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ESTIMATION OF GENETIC COMPONENTS, HERITABILITY, GENETIC ADVANCE AND INTERRELATIONSHIPS OF KERNEL WEIGHT AND VOLUME, PROTEIN, LYSINE AND OIL CONTENT AND CERTAIN OTHER TRAITS IN FOUR SEGREGATING POPULATIONS OF GRAIN SORGHUM

A Thesis

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by

Samwiri Z. Mukuru

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To my Father and Mother who sent me to school.

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ABSTRACT

Mukuru, Samwiri Z. Ph.D., Purdue University, December 1973. Estimation of Genetic Components, Heritability, Genetic Advance and Interrelationships of Kernel Weight and Volume, Protein, Lysine and Oil Content and Certain Other Traits in Four Segregating Populations of Grain Sorghum. Major Professor: J. D. Axtell.

From four crosses of grain sorghum, 45 F_2 random plant selections from each cross were advanced to the third generation. Two random plants were selected from each of 180 F_3 progeny rows and the resulting 360 F_3 selections were evaluated in the fourth generation in one replication and two locations. Each cross is referred to as a populatio

The percent heterosis over midparent for kernel weight and volume was negative in all populations. On the other hand positive percent heterosis was obtained for percent protein in only population IV, lysine as percent of protein in all populations and percent oil in populations II and IV. A wide range of variation was exhibited for several characters in many populations. Transgressive segregation occurred in both directions for several of the plant characters and also for percent protein, percent lysine of protein and catechin equivalents.

Statistically significant differences were indicated among either th F_2 subpopulations or F_3 subpopulations within F_2 subpopulations or both for several characters in all populations. No significant differences however were obtained for grain yield, kernel density and percent lysine of sample in any populations.

Several estimates of additive genetic variances for chemical and seed characters were negative and even those that were positive were always small in magnitude relative to estimated dominance genetic variances. This implied that dominance gene action was relatively more important than additive gene action for the inheritance of chemical and seed characters in the four populations studied. Estimates of heritability and the genetic progress to be expected under selection for the chemical and seed characters were not very high but they did give sufficient evidence that substantial improvement can be made in several populations for some characters including kernel weight and volume, percent protein, percent lysine of protein and percent oil.

Grain yield was positively correlated with panicles per plot, panicle weight and kernels per panicle in all populations. However, correlations of grain yield with kernel weight and volume were non-significant, which suggests that kernel weight and volume are not components of yield. There were no consistent and favourable correlations, to give a clue as to which of the seed or plant characters could be used as indicators of protein, lysine and oil in all the four populations. However, kernel weight or volume could reasonably be used as an indicator in selecting percent protein in population I and percent oil in population III.

INTRODUCTION

Grain sorghum is a major source of food and feed in tropical and sub-tropical countries of the world and its importance as a raw material for industrial use is growing annually. With the world's population increasing at a geometrical rate, grain sorghum has to play an even greater role as a protein source in man's diet more than ever before. The nutritional quality of grain sorghum has been rather poor due to the fact that lysine, which is the first limiting amino acid, is present in low concentrations. Fortunately, genotypes with high levels of lysine and protein have recently been identified in the sorghum world collection and their nutritional quality equals that of high lysine opaque-2 corn when their grain is fed to rats as 95% of the ration (71). Incorporation of these high lysine genes into well adapted local varieties will, in my view, revolutionize grain sorghum.

Improvement programes in self-pollinated crops have emphasized the exploitation of crosses involving homozygous parents followed by selection to concentrate as many desirable traits as possible in one strain. A knowledge concerning the inheritance of quantitative characters should increase the effectiveness of selection. The magnitude of the estimated additive and dominance variances together with epistatic gene effects should suggest the extent to which improvement is possible

and also should provide the necessary information useful in choosing the most appropriate and effective breeding procedure.

Estimates of phenotypic correlations among characters are equally useful in planning and evaluating programs. A knowledge of correlations that exist between important characters may facilitate the interpretation of previous results and provide the basis for planning more efficient breeding programs for the future.

In grain sorghum, analytical procedures for protein, lysine and oil are both expensive and time consuming for the large numbers of progenies arising from crosses. Correlations among these important characters and plant characters may reveal which of the plant characters are useful as indicators of one or more of these chemical traits.

The present study was undertaken in an attempt:

a) To investigate the genetic variability present for 17 characters in each of four segregating populations of grain sorghum.

b) To determine the magnitude and relative importance of additive and dominance variance estimates for chemical and seed characters in four segregating populations of grain sorghum.

c) To estimate heritability and the progress to be expected from selection for weight and volume of 100 kernels, protein content, lysine as percent of protein and oil content for each of the four grain sorghum segregating populations.

d) To estimate the phenotypic correlations between all possible pairs of 17 chemical, seed and plant characters for four

identifying any seed or plant characters that might possibly be used as indicators of protein, lysine and oil.

REVIEW OF THE LITERATURE

Genetic Diversity in Grain Sorghum

Over 10,000 different types of sorghum have been collected throughout the world which represents tremendous potential genetic diversity for agronomic and chemical traits. Miller (51) studied part of the world collection being grown at Puerto Rico and observed significant variability for digestibility, herbicidal and salinity tolerance, head shape and size, weathering ability, disease tolerance and seed size. Diversity is readily available to breeders for head types, grain colors, leaf angles and shapes, grain sizes, endosperm properties, nutritive properties, and insect resistance from the world sorghum collection (20).

Grain sorghum kernels vary considerably in size (0.5 to 6.5g/100 kernels), shape, pigmentation, pericarp thickness, hardness, germ size and the endosperm texture ranges from all corneous to all floury while the endosperm type may be waxy, sugary, yellow etc. (66, 76). Haikerwal et al (33) separated kernels of one variety of grain sorghum into pericarp, endosperm and germ and analyzed each part for protein content and amino acid compositions. Their data showed that the germ had more protein content and higher proportions of essential amino acids than any other part. They concluded that an increase in the proportion of the germ would raise the total protein and the proportion

of certain essential amino acids. It is also believed that sorghum grain types with larger kernels might improve starch recovery by wet-milling and that larger kernels might be expected to have more of the germ portion and hence oil content and protein quality might be higher (64). Malm, (47) has indicated that sorghum breeders using similar exotic material that he used, should be able to make significant progress in selecting for grain yield by screening on the basis of kernel size within segregating populations.

Rooney (66) has indicated that diversity for chemical and processing properties also exist in the world collection of sorghum. Pickett (58, 59) has reported significant variability for protein quantity and quality and for oil content within the world collection that has been screened. Deyoe et al (21) found protein ranges from 8.65 to 12.50 percent and ascribed the variation to be due to genetic and environmental causes. Similar observations were made by Bressani and Rios (8). Singh (71) has screened the world sorghum collection for endosperm phenotype and has identified waxy, sugary, shrunken and floury endosperm lines. He observed that two of these endosperm mutant lines were high in protein and lysine and that their nutritional value, when fed to rats, was equal to that of high lysine opaque-2 corn. Information on kernel structure, composition, chemical properties and problems in utilization has been reviewed by Wall et al (76) and Rooney (66) who also estimated sorghum's food and industrial potential.

Identification and dissemination of superior genotypes for nutritional quality and agronomic traits followed by appropriate hybridization and selection in the resulting progeny to concentrate desirable

traits in one line, will lead to great advances in grain sorghum improvement.

Models for Estimating Genetic Components in Self-Fertilizing Crops

Experiments for estimation of genetic variability in self-fertilizing plants has primarily come from the evaluation of various generations of material arising from crosses between pure lines where the gene frequency of segregating loci is one half and from the diallel cross to a limited extent (48). It is generally helpful to consider covariances between relatives because they can be estimated and their composition can be expressed in terms of components of genetic variances. The portion of the hereditary variance can then be partitioned into portions due to additive effects, dominance effects and epistatic effects of genes in providing information on the inheritance of quantitative characters and in formulating breeding procedure.

Horner et al (38) generalized the genetic variances and covariances for a series of selfed generations under assumptions of no multiple alleles, no linkage and a gene frequency of one half. Under similar assumptions they derived an expression for the set of variances and covariances among and within families obtained by self-fertilization for each of various models. Hanson et al (34) considered the resolution of genetic variability in self-pollinated species with reference to the population of homozygous lines generated by a segregating population. Gates et al (29) derived explicit expressions for all possible genetic variances and covariances in self-fertilized crops assuming linkage but no episitasis or multiple alleles. Many different characters for

practically all of the self-fertilized crops have been studied in a number of crosses utilizing the above procedures for several models.

Gene Action, Heritability and Genetic Advance

Collins et al (18) studied the inheritance of protein level in five F_2 segregating populations, their F_1's and parents and his data indicated that each parent had different genes for controlling protein level. The F_2 populations exhibited partial to complete dominance for high percentage protein. Their results also suggest that both additive and nonadditive gene action influences yield, protein and lysine. Liang et al (46) determined estimates of heritability and various gene effects for a number of agronomic traits among parental lines, backcross progeny and derivatives of three crosses of grain sorghum. They found that the magnitude of the estimates varied greatly among crosses for some traits. They indicated that additive gene effects seemed to have a minor contribution to the inheritance for grain yield, head weight, plant height, stalk diameter and germination percentage. However they found dominance gene effects to be important in the inheritance of most of the traits. Additive by additive and dominance by dominance gene effects were important types of epistasis but additive by dominance effects were of minor importance except for germination percentage. Beil et al (5) studied the inheritance of quantitative characters in two crosses of grain sorghum. Their estimates of heritability for days to mid-bloom and plant height were high in both magnitude and similarity in the two crosses while weight of 100-seeds was moderate. Grain yield showed the greater divergence in heritability between the two crosses. Estimates of dominance variance for plant height, 100-seed weight and grain yield were high. They observed marked heterosis for plant height, 100-seed weight and grain yield

which indicated a gross deviation from the strictly additive action.

Fanous et al (24) investigated the quantitative inheritance of some head and seed characteristics in five crosses of sorghum and obtained relatively high estimates of heritability and genetic advance for head length and seed branch length while node number and 100-seed weight exhibited low heritabilities and genetic advance. Sindagi et al (70) found that additivity in the inheritance of stalk diameter, leaf width, head length, days to bloom, leaf length, number of tillers, plant height, head weight and threshing percentage was rather low and there were indications also that dominance and overdominance were involved. V. H. Reich et al (62) determined protein and oil percentages and 100-seed weight on parental, F_1 and F_2 hybrid seed of grain sorghum. Protein percentage among the F_1 and F_2 hybrid seed ranged from 8 to 18 and 10 to 16 respectively. Although their investigations did not include reciprocal crosses they reported that their data, generally were not indicative of a strong maternal influence on oil content.

Voigt et al (74) studied the inheritance of seed size in sorghum and reported that gene action appeared to be almost entirely additive. They did not get evidence for dominance and epistasis as an important contribution to seed size. They estimated a minimum of 3 or 4 genetic factors or blocks of genes, primarily additive in their effects which appeared to control seed size. High heritabilities for seed size were estimated. Gorbet et al (31) studied the inheritance of six endosperm types in sorghum, i.e., normal, waxy, sugary, yellow, dent and defective. Defective endosperm appeared to be conditioned by recessive genes at a single locus but normal endosperm was incompletely dominant or gave a dosage effect.

The expression of yellow endosperm appeared to be conditioned by more than one and possibly several factors with some evidence of dosage effect and of dominance toward non-yellow. Reciprocal differences were noted for F_1 endosperms from all crosses involving the defective and the yellow endosperm types. Dent, sugary and waxy endosperms were inherited as independent recessives, however, some modifying factors altered the inheritance of the waxy phenotype in some crosses. No linkage was indicated in their study. Webster (77) studied the inheritance of one seedling character and 18 mature plant characteristics of grain sorghum and found that the inheritance of each character except scaly is controlled by a single factor pair. He also reported a number of linkages with crossing-over percentages not previously reported.

Data regarding heritability and different types of gene action in soybean, small grains and corn indicate that the magnitude of these genetic parameters for any character vary from location to location and year to year in the same cross and also varies from cross to cross (27, 28, 63). The method of calculations also causes the magnitude of the genetic parameters to be variable. Brim et al (9) estimated hereditary variances for populations derived from crossing inbred lines of soybean. Their results indicated that additive variance was the principal component of genetic variances for all the characters they studied. Findley et al (26) studied types of gene action in Oh45 and Oh45B cross of Zea mays L. They reported that differences in average yield of the Oh45 and Oh45B families were due primarily to dominance effects. Most of the variation among generation means was accounted

attr butes they studied. Yap et al (78) investigated the inheritance of agronomic and morpho-physiogical traits in barley and found them to be controlled mainly by additive gene action. They also observed dominance effects, but these were not stable in controlling grain yield, kernel weight and flag leaf angle. Chapman et al (13) used Hayman's model for six generations of each of five spring wheat crosses. They found that the additive genetic effect was highly significant in all crosses but the dominance effect was significant in only two of the five crosses while epistasis was not significant in all crosses. Stuber et al (75) studied a cross of high protein with low protein wheat variety. Their data provided evidence that protein concentration was under polygenic control. There was no indication of a preponderance of dominant genes for either high or low protein content.

Interrelationships

Several workers have estimated correlations among inbred lines, hybrids and selfed generations of grain sorghum and the results are not always consistent. Liang et al (45) estimated genotypic and phenotypic correlations among 12 characters in two segregating populations and in pure lines of grain sorghum. They obtained positive and significant correlations of grain yield with head weight, kernel number, half bloom date and leaf number but negative correlations with germination percentage and protein percentage in both populations. Gelaw (32) reported a negative, significant correlation between grain yield and percent protein but a positive, significant correlation between grain yield and days to 50% flowering. Beil et al (5) obtained positive, significant correlations for days to mid-bloom with height, weight/100 seeds and

grain yield; plant height with grain yield and weight/100 seeds; and grain yield with weight/100 seeds.

Malm (47) reported kernel weight and protein percentage to be positively associated and concluded that larger kernels may have relatively larger embryos, which would account for the higher percentages of protein. They also found that seed density and test weight, and kernel weight and yield were positively and significantly associated, but protein percent was negatively correlated with yield. Reich et al (62) obtained positive, significant correlation in the F_2 population between oil and protein percentage and between protein percentage and 100 seed weight. Collins (18) found that protein level was negatively correlated with yield and lysine. Schaffert (67) reported negative correlations between grain yield and percent oil and positive correlation between grain yield and seed weight. Also percent protein was positively correlated with percent oil and percent oil was negatively correlated with yield.

Some workers have studied several traits in sorghum in an attempt to find out which ones are highly related to yield. Sindagi et al (71) have estimated correlations between characters contributing to yield in the F_2 progenies of an intervarietal cross and obtained positive correlations between plant height and grain yield but negative correlative between grain yield and days to flowering. Blum et al (6) reported that of all the panicle weight components, significant, consistent effect of heterosis (superiority over better parent) was found only in the number of grains per branch and mostly at the lower branches within the panicle. They also indicated that weight per grain

and number of grains per panicle were negatively and significantly associated. Ali-Khan et al (1) observed high positive association between head weight and grain yield in the two crosses they studied. Grain yield and kernels per plant were also positively correlated and concluded that increase in yield in the hybrids they studied was mainly due to the increased number of kernels rather than the increased kernel weight. Nielhaus et al (54) reached the same conclusion that number of seeds per head was the most important component of yield in the F_1 generation. Beil et al (5) estimated the correlations of grain yield with its components and found that number of seeds per head was the component most highly related to yield and that the expression for yield was not affected appreciably by 100-seed weight.

Selection for high protein and oil percentages have been carried out in selfed generations in soybean based on seed density (36) and specific gravity (25, 72). Maximum progress for high protein percentage has resulted by selecting seed which have high density while selecting seed with low density has resulted in maximum progress for oil.

Johnson et al (41) found low and inconsistent correlations between 13 characters measured on an individual plant basis in two populations of soybean, but when the characters were measured on a plot basis, the correlations were more consistent. Kwon et al (43) reported strong negative correlations between protein and oil and protein and yield but a slight negative correlation between oil and kernel weight. Little or no association has been shown between protein content and maturity, height or seed weight in oats, barley and wheat (10, 39, 62, 68).

MATERIALS AND METHODS

Field and Laboratory Technique

Using the hot water emasculation technique (70) four crosses were made in 1970 at the Purdue Agronomy Farm at West Lafayette. The six lines used in making these crosses and their descriptions are presented in Table 1. All the parents were considered homozygous and unrelated. The four crosses were designated as follows:

Population Number	Cross
I	IS 3941 x 954 086
II	IS 0470 x 954 086
III	954 086 x IS 2319
IV	IS 0628 x IS 1210

The F_2 derived lines from these crosses will be referred to as populations I, II, III and IV respectively in this study. F_1 plants from each cross were grown in the greenhouse during the winter of 1970-71 and the F_2 plants were grown at Purdue Agronomy Farm the following summer. At harvest, 45 open pollinated panicles out of approximately 200 panicles for each population were randomly selected and each of the 180 F_2 panicles selected, was planted in a single row 3 metres long and 70 cm. wide at the Purdue University winter nursery in Puerto Rico during the winter of 1972. Two random panicles from each of the 180 F_3 progeny rows with sufficient seed for a replicated

Table 1. Identification and means of 6 characteristics of the six parent lines planted at Lafayette in summers of 1970 and 1971.

