained from the sample of whole seed.

Seed coat type was determined visually in most cases; however, some samples were difficult to classify by this means. Classification of these samples was made by rubbing a small amount of seed in the palm of the hand. When the seed was rubbed the seed coat of the rough type was removed, but the seed coat of the smooth type remained intact.

Samples were prepared for oil content determination by grinding a two gram sample of seed with a mortar and pestle. The ground material was then extracted with petroleum ether for four hours on a Goldfish fat extractor, and the weight of the extract was reported as percentage oil on an air-dry basis.

Percentage protein of the seed was calculated by determining the total nitrogen in a 1.75 gram sample of seed using the Kjeldahl-Wilfarth-Gunning method (A.O.A.C. 1950), and by converting total nitrogen to crude protein by using a multiplicative conversion factor of 6.25.

In order to determine whether any oil or protein was carried in the seed coat, the seed coat was removed from 20 rough-seeded samples of the F_3 generation with a modified Buckeye barley pearler. Oil and protein content of the seed coat were determined in a manner similar to that described above.

Oil and protein content of the germ were determined as the ratio of oil or protein content of the whole seed to percentage germ of the seed.

Analyses of variance were made as outlined by SNEDECOR (1946). Scaling tests were made and the variance was partitioned into the fixable genetic (D), unfixable genetic (H) and nonheritable components (E) as outlined by MATHER (1949). Correlation and regression coefficients for all pairs of characters were calculated by the methods outlined by SNEDECOR (1946). Genetic correlations were estimated using the method suggested by HAZEL (1943). Estimates of heritability were calculated using the different methods suggested by LUSH (1948), WARNER (1952), and BURTON (1951). The number of genes was estimated using various formulas given by MATHER (1949), CASTLE and WRIGHT (1921), WEBER (1950), and BURTON (1951).

EXPERIMENTAL RESULTS AND DISCUSSION

The two sesame lines used as parents in this study of quantitative and qualitative inheritance were representative of the most divergent types available for percentage germ and oil of the whole seed. Mean differences between parents for percentage germ, oil and protein of the whole seed were 8.40, 7.18 and 1.11 per-

cent respectively. Except for the small mean difference in protein content of the whole seed, it was assumed that all the characters possessed acceptable differences for inheritance studies of polygenic traits. This assumption is supported by analysis of variance based on generation means. The mean squares for all characters except protein content of the whole seed were significant or highly significant. No significant differences were found between replications.

Segregation of characters

Seed coat type and percentage germ: Percentage germ of the whole seed as calculated in this study is the remaining complement of the seed after removal of the seed coat. The amount of seed coat is highly dependent on whether the seed coat is rough or smooth. The presence of either rough or smooth seed is apparently simply inherited and controlled by one pair of genetic factors. The F_1 and BC_1 ($F_1 \times N124$) plants possessed rough seed, indicating dominance of this character. The F_2 generation of 252 plants consisted of 185 rough and 67 smooth seeded plants. This segregation conforms to an expected 3:1 ratio (Chi-square = 0.339). The BC_2 ($F_1 \times K8$) of 112 plants was composed of 49 rough and 63 smooth seeded segregates. This conforms to an expected 1:1 ratio (Chi-square = 1.750). In the F_3 generation grown from 135 rough and 45 smooth seeded F_2 plants, all the smooth seeded plants produced smooth seeded offspring. The 135 rough seeded plants gave 61 rough seeded lines and 74 lines segregating for seed coat type. These data did not conform to the expected 1:2 ratio (Chi-square = 8.533). This can probably be attributed to sampling error in choosing the F_2 plants for the production of the F_3 lines. The symbol *rr* is suggested as the designation for the smooth seed factors.

Although the presence of rough or smooth seed coat type is simply inherited, being conditioned by one pair of genes, the inheritance of the amount of seed coat is much more complex. The inheritance of the amount of seed coat as such was not investigated, but percentage germ of the whole seed was studied.