Identification #	Days to flower	Plant height in cm.	Weight of 100 kernels	Percent protein	Percent lysine of protein	Percent oil
IS 3941	80.33	173.33	4.81	14.85	2.00	4.12
954 086	83.67	202.67	5.56	13.75	2.05	3.32
IS 0470	69.00	174.33	2.21	16.00	1.68	3.63
IS 2319	92.33	249.33	3.51	13.55	2.33	5.16
IS 0628	83.67	145.00	3.95	10.95	2.33	2.15
IS 1210	84.00	284.67	1.95	14.85	1.97	5.37

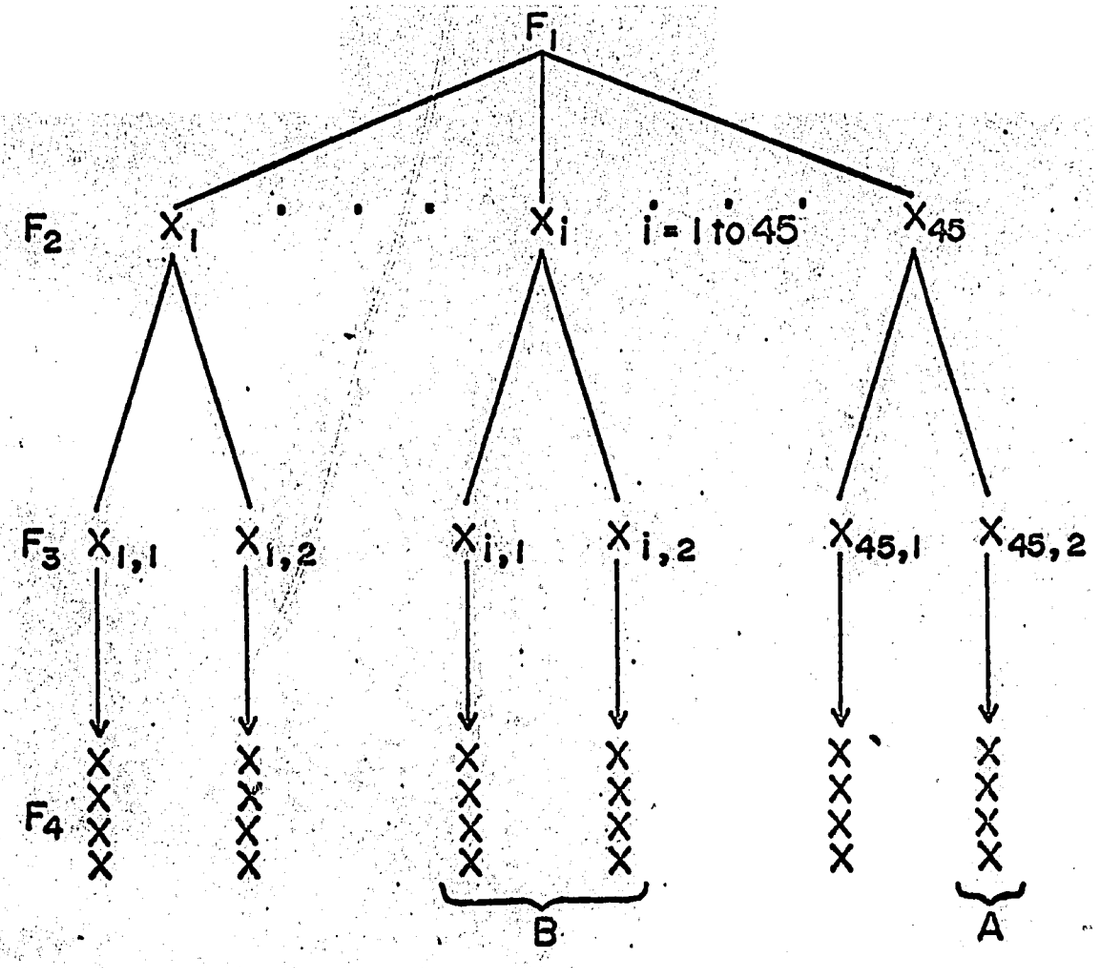
experiment, were selected and selfed. The hierarchial structure of the experiment is indicated in Figure 1.

The 45 F_2 subpopulations from each cross were divided at random into three equal groups which will be referred to in this study as sets. Each set contained 30 F_3 subpopulations-two within each F_2 subpopulation. Four random F_3 subpopulations in each set were replicated two times and grown in the F_4 generation. The female and male parents, and the U. S. hybrid NK300, were replicated twice in each set as checks. For each set, the 30 F_3 subpopulations plus 4 replicates, parents and checks were randomly assigned to experimental units in each of the two locations one at Purdue Agronomy Farm and the other at the Baker Farm near the Purdue Agronomy Farm. The 12 sets were also allocated to 12 experimental blocks at random per location. The field layout for the populations with number of plots is shown in Table 2. The experiment was planted by tractor on May 22, 1972, at the Agronomy Farm and May 25, 1972, at the Baker Farm. Each plot consisted of three rows 76 cm. apart and 3 meters long. Thinning was carried out by hand when the plants were about 10 cm. tall thereby reducing the population to approximately 240,000 plants per hectare. Herbicides and cultivation were used to control the weeds.

Heavy rains that caused flooding in some areas for a short time at the early stages of development plus a rather cool summer did not appear to have affected the growth of the plants.

The characters on which data were recorded as a single observation for a plot are described below:

<u>Days to flower</u>: Recorded as the number of days from planting to when approximately 50 percent of the panicles per plot were in anthesis.



A = F_3 subpopulation within F_2 subpopulation in the 4th generation
B = F_2 subpopulation in the 4th generation

Figure 1. Hierarchial structure of the progenies in each population.

Table 2. Field layout for populations with number of plots.

	Population I Block or set*			Population II Block or set			Population III Block or set			Population IV Block or set			Number of plots	
	1	2	3	4	5	6	7	8	9	10	11	12	Each location	Total
Female parent	2	2	2	2	2	2	2	2	2	2	2	2	24	48
Male parent	2	2	2	2	2	2	2	2	2	2	2	2	24	48
Check - NK 300	2	2	2	2	2	2	2	2	2	2	2	2	24	48
F_3 subpopulations**	30	30	30	30	30	30	30	30	30	30	30	30	360	720
F_3 subpopulation duplicates	4	4	4	4	4	4	4	4	4	4	4	4	48	96
Total entries	40	40	40	40	40	40	40	40	40	40	40	40	480	960

* sets and blocks are confounded.

** each two F_3 subpopulations in the 4th generation trace back to a single F_2 plant. Sets were randomized within each location and entries per set were randomized within each block.

Plant height: Average height in centimeters, on a plot basis, was measured from the ground to the tip of the main panicles, at the time of seed maturity.

Panicles per plot: Number of panicles harvested per plot.

Weight per panicle: The weight in grams of threshed grain per plot divided by the number of panicles harvested per plot.

Kernels per panicle: (Weight per panicle x 100) divided by weight of 100 kernels.

Grain yield (kg/ha): This was determined by harvesting all the panicles from the center three meters of the single center row. The panicles were air dried and threshed. The threshed grain per plot was weighed and using appropriate calculations kilograms/hectare were determined.

Kernel weight: The threshed grain from each plot was air blown and 100 kernels were selected at random and weighed in grams.

Kernel volume: The volume of the 100 kernels was obtained by completely emersing the 100 kernels in alcohol in a graduated cylinder and r[illegible]ng the volume of alcohol displaced, in cubic centimeters.

Kernel density: Was calculated as the weight of 100 kernels divided by the volume of alcohol they displaced.

Percent protein: Was determined at Shuman Chemical Laboratories, Battle Ground, Indiana, by multiplying 6.25 times the percent nitrogen determined by the micro-Kjeldahl procedure on a fat-free sample.

Mg of protein per kernel: (Weight of 100 kernels (in grams) x percent protein divided by 10.)

Percent lysine of protein: Was also determined at Sherman Chemical Laboratories, Battle Ground, Indiana by short column chromatograph.

Percent lysine of sample: Was computed by multiplying percent protein with percent lysine of protein divided by 100.

Mg of lysine per kernel: (Weight of 100 kernels (in grams) x percent lysine of sample) x 10.

Percent oil: Was determined on whole grain samples at the University of Illinois by the use of the nuclear magnetic resonance spectroscopy (NMR) technique.

Mg of oil per kernel: (Weight of 100 kernels (in grams) x percent oil) divided by 10.

Catechin equivalent values: Were determined as percent of dry weight sample by using the Vanillin-HCl procedure described by Burns (11). Catechin equivalent values measure the amount of polyphenolic compounds present in the pericarp and testa of the sorghum grain. High values of catechin equivalents have been associated with lower growth responses in weanling rats and vice versa (40, 55).

Statistical Analysis

The mathematical model for each population is:

$$Y_{ijklm} = \mu + L_i + S_j + (LS)_{ij} + F2_{(j)k} + (LF2)_{(j)ik} + F3/2_{(jk)l} + (LF3/2)_{(jk)il} + E_{(ijkl)m}$$

Where Y_{ijkl} = an observation in the ith location, jth set of the lth F_3 subpopulation within kth F_2 subpopulation.

μ = Mean

L_i = effect of ith location

S_j = effect of jth set

$F_{2(j)k}$ = effect of the kth F_2 subpopulations within the jth set

$F_{3/2(jk)l}$ = effect of lth F_3 subpopulation within the kth F_2 subpopulations within jth set

$E_{(ijkl)m}$ = random error effect of ijklmth observation, m = 2 for four random F_3 subpopulations and m = 1 otherwise

other terms represent interactions between the above factors. The analysis variance table is presented in Table 3.

An F' test criterion was used to test among F_2 subpopulations as was suggested by Cochran (15) and the degrees of freedom were approximated using the rule suggested by Smith and Satterthwaite presented by Cochran (15).

All populations were derived without selection from a pair of homozygous lines. However, it is recognized that natural selection can never be completely eliminated. All the F_2 derived lines in each population and locations were considered random.

From the analysis of variance table the genetic variances among F_2 subpopulations ($\hat{\sigma}^2_{F_2}$) and among F_3 subpopulations within F_2 subpopulations ($\hat{\sigma}^2_{F_{3/2}}$) may be estimated by:

$$\hat{\sigma}^2_{F_2} = \tfrac{1}{4}\,(MS_4 - MS_5 - MS_6 + MS_7)$$

$$\hat{\sigma}^2_{F_{3/2}} = \tfrac{1}{2}\,(MS_6 - MS_7)$$

Table 3. Source of variation, degrees of freedom and expected mean squares for the analysis of variance in each population.

Source of variation	D.F.	M.S.	Expected mean square
Location	(l-1)	MS_1	
Set	(s-1)	MS_2	
Location x sets	(l-1)(s-1)	MS_3	
Among F_2 subpopulations within set	$s(n_1-1)$	MS_4	$\sigma_\epsilon^2 + \sigma^2_{LF_{3/2}} + l\sigma^2_{F_{3/2}} + n_2\sigma^2_{LF_2} + ln_2\sigma^2_{F_2}$
Location x F_2 subpopulation within set	$s(n_1-1)(l-1)$	MS_5	$\sigma_\epsilon^2 + \sigma^2_{LF_{3/2}} + n_2\sigma^2_{LF_2}$
Among F_3 subpopulations within F_2 subpopulations within set	$sn_1(n_2-1)$	MS_6	$\sigma_\epsilon^2 + \sigma^2_{LF_{3/2}} + l\sigma^2_{F_{3/2}}$
Location x F_3 subpopulations within F_2 subpopulations within set	$sn_1(n_2-1)(l-1)$	MS_7	$\sigma_\epsilon^2 + \sigma^2_{LF_{3/2}}$
Among replicates	lsr(m-1)	MS_8	σ_ϵ^2

Where l = 2, being the number of locations
s = 3, being the number of sets/location
n_1 = 15, being the number of F_2 subpopulations
n_2 = 2, being the number of F_3 subpopulations within each F_2 subpopulation
m = 2, being the number of replications of four F_3 subpopulations in each set

Using the notation of T. W. Horner et al (37), the progeny components of variance which are of primary interest in this study, may be expressed in terms of covariances as follows:

$$\hat{\sigma}^2_{F_2} \cong \text{Cov}\ (x, x'/k; n, n')$$

where $k = 2$, $n = n' = 4$ in this study

$$\hat{\sigma}^2_{F_{3/2}} \cong \text{Cov}\ (x, x'/k; n, n')$$

where $k = 3$, $n = n' = 4$ in this study

Cov $(x, x/k; n, n')$ refers to the genotypic covariance in the nth generation with progenies in the n'th generation where all progenies trace to particular genotypes in the kth generation. But when $n = n'$ as is the case in this study the covariance is actually a variance.

These two progeny components of variances are composed of additive and dominance variances, and under certain basic assumptions their coefficients may be obtained from Table 5.1 of Horner, et al (37) or Table 17.4 of Kempthorne (41).

For this study the coefficient for the additive ($\hat{\sigma}^2_A$) and dominance ($\hat{\sigma}^2_D$) variances on the assumption of an additive model with dominance were:

$$\hat{\sigma}^2_{F_2} = \hat{\sigma}^2_A + 1/16\ \hat{\sigma}^2_D$$

$$\hat{\sigma}^2_{F_{3/2}} = 1/2\ \hat{\sigma}^2_A + 1/8\ \hat{\sigma}^2_D$$

where A and D refer to the additive and dominance gene effects respectively. Solving these quadratic equations, additive and dominance effects were estimated as shown below:

$$\hat{\sigma}^2_A = 1/3\ (M\quad - MS_5 - 2MS_6 + 2MS_7)$$

$$\hat{\sigma}^2_D = 4/3\ (-MS_4 + MS_5 + 5MS_6 - 5MS_7)$$

The standard error for the estimates of additive ($\hat{\sigma}^2_A$) and dominance ($\hat{\sigma}^2_D$) variances may be calculated using the theorem of linear combination (19). For this study the variance for the estimates of additive and dominance variances were computed thus:

$$S^2_{\hat{\sigma}^2_A} = (1/3)^2 \frac{2(MS_4)^2}{44} + (-1/3)^2 \frac{2(MS_5)^2}{44} + (-2/3)^2 \frac{2(MS_6)^2}{47} + (2/3)^2 \frac{2(MS_7)^2}{47}$$

$$S^2_{\hat{\sigma}^2_D} = (-4/3)^2 \frac{2(MS_4)^2}{44} + (4/3)^2 \frac{2(MS_5)^2}{44} + (20/3)^2 \frac{2(MS_6)^2}{47} + (-20/3)^2 \frac{2(MS_7)^2}{47}$$

Estimates of heritability for seed and chemical traits among F_2 subpopulation family means and F_3 subpopulation means in the 4th generation were computed as follows:

$$H_2 \text{ (heritability for } F_2 \text{ subpopulations)} = \frac{\hat{\sigma}^2_A}{\hat{\sigma}^2_{Ph_2}}$$

$$H_3 \text{ (heritability for } F_3 \text{ subpopulations)} = \frac{3/2\,\hat{\sigma}^2_A}{\hat{\sigma}^2_{Ph_3}}$$

where $\hat{\sigma}^2_{Ph_2} = \hat{\sigma}^2_{F_2} + \frac{\hat{\sigma}^2_{LF_2}}{2} + \frac{\hat{\sigma}^2_{\epsilon}}{2}$

$$\hat{\sigma}^2_{Ph_3} = \hat{\sigma}^2_{F_2} + \hat{\sigma}^2_{F_{3/2}} + \frac{\hat{\sigma}^2_{LF_2}}{2} + \frac{\hat{\sigma}^2_{LF_{3/2}}}{2} + \frac{\hat{\sigma}^2_{\epsilon}}{2}$$

Expected genetic advance for the seed and chemical characters at 5% selection pressure among the F_2 subpopulations and F_3 subpopulations

for each of the four segregating populations was estimated as follows:

$$\Delta_2 = K\,\hat{\sigma}^2_{Ph_2}H_2$$

where Δ_2 = Genetic advance for F_2 subpopulations

$$\Delta_3 = K\cdot\hat{\sigma}^2_{Ph_3}H_3.$$

where Δ_3 = Genetic advance for F_3 subpopulations

The selection unit was the bulked F_2 subpopulation mean and F_3 subpopulation mean in the 4th generation over two locations with one replication per location. K is the selection differential expressed in phenotypic standard deviations and K is given the value 2.06, the expected value for a normally distributed population when 5% of the superior F_2 subpopulations and F_3 subpopulations are selected (41). The genetic advance was expressed as percentage of each population mean.

The phenotypic correlations between all possible pairs of the 17 characters for F_2 subpopulations ($r_{F_{2Ph}}$) and F_3 subpopulations within F_2 subpopulation ($r_{F_{3/2Ph}}$) were calculated for each cross:

$$r_{F_{2Ph}} = M_{F_{2ij}} \Big/ \sqrt{(M_{F_{2i}})(M_{F_{2j}})}$$

$$r_{F_{3/2Ph}} = M_{F_{3/2ij}} \Big/ \sqrt{(M_{F_{3/2i}})(M_{F_{3/2j}})}$$

Where ($M_{F_{2ij}}$) and ($M_{F_{3/2ij}}$) are the mean cross products of the F_2 subpopulations and F_3 subpopulations within F_2 subpopulations for traits i and j, respectively.

($M_{F_{2i}}$) and ($M_{F_{3/2i}}$) are the mean squares of the F_2 subpopulations and F_3 subpopulations within F_2 subpopulations respectively for trait i. Similar notation is used for trait j.

RESULTS AND DISCUSSION

Population Means, Ranges and Frequency Distributions

Average population means, ranges and percent heterosis over the midparent for all characters in populations I, II, III and IV are presented in Tables 4, 5, 6 and 7 respectively, together with their parental and commercial hybrid NK300 means. The average mean for the F_3 subpopulations in the F_4 generation in population I for all the plant characters was above the midparent as is reflected by the positive percentage heterosis. On the other hand all the seed and chemical traits with the exception of kernel density, percent lysine of protein and catechin equivalent had negative percentage heterosis.

The percent heterosis over the midparent for the plant characters in populations II and III was positive except for panicles per plot in population II and panicle weight and grain yield in population III. However, the percent heterosis over the midparent for the seed and chemical characters in the same populations was negative except for kernel density, percent lysine of protein, percent oil and catechin equivalents in population II and percent lysine of protein and catechin equivalents in population III. In population IV, however, the percent heterosis over the midparent for the plant, seed and chemical characters was positive except for panicles per plot, grain yield, kernel weight and volume, mg of protein per kernel, mg of lysine per kernel and mg of oil per kernel.

Table 4. Means, ranges and percent heterosis over midparent for population I and its parental and hybrid NK 300 means of 17 characters of grain sorghum.

Characters	Population I	Percent heterosis over midparent	Ranges	Female parent (IS 3941)	Male parent (954 086)	Hybrid NK 300
Days to flower	91	6.09	81-110	85	86	84
Plant height	244	14.78	120-320	197	229	204
Panicles/plot	32.6	2.64	19.0-47.5	31.4	32.2	42.1
Panicle weight	34.1	11.25	19.1-64.6	29.6	31.7	44.6
Kernels/panicle	893	41.16	454-1757	650	611	1894
Grain yield (kg/ha)	4664	13.22	1754-7479	3949	4290	7967
Kernel weight	3.93	-19.96	2.09-5.20	4.58	5.25	2.40
Kernel volume	3.06	-20.15	1.63-4.20	3.55	4.13	1.80
Kernel density	1.282	.18	1.186-1.377	1.288	1.272	1.328
Percent protein	12.77	-10.90	10.40-14.80	14.58	14.10	10.59
Mg of protein/kernel	5.05	-28.31	2.80-7.52	6.68	7.41	2.24
Percent lysine of protein	2.00	.60	1.74-2.39	1.97	1.85	2.01
Percent lysine of sample	.254	- 7.12	.223-.291	.288	.260	.212
Mg of lysine/kernel	.0998	-25.47	.0714-.1354	.1315	.1363	.0517
Percent oil	3.46	- 9.08	2.66-5.01	4.21	3.40	3.38
Mg of oil/kernel	1.361	-26.68	.670-1.835	1.928	1.783	.813
Catechin equivalent	.816	73.76	.095-4.350	.280	.659	3.36

Table 5. Means, ranges and percent heterosis above midparent for population II and its parental and hybrid NK 300 means of 17 characters of grain sorghum.

Characters	Population II	Percent heterosis over midparent	Ranges	Female parent (IS 0470)	Male parent (954 086)	Hybrid NK 300
Days to flower	87	7.26	79-108	75	87	84
Plant height	239	21.66	143-335	180	212	198
Panicles/plot	38.8	-22.77	21.0-62.5	62.0	38.4	39.1
Panicle weight	30.9	43.97	7.5-48.2	14.7	28.2	46.3
Kernels/panicle	965	58.92	248-1608	665	549	1947
Grain yield (kg/ha)	4952	18.27	1649-7689	3775	4599	7619
Kernel weight	3.30	-11.20	2.29-4.67	2.22	5.20	2.40
Kernel volume	2.52	-13.08	1.68-3.63	1.69	4.11	1.85
Kernel density	1.309	1.43	1.219-1.389	1.317	1.265	1.294
Percent protein	13.89	- 7.16	10.80-16.45	15.90	14.02	10.38
Mg of protein/kernel	4.60	-1[illegible] 1	2.88-6.16	3.53	7.31	2.52
Percent lysine of protein	1.77	5.81	1.44-2.51	1.54	1.80	2.05
Percent lysine of sample	.244	- 2.13	.206-.291	.245	.253	.211
Mg of lysine/kernel	.0809	- 7.65	.0582-.1326	.0545	.1206	.0508
Percent oil	3.72	9.14	2.83-4.50	3.54	3.28	3.32
Mg of oil/kernel	1.226	- 1.81	.890-1.730	.788	1.709	.800
Catechin equivalent	.610	32.01	.030-3.470	.157	.768	3.81

Table 6. Means, ranges and percent heterosis over midparent for population III and its parental and hybrid NK 300 means of 17 characters of grain sorghum.

Characters	Population III	Percent heterosis over midparent	Ranges	Female parent (954 080)	Male parent (IS 2319)	Hybrid NK 300
Days to flower	94	4.96	76-109	86	93	84
Plant height	271	9.88	170-325	215	277	200
Panicles/plot	30.4	7.80	16.5-60.0	35.8	30.2	41.6
Panicle weight	35.0	- 7.78	13.7-62.9	29.7	49.3	43.4
Kernels/panicle	986	1.50	354-1816	545	1398	1900
Grain yield (kg/ha)	4620	-10.05	1702-7909	4321	5953	7658
Kernel weight	3.75	-15.62	2.73-4.73	5.32	3.58	2.31
Kernel volume	2.95	-15.10	2.23-3.80	4.15	2.80	1.79
Kernel density	1.272	- .27	1.165-1.486	1.280	1.275	1.290
Percent protein	12.99	- 6.98	11.15-15.35	14.09	13.84	10.13
Mg of protein/kernel	4.89	-21.53	3.51-6.55	7.51	4.96	2.35
Percent lysine of protein	2.03	1.70	1.82-2.52	1.80	2.18	2.11
Percent lysine of sample	.262	- 5.48	.227-.314	.254	.300	.213
Mg of lysine/kernel	.0980	-19.21	.0758-.1366	.1352	.1074	.0494
Percent oil	3.72	-13.54	2.46-4.83	3.28	5.33	3.32
Mg of oil/kernel	1.415	-21.68	.690-2.225	1.748	1.865	.771
Catechin equivalent	.788	34.18	.150-2.90	.697	.478	3.67

Table 7. Means, ranges and percent heterosis over midparent for population IV and its parental and hybrid NK 300 means of 17 characters of grain sorghum.

Characters	Population IV	Percent heterosis over midparent	Ranges	Female parent (IS 0628)	Male parent (IS 1210)	Hybrid NK 300
Days to flower	92	6.22	83-105	87	87	85
Plant height	287	23.61	195-350	179	286	200
Panicles/plot	31.9	- 9.85	18.5-47.0	35.8	35.0	40.6
Panicle weight	32.2	2.64	18.2-59.0	30.4	32.4	40.9
Kernels/panicle	1333	10.05	663-2365	802	1621	1774
Grain yield (kg/ha)	4252	-11.14	2055-6732	4712	4859	7096
Kernel weight	2.45	-15.98	1.31-3.61	3.83	2.00	2.33
Kernel volume	1.85	-16.53	1.00-2.78	2.93	1.50	1.75
Kernel density	1.329	.53	1.258-1.602	1.308	1.335	1.324
Percent protein	13.22	.60	10.90-16.30	11.44	14.84	10.41
Mg of protein/kernel	3.24	-11.89	1.89-4.56	4.38	2.96	2.43
Percent lysine of protein	2.07	4.72	1.71-2.61	2.06	1.89	2.05
Percent lysine of sample	.271	5.44	.212-.324	.235	.280	.212
Mg of lysine/kernel	.0661	- 9.20	.0389-.1036	.0896	.0560	.0494
Percent oil	4.02	2.10	2.89-5.32	2.54	5.34	3.34
Mg of oil/kernel	.980	- 4.16	.585-1.285	.979	1.067	.780
Catechin equivalent	3.157	19.99	.135-7.365	.435	4.827	2.86

The F_3 subpopulations exhibited a wide range of variation for many characters in several populations. Transgressive segregation occurred in both directions in all populations for days to flower, plant height, panicles per plot, panicle weight, kernels per panicle, grain yield, percent protein, percent lysine of protein and catechin equivalent. Transgressive segregation occurred also for percent oil in both directions in populations I, II and III. On the other hand, transgressive segregation was toward the lower kernel weight and volume in all populations except in population II. The majority of the segregates in each population for all characters lie around the means of their respective populations. The means of all F_3 subpopulations in populations I, II, III and IV are presented in Appendix tables 1, 2, 3 and 4 respectively.

Greatest segregation for a trait would normally be expected in the population in which the parents differed most for that contrasting trait. However this did not seem to be the case for certain characters in this study. For instance, greatest segregation was observed in population I for kernel weight despite the factor that the difference between the parents of this population for this particular trait was only .67 gms as compared to a difference of 2.98 gms for the parents of population II. There was also a small difference between the parents of populations I and IV for days to flower and populations I and III for percent protein and yet significant segregation was obtained in these populations.

The parent lines for all these populations are assumed homozygous and where values for a particular trait were essentially similar in both parents, one would expect no genetic variability among the segregates, if the trait is controlled by a single pair of genes. The fact that segregation did take place resulting in variable genetic segregates in

the 4th generation for traits such as kernel weight and volume, percent protein and percent oil, suggests that these traits are under polygenic control.

Frequency distributions for kernel weight for each of the four populations are presented in Figure 2. The F_3 subpopulation frequency distributions appear normal for all populations. Frequency distributic curves for populations II and IV are similar in shape but rather distinct, only overlapping at the low and high values of populations II and IV respectively. Frequency distribution curves for populations I and III are bimodal and are essentially similar in all respects. In all populations transgressive segregation was indicated only toward small kernels. However there were several genotypes in all populations that were approximately equal or slightly less than the large seeded parent.

Frequency distributions for percent protein for each of the four populations are presented in Figure 3. Frequency distribution curves for populations I and III are similar while that for populations II and IV are also similar. Extreme segregates in all populations beyond the parents occurred. Populations II and IV had wider ranges for percent protein.

Frequency distribution for percent lysine for each of the four populations are presented in Figure 4. Frequency distribution curves are essentially similar in shape for all populations. However the distribution of population II overlaps the distributions of other populations at their low values. Transgressive segregation in both directions is indicated in all populations. Population IV has some

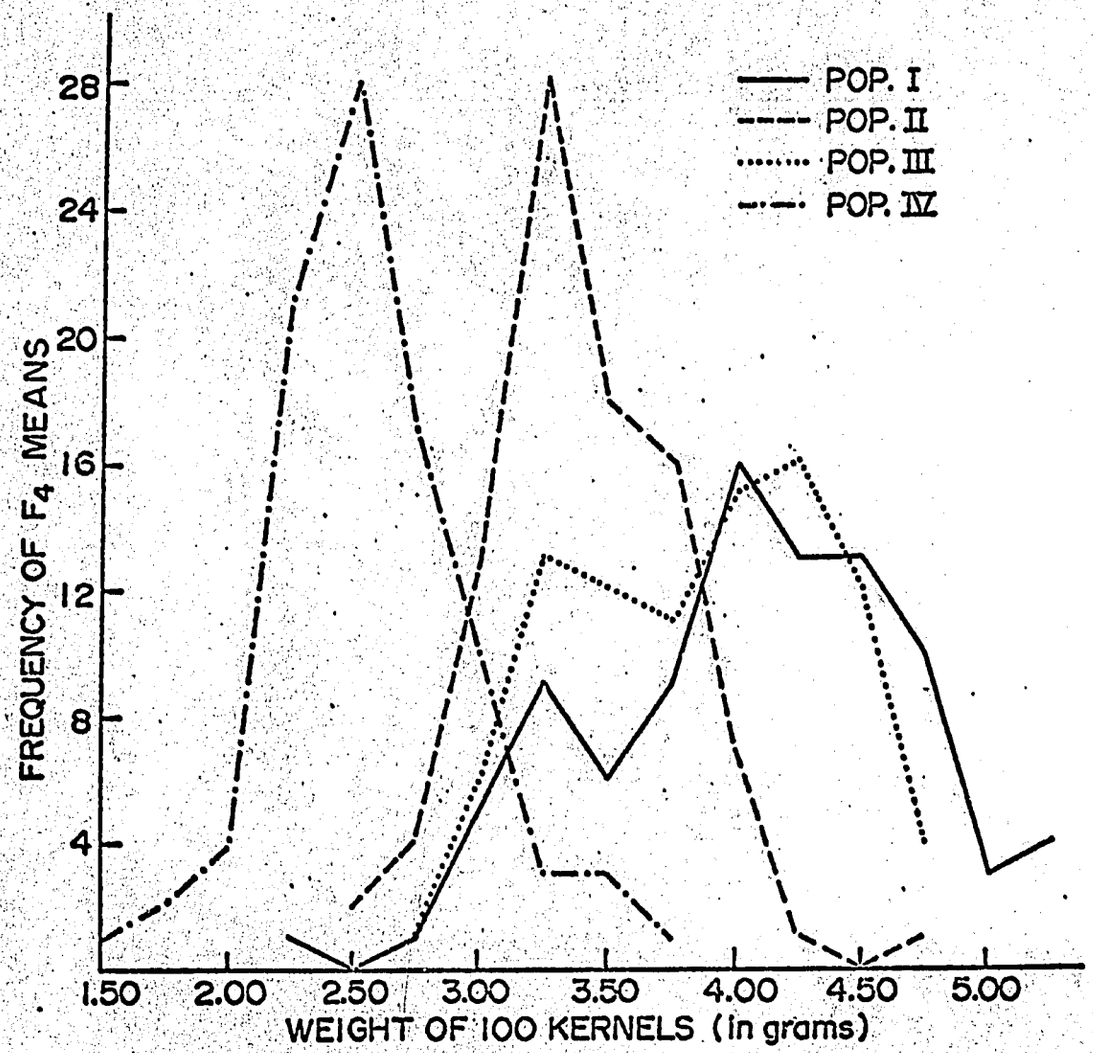


Figure 2. Frequency distribution of F_3 subpopulation means in the 4th generation for kernel weight in Populations I, II, III and IV.

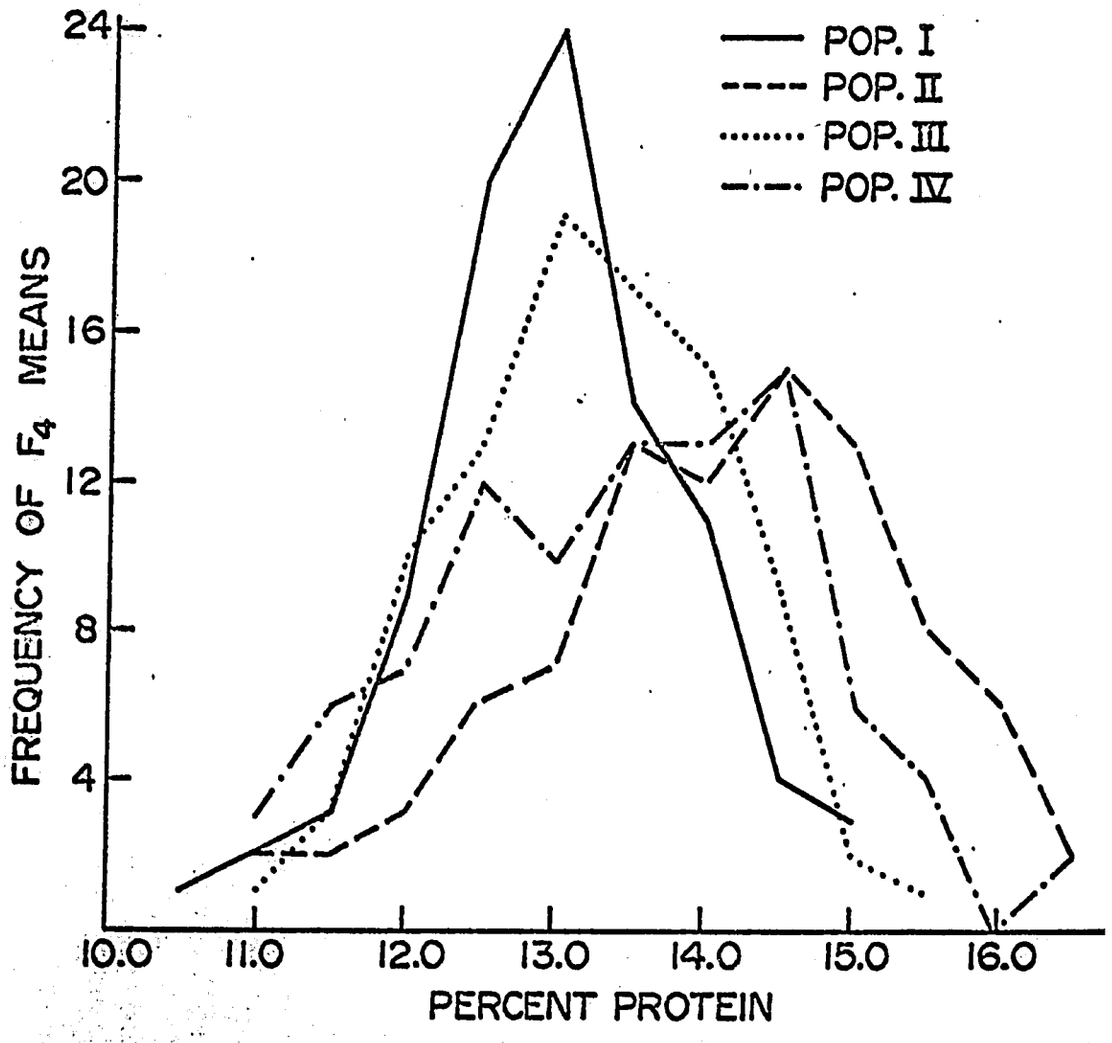


Figure 3. Frequency distribution of F_3 subpopulation means in F_4 for percent protein in Populations I, II, III and IV.

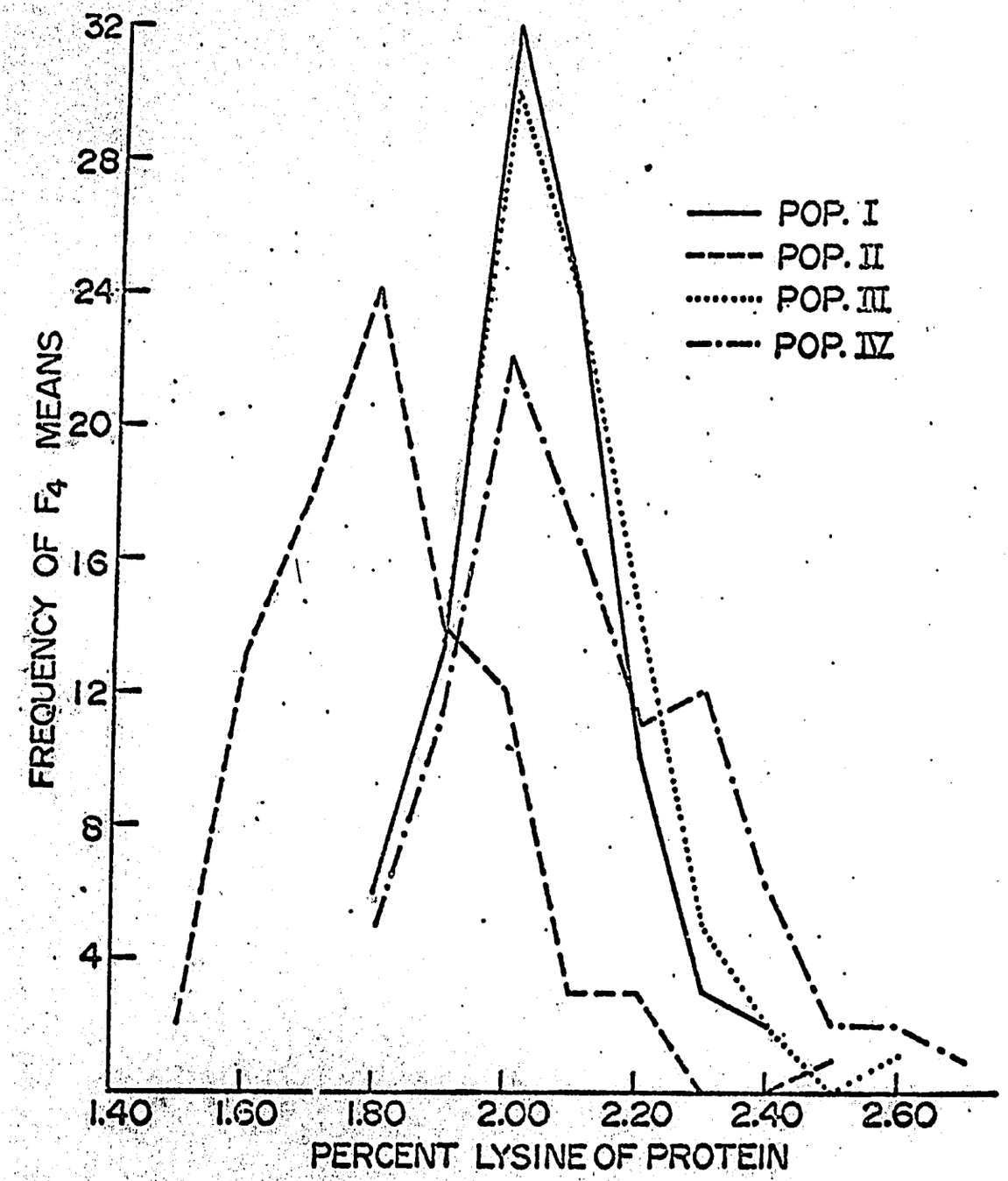


Figure 4. Frequency distribution of F_3 subpopulation means in F_4 for percent lysine of protein populations I, II, III and IV.

segregates which have the highest values for percent lysine of protein in all populations while lowest values for percent lysine of protein are contained in population II.