The ranges, means, midparental values and standard errors of percentage germ of the parents and generations are presented in Table 1. The wide ranges in percentage germ of the parents and F_1 generation indicate that this character is highly influenced by environment. The means of all generations are lower than expected when the midparental values are used as the expected values. These data indicate either that partial dominance of low percentage germ exist or that rough seed coat is associated with low germ percentage.

Oil content: The ranges, means, midparental values, and standard errors of oil content of the whole seed of the parents and generations are shown in Table 1. The wide ranges in oil content of the parents and F_1 generation indicate that oil content is highly influenced by environment. The means of the F_1 , F_2 and back-cross generations are lower than expected with respect to the midparental values. Since low germ percentage may be associated with rough seed this indication of partial dominance for low oil content may be attributed to the presence of rough seeded plants.

Since it was believed that the type of seed coat present exerted an influence on

TABLE 1

Ranges, means, standard errors and mid-parental values for the five characters under study in the sesame cross, N124 × K8

Character	Parent or cross	Number of plants	Range	Mean	S.E.	Mid-parental value
Percentage germ	P ₁	55	77.7–85.7	82.4	.25	....
	P ₂	66	84.2–94.7	90.8	.28	....
	F ₁	44	81.0–89.9	84.3	.26	86.6
	F ₂	212	75.5–93.0	84.7	.24	86.6
	BC ₁	108	77.7–87.6	83.2	.19	83.4
	BC ₂	105	76.3–93.9	87.0	.38	87.6
Percentage oil of whole seed	P ₁	62	40.33–47.62	44.00	.22	....
	P ₂	67	48.82–55.20	51.18	.20	....
	F ₁	54	42.59–49.87	46.39	.25	47.59
	F ₂	236	41.38–56.16	46.76	.17	47.59
	BC ₁	126	39.50–49.57	44.97	.17	45.20
	BC ₂	110	41.46–53.68	47.74	.24	48.78
Percentage oil of the germ	P ₁	55	49.36–55.96	53.08	.25	....
	P ₂	66	53.12–60.36	56.34	.22	....
	F ₁	44	51.56–57.55	54.96	.25	54.71
	F ₂	212	45.98–62.79	55.09	.18	54.71
	BC ₁	108	50.50–57.34	54.11	.15	54.02
	BC ₂	105	47.71–61.13	54.77	.26	55.65
Percentage protein of the whole seed	P ₁	62	25.12–29.28	27.28	.12	....
	P ₂	67	23.80–28.04	26.17	.12	....
	F ₁	54	24.96–28.64	26.59	.13	26.72
	F ₂	236	22.40–31.78	26.90	.12	26.72
	BC ₁	126	24.00–30.16	26.82	.11	26.93
	BC ₂	110	21.24–30.16	26.90	.16	26.38
Percentage protein of the germ	P ₁	55	30.23–34.90	33.28	.14	....
	P ₂	66	25.55–32.43	28.85	.19	....
	F ₁	44	28.97–35.10	31.51	.21	31.06
	F ₂	212	25.36–36.53	31.71	.14	31.06
	BC ₁	108	27.66–35.82	32.04	.16	32.40
	BC ₂	105	26.47–35.54	30.99	.18	30.18

the inheritance of percentage germ, oil and protein, it should be helpful in this study if the effects of seed coat type were removed. By using percentage germ of the whole seed and oil and protein percentage of the whole seed, it was possible to calculate percentage oil and protein on the basis of percentage germ of the seed. In order to make these calculations it was necessary to assume that all the oil and protein in the seed was carried in the germ. The mean oil and protein content of the seed coat of 20 rough seeded F₃ lines was 1.13 and 3.72 percent, respectively. These values may be higher than the true values since the barley pearler used to decorticate these samples may have removed some tissue other than seed coat. These data indicate that oil content of the seed coat was very close to zero, but a

small amount of protein was carried in the seed coat. Nevertheless, it was assumed that no gross errors were made in converting oil and protein content of the whole seed to oil and protein content of the germ.