Frequency distributions for percent oil for each of the four populations are indicated in Figure 5. The frequency distribution curve for population IV has two peaks, one at 3.75 and the other at 4.75. Transgressive segregation for percent oil in both directions appears in populations I and II. However transgressive segregation was in only one direction toward the lower percent oil parent in population III but there was no transgressive segregation for percent oil in population IV though there were several segregates that equaled the lower percent oil parent while many other segregates approached the higher percent oil parent.

Analysis of Variance

Mean squares of 17 characters in populations I, II, III and IV are presented in Tables 8, 9, 10 and 11 respectively. In population I, significant differences were obtained among both the F_2 subpopulation means and F_3 subpopulations within F_2 subpopulations for days to flower, panicle weight, kernels per panicle, kernel weight, percent protein and mg of protein per kernel. However significant differences were only found among F_2 subpopulation means for panicles per plot and mg of oil per kernel while significant differences for plant height, kernel volume, percent lysine of protein, mg of lysine per kernel, percent oil and catechin equivalent were obtained among F_3 subpopulations within F_2 subpopulations only. No significant differences were indicated among

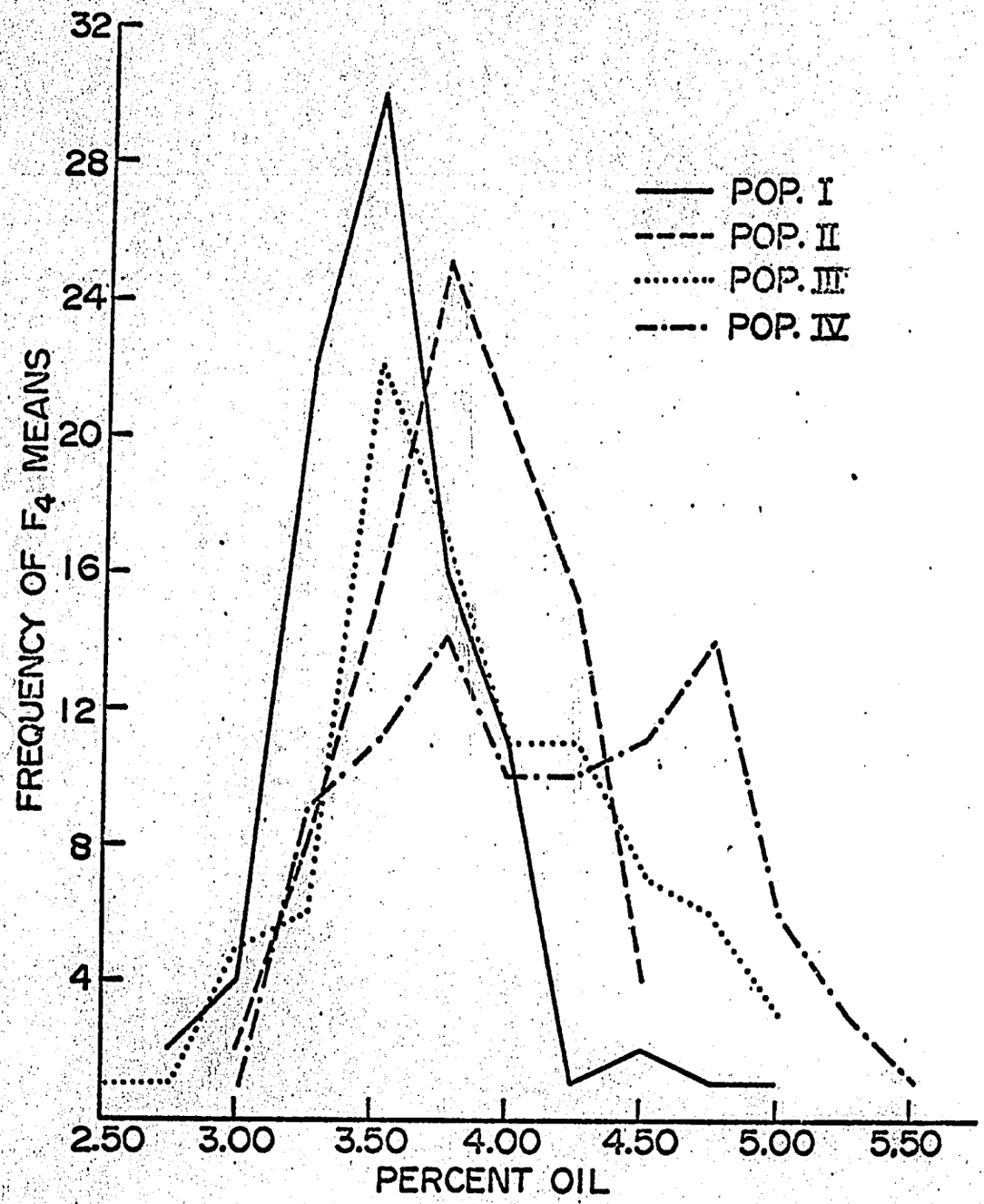


Figure 5. Frequency distribution of F_3 subpopulation means for percent oil in Populations I, II, III and IV.

Table 8. Mean squares in analyses of variance of 17 characters for population I.

Source	D.F.	Days to flower	Plant height	Panicles /plot	Panicle weight	Kernels /panicle (x 10^{-1})	Grain yield (kg/ha) (x 10^{-1})	Kernel weight	Kernel volume	Kernel density (x 10^{-3})	Percent protein	Mg. of protein /kernel	Percent lysine of protein (x 10^{-2})	Percent lysine of sample (x 10^{-4})	Mg. of lysine/kernel (x 10^{-4})	Percent oil	Mg. of oil/ kernel	Cor. K.
Location	1	451.25	6461.25	1155.20	457.45	118.6	297.0	5.712	1.701	3.545	12.48	19.66	149.76	76.00	6.30	1.378	1.553	.032
Rate	2	50.28	3203.09	120.07	284.45	8.3	347.2	1.979	.642	1.493	.06	3.32	1.95	3.43	30.21	.308	.574	1.753
Location x rate	2	43.46	921.67	146.60	103.20	9.6	344.0	.028	.108	.573	1.16	.15	.51	3.38	.38	.045	.002	1.437
Among F_2 subpopulation/rate	42	137.58**	6081.01	314.52*	214.88**	19.0**	320.7	1.014*	.599	.198	2.01*	2.60**	4.06	3.60	7.32	.343	.174**	1.232
Location x F_2 subpopulation /rate	42	6.78	853.69	59.75	57.88	4.0	177.0	.064	.041	.162	.38	.27	1.46	1.90	.78	.051	.017	.464
Among F_3 subpopulation within F_2 subpopulation /rate	45	34.15**	4343.42**	43.11	84.08*	6.9**	183.0	.519**	.350**	.194	1.02**	1.15**	2.74**	2.44	3.63**	.260**	.071	1.244**
Location x F_3 subpopulation within F_2 subpopulation /rate	45	7.34**	1043.19	34.31	45.01	3.3	161.8	.089	.058**	.179	.33	.21	.86	2.43	.94	.041*	.013*	.318**
Among replicates	24	3.41	1534.45	55.48	71.86	4.8	121.5	.029	.025	.267	.36	.18	.86	1.42	.64	.027	.006	.073

* Significant at .05 level
** Significant at .01 level

Table 9. Mean squares in analyses of variance of 17 characters for population II.

Source	D.F.	Days to flower	Plant height	Panicles /plot	Panicle weight	Kernels /panicle (x 10^{-1})	Grain yield (kg/ha) (x 10^{-1})	Kernel weight	Kernel volume	Kernel density (x 10^{-2})	Percent protein	Mg. of protein /kernel	Percent lysine of protein (x 10^{-2})	Percent lysine of sample (x 10^{-2})	Mg. of lysine/kernel (x 10^{-2})	Percent oil	Mg. of oil/ kernel	Cor. Vg.
Location	1	680.55	160.56	399.02	2223.38	445.3	2569.1	3.686	1.901	.221	85.14	31.85	73.22	16.60	28.48	.480	.940	.319
Sets	2	241.60	32327.92	362.54	533.35	72.1	201.0	.705	.451	1.039	3.03	2.18	1.32	12.90	14.70	.348	.189	2.749
Location x sets	2	14.73	1119.31	129.71	279.52	19.9	530.2	.006	.025	.743	3.17	.18	1.39	24.15	3.30	.097	.018	1.215
Among F_2 subpopulation/set	42	56.19*	4706.29**	171.06	146.92	19.9	306.1	.407*	.262**	.208	2.81	1.11	7.09	6.42	1.46	.267	.080*	.573
Location x F_2 subpopulation /set	42	6.93	633.93	32.62	55.02	5.2	183.2	.037	.021	.110	.90	.15	3.43	2.90	1.09	.026	.011	.134
Among F_3 subpopulation within F_2 subpopulation /set	45	31.50**	1445.56*	109.01	79.99**	12.0**	197.2	.200**	.123**	.124	3.02**	.84**	5.32**	4.68	2.73**	.210**	.041**	.532**
Location x F_3 subpopulation within F_2 subpopulation /set	45	3.96	746.67	98.61	30.44	4.4	157.3	.033	.018**	.087	.86	.16	2.94	2.91	1.08**	.019**	.003**	.153
Among replicates	24	4.60	603.21	61.81	84.82	11.1	159.5	.010	.006	.071	1.28	.15	2.84	1.83	.19	.005	.001	.152

* Significant at .05 level
** Significant at .01 level

Table 10. Mean squares in analyses of variance of 17 characters for population III.

Source	D.F.	Days to flower	Plant height	Panicles /plot	Panicle weight	Kernels /panicle ($\times 10^{-1}$)	Grain yield (kg/ha) ($\times 10^{-1}$)	Kernel weight	Kernel volume	Kernel density ($\times 10^{-2}$)	Percent protein	Mg. of protein /kernel	Percent lysine of protein ($\times 10^{-2}$)	Percent lysine of sample ($\times 10^{-2}$)	Mg. of lysine/kernel ($\times 10^{-2}$)	Percent oil	Mg. of oil/ kernel	Cat. Fe.
Location	1	1578.37	781.25	299.02	268.57	163.5	63.7	11.036	3.904	.413	20.20	37.51	113.60	22.60	53.39	3.042	3.314	1.299
Sets	2	80.57	1217.92	240.94	563.24	66.2	12736.3	.416	.247	.355	1.68	.24	2.36	16.75	1.55	.894	.086	.489
Location x sets	2	29.53	1065.42	32.61	103.44	11.7	94.3	.322	.207	.172	12.97	6.42	28.80	1.80	3.80	.400	.139	.449
Among F_2 subpopulation/set	42	225.77**	2766.59*	127.16**	204.96	19.4*	476.7*	.747**	.429**	.414	2.20*	1.73*	4.45*	10.10	4.90*	.781**	.257*	.597
Location x F_2 subpopulation /set	42	18.03	694.80**	34.59	84.55	5.7	181.3	.090	.049	.194	.64	.28	1.60	3.84	.82	.091	.030	.168
Among F_3 subpopulation within F_2 subpopulation /set	43	70.81**	1783.19**	51.62*	124.02*	9.0	199.1	.312**	.194**	.191	1.01**	.76**	2.40	6.66	2.38**	.350**	.124**	.504**
Location x F_3 subpopulation within F_2 subpopulation /set	43	16.97**	201.46	28.36	64.68	3.8	124.3	.053	.028	.163	.46*	.28	1.98	3.97	.39*	.069	.021	.189**
Among replicates	24	6.41	716.15	31.25	63.16	3.9	99.6	.039	.039	.300	.21	.12	2.60	4.72	.29	.074	.020	.044

* Significant at .05 level
** Significant at .01 level

Table 11. Mean squares in analyses of variance of 17 characters for population IV.

Source	D.F.	Days to flower	Plant height	Panicles /plot	Panicle weight	Kernels /panicle ($\times 10^{-1}$)	Grain yield (kg/ha) ($\times 10^{-4}$)	Kernel weight	Kernel volume	Kernel density ($\times 10^{-2}$)	Percent protein	Mg. of protein /kernel	Percent lysine of protein ($\times 10^{-2}$)	Percent lysine of sample ($\times 10^{-2}$)	Mg. of lysine/kernel ($\times 10^{-1}$)	Percent oil	Mg. of oil/ kernel	Coe. Var.
Location	1	196.05	1901.25	510.05	12.48	60.7	354.8	1.590	.612	.975	12.53	6.05	136.76	52.50	3.30	1.763	.541	9.393
Sets	2	344.15	5781.81	373.37	57.20	8.0	733.2	.300	.202	1.443	7.16	2.02	32.12	24.25	9.40	2.272	.371	10.050
Location x sets	2	176.51	775.42	85.72	110.30	19.9	734.5	.314	.222	.327	7.75	1.92	3.72	39.05	6.70	.111	.689	24.512
Among F_2 subpopulation/set	42	56.98*	2225.16**	94.55	163.62	26.9*	896.6*	.416*	.256*	.508	3.15	.71*	8.50	18.56*	2.55*	.910**	.067**	8.943
Location x F_2 subpopulation /set	42	18.95	455.16	56.63	57.37**	8.2	139.8	.045	.027	.499	.33	.09	2.12	3.06	.27	.099	.009	4.022
Among F_3 subpopulation within F_2 subpopulation /set	43	38.93**	903.75	[illegible].91	100.43**	11.0*	134.7	.201**	.133**	.430	2.17**	.43**	6.12**	4.87**	1.39**	.412**	.30**	6.332*
Location x F_3 subpopulation within F_2 subpopulation /set	43	8.07	588.75	66.15	23.72	3.5	149.1	.034	.029*	.515*	.44	.11	1.29	1.78	.23	.091	.012	3.672
Among replicates	24	6.22	459.90	33.54	43.56	6.1	170.4	.023	.015	.176	.39	.07	1.43	3.41	.27	.075	.006	2.167

* Significant at .05 level
** Significant at .01 level

F_2 subpopulations or F_3 subpopulation within F_2 subpopulations for grain yield, kernel density and percent lysine of sample.

In population II, days to flower, plant height, kernel weight and volume and mg of oil per kernel were significant among both the F_2 subpopulations and F_3 subpopulations within F_2 subpopulations but panicle weight, kernels per panicle, percent protein, mg of protein per kernel, percent lysine of protein, mg of lysine per kernel, percent oil and catechin equivalents were only significant among the F_3 subpopulations within F_2 subpopulations. There were no significant differences among F_2 subpopulations or F_3 subpopulations within F_2 subpopulations for grain yield, kernel density and percent lysine of sample.

In population III, days to flower, plant height, panicles per plot, kernel weight and volume, percent protein, mg of protein per kernel, mg of lysine per kernel, percent oil and mg of oil per kernel were all significant among the F_2 subpopulations and F_3 subpopulations within F_2 subpopulations. Kernels per panicle, grain yield and percent lysine of protein were significant only among F_2 subpopulations while panicle weight, and catechin equivalents were significant only among F_3 subpopulations within F_2 subpopulations. There were no significant differences among F_2 subpopulations or F_3 subpopulations within F_2 subpopulations for kernel density and percent lysine of sample.

In population IV, significant differences among F_2 subpopulations and F_3 subpopulations within F_2 subpopulations were detected for days to flower, kernels per panicle, kernel weight and volume, percent lysine of sample, mg of lysine per kernel, percent oil and mg of oil per kernel.

Significant differences among F_2 subpopulations were found only for plant height and grain yield while significance among F_3 subpopulations within F_2 subpopulations were only found for panicle weight, percent protein, percent lysine of protein and catechin equivalents. There wer no significant differences among F_2 subpopulations or F_3 subpopulations within F_2 subpopulations for panicles per plot and kernel density.

Location x F_2 subpopulation interactions in all populations for all characters were generally nonsignificant except for plant height in population III and panicle weight in population IV. Location x F_3 subpopulation interactions likewise were nonsignificant in all populations for all characters except for days to flower, kernel volume, percent oil, mg of oil per kernel and catechin equivalents in population I, kernel volume, mg of lysine per kernel, percent oil and mg of oil per kernel in population II, days to flower, percent protein, mg of lysine per kernel and catechin equivalents in population III and kernel volume and kernel density in population IV.

Estimates of progeny genetic variance components of 17 characters for each population are presented in Table 12. All progeny genetic variance components estimates that were negative were assumed to be zero. It is important to note that certain traits in some populations were statistically significant among the F_3 subpopulations within F_2 subpopulations but nonsignificant among the F_2 subpopulations. The estimates of genetic variance components among F_3 subpopulations within F_2 subpopulations for all of those traits were clearly larger than the estimated genetic variance components among the F_2 subpopulations for the same traits. This would come about only if the dominance variance

Table 12. Estimates of genetic component variances for among F_2 subpopulations ($\hat{\sigma}^2_g$) and among F_3 subpopulations within F_2 subpopulations ($\hat{\sigma}^2_{3/2}$) in the 4th generation for populations I, II, III and IV.

Populations	Subpopulations	Days to flower	Plant height	Panicle /plot	Panicle weight	Kernels /panicle (x 10^4)	Grain yield (kg/ha) (x 10^4)	Kernel weight (x 10^{-2})	Kernel volume (x 10^{-2})	Kernel density (x 10^{-4})	Percent protein (x 10^{-2})	Mg. of protein/kernel (x 10^{-4})	Percent lysine of protein (x 10^{-4})	Percent lysine of sample (x 10^{-4})	Mg. of lysine/kernel (x 10^{-4})	Percent oil (x 10^{-2})	Mg. of oil/kernel (x 10^{-4})	Cat. Eq. (x 10^{-2})
I *	$\hat{\sigma}^2_2$ **	20.06	431	15.99	29.48	2.8	30.6	12.49	6.66	.53	23.40	34.13	17.25	.37	.96	3.87	2.53	- 3.98
	$\hat{\sigma}^2_{3/2}$ ***	13.29	1751	- 4.60	19.54	1.7	10.6	21.51	14.58	.78	34.66	48.25	95.60	.12	1.34	10.95	2.79	44.45
II	$\hat{\sigma}^2_2$	5.43	843	14.51	10.59	1.7	20.7	5.09	3.42	1.52	- 6.29	6.93	32.23	.44	.18	1.25	.92	.92
	$\hat{\sigma}^2_{3/2}$	13.77	349	5.20	24.77	3.7	19.9	8.32	5.23	1.87	108.10	33.82	119.00	.81	.82	9.52	1.59	19.19
III	$\hat{\sigma}^2_2$	38.47	993	17.33	14.77	2.6	33.1	9.85	5.35	4.83	23.36	22.20	60.75	.89	.57	11.51	3.06	2.85
	$\hat{\sigma}^2_{3/2}$	26.92	791	11.63	29.67	1.5	37.3	12.95	8.27	1.30	27.52	28.32	29.50	1.34	.89	11.52	5.35	15.67
IV	$\hat{\sigma}^2_2$	11.29	364	6.54	7.89	3.2	42.7	5.11	3.10	2.35	27.46	7.37	42.75	1.10	.30	12.23	1.01	34.03
	$\hat{\sigma}^2_{3/2}$	15.43	158	5.88	37.35	2.7	- 7.1	8.35	5.22	-4.24	86.32	16.26	241.00	1.34	.33	16.09	.88	232.98

* I, II, III and IV refer to populations

** Estimates of variance genetic component for among F_2 subpopulation in the 4th generation

*** Estimates of variance genetic component for among F_3 subpopulation within F_2 subpopulation in the 4th generation

component was much larger than the additive variance component. This does not seem very likely. The other plausible explanation for this occurrence could possibly have arisen from outcrossing. The random F_2 panicles selected had not been bagged to exclude foreign pollen. On the other hand two F_3 panicles randomly selected from each F_3 progeny row had been bagged to insure 100% selfing. If a substantial amount of outcrossing did actually take place on these F_2 panicles, the genetic variability among F_3 subpopulations would be increased while at the same time, that among F_2 subpopulations would be decreased leading to larger estimates of genetic variance components among F_3 subpopulations within F_2 subpopulations than among F_2 subpopulations.

Grain sorghum is normally self-fertilized and has perfect flowers with no known barriers to cross fertilization. Most studies indicate that about 6% outcrossing occurs between sorghum plants in adjacent rows (48, 58) and that under some conditions the percentage of outcrossing may be less or much greater (58). The percentage of outcrossing is probably much greater within rows. It would appear highly unlikely, therefore, that this small amount of outcrossing would affect the magnitude of the estimates of genetic variance components in this study.

The results show that significant heterozygosity was present among the F_2 families in the fourth generation for kernel weight and kernel volume, percent protein, mg of protein per kernel, percent oil, mg of oil per kernel and a few other plant traits in the majority of the populations. This suggests that selection within families in the early generations of segregating populations for these traits would be most effective. In some populations significant segregation was not indicated

within the F_3 families but significant variation among F_2 subpopulation did exist which presumably implies that selection among the F_2 families in the F_3 generation would be as effective as selection among F_2 families in some later generations.

Gene Action

The estimates of additive ($\hat{\sigma}^2_A$) and dominance ($\hat{\sigma}^2_D$) variances and their associated standard errors for seed and chemical traits in each of the four populations are shown in Table 13. Since no statistically significant differences for kernel density were found among F_2 subpopulations or F_3 subpopulations for any population, their estimates of additive and dominance variances were not computed. Negative estimates of additive or dominance variances were found for some traits in one or more populations. These were assumed to be essentially zero. In all populations and for all characters, the estimated standard errors for additive variances were generally large relative to the estimates of additive variances but the estimated standard errors for dominance variances were small relative to the estimates of dominance variances.

Estimates of additive and dominance variances for kernel weight and volume were always positive in all populations except for kernel volume in population I, and were always consistent from one population to another in that the estimates of dominance variances were always larger than those of additive variances. This clearly indicates that, while additive gene action is present in the inheritance of kernel weight and volume, dominance is the most important gene action in the expression of kernel weight and volume. Likewise the estimates of dominance variance were larger than the estimates of additive variance in all populations for percent protein, mg of protein per kernel, percent lysine of protein

Table 13. Estimates of additive ($\hat{\sigma}^2_A$) and dominance ($\hat{\sigma}^2_D$) genetic variances and their standard errors in parenthesis for seed and chemical traits for populations I, II, III and IV.

Character	Population	$\hat{\sigma}^2_A$		$\hat{\sigma}^2_D$	
Kernel weight	I	.0231	(.1024)	1.6283	(.7803)
	II	.0124	(.0400)	.6160	(.3021)
	III	.0464	(.0692)	.8505	(.4854)
	IV	.0125	(.0412)	.6184	(.3052)
Kernel volume	I	-.0084	(.0916)	1.1999	(.5170)
	II	.0108	(.0244)	.3749	(.1870)
	III	.0162	(.0412)	.5967	(.2968)
	IV	.0066	(.0264)	.3910	(.2022)
Percent protein	I	.0809	(.2078)	2.4487	(1.5922)
	II	-.8045	(.4806)	11.8659	(4.4026)
	III	.1546	(.2253)	1.5837	(1.6745)
	IV	-.2094	(.3796)	7.7432	(3.1830)
Mg of protein/kernel	I	.1482	(.2463)	3.1780	(1.7795)
	II	-.1330	(.1428	3.2377	(1.2278)
	III	.1072	(.2244)	1.8369	(1.6724)
	IV	-.0100	(.0806)	1.3408	(.6565)
Percent lysine of protein (x 10^{-4})	I	-40.73	(50.20)	927.73	(415.64)
	II	-36.63	(100.64)	1099.33	(862.75)
	III	67.17	(54.49)	-1030.67	(449.23)
	IV	-10.88	(106.24)	2364.93	(895.70)
Percent lysine of sample (x 10^{-4})	I	.4117	(.5750)	9.2187	(5.1000)
	II	-.3073	(.9088)	7.8253	(2.4797)
	III	.2930	(1.3153)	6.4613	(3.5133)
	IV	.4427	(1.0587)	4.0547	(2.4656)
Mg of lysine/kernel (x 10^{-4})	I	.3863	(.7360)	9.2187	(5.5836)
	II	-.3073	(.4803)	7.8253	(4.1786)
	III	.1707	(.4890)	6.4613	(3.6639)
	IV	.0513	(.2691)	4.0547	(2.1044)
Percent oil	I	-.0480	(.0436)	1.0676	(.3754)
	II	-.0468	(.0346)	.9488	(.3000)
	III	.0767	(.0700)	.6148	(.4793)
	IV	.0556	(.0872)	1.0645	(.6370)
Mg of oil/kernel (x 10^{-2})	I	1.52	(1.60)	16.21	(11.19)
	II	.16	(.82)	12.08	(6.25)
	III	.57	(2.55)	39.71	(19.14)
	IV	.76	(.66)	4.05	(4.92)
Catechin equivalent	I	-.3625	(.2000)	5.1661	(1.8066)
	II	-.1152	(.0872)	1.9888	(.7800)
	III	-.0679	(.0866)	1.5411	(.7641)
	IV	-.1462	(1.2264)	11.3035	(10.4691)

except in population III, percent lysine of sample, mg of lysine per kernel, percent oil, mg of oil per kernel and catechin equivalent value.

It is apparent from this study that much of the genotypic variance for several of the seed and chemical traits in almost all populations arises from dominance gene effects. Therefore an effective improvement procedure would result from selection among large numbers of families at a somewhat high level of inbreeding and since dominance variance is predominant for several of the characters in all populations hybrid development would appear to be an appropriate procedure.

In this study epistatic gene interactions were presumed nonexistent. However, in the event that epistasis was present, the estimates of additive and dominance variances would be biased upward.

Heritability and Genetic Advance

The magnitude of additive genetic variance and heritability has its use in estimating progress possible through selection in segregating populations. Estimates of heritability and genetic advance expressed in percent of the mean over two locations for seed and chemical traits were computed for each segregating population and are presented in Table 14. Heritabilities range from 5.19% for mg lysine per kernel in population IV to 59.84% for mg of oil per kernel in population IV among F_2 subpopulations and 7.29% for mg of oil per kernel in population II to 65% for percent lysine of sample in population I among the F_3 subpopulations. Estimates of heritability for each trait were variable from population to population in F_2 subpopulations and F_3 subpopulations. In general the estimates of heritabilities of each trait for F_2 subpopulations were consistently greater than those for F_3 subpopulations except percent

Table 14. Estimates of heritability and genetic advance as percent of the population mean for seed and chemical traits in Populations I, II, III and IV.

Character	Population	H_2	H_3	Δ_2 as percent of mean	Δ_3 as percent of mean
Kernel weight	I	16.14	9.04	3.20	2.93
	II	21.72	12.25	3.24	2.98
	III	32.98	26.27	6.79	7.43
	IV	19.11	12.13	4.11	4.01
Kernel volume	I	---	---	---	---
	II	28.65	16.80	4.54	4.27
	III	20.69	15.58	3.18	4.30
	IV	17.19	10.24	3.75	3.35
Percent protein	I	18.72	15.97	1.98	2.25
	II	---	---	---	---
	III	38.21	28.77	3.85	4.10
	IV	---	---	---	---
Mg of protein/kernel	I	32.90	23.53	9.01	9.33
	II	---	---	---	---
	III	35.19	25.65	8.18	8.56
	IV	---	---	---	---
Percent lysine of protein	I	---	---	---	---
	II	---	---	---	---
	III	37.07	58.83	5.06	7.81
	IV	---	---	---	---
Percent lysine of sample	I	26.24	65.07	2.67	5.16
	II	---	---	---	---
	III	6.99	40.70	1.11	1.91
	IV	11.47	21.23	1.70	2.84
Mg of lysine per kernel	I	14.41	47.72	4.87	10.83
	II	---	---	---	---
	III	9.37	32.98	2.65	6.12
	IV	5.19	16.16	1.66	3.48
Percent oil	I	---	---	---	---
	II	---	---	---	---
	III	48.06	42.52	10.57	12.25
	IV	34.30	25.22	7.08	7.43
Mg of oil per kernel	I	52.05	37.12	13.46	13.92
	II	14.95	7.92	2.60	2.32
	III	13.22	8.90	3.99	4.01
	IV	59.84	48.13	13.93	15.57

H_2 = Heritability among F_2 subpopulations

H_3 = Heritability among F_3 subpopulations

Δ_2 = Genetic advance within F_2 subpopulations as percent of the mean

Δ_3 = Genetic advance within F_3 subpopulations as percent of the mean

lysine of protein in population III, percent lysine of sample in populations I, III and IV and mg of lysine per kernel in populations I, III and IV.

Estimates of genetic advance as percent of each population mean for seed and chemical traits ranged from 1.11% to 15.57%. Genetic advance in F_2 and F_3 subpopulations for all the traits were generally small except for mg of lysine per kernel in population I, percent oil in population III and mg of oil per kernel in populations I and IV. Genetic advance as percent of each population mean for all seed and chemical traits for F_2 and F_3 subpopulations within each population were not as different as the heritabilities for F_2 and F_3 subpopulations. It is interesting to note that those traits with high estimates of heritability values had high estimates of genetic advance as percent of the mean and vice versa.

The four populations were grown in one year and two locations that were a couple of miles apart. Much more reliable estimates would have been obtained if a larger sample of the populations and environments (locations and years) had been used. The extension of experiments of this nature over several locations and years necessitates large supplies of seed from individual F_3 panicles which is not practicable. Horner et al. (37) realized this problem and indicated that accumulated results from a series of smaller experiments, whether conducted by the same worker or different ones, should eventually provide whatever information is within the potential approach itself.

Heritabilities and genetic progress expected under selection obtained in this study give sufficient evidence that substantial improvement can be made for kernel weight and volume, percent protein in

population III, percent lysine of protein in population III and percent oil in population III and IV.

Correlations

All the phenotypic correlations among all characters in populations I, II, III and IV for F_2 subpopulations and F_3 subpopulations within F_2 subpopulations are presented in Appendix Tables 5, 6, 7 and 8 respectively. The phenotypic correlations between a pair of characters from population to population are in agreement in the majority of cases. However the phenotypic correlations for any pair of characters for F_2 subpopulations and F_3 subpopulations within F_2 subpopulations in each population tend to be variable. In most cases the correlations for F_2 subpopulations tend to be larger than those for the F_3 subpopulations in each population. Phenotypic correlations between kernel weight and kernel volume were positive and highly significant in all populations. Mg of protein per kernel, mg of lysine per kernel and mg of oil per kernel involved weight of 100 kernels in their computations. It is interesting to note that all correlations of kernel weight or kernel volume with all these characters are positive and highly significant. Futhermore the phenotypic correlations among all these five characters are also positive and highly significant.

Phenotypic correlations in all populations of grain yield with all the other traits for F_2 subpopulations and F_3 subpopulations within F_2 subpopulations are presented in Table 15. Phenotypic correlations of grain yield with panicles per plot, panicle weight and kernels per panicle were found to be positive and significant. It was also found that the correlations of grain yield with kernel weight, kernel volume,

Table 15. Phenotypic correlations between grain yield and 16 plant, seed and chemical characters in F_2 subpopulations (F_2) and F_3 subpopulations within F_2 subpopulations [$F_{3/2}$] in the fourth generation for segregating grain sorghum populations I, II, III and IV.

		Grain yield			
		I	II	III	IV
Days to flower	F_2	-.3313*	-.1799	-.6324**	-.5547**
	$F_{3/2}$	-.3512*	-.0956	-.1543	-.2521
Plant height	F_2	.0903	-.0601	-.3821*	-.0759
	$F_{3/2}$	-.1592	-.0279	-.2209	.0470
Panicles/plot	F_2	.3419*	.1225	.5735*	.4817**
	$F_{3/2}$	.4456**	.2747	.3075*	.3287*
Panicle weight	F_2	.6413*	.7555**	.6644**	.6392**
	$F_{3/2}$	.2293	.6092**	.7291**	.5097**
Kernels/panicle	F_2	.4481**	.7347**	.4386**	.3561*
	$F_{3/2}$	.5154**	.5420**	.6676**	.3621*
Kernel weight	F_2	.1956	-.2838	.2640	.4198**
	$F_{3/2}$	.2166	-.0669	.1122	.2891*
Kernel volume	F_2	.1566	-.2934	.1990	.3578*
	$F_{3/2}$	.0830	-.1304	.0712	.2848
Kernel density	F_2	.2759	.1722	.4251**	.3719*
	$F_{3/2}$	-.0321	.3779**	.1193	-.0782
Percent protein	F_2	-.2274	-.2063	-.6231**	.0530
	$F_{3/2}$	-.2491	-.4265**	-.3802*	-.0402
Mg of protein/kernel	F_2	.0643	-.3412*	-.0307	.4292**
	$F_{3/2}$	-.0540	-.2916	-.0723	.2368
Percent lysine of protein	F_2	-.0187	.0005	-.0734	-.3665*
	$F_{3/2}$	.0660	.1648	.0011	-.1151
Percent lysine of sample	F_2	-.3352*	-.2587	-.6358**	-.3403*
	$F_{3/2}$	-.2201	-.3786**	-.3395*	-.1975
Mg of lysine/kernel	F_2	.0817	-.3558*	-.0646	.3005*
	$F_{3/2}$	-.0069	-.2082	-.0707	.2129
Percent oil	F_2	.2054	.0006	.2757	.1653
	$F_{3/2}$	.3465*	.2106	.1749	.0507
Mg of oil/kernel	F_2	.2585	-.2454	.3571*	.5107**
	$F_{3/2}$	.3260*	-.0930	.1363	.3514*
Catechin equivalent	F_2	.0085	.0661	.3825*	-.1002
	$F_{3/2}$	.0849	.3574*	.1561	.0549

* Significant at .05 level
** Significant at .01 level

kernel density and percent oil were mainly nonsignificant with a few exceptions. These results confirm what many other workers have found (6, 5, 53) that panicle weight and kernels per panicle are indicators of grain yield. In this study it appears that increase of grain size has no direct relationship with yield except in population IV, where increase of grain size would appear to increase yield.

On the other hand the interrelationships of grain yield with days to flower and percent protein were negative and in most cases significant. It is, however, interesting to note that the correlation between grain yield and days to flower were nonsignificant in population II which was in general, earlier maturing. It appears that the significant, positive correlation in populations I, III and IV, which were late maturing, are probably due to the factor that over 20% of the segregates in these populations flowered late and hence the filling up of their kernels was terminated by the cold weather. This resulted into small and shriveled kernels and lower yields for these segregates. This may have had an effect on other correlations between days to flower and other characters.

Phenotypic correlations of kernel weight with all other characters in all populations are presented in Table 16. The relationship between kernel weight and kernel volume was found to be positive and highly significant in all populations while that between kernel weight and kernel density was nonsignificant in all populations. This implies that selection of kernel weight results in the selection of kernel volume and vice versa. The density of the kernel does not appear to be associated with kernel weight or kernel volume directly or indirectly. Kernel weight and percent protein were not significantly correlated except in population I for F_2 subpopulations.

Table 16. Phenotypic correlations between weight of 100 kernels and 16 plant, seed and chemical characters in F_2 subpopulations (F_2) and F_3 subpopulations within F_2 subpopulations [$F_{3/2}$] in the fourth generation for segregating grain sorghum populations I, II, III and IV.

		Kernel weight			
		I	II	III	IV
Days to flower	F_2	-.6738**	-.1131	-.7314**	-.4451**
	$F_{3/2}$	-.3858**	.1297	-.6847**	-.3853**
Plant height	F_2	-.5375**	-.0959	-.7594**	-.2522
	$F_{3/2}$	-.4951**	.0836	-.6529**	-.3146*
Panicles/plot	F_2	.2491	-.0585	.4609*	.1527
	$F_{3/2}$	-.0608	.0019	-.1420	-.2820
Panicle weight	F_2	.0168	-.1912	-.0569	.3543*
	$F_{3/2}$	.1050	-.0776	.2840	.5190**
Kernels/panicle	F_2	-.4758**	-.5742**	-.5360**	-.3225*
	$F_{3/2}$	-.1829	-.5037**	-.1021	-.0844
Grain yield (kg/ha)	F_2	.1956	-.2838	.2640	.4198**
	$F_{3/2}$	.2166	-.0669	.1122	.2891*
Kernel volume	F_2	.9901**	.9860**	.9837**	.9882**
	$F_{3/2}$	.9841**	.9826**	.9844**	.9819**
Kernel density	F_2	.1635	-.2154	.2752	-.0828
	$F_{3/2}$	-.2139	.0653	-.0622	-.1750
Percent protein	F_2	.4408**	.0891	.1092	-.2493
	$F_{3/2}$	.1974	.2569	.1908	-.0595
Mg of protein/kernel	F_2	.9480**	.8514**	.9094**	.8737**
	$F_{3/2}$	.9267**	.8088**	.9095**	.8357**
Percent lysine of protein	F_2	-.4493**	-.0364	-.5264**	-.1388
	$F_{3/2}$	-.2438	-.2037	-.4378**	-.1806
Percent lysine of sample	F_2	.0501	.1168	-.3335*	-.4152**
	$F_{3/2}$	-.0855	.0835	-.1877	-.2938*
Mg of lysine/kernel	F_2	.9604**	.8225**	.8643*	.8874**
	$F_{3/2}$	.9476**	.8113**	.8442*	.8697**
Percent oil	F_2	.0472	.0033	.2688	-.3924**
	$F_{3/2}$	-.2724	-.1783	.4752**	-.3319*
Mg of oil/kernel	F_2	.8411**	.8094**	.7738**	.6156**
	$F_{3/2}$	.7424**	.6666	.8408**	.6205**
Catechin equivalent	F_2	-.2564	-.0395	.3490*	-.3193*
	$F_{3/2}$	-.3718*	.0565	-.2612	-.3743**

* Significant at .05 level
** Significant at .01 level

Phenotypic correlations of kernel weight with days to flower, plant height, kernels per panicle and percent lysine of protein were negative and significant in most populations. There were no significant correlations obtained for kernel weight with days to flower and plant height in population II which was earlier maturing. The significant correlations of kernel weight with days to flower and plant height in other populations are probably due to the factor that several segregates in these populations flowered late.