The ranges, means, midparental values, and standard errors of oil content of the germ of the parents and generations are given in Table 1. These data indicate that converting oil content of the whole seed to oil content of the germ reduced the variability between the parents and segregating progenies. The means of the segregating generations were slightly higher than the expected midparental values. Thus the indications of partial dominance of low oil content can be attributed to rough seeded segregates which were usually lower in oil. When the effects of the rough seed coat were eliminated, there was some evidence for partial dominance of high oil content.

Although the ranges of the high and low oil parents overlapped after converting oil content of the whole seed to oil content of the germ, the means of all generations are very close to the expected midparental values. It is evident that the low oil parent carried factors for high oil content and the high oil parent carried factors for low oil content.

Protein content: The ranges, means, midparental values and standard errors of protein content of the whole seed of the parents and generations are given in Table 1. The mean difference in protein content of the whole seed between the parental lines was only 1.11 percent. Apparently a high protein line of K8 was chosen as the low protein parent by chance since KINMAN and STARK (1954) reported the protein content of N124 and K8 as 25.62 and 18.44 percent, respectively. Although the mean difference in protein content between the parents is very small, it is interesting to note that the means of the F_1 and F_2 generation are almost midway between the parental means. Transgressive segregation of protein content is evident.

The ranges, means, midparental values and standard errors of protein content of the germ of the parents and generations are presented in Table 1. Converting protein content of the whole seed to protein content of the germ increased the difference between parental means by 3.32 percent, a statistically significant difference. The F_1 mean was almost midway between the parental means and the F_2 mean approximated the F_1 mean. There is some evidence for partial dominance of high protein content since the observed means of most of the generations were slightly higher than the expected midpoint values.

Associations in the F_2 generation

Correlation and regression coefficients for pairs of characters in the F_2 generation are presented in Table 2. The correlation and regression coefficients indicate a highly significant positive association of percentage germ with oil ($r=.531$, $b=.360$) and protein ($r=.337$, $b=.166$) content of the whole seed. The correlation and regression coefficients for percentage germ paired with oil and protein percentage of the germ indicate a highly statistically significant negative association between percentage germ and these two characters.

TABLE 2

Correlation coefficients, regression coefficients and genetic correlations for pairs of characters of F_2 plants and F_3 lines of the sesame cross N124 and K8

Characters correlated	F_2 Generation		F_3 Generation		Genetic correlation coefficient	
	Correlation coefficient	Regression coefficient	Correlation coefficient	Regression coefficient	Observed	Estimated
Percentage germ and percentage oil of the whole seed	.531**	.360**	.587**	.396**	1.030	.806
protein of the whole seed	.337**	.166**	.268**	.124**	.512	.308
oil of the germ	-.311**	-.218**	-.304**	-.201**	.000	-.158
protein of the germ	-.314**	-.179**	-.339**	-.197**	-.232	-.127
Percentage oil of the whole seed and percentage protein of the whole seed	-.131	-.095	-.194	-.134	-.056	-.118
oil of the germ	.640**	.660**	.588**	.578**	.000	.023
protein of the germ	.478**	.402**	-.532**	-.445**	-.535	-.184
Percentage protein of the whole seed and percentage oil of the germ	-.449**	-.637**	-.575**	-.821**	-.912	-.143
protein of the germ	.787**	.910**	.793**	.964**	.000	.000
Percentage oil of the germ and percentage protein of the germ	-.249**	-.203**	-.261**	-.222**	.000	.000

** Indicates significance at the 1 percent level.

Oil percentage of the whole seed exhibited a high degree of association with oil and protein percentage of the germ. A negative correlation between oil and protein content of the whole seeds was expected, but no such relationship was established in this study. A highly significant negative relationship was exhibited by the correlation and regression coefficients involving oil and protein content of the germ. Although the correlation and regression coefficients were highly significant in most cases, the magnitude of these coefficients throughout this study was expected to be greater than was actually observed.