Phenotypic correlations between kernel weight and percent oil are nonsignificant in populations I and II but are positive and only significant for F_3 subpopulations within F_2 subpopulations in population III and negative and significant in population IV. One of the parents of population III had very large kernels and medium oil content while the other parent had medium kernel weight but high oil. For population IV, one of the parents had medium kernel weight but low oil content while the other parent had very small kernels but high oil content. A large number of lines that have been identified to have high percent oil are small seeded sudan grass type. Simultaneous selection for large kernels and high percent oil would seem extremely difficult where one of the parent line was small seeded but with high percent oil content.

Phenotypic correlations of percent protein with all other characters in all populations are presented in Table 17. Phenotypic correlations between percent protein and percent oil are positive and highly significant in population IV. Percent protein and percent lysine of protein were found to be negatively and significantly correlated in all populations but percent protein and percent lysine of sample were

Table 17. Phenotypic correlations between percent protein and 16 plant, seed and chemical characters in F_2 subpopulations (F_2) and F_3 subpopulations within F_2 subpopulations [$F_{3/2}$] in the fourth generation for segregating grain sorghum populations I, II, III and IV.

		Percent protein			
		I	II	III	IV
Days to flower	F_2	-.1997	-.2346	.2646	-.2817
	$F_{3/2}$	-.0145	-.2723	-.0814	-.4348**
Plant height	F_2	-.3221*	-.1392	.1012	.3750*
	$F_{3/2}$	-.0172	-.1293	.0507	.0114
Panicles/plot	F_2	.1832	-.0908	-.0795	-.1066
	$F_{3/2}$	-.0318	.3016*	-.0383	.1229
Panicle weight	F_2	-.2778	-.0726	-.6286**	.1426
	$F_{3/2}$	-.2047	-.6325**	-.3162*	-.1557
Kernels/panicle	F_2	-.4261**	-.1003	-.6463**	.3500*
	$F_{3/2}$	-.2680	-.6898**	-.3675*	-.0492
Grain yield	F_2	-.2274	-.2063	-.6231**	.0530
	$F_{3/2}$	-.2491	-.4265**	-.3802**	-.0402
Kernel weight	F_2	.4408**	.0891	.1092	-.2493
	$F_{3/2}$	.1974	.2569	.1908	-.0595
Kernel volume	F_2	.4660**	.0827	.1173	-.2969*
	$F_{3/2}$	.2028	.2739	.2159	-.0982
Kernel density	F_2	-.0961	.0103	-.0672	.3586*
	$F_{3/2}$	-.0874	-.1793	-.0980	.2118
Mg of protein/kernel	F_2	.6982**	.5946**	.5077**	.2458**
	$F_{3/2}$	.5433**	.7734**	.5773**	.4912**
Percent lysine of protein	F_2	-.7475**	-.6912**	-.3594*	-.6105**
	$F_{3/2}$	-.7936**	-.7543**	-.2553	-.7314**
Percent lysine of sample	F_2	.4914**	-.2668	.6113**	.4015**
	$F_{3/2}$	.3204*	-.4696**	.6096**	.3250*
Mg of lysine/kernel	F_2	.5513**	.2212	.4422**	-.0694
	$F_{3/2}$	.2979*	.3664*	.5467**	.1118
Percent oil	F_2	.2414	.1778	.0716	.7962**
	$F_{3/2}$	.1075	.0085	.0250	.7879**
Mg of oil/kernel	F_2	.4820	.1855	.1132	.4569**
	$F_{3/2}$	.2210	.2492	.1416	.5844**
Catechin equivalent	F_2	-.1133	-.0740	-.2200	.1782
	$F_{3/2}$	.1152	-.3289	-.0975	-.2631

* Significant at .05 level
** Significant at .01 level

positively and significantly correlated in all populations except population II. A good indicator for percent protein in this study wa found to be percent oil in population IV.

Phenotypic correlations of percent lysine with all other characters in all populations for F_2 subpopulations and F_3 subpopulations within F_2 subpopulations are presented in Table 18. Correlations between percent lysine of protein and days to flower were positive and significant in all populations. Plant height and percent lysine were positively correlated and significant in populations I and III for F_2 subpopulations. Percent lysine of protein and percent lysine of sample are positively and significantly correlated except in population I for F_2 subpopulations. Correlations of percent lysine with kernel density, mg of protein per kernel, mg of lysine per kernel and mg of oil per kernel are negative and significant in the majority of populations.

Phenotypic correlations of percent oil with all other characters in all populations for F_2 subpopulations and F_3 subpopulations are presented in Table 19. Correlations between percent oil and mg of oil per kernel are positive and highly significant. Percent oil and catechin equivalents are positively and significantly correlated except in population II.

In this study no stable and favorable associations of chemical traits with any plant or seed traits were found in all populations. However kernel weight or volume could probably be used as a good indicator in selecting percent protein in population I and percent oil in population II while at the same time it would be a very poor

Table 18. Phenotypic correlations between percent lysine of protein and 16 plant, seed and chemical characters in F_2 subpopulations (F_2) and F_3 subpopulations within F_2 subpopulations [$F_{3/2}$] in the fourth generation for segregating grain sorghum populations I, II, III and IV.

		Percent lysine of protein			
		I	II	III	IV
Days to flower	F_2	.4540**	.3134*	.4768**	.4980**
	$F_{3/2}$	.1880	.5267**	.4381**	.5277**
Plant height	F_2	.3622*	.0316	.4586**	-.0877
	$F_{3/2}$	.2251	.1774	.2920	.1028
Panicles/plot	F_2	-.1638	.0608	-.2884	-.1514
	$F_{3/2}$	.0851	-.2337	.0717	-.0058
Panicle weight	F_2	.0094	-.0567	.0837	-.3565*
	$F_{3/2}$	.0196	.3080*	-.1437	-.0340
Kernels/panicle	F_2	.1811	-.0120	.3319	-.2938
	$F_{3/2}$	.2384	.3994	-.0467	.0987
Grain yield	F_2	-.0187	.0005	-.0734	-.3665*
	$F_{3/2}$	.0660	.1648	.0011	-.1151
Kernel weight	F_2	-.4493**	-.0364	-.5264**	-.1388
	$F_{3/2}$	-.2438	-.2037	-.4378**	-.1806
Kernel volume	F_2	-.4478**	-.0163	-.4796**	-.0899
	$F_{3/2}$	-.2218	-.1719	-.4299**	-.1285
Kernel density	F_2	-.0915	-.1172	-.4035**	-.3077*
	$F_{3/2}$	-.0865	-.1099	-.1399	-.2352
Percent protein	F_2	-.7475**	-.6912**	-.3594*	-.6105**
	$F_{3/2}$	-.6936**	-.7543**	-.2553	-.7314**
Mg of protein/kernel	F_2	-.6122**	-.3868**	-.5938**	-.4399**
	$F_{3/2}$	-.4654**	-.5889**	-.4818**	-.5308**
Percent lysine of sample	F_2	.2038	.4912**	.5151**	.4752**
	$F_{3/2}$	.4571**	.1963**	.5767**	.3966**
Mg of lysine/kernel	F_2	-.3655*	.1347	-.2788	.0854
	$F_{3/2}$	-.0971	-.0645	-.1247	.0023
Percent oil	F_2	-.2087	.0272	-.3653*	-.5060**
	$F_{3/2}$	-.0218	.0579	-.1132	-.4794**
Mg of oil/kernel	F_2	-.4652**	-.0204	-.5506**	-.5536**
	$F_{3/2}$	-.2207**	-.1347	-.3027*	-.5011**
Catechin equivalent	F_2	.1067	.0850	-.2373	.2012
	$F_{3/2}$	.0425	.2725	.2381	.3097*

* Significant at .05 level
** Significant at .01 level

Table 19. Phenotypic correlations between percent oil and 16 plant, seed and chemical characters in F_2 subpopulations (F_2) and F_3 subpopulations within F_2 subpopulations [$F_{3/2}$] in the fourth generation for segregating grain sorghum populations I, II, III and IV.

		Percent oil			
		I	II	III	IV
Days to flower	F_2	.1134	.0321	-.3250*	-.3268*
	$F_{3/2}$	-.1943	-.1002	-.2572	-.3514*
Plant height	F_2	.1967	-.1326	-.2372	.3320*
	$F_{3/2}$	.3041*	.0911	-.3345*	.0786
Panicles/plot	F_2	-.0262	-.0680	.3762*	.0811
	$F_{3/2}$	.0286	.2094	-.0627	.2979*
Panicle weight	F_2	.2814	.0151	-.0269	.1358
	$F_{3/2}$	.2290	.0406	.2584	-.2026
Kernels/panicle	F_2	.2477	.0256	-.1759	.4532**
	$F_{3/2}$	.3826**	.1222	.0325	-.0290
Grain yield	F_2	.2054	.0006	.2757	.1653
	$F_{3/2}$	.3465*	.2106	.1749	.0507
Kernel weight	F_2	.0472	.0033	.2688	-.3924**
	$F_{3/2}$	-.2724	-.1783	.4752**	-.3319*
Kernel volume	F_2	.0128	-.0545	.1561	-.4366**
	$F_{3/2}$	-.3189	-.1340	.3926**	-.3607*
Kernel density	F_2	.2426	.3255*	.1015	.3686*
	$F_{3/2}$	.3457*	.0149	.3849**	.1904
Percent protein	F_2	.2414	.1778	.0716	.7962**
	$F_{3/2}$	.1075	.0085	.0250	.7879**
Mg of protein/kernel	F_2	.1134	-.0843	.2649	-.0012
	$F_{3/2}$	-.2237	.1120	.3955*	.1226
Percent lysine of protein	F_2	-.2087	.0272	-.3653*	-.5060**
	$F_{3/2}$	-.0218	.0579	-.1132	-.4794**
Percent lysine of sample	F_2	.0820	.2821	-.2472	.2991*
	$F_{3/2}$	.0928	.0283	-.0600	.3767**
Mg of lysine/kernel	F_2	.0546	.1998	.1655	-.2672
	$F_{3/2}$	-.2270	-.1856	.4252**	-.1412
Mg of lysine/kernel	F_2	.0546	.1998	.1655	-.2672
	$F_{3/2}$	-.2270	-.1856	.4252**	-.1412
Mg of oil/kernel	F_2	.5716**	.5745**	.8117**	.4681**
	$F_{3/2}$	.4335**	.5933**	.8601**	.5116**
Catechin equivalent	F_2	.3756*	-.0856	.3006*	.3057*
	$F_{3/2}$	.5307**	.1438	.0345	.0545

* Significant at .05 level
** Significant at .01 level

indicator in selecting percent lysine of protein in all populations. Correlations between days to flower and percent lysine of protein though positive and highly significant are suspected of being spurious. Correlations between percent protein and percent oil in population IV are highly significant. Since the analysis for percent oil is much cheaper than that for percent protein, percent oil could be used as an indicator in selecting percent protein in population IV although this would tend to reduce kernel size.

Phenotypic correlations among kernel characters are mainly positive and significant which suggests that kernel weight and volume could be increased together without any appreciable change in kernel density. At the same time, though, kernel number per panicle would be reduced which would lead to reduced yields.

SUMMARY AND CONCLUSIONS

Four crosses were made using the hot water technique among six parental lines that were considered homozygous and unrelated. From each cross random 45 F_2 plants were selected and these were advanced to the third generation in Puerto Rico. From each F_3 progeny row, two random plants were selected and selfed. All the 360 F_3 selections from the four crosses were evaluated in the fourth generation in one replication and two locations. The segregating progenies from each cross are referred to as a population.

The characters on which data were recorded as a single observation for a plot were days to flower, plant height, panicles per plot, grain yield (kg/ha), kernel weight and volume, percent protein, percent lysine of protein, percent oil and catechin equivalent values. All other characters were appropriately computed. Percent heterosis over midparent for kernel weight and volume was negative in all populations but the percent heterosis over midparent for other characters were variable from population to population.

Transgressive segregation occurred in both directions in most populations for most characters except kernel weight and volume where transgressive segregation occurred only towards the lower kernel weight and volume except in population II where no transgressive segregation was indicated. Each population exhibited a wide range of variation for most characters in the fourth generation.

The analysis of variance indicated significant differences among the F_2 subpopulations and F_3 subpopulations within F_2 subpopulations in all populations for several characters but for some other characters significance was indicated for F_2 subpopulations only or F_3 subpopulations within F_2 subpopulations. In most populations there were no significant differences for either F_2 subpopulations or F_3 subpopulations within F_2 subpopulations for grain yield, kernel density and percent lysine of sample.

The results suggest significant heterozygosity in the F_2 subpopulations in the fourth generation for kernel weight and volume, percent protein and percent oil. For these characters selection both within and among F_2 families in early generations would be most effective.

Estimates of dominance genetic variances in all populations for all the seed and chemical characters were always larger than those for additive genetic variances. This clearly indicates that, while additive gene action is present in the inheritance of the seed and chemical characters, dominance gene action appeared to be the most important in these populations.

Heritability estimates for each character were variable from population to population, and the heritabilities among the F_2 and F_3 subpopulations in the fourth generation for each character in a population were equally variable.

Estimates of heritability and genetic progress expected under selection for the chemical and seed characters were not very high but they do give sufficient evidence that substantial improvement can be made particularly for kernel weight and volume in most populations, percent protein in population III, percent lysine of protein

in population III and percent oil in populations III and IV.

Phenotypic correlations of grain yield with panicles per plot, panicle weight and kernels per panicle were positive and significant in all populations but the correlations between grain yield and kernel weight or kernel volume were nonsignificant in most cases. This implies that panicles per plot, panicle weight and kernels per panicle are the only components of yield.

Kernel weight and kernel volume were highly positively associated in all populations but the associations of kernel weight or volume with days to flower, plant height, kernels per panicle and percent lysine of protein were negative and significant in most populations. The phenotypic correlations between kernel weight and percent oil were negative and significant in population IV and this might be a barrier to simultaneous selection for large kernels and high percent oil in this population.

In population IV, percent protein and percent oil were positive, significantly correlated but percent protein and percent lysine of protein were negative, significantly correlated in all populations.

In this study no consistent and favourable correlations of chemical traits with any plant or seed characters were found in all populations. However, kernel weight or volume could be used as a good indicator in selecting percent protein in population I and percent oil in population III while percent oil could be used as a good indicator in selecting percent protein in population IV.

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APPENDIX

APPENDIX TABLE 1. MEANS OF ALL CHARACTERS OVER TWO LOCATIONS FOR ALL ENTRIES IN POPULATION 1.+

F2(4)	F3(4)	D.FL PROT.	HT. P/K	P/FL LYS.	P/WT LYS.S	K/P LYS/K	G.Y. OIL	K.WT. OIL/K	K.V. C.EQ.	K.D.
1	1	93	300	30.0	41.1	1250	5296	3.30	2.55	1.30
		11.65	3.85	2.14	.249	.082	3.29	1.09	.765	
	2	95	240	27.5	37.9	989	4500	3.84	3.15	1.22
		12.95	4.98	1.95	.251	.096	2.83	1.09	.380	
2	3	96	265	32.5	25.8	793	3381	3.26	2.60	1.25
		12.20	3.97	2.09	.255	.083	3.25	1.06	.440	
	4	95	275	25.0	40.9	1196	4353	3.52	2.88	1.23
		12.35	4.38	2.11	.261	.093	3.79	1.35	1.850	
3	5	93	292	45.5	29.7	716	5808	4.15	3.33	1.25
		13.10	5.44	2.02	.264	.110	3.31	1.38	1.210	
	6	91	275	28.5	36.3	907	4457	4.05	3.05	1.33
		12.80	5.22	1.93	.246	.100	3.16	1.27	.390	
4	7	89	290	44.0	30.0	1100	4625	2.80	2.13	1.32
		14.05	3.93	2.00	.280	.078	5.00	1.41	4.350	
	8	85	125	44.0	23.3	554	4373	4.26	3.45	1.23
		13.15	5.62	1.99	.261	.111	3.20	1.36	.695	
5	9	86	263	32.5	31.2	836	4304	3.77	2.95	1.28
		11.90	4.48	2.28	.271	.102	3.73	1.41	.470	
	10	99	288	27.5	21.9	685	2701	3.20	2.45	1.31
		12.50	4.00	2.06	.257	.082	3.24	1.04	.355	
6	11	81	247	30.5	37.2	850	4769	4.38	3.35	1.31
		12.15	5.33	2.01	.244	.107	3.16	1.39	.640	
	12	83	182	35.5	30.1	584	4211	5.20	4.20	1.24
		14.45	7.52	1.80	.261	.135	3.19	1.66	1.480	
7	13	94	163	33.5	23.4	556	3359	4.20	3.33	1.26
		13.15	5.53	2.09	.275	.116	3.32	1.40	.675	
	14	93	177	32.5	19.6	453	2799	4.30	3.40	1.27
		14.70	6.31	1.74	.253	.109	3.39	1.46	.820	
8	15	89	120	35.0	28.3	639	4740	4.51	3.60	1.25
		12.80	5.78	1.98	.254	.115	3.46	1.56	.610	
	16	95	313	37.0	19.2	712	2993	2.76	2.10	1.32
		13.15	3.64	1.99	.262	.073	4.02	1.12	2.665	

+See page 98 for identification of column headings and any other abbreviations.

APPENDIX TABLE 1 (CONTINUED).

F2(4)	F3(4)	D.FL PROT.	HT. P/K	P/FL LYS.	F/HT LYS.S	K/F LYS/K	G.Y. OIL	K.HT. OIL/K	K.V. C.EQ.	K.D.
9	17	93	272	36.5	31.5	737	4816	4.27	3.35	1.27
		12.50	5.33	2.17	.271	.116	3.38	1.45	.385	
	18	92	160	31.5	24.7	580	3337	4.26	3.45	1.23
		12.80	5.45	2.07	.265	.113	3.13	1.34	.350	
10	19	88	255	29.0	38.5	844	4807	4.56	3.55	1.29
		12.85	5.88	1.91	.244	.111	3.50	1.60	.775	
	20	89	250	33.5	45.8	1227	6434	3.82	3.10	1.24
		12.55	4.82	2.09	.262	.101	4.36	1.67	1.290	
11	21	95	238	35.0	33.8	1038	5141	3.25	2.55	1.28
		12.35	4.02	1.89	.234	.076	3.39	1.10	1.185	
	22	86	167	37.5	29.0	652	4775	4.45	3.55	1.25
		13.60	6.05	2.00	.273	.120	3.22	1.44	.310	
12	23	99	288	43.0	23.1	1104	4274	2.09	1.63	1.29
		12.35	2.80	2.05	.253	.053	3.21	.67	2.570	
	24	90	250	30.0	46.8	1148	6008	4.15	3.25	1.28
		12.25	5.13	1.97	.239	.099	3.34	1.38	.455	
13	25	95	307	28.0	40.6	1018	4891	3.98	3.05	1.31
		13.00	5.18	1.91	.248	.099	3.06	1.23	.330	
	26	88	260	41.0	37.3	907	6613	4.11	3.15	1.30
		11.65	4.56	2.23	.246	.101	3.81	1.57	1.445	
14	27	88	270	21.0	46.2	1318	4353	3.70	2.90	1.27
		12.55	4.67	2.03	.254	.094	3.92	1.45	2.065	
	28	90	230	34.0	32.3	761	4876	4.24	3.25	1.31
		13.80	5.85	1.77	.244	.103	3.58	1.52	.475	
15	29	86	265	40.0	27.3	681	4977	4.01	3.05	1.31
		12.30	4.88	2.07	.254	.102	3.42	1.38	.615	
	30	100	265	47.0	26.3	795	5589	3.27	2.50	1.31
		13.00	4.24	2.01	.261	.085	3.33	1.10	.185	
16	31	86	265	35.5	42.2	965	6445	4.37	3.40	1.29
		13.05	5.70	1.92	.250	.110	4.50	1.96	1.140	
	32	83	132	36.0	22.4	466	3464	4.83	3.70	1.30
		14.75	7.16	1.74	.255	.123	3.66	1.77	.470	

APPENDIX TABLE 1 (CONTINUED).

F2(4)	F3(4)	D.FL PROT.	HT. P/K	P/PL LYS.	P/WT LYS.S	K/P LYS/K	G.Y. OIL	K.WT. OIL/K	K.V. C.EC.	K.D.
17	33	98	307	28.0	28.5	773	3387	3.75	2.80	1.34
		13.70	5.13	1.81	.248	.093	3.75	1.41	.100	
	34	102	297	26.0	32.6	827	3714	3.89	3.08	1.26
		14.80	5.75	1.96	.290	.113	3.62	1.40	1.085	
18	35	90	245	30.0	44.2	1175	5922	3.74	2.88	1.30
		12.85	4.84	1.95	.248	.093	3.32	1.24	.170	
	36	90	267	32.0	37.5	944	5169	3.97	3.10	1.28
		12.25	4.87	2.01	.246	.096	3.37	1.34	.270	
19	37	100	315	30.0	35.9	1119	4629	3.22	2.45	1.31
		11.90	3.84	2.17	.255	.082	3.43	1.10	.095	
	38	104	305	28.5	29.9	1019	3658	2.97	2.27	1.30
		12.30	3.66	2.10	.256	.075	3.17	.95	.115	
20	39	91	197	26.5	38.2	852	4450	4.47	3.50	1.27
		12.55	5.65	2.02	.253	.113	3.55	1.59	.175	
	40	90	192	31.0	35.6	783	4794	4.60	3.60	1.28
		12.50	5.75	2.00	.250	.115	3.50	1.61	.300	
21	41	86	167	35.5	43.7	1004	6886	4.40	3.40	1.29
		11.60	5.11	2.10	.243	.107	2.94	1.30	.215	
	42	90	277	34.0	30.1	592	4429	5.03	3.65	1.38
		12.60	6.34	2.14	.269	.135	3.49	1.77	1.180	
22	43	89	235	23.5	39.7	870	4028	4.57	3.50	1.31
		13.60	6.23	1.92	.261	.119	3.88	1.78	.215	
	44	86	240	30.5	43.7	958	5732	4.56	3.45	1.32
		13.70	6.25	1.90	.259	.118	3.57	1.63	.205	
23	45	96	200	32.0	39.0	917	5380	4.24	3.40	1.25
		13.35	5.67	2.03	.270	.114	3.10	1.31	.225	
	46	93	185	29.5	30.5	645	3919	4.73	3.75	1.26
		14.40	6.81	1.94	.279	.132	3.07	1.45	.210	
24	47	85	197	25.0	46.6	1351	5012	3.45	2.55	1.35
		11.45	3.95	1.96	.224	.077	3.55	1.23	.435	
	48	89	297	30.0	38.4	962	47.3	3.97	3.00	1.32
		13.55	5.38	1.76	.239	.095	3.61	1.52	.150	

APPENDIX TABLE 1 (CONTINUED).

F2(4)	F3(4)	D.FL PROT.	HT. P/K	P/PL LYS.	P/HT LYS.S	K/P LYS/K	G.Y. CIL	K.HT. CIL/K	K.V. C.EC.	K.D.
25	49	80	247	47.5	36.3	917	7478	3.98	3.00	1.33
		13.35	5.31	1.80	.240	.096	4.52	1.80	.880	
	50	88	245	42.0	26.0	539	4691	4.82	3.75	1.29
		12.85	6.19	2.02	.261	.125	3.26	1.58	1.545	
26	51	86	185	31.0	38.0	822	5109	4.64	3.55	1.31
		12.45	5.78	2.00	.248	.115	3.43	1.59	.345	
	52	86	250	33.0	37.1	848	5244	4.38	3.30	1.33
		12.70	5.57	1.98	.251	.110	3.59	1.58	.960	
27	53	86	215	34.0	27.8	786	4067	3.55	2.70	1.31
		13.15	4.66	1.83	.240	.085	3.22	1.14	1.265	
	54	85	190	34.0	23.7	633	3340	3.74	2.88	1.30
		11.75	4.40	2.00	.236	.088	3.19	1.19	.680	
28	55	90	217	26.5	32.5	739	3712	4.40	3.38	1.30
		12.85	5.64	1.88	.242	.106	3.67	1.62	.345	
	56	94	188	31.0	43.5	959	5789	4.53	3.47	1.30
		12.10	5.49	1.95	.236	.107	3.60	1.63	.145	
29	57	91	307	25.0	42.2	1087	4530	3.90	3.10	1.26
		12.55	4.90	2.06	.259	.101	3.36	1.31	1.780	
	58	86	255	32.0	38.9	950	5208	4.13	3.15	1.31
		12.40	5.13	2.05	.253	.105	3.71	1.52	3.115	
30	59	88	295	28.5	50.4	1297	6206	3.92	3.10	1.26
		12.10	4.74	2.11	.255	.100	3.77	1.47	2.020	
	60	90	202	46.0	35.9	1350	7117	3.41	2.65	1.29
		10.40	3.55	2.24	.233	.080	3.73	1.27	.320	
31	61	90	260	32.0	37.3	951	4222	4.52	3.55	1.27
		13.85	6.30	1.88	.259	.115	3.43	1.56	.765	
	62	84	270	32.0	25.2	533	3239	4.81	3.70	1.30
		14.50	7.00	1.81	.262	.126	3.82	1.84	.325	
32	63	91	270	28.0	50.1	1270	6038	3.90	3.10	1.26
		13.15	5.13	1.95	.256	.099	3.82	1.50	1.310	
	64	98	300	30.0	35.7	969	4611	3.70	2.90	1.28
		12.85	4.76	2.00	.256	.094	3.67	1.36	.230	

APPENDIX TABLE 1 (CONTINUED).

F2(4)	F3(4)	D.FL PROT.	HT. P/K	P/FL LYS.	P/HT LYS.S	K/P LYS/K	G.Y. OIL	K.HT. OIL/K	K.V. C.EQ.	K.D.
33	65	109	315	19.0	21.3	690	1754	3.13	2.50	1.25
		12.15	3.83	1.99	.242	.077	3.22	1.00	2.490	
	66	107	320	25.5	29.9	1093	3267	2.74	2.20	1.24
		13.35	3.66	2.05	.274	.075	3.40	.93	.370	
34	67	85	125	44.0	22.8	.558	4280	4.10	3.35	1.23
		13.55	5.56	1.85	.251	.103	2.66	1.09	.475	
	68	85	163	42.5	21.3	567	3895	3.80	3.20	1.19
		13.70	5.22	1.88	.257	.098	2.77	1.05	.360	
35	69	81	213	33.5	30.2	842	4347	3.58	2.70	1.33
		12.95	4.63	1.96	.254	.091	3.42	1.22	.475	
	70	89	190	34.0	25.5	498	3764	5.13	4.00	1.28
		12.70	6.53	2.08	.263	.135	3.53	1.81	.405	
36	71	81	247	34.5	25.7	577	3630	4.58	3.67	1.24
		13.25	6.09	1.85	.245	.112	3.35	1.54	.465	
	72	84	177	43.5	19.1	486	3587	4.58	3.55	1.29
		13.65	6.26	1.93	.263	.120	3.42	1.56	.235	
37	73	90	297	22.0	64.6	1640	6019	3.98	3.15	1.27
		11.80	4.69	1.98	.233	.093	3.39	1.34	.360	
	74	84	265	20.0	55.0	1756	4708	3.13	2.45	1.28
		13.15	4.13	1.87	.246	.077	4.41	1.38	2.950	
38	75	99	300	27.0	34.6	1118	4099	3.08	2.45	1.26
		11.65	3.59	2.35	.275	.084	3.16	.99	1.515	
	76	87	227	33.0	40.1	942	5673	4.29	3.38	1.27
		13.65	5.88	1.91	.260	.112	3.86	1.66	.745	
39	77	90	313	32.5	30.6	736	4398	4.17	3.25	1.28
		13.10	5.47	2.10	.275	.114	3.25	1.36	.660	
	78	91	210	38.5	39.8	984	6598	4.06	3.10	1.31
		12.60	5.12	2.03	.255	.104	3.91	1.59	.565	
40	79	85	190	34.0	44.1	874	6385	5.05	3.80	1.33
		12.55	6.35	1.78	.223	.113	3.10	1.55	.280	
	80	86	292	40.5	37.8	922	6589	4.12	3.20	1.29
		12.30	5.07	1.99	.245	.102	3.28	1.34	.940	

APPENDIX TABLE 1 (CONTINUED).

F2(4)	F3(4)	D.FL PROT.	HT. P/K	P/PL LYS.	P/HT LYS.S	K/P LYS/K	G.Y. CIL	K.HT. CIL/K	K.V. C.EC.	K.D.
41	81	88	220	29.5	40.0	1107	5061	3.68	2.92	1.26
		13.45	4.97	1.84	.248	.091	3.37	1.24	1.985	
	82	102	325	27.5	30.7	1089	3731	2.80	2.15	1.30
		12.10	3.38	2.28	.276	.077	3.19	.90	.160	
42	83	98	277	26.5	32.0	1058	3617	3.04	2.45	1.24
		10.90	3.32	2.39	.259	.079	2.90	.88	1.400	
	84	108	275	26.5	21.4	716	2524	2.96	2.35	1.26
		11.05	3.27	2.17	.240	.071	3.34	.99	1.565	
43	85	82	205	31.0	36.9	940	4172	3.95	3.00	1.32
		12.00	4.74	2.07	.249	.098	3.11	1.23	.685	
	86	81	227	25.0	37.2	1016	4003	3.89	3.20	1.22
		11.60	4.52	2.05	.237	.093	2.62	1.02	.550	
44	87	98	270	43.5	28.2	746	5328	3.84	2.90	1.33
		12.10	4.64	2.08	.251	.096	3.52	1.34	.380	
	88	102	295	30.5	24.8	809	3262	3.08	2.52	1.22
		12.80	3.96	2.06	.264	.082	3.18	.98	.110	
45	89	99	230	31.5	34.4	1168	4670	2.98	2.35	1.27
		12.80	3.82	1.98	.254	.076	3.32	1.00	.125	
	90	96	288	37.5	39.2	1206	6473	3.27	2.57	1.26
		12.90	4.19	1.97	.254	.082	3.42	1.13	.175	
IS 3941		85	197	31.4	29.6	650	3949	4.58	3.55	1.29
		14.57	6.67	1.97	.287	.132	4.21	1.93	.280	
954 086		86	229	32.2	31.7	611	4290	5.24	4.12	1.27
		14.10	7.41	1.85	.260	.136	3.40	1.78	.659	
NK 300		84	204	42.1	44.6	1894	7967	2.40	1.80	1.33
		10.59	2.24	2.01	.212	.092	3.37	.81	3.355	

APPENDIX TABLE 2. MEANS OF ALL CHARACTERS OVER TWO LOCATIONS FOR ALL ENTRIES IN POPULATION 2.+

F2(4)	F3(4)	D.FL PROT.	HT. P/K	P/PL LYS.	P/WT LYS.S	K/P LYS/K	G.Y. OIL	K.WT. OIL/K	K.V. C.EQ.	K.D.
1	1	88	235	27.5	24.2	621	2763	3.90	2.95	1.32
		13.40	5.24	1.86	.247	.096	3.96	1.54	.575	
	2	86	190	43.0	20.9	576	4205	3.63	2.75	1.32
		15.10	5.48	1.71	.258	.094	4.12	1.50	.620	
2	3	84	235	29.0	40.3	1198	5068	3.37	2.50	1.35
		13.95	4.70	1.67	.233	.079	3.70	1.25	.600	
	4	86	245	45.0	36.6	1101	7127	3.36	2.42	1.39
		13.65	4.64	1.72	.232	.079	3.66	1.23	.485	
3	5	85	222	40.0	28.0	958	4752	3.00	2.22	1.35
		11.85	3.62	1.82	.212	.064	3.49	1.05	.285	
	6	88	225	30.0	30.3	835	3940	3.67	2.79	1.34
		14.85	5.45	1.60	.238	.088	3.92	1.45	.115	
4	7	89	210	36.0	40.0	1607	6253	2.50	1.85	1.35
		11.50	2.88	2.03	.233	.058	3.92	.98	.445	
	8	84	232	46.0	32.0	1088	6339	2.96	2.20	1.34
		14.45	4.28	1.82	.263	.078	4.25	1.25	.260	
5	9	81	220	41.5	38.2	1497	6916	2.59	1.92	1.35
		11.65	3.04	1.93	.223	.058	3.66	.95	.745	
	10	84	220	38.0	27.4	779	4476	3.51	2.70	1.30
		15.80	5.55	1.53	.242	.085	3.48	1.22	.855	
6	11	84	213	34.5	28.1	913	4334	3.09	2.45	1.26
		15.35	4.75	1.66	.255	.079	3.05	.95	1.465	
	12	88	210	37.0	44.1	1724	6215	2.55	1.90	1.34
		13.45	3.43	1.76	.231	.059	3.48	.89	1.330	
7	13	83	152	41.0	31.9	1093	5625	2.94	2.22	1.32
		14.20	4.17	1.58	.224	.066	3.61	1.06	.180	
	14	80	177	46.0	27.6	948	5481	2.92	2.20	1.33
		13.95	4.08	1.80	.252	.074	3.44	1.00	1.245	
8	15	85	255	30.5	38.1	1124	4629	3.42	2.53	1.36
		13.95	4.78	1.72	.240	.082	4.03	1.38	.990	
	16	85	230	48.5	31.9	998	6662	3.22	2.42	1.33
		13.40	4.34	1.91	.255	.082	4.19	1.35	.885	

+See page 98 for identification of column headings and any other abbreviations.

APPENDIX TABLE 2 (CONTINUED).

F2(4)	F3(4)	D.FL PROT.	HT. P/K	P/FL LYS.	F/WT LYS.S	K/P LYS/K	G.Y. OIL	K.WT. OIL/K	K.V. C.EC.	K.D.
9	17	91	265	24.0	29.6	954	3034	3.14	2.45	1.28
		14.70	4.63	1.75	.256	.080	3.47	1.09	.070	
	18	89	245	40.5	31.7	889	5502	3.68	2.82	1.30
		14.35	5.32	1.69	.243	.090	3.91	1.44	.485	
10	19	85	250	33.5	25.3	871	3837	2.93	2.20	1.33
		13.65	4.01	1.66	.227	.067	3.80	1.12	.735	
	20	81	245	48.5	12.9	363	2709	3.61	2.65	1.36
		15.10	5.45	1.57	.237	.085	3.79	1.37	1.005	
11	21	86	205	33.0	36.4	948	4986	3.88	3.03	1.28
		14.15	5.50	1.68	.237	.092	3.63	1.41	.510	
	22	86	190	34.5	42.0	1167	6264	3.63	2.85	1.27
		14.55	5.27	1.68	.245	.089	3.23	1.17	.480	
12	23	83	200	40.5	31.4	918	5468	3.41	2.60	1.31
		15.80	5.39	1.68	.266	.091	4.06	1.39	.505	
	24	89	277	37.5	34.9	1602	5061	2.29	1.67	1.36
		13.45	3.11	1.91	.255	.059	4.50	1.03	.115	
13	25	89	222	43.0	35.5	996	6492	3.61	2.80	1.29
		13.40	4.88	1.97	.262	.095	4.26	1.54	1.725	
	26	81	142	48.0	18.4	582	3781	3.17	2.50	1.27
		15.70	4.98	1.70	.267	.085	3.71	1.18	.830	
14	27	84	238	40.0	30.3	781	5051	3.90	2.95	1.32
		12.25	4.78	1.91	.234	.091	2.82	1.10	.320	
	28	80	225	45.5	22.7	727	4424	3.13	2.35	1.33
		14.40	4.49	1.78	.254	.079	3.80	1.19	.625	
15	29	88	242	23.0	19.1	674	2251	3.31	2.52	1.31
		14.25	4.77	1.83	.260	.086	3.74	1.24	.845	
	30	79	290	48.5	19.0	641	3988	2.95	2.22	1.33
		13.95	4.12	1.72	.239	.071	3.73	1.10	.860	
16	31	100	320	29.0	39.2	1267	4967	3.09	2.40	1.29
		11.25	3.48	2.09	.234	.072	3.64	1.13	.355	
	32	102	300	25.5	27.6	899	3092	3.06	2.45	1.25
		13.70	4.22	2.14	.291	.088	3.48	1.09	.430	

APPENDIX TABLE 2 (CONTINUED).