Associations in the F_3 generation

Correlation and regression coefficients for pairs of characters in the F_3 generation are given in Table 2. The correlation and regression coefficients exhibited the same character associations as those observed in the F_2 generation. The magnitude of the correlation and the regression coefficients in the F_3 generation was larger in most cases than corresponding values in the F_2 generation. This suggests that the mean of an F_3 line provides a better measure of the genotype than does that of an individual F_2 plant.

Associations in the F_2 and F_3 generation

Correlation and regression coefficients between the values for given characters of 157 F_2 plants and the means for the same characters in their F_3 progenies are presented in Table 3. Although all of the correlation and regression coefficients except those for oil percentage of the germ were highly significant, the magnitude

TABLE 3

Correlation and regression coefficient for given characters of 157 F₂ plants and for the same characters of their F₃ progeny rows from the sesame cross, N124 and K8

Characters correlated	Correlation coefficients		Regression coefficients	
	Observed	Estimated	Observed	Estimated
Percentage germ	.513**	.734	.483**	.690
Percentage oil of the whole seed	.464**	.591	.434**	.496
Percentage protein of whole seed	.338**	.564	.299**	.579
Percentage oil of the germ	-.038	.470	-.034	.404
Percentage protein of the germ	.252**	.586	.234**	.546

** Indicates significance at the 1 percent level.

of these values was lower than expected. The small correlation and regression coefficients as well as the negative correlation and regression coefficients for oil content of the germ are attributed to experimental error.

Since the correlation and regression coefficients were unexpectedly low and oil percentage of the germ gave negative coefficients, correlation and regression coefficients were estimated by the following formulas. These formulas were de-

$$r_{F_3/F_2} = \frac{1/2D + 1/8H}{\sqrt{1/2D + 1/4H + E_1 \times 1/2D + 1/16H + E_2}}$$

$$b_{F_3/F_2} = \frac{1/2D + 1/8H}{\sqrt{1/2D + 1/4H + E_1}}$$

rived by substituting the components of variation (MATHER 1949) for the covariance, F₂ and F₃ variances. These formulas should give reliable estimates since the *D*, *H* and *E* values were calculated using the progenies of all generations of the cross whereas the correlations were obtained from a portion of the F₂ generations along with the respective F₃ means. Experimental errors which would account for negative and low coefficients were reduced by using these formulas.

The estimated correlation and regression coefficients are presented in Table 3 for the five characters under study. The correlation and regression coefficients as estimated by the above formulas were about 20 to 40 percent greater than observed coefficients and may be of more practical value to plant breeders than the actual values obtained.

Genetic and environmental associations

Genetic correlations were estimated using the formula given by HAZEL (1943) and HAZEL, *et al.* (1943). This formula provides an estimate of the genetic correlation between a pair of characters, eliminating most of the dominant and epistatic deviations and all the environmental deviations.

The observed and estimated genetic correlation coefficients for characters in the F₂ and F₃ generations are presented in Table 2. Two estimates of the genetic correlations were possible since observed and estimated regression coefficients

were available for the same characters in the F_2 and F_3 generations. Although a comparison of the observed correlation coefficients between characters in the F_2 and F_3 generations has been made, it is of interest to compare them with the genetic correlation coefficient. In general, when the F_2 and F_3 observed correlations were large, the magnitude of the genetic correlations was also large. This did not hold true for the association between oil percentage of the whole seed and oil percentage of the germ or for that between protein percentage of the whole seed and protein percentage of the germ. In most cases, the genetic correlations of percentage germ with oil and with protein percentages of the whole seed for germ were large, whereas genetic correlations between oil and protein percentage of the whole seed or germ were small.

The genetic correlation coefficients calculated using estimated regression for the same characters in the F_2 and F_3 generations were in most cases much smaller than expected. This can be attributed to the method of calculating these values. There was no way to adjust the values which made up the numerator of the formula. Because of this, the genetic correlations are perhaps underestimated in most cases.

Components of variation

Partitioning of the variance into the four components, fixable genetic (D), unfixable genetic (H), nonheritable within plots (E_1), and nonheritable between plots (E_2) for all characters studied was conducted as outlined by MATHER (1949). The mean variance for the three replications was used wherever possible. Direct estimates of E_2 were calculated, using the five rows of the F_2 generation in each replication. Only one estimate of the covariance (W_{F_3/F_2}) was available, since the F_3 generation was not replicated. The D , H , E_1 , and E_2 values for the five characters are given in Table 4. The D values for the two characters, percentage germ and percentage oil of the whole seed were highly significant. The E_1 value for percentage oil of the whole seed was significant at the five percent level of probability. The D and E_1 values for the other characters approached significance at the five percent level of probability. Standard errors of all determinations were very large. This may be at least partially attributed to having only two degrees of freedom by which to divide the sum of squares of the deviations of the observed variances from that of the expected variances. The unfixable genetic variance (H) for percentage germ, protein percentage of the whole seed and protein percentage of the germ were negative but not significant. These data indicate that: (1) a large part of the variance is additive or fixable genetic variance, (2) a large part of the variance can be attributed to environmental or nonheritable causes and (3) very little of the variance can be attributed to unfixable genetic factors for the characters under study.

Heritability of characters

Heritability of characters was estimated by methods suggested by LUSH (1948), WARNER (1952), MATHER (1949), and BURTON (1951). These estimates of heritability for each of the characters studied are presented in Table 5.

TABLE 4

D (fixable genetic variance), *H* (unfixable genetic variance), *E*₁ and *E*₂ (environmental variance) values for the characters studied in the sesame cross *N124* × *K8*

Components	Estimate	Standard error
Percentage germ		
<i>D</i>	16.7238**	4.2164
<i>H</i>	—3.5934	11.2960
<i>E</i> ₁	4.0125**	1.8845
<i>E</i> ₂	1.9962	1.6112
Oil percentage of the whole seed		
<i>D</i>	6.5587**	2.1313
<i>H</i>	1.4959	5.7099
<i>E</i> ₁	2.5765*	.9526
<i>E</i> ₂	1.0266	.8144
Protein percentage of the whole seed		
<i>D</i>	3.0751	1.5883
<i>H</i>	— .0088	4.2552
<i>E</i> ₁	1.1170	.7099
<i>E</i> ₂	.7133	.6064
Oil percentage of the germ		
<i>D</i>	4.0441	5.4996
<i>H</i>	.5976	46.5932
<i>E</i> ₁	3.0159	2.4580
<i>E</i> ₂	1.7790	2.1016
Protein percentage of the germ		
<i>D</i>	4.0274	2.0594
<i>H</i>	— .9479	5.5173
<i>E</i> ₁	1.6942	.9204
<i>E</i> ₂	1.0604	.7875

* Significant at the 5 percent level.

** Significant at the 1 percent level.

The estimates using regression coefficients were lower than expected for all characters. This is due to the small magnitude of the covariance values. Using estimated regression coefficients the values of heritability for all characters were increased to within the range of the other estimates. The high estimates obtained using WARNER's method (1952) may be attributed to the variance of the *F*₂ being greater than expected in comparison to the variance of the *BC*₁ and *BC*₂ generations. Heritability estimates using the ratio of $1/2D$, as calculated by MATHER (1949), with either the observed or estimated *F*₂ variance gave about the same values. The calculation of $1/2D$ using WARNER's method (1952) as $2V_{F_2} - V_{BC_1} + V_{BC_2}$ has more practical application than MATHER's method (1949); however, the chance for error in heritability estimates becomes greater. When $1/2D$ is calculated as suggested by MATHER (1949) and substituted in WARNER's formula (1952), heritability estimates were reduced 10 to 20 percent.

TABLE 5

Heritability estimates for germ, oil and protein content of sesame calculated by different statistical methods

Method	Whole seed			Germ	
	Germ	Oil	Protein	Oil	Protein
†Regression =					
Observed	.483	.434	.299	-.034	.234
Estimated	.690	.496	.579	.404	.546
‡ $\frac{2V_{F_2} - V_{B_1} + V_{B_2}}{V_{F_2}} =$	.859	.638	.870	.815	.727
§ $\frac{1/2D}{V_{F_2}} =$	.663	.499	.459	.326	.489
†† $\frac{1/2D}{1/2D + 1/4H + E_1} =$	.729	.526	.580	.413	.580
‡‡ $\frac{V_{F_2} - V_{F_1}}{V_{F_2}} =$	.766	.562	.750	.636	.609
Mean	.712	.521	.592	.445	.556

† LUSH's method (1948).

‡ WARNER's method (1952).

§ WARNER's method (1952) using MATHER's (1949) $1/2D$ and the phenotypic variance.

†† WARNER's method (1952) using $1/2D$ and expected variance.

‡‡ BURTON's method (1951).

Although BURTON's method (1951) of estimating heritability of a character is in the broad sense of the term, such estimates were made for comparison with those obtained by other methods. Since it was shown that the phenotypic variances of the characters were not influenced by unfixable genetic factors, BURTON's method (1951) should give heritability values equal to those obtained by the other methods. It is of interest to note that heritability values calculated using estimated regression coefficients, WARNER's method (1952) using $1/2D$ as calculated using MATHER's method (1949) and BURTON's method (1951) gave heritability values of about equal magnitude. An average of the heritability values obtained with these methods indicates that heritabilities of about 70, 60 and 50 percent can be assumed for the characters percentage germ, protein and oil, respectively. With heritability values of these magnitudes, breeders can expect to make rapid progress in altering percentage germ, oil and protein by selection of superior plants.

Gene number

The number of effective factors determining each character studied (Table 6) was estimated by formulas suggested by MATHER (1949), CASTLE-WRIGHT (1921), WEBER (1950) and BURTON (1951). All the formulas gave about the same results. These data indicate that one or two genes condition each of the

TABLE 6

Estimates of the number of genes conditioning the expression of the characters in the sesame cross, N124 × K8

Character	Estimate	Number of genes			
		†	‡	§	††
Percentage germ		1.08	.93	.97	1.07
Percentage oil of the seed		1.94	1.72	1.45	1.79
Percentage protein of the seed		.11	.07	.06	.07
Percentage oil of the germ		1.01	.53	.50	.57
Percentage protein of the germ		1.29	.96	1.35	1.01

† Calculated using MATHER's method (1949).

‡ Calculated using the CASTLE-WRIGHT formula (1921).

§ Calculated using WEBER's method (1950).

†† Calculated using BURTON's method (1951).

characters under study. These values are probably lower than the true gene number but indicate that only a few factors conditioned the inheritance of the characters in this study. Since heritability estimates were rather large and gene numbers low, rapid progress in altering percentage germ, oil and protein by the process of selection can be expected.

SUMMARY

Segregating progenies of a cross were studied in an attempt to investigate the inheritance of oil and protein content in the presence and absence of rough and smooth seed coat type. Seed coat type was found to be simply inherited. Segregation into rough and smooth seed coat types was controlled by one pair of genes with rough seed coat dominant. The inheritance of percentage germ, oil and protein content was found to be more complex.

Partitioning of the phenotypic variance of each of the characters under study into the component parts indicated that: (1) a large part of the variance was additive or fixable genetic variance, (2) another large part of the variance can be attributed to nonheritable causes, and (3) very little of the variance can be attributed to dominance deviations.

Heritability values of about 70, 60 and 50 percent were found for the characters percentage germ, protein and oil, respectively. The number of genes determining the inheritance of each character was estimated as one or two. Since heritability of characters was high and only a few genes are involved for each character, breeders can expect to make rapid progress in altering percentage germ, oil and protein by selection.

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