F2(4)	F3(4)	D.FL. PROT.	HT. P/K	P/PL LYS.	P/WT LYS.S	K/P LYS/K	G.Y. OIL	K.WT. OIL/K	K.V. C.EQ.	K.D.
17	33	86	238	31.0	32.4	1007	4188	3.19	2.50	1.28
		13.10	4.17	1.63	.213	.068	3.33	1.06	.170	
	34	88	290	34.5	42.4	1382	6318	3.07	2.38	1.29
		14.20	4.36	1.59	.226	.070	3.70	1.14	.210	
18	35	86	240	37.0	24.8	726	4005	3.45	2.60	1.33
		13.90	4.80	1.91	.264	.091	3.47	1.20	.180	
	36	86	242	44.0	25.1	710	4674	3.58	2.67	1.34
		15.70	5.63	1.67	.262	.094	4.00	1.44	.090	
19	37	90	305	31.0	38.5	1118	5160	3.44	2.65	1.30
		12.55	4.31	1.88	.236	.081	3.52	1.21	.160	
	38	96	290	34.5	42.0	1375	6238	3.08	2.53	1.22
		13.20	4.09	1.95	.258	.080	3.70	1.14	.315	
20	39	108	330	21.0	33.5	1032	3039	3.24	2.60	1.25
		12.10	3.92	2.17	.264	.085	3.19	1.04	.150	
	40	85	295	37.5	35.7	1207	5433	2.99	2.30	1.30
		13.35	4.00	1.60	.213	.064	3.78	1.13	.260	
21	41	90	282	44.0	31.3	763	4971	3.45	2.63	1.31
		14.60	5.05	1.60	.233	.081	4.19	1.45	.095	
	42	88	200	34.5	34.2	1198	5033	2.85	2.20	1.30
		12.35	3.52	1.88	.231	.066	3.70	1.06	1.450	
22	43	80	177	44.0	21.6	673	3772	3.26	2.55	1.28
		16.05	5.24	1.59	.255	.083	3.71	1.21	.115	
	44	84	182	41.0	29.9	817	5309	3.70	2.88	1.29
		13.45	5.00	1.74	.231	.086	3.69	1.37	.630	
23	45	87	280	26.0	48.2	1564	5399	3.10	2.35	1.32
		14.60	4.54	1.62	.236	.073	3.75	1.17	.040	
	46	84	272	39.5	38.6	1240	6557	3.11	2.30	1.35
		14.70	4.59	1.54	.226	.071	3.90	1.22	.095	
24	47	90	265	26.5	43.1	1035	4917	4.18	3.25	1.29
		12.85	5.39	1.80	.232	.097	3.16	1.33	.480	
	48	97	305	37.5	26.5	734	4203	3.60	2.80	1.28
		13.25	4.79	1.88	.249	.090	3.98	1.44	.265	

APPENDIX TABLE 2 (CONTINUED).

F2(4)	F3(4)	D.FL PROT.	HT. P/K	P/FL LYS.	P/WT LYS.S	K/F LYS/K	G.Y. OIL	K.WT. OIL/K	K.V. C.EQ.	K.D.
25	49	83	295	38.0	39.2	1228	6241	3.17	2.45	1.29
		14.05	4.47	1.62	.227	.072	4.10	1.30	.435	
	50	96	300	34.5	42.4	1397	6292	3.12	2.45	1.27
		12.25	3.83	2.00	.245	.075	2.93	.94	.400	
26	51	86	255	37.5	34.7	1094	5569	3.17	2.42	1.31
		14.15	4.48	1.52	.214	.068	3.55	1.13	.185	
	52	89	210	36.0	30.2	1084	4667	2.80	2.15	1.30
		14.40	4.03	1.69	.242	.068	3.64	1.02	.195	
27	53	85	280	34.5	37.3	1096	5670	3.44	2.65	1.30
		14.75	5.08	1.50	.221	.076	3.85	1.33	.080	
	54	86	280	31.0	42.2	1265	5756	3.31	2.50	1.33
		14.30	4.74	1.44	.205	.068	3.38	1.13	.030	
28	55	79	245	62.5	18.0	674	4868	2.68	2.05	1.31
		12.35	3.31	1.98	.244	.066	3.97	1.07	.080	
	56	85	190	45.5	32.4	1140	6511	2.87	2.20	1.30
		12.55	3.61	1.84	.231	.066	3.63	1.04	.335	
29	57	86	232	33.0	32.3	1034	4450	3.17	2.45	1.29
		14.70	4.66	1.65	.243	.077	4.11	1.31	1.975	
	58	85	255	46.5	22.2	590	4080	3.74	2.80	1.34
		16.45	6.16	1.60	.263	.098	3.40	1.27	.215	
30	59	91	295	41.0	43.9	1589	7688	2.77	2.10	1.32
		10.80	3.01	2.19	.234	.065	3.44	.96	1.510	
	60	89	305	37.0	33.8	1136	5375	3.00	2.30	1.30
		13.20	3.99	1.76	.231	.068	3.09	.95	.215	
31	61	83	210	50.5	20.6	521	4216	3.98	3.10	1.28
		14.10	5.62	1.75	.247	.098	3.50	1.39	.935	
	62	89	215	51.5	7.5	248	1648	3.52	2.75	1.28
		14.90	5.24	1.79	.267	.094	3.22	1.13	.260	
32	63	97	267	42.5	22.5	727	4149	3.13	2.35	1.33
		14.65	4.58	1.76	.257	.080	4.22	1.32	.305	
	64	91	230	32.0	35.3	1218	4645	2.99	2.35	1.27
		13.80	4.14	1.72	.236	.070	4.08	1.23	.410	

APPENDIX TABLE 2 (CONTINUED).

F2(4)	F3(4)	D.FL PROT.	HT. P/K	P/FL LYS.	P/WT LYS.S	K/P LYS/K	G.Y. OIL	K.WT. OIL/K	K.V. C.EQ.	K.D.
33	65	85	247	55.5	21.9	637	5367	3.45	2.60	1.33
		15.45	5.33	1.59	.246	.085	3.84	1.32	.635	
	66	88	280	38.0	35.5	1102	5761	3.25	2.55	1.28
		14.85	4.84	1.78	.264	.085	4.23	1.38	.465	
34	67	87	250	49.0	18.0	480	3703	3.74	2.88	1.30
		14.05	5.25	1.82	.257	.096	3.75	1.40	.660	
	68	86	242	39.5	28.7	939	4723	3.11	2.40	1.29
		13.30	4.16	1.71	.226	.070	3.32	1.03	1.080	
35	69	84	165	40.0	29.9	747	5197	3.99	3.00	1.33
		13.15	5.24	1.88	.247	.099	4.06	1.61	.540	
	70	86	200	44.0	27.3	585	5010	4.67	3.63	1.29
		12.75	5.95	2.03	.258	.121	4.22	1.73	1.380	
36	71	79	157	52.5	21.3	678	4848	3.16	2.30	1.37
		14.55	4.59	1.80	.262	.083	3.15	1.00	.920	
	72	83	190	36.5	31.6	1028	4676	3.12	2.40	1.30
		10.90	3.33	2.50	.249	.078	4.13	1.29	.755	
37	73	85	172	36.5	27.4	909	4250	3.05	2.30	1.33
		13.35	4.09	1.71	.226	.069	3.66	1.12	.305	
	74	86	202	45.5	26.4	776	5341	3.44	2.60	1.32
		13.70	4.73	1.81	.247	.085	3.80	1.30	1.205	
38	75	87	245	35.5	29.4	793	4476	3.84	2.90	1.32
		13.90	5.35	1.72	.239	.092	3.89	1.50	.700	
	76	86	232	33.5	31.5	852	4433	3.85	2.90	1.32
		12.70	4.93	1.99	.251	.097	4.34	1.68	.415	
39	77	80	232	43.0	21.8	721	4065	3.02	2.35	1.29
		14.95	4.52	1.53	.229	.069	3.52	1.06	.400	
	78	87	217	42.5	32.9	1071	6000	3.06	2.30	1.33
		11.90	3.65	1.95	.231	.071	3.90	1.20	3.470	
40	79	80	177	30.0	33.2	1041	4297	3.20	2.50	1.28
		15.55	4.98	1.69	.262	.084	3.80	1.21	.400	
	80	85	245	28.5	38.3	1231	4454	3.19	2.40	1.33
		15.40	4.94	1.67	.254	.081	3.77	1.20	.765	

APPENDIX TABLE 2 (CONTINUED).

F2(4)	F3(4)	D.FL PROT.	HT. P/K	P/PL LYS.	P/WT LYS.S	K/P LYS/K	G.Y. OIL	K.WT. OIL/K	K.V. C.EC.	K.D.
41	81	83	177	43.5	28.7	772	5350	3.71	2.95	1.26
		13.95	5.19	1.53	.212	.079	3.59	1.34	2.145	
	82	83	240	54.0	25.6	724	5986	3.53	2.70	1.31
		12.55	4.43	1.84	.231	.081	3.51	1.24	.625	
42	83	93	220	37.0	33.2	1266	5281	2.63	1.95	1.35
		14.20	3.74	1.71	.244	.064	4.36	1.14	.285	
	84	87	282	36.0	29.1	839	4368	3.47	2.60	1.33
		14.50	5.03	1.64	.238	.133	3.72	1.29	.425	
43	85	86	270	53.0	18.0	523	3703	3.47	2.75	1.26
		15.30	5.31	1.71	.262	.091	3.87	1.34	.150	
	86	93	335	36.5	29.8	877	4652	3.47	2.65	1.31
		13.45	4.69	1.77	.238	.083	3.01	1.05	.385	
44	87	84	245	36.0	45.7	1256	7009	3.67	2.77	1.32
		13.00	4.78	1.77	.230	.085	3.42	1.25	.500	
	88	89	275	45.5	29.5	945	5690	3.13	2.40	1.31
		15.70	4.93	1.75	.274	.086	3.49	1.09	.400	
45	89	85	157	38.5	35.7	1022	5980	3.49	2.67	1.31
		15.15	5.29	1.91	.290	.101	4.00	1.40	1.505	
	90	89	215	35.0	31.2	998	4338	3.25	2.52	1.29
		15.15	4.98	1.73	.260	.085	4.13	1.34	1.140	
IS 0470		75	180	62.0	14.7	665	3775	2.22	1.69	1.32
		15.90	3.53	1.54	.245	.055	3.54	.79	.157	
954 086		87	212	38.4	28.2	549	4599	5.20	4.11	1.27
		14.02	7.31	1.80	.252	.121	3.28	1.71	.767	
NK 300		83	198	39.1	46.3	1947	7619	2.40	1.85	1.29
		10.37	2.51	2.05	.211	.051	3.32	.80	3.805	

APPENDIX TABLE 3. MEANS OF ALL CHARACTERS OVER TWO LOCATIONS FOR ALL ENTRIES IN POPULATION 3.+

F2(4)	F3(4)	D.FL PROT.	HT. P/K	P/PL LYS.	F/WT LYS.S	K/F LYS/K	G.Y. OIL	K.WT. OIL/K	K.V. O.EQ.	K.D.
1	1	84	217	36.0	16.6	353	2517	4.71	3.60	1.31
		13.80	6.49	1.85	.255	.120	4.73	2.22	1.010	
	2	101	305	33.5	35.5	1155	5076	3.10	2.40	1.29
		12.60	3.91	1.95	.245	.076	3.52	1.09	.645	
2	3	83	225	46.0	35.8	860	7093	4.22	3.25	1.30
		12.75	5.38	2.03	.259	.109	4.87	2.05	.735	
	4	81	207	37.0	35.1	780	5614	4.51	3.45	1.31
		13.25	5.98	1.85	.245	.110	4.55	2.06	.895	
3	5	100	290	24.0	35.4	813	3863	4.20	3.45	1.22
		12.05	5.07	2.24	.265	.111	3.22	1.36	.530	
	6	109	338	33.5	31.7	941	4842	3.28	2.67	1.23
		12.75	4.20	2.38	.302	.098	2.87	.95	.320	
4	7	93	313	29.5	32.9	978	4140	3.36	2.57	1.30
		12.25	4.11	1.99	.244	.082	3.72	1.25	.460	
	8	79	232	27.0	31.7	706	3684	4.48	3.60	1.25
		12.95	5.81	1.89	.245	.110	3.36	1.50	1.280	
5	9	88	242	33.5	35.8	832	5171	4.35	3.50	1.24
		12.25	5.33	1.94	.238	.104	3.47	1.52	1.025	
	10	80	255	40.5	31.0	714	5369	4.43	3.42	1.29
		11.15	4.97	2.08	.231	.102	4.45	1.98	2.520	
6	11	108	290	29.0	13.7	443	1702	3.15	2.50	1.26
		15.35	4.85	2.05	.313	.098	3.46	1.10	.250	
	12	108	307	29.0	21.8	687	2582	3.02	2.45	1.23
		14.30	4.32	1.91	.257	.082	3.36	1.02	.150	
7	13	101	295	23.5	32.7	840	3293	3.86	3.05	1.27
		13.55	5.24	1.87	.253	.097	3.33	1.29	.475	
	14	104	295	30.0	23.6	643	3041	3.73	2.90	1.28
		13.55	5.09	2.15	.291	.108	3.52	1.30	.300	
8	15	103	313	28.0	33.5	1018	4396	3.18	2.50	1.27
		11.95	3.78	2.05	.245	.077	2.94	.95	.275	
	16	90	227	31.0	46.6	1138	6047	4.13	3.17	1.30
		11.45	4.73	2.19	.250	.103	3.68	1.52	.890	

+See page 98 for identification of column headings and any other abbreviations.

APPENDIX TABLE 3 (CONTINUED).

F2(4)	F3(4)	D.FL PROT.	HT. P/K	P/FL LYS.	P/WT LYS.S	K/F LYS/K	G.Y. OIL	K.WT. OIL/K	K.V. C.EQ.	K.D
9	17	88	207	31.0	37.3	834	4982	4.47	3.47	1.2
		12.00	5.37	1.97	.236	.106	3.31	1.48	.775	
	18	90	197	29.5	36.4	842	4511	4.42	3.50	1.2
		12.75	5.66	1.94	.246	.109	3.30	1.66	.755	
10	19	105	317	25.0	27.7	930	2944	2.97	2.45	1.22
		12.05	3.58	2.52	.304	.090	2.56	.77	.905	
	20	105	313	26.0	36.6	1347	4211	2.90	2.35	1.24
		12.70	3.67	2.17	.275	.080	2.89	.83	.370	
11	21	86	220	40.5	31.9	721	5563	4.43	3.47	1.27
		13.65	6.04	1.95	.267	.118	4.04	1.79	1.780	
	22	83	257	60.0	18.9	424	4728	4.46	3.55	1.26
		14.20	6.33	1.81	.258	.115	3.42	1.53	1.235	
12	23	86	230	35.5	40.7	993	6221	4.10	3.20	1.28
		11.85	4.87	1.92	.228	.094	4.00	1.64	.660	
	24	82	210	34.5	43.9	1185	6535	3.71	2.95	1.26
		12.50	4.66	1.94	.243	.090	3.68	1.37	.[illegible]5	
13	25	102	315	25.0	36.9	1171	3936	3.19	2.55	1.25
		12.80	4.07	2.15	.275	.087	2.97	.96	.330	
	26	96	305	29.0	41.0	1069	5137	3.81	3.05	1.25
		12.75	4.86	1.98	.252	.096	3.58	1.38	.625	
14	27	98	297	26.5	38.9	1115	4502	3.47	2.70	1.28
		13.35	4.66	1.98	.261	.089	3.67	1.28	1.260	
	28	96	285	26.0	41.8	1080	4581	4.05	3.13	1.29
		12.45	5.12	1.94	.239	.096	4.63	1.89	.380	
15	29	99	282	30.5	31.9	843	4349	3.75	2.85	1.32
		13.35	5.00	1.95	.261	.098	4.17	1.57	.390	
	30	86	205	39.5	40.0	1017	6570	4.00	3.10	1.29
		12.35	4.96	2.07	.256	.103	4.04	1.61	.520	
16	31	85	242	41.5	44.9	1248	7908	3.59	2.70	1.33
		10.80	3.88	2.12	.226	.081	4.51	1.62	.505	
	32	96	325	30.5	39.9	1138	5225	3.56	2.75	1.29
		13.40	4.76	2.05	.274	.098	4.38	1.57	.270	

APPENDIX TABLE 3 (CONTINUED).

F2(4)	F3(4)	D.FL PROT.	HT. P/K	P/FL LYS.	F/WT LYS.S	K/F LYS/K	G.Y. OIL	K.HT. OIL/K	K.V. C.EQ.	K.D.
17	33	90	255	25.5	34.6	835	3620	4.24	3.40	1.25
		14.10	6.01	1.87	.264	.113	4.19	1.78	.925	
	34	93	242	28.0	34.6	867	4258	3.99	3.10	1.29
		13.70	5.47	1.98	.271	.108	4.27	1.71	.640	
18	35	95	250	25.0	62.9	1435	6387	4.45	3.60	1.23
		12.55	5.56	2.00	.251	.111	3.42	1.53	.345	
	36	93	255	25.0	47.1	1180	4975	4.07	3.25	1.25
		13.15	5.35	1.89	.249	.101	3.22	1.31	1.200	
19	37	88	238	32.0	43.6	1045	5946	4.17	3.30	1.26
		12.90	5.38	1.93	.250	.105	4.05	1.70	.660	
	38	81	245	35.0	41.3	1205	5974	3.51	2.72	1.29
		12.10	4.24	1.99	.240	.084	3.60	1.26	1.015	
20	39	96	300	27.0	42.0	1070	5070	3.89	3.07	1.27
		13.70	5.33	1.85	.253	.099	4.50	1.76	.600	
	40	98	285	29.5	44.2	1160	5518	3.79	2.92	1.29
		13.35	5.04	1.91	.255	.097	4.33	1.65	1.915	
21	41	91	290	33.5	31.1	813	4261	3.88	3.05	1.27
		14.30	5.56	1.94	.277	.107	4.10	1.60	.815	
	42	99	235	25.5	38.2	996	4188	3.84	2.95	1.30
		14.40	5.53	1.82	.262	.101	4.42	1.70	.555	
22	43	92	330	34.0	43.5	1441	6322	3.02	2.32	1.30
		11.65	3.51	1.95	.227	.068	3.25	.98	1.575	
	44	93	305	27.0	52.3	1753	5929	3.00	2.35	1.28
		11.95	3.59	2.13	.252	.076	3.91	1.18	1.050	
23	45	98	313	29.0	21.7	708	2939	3.23	2.55	1.26
		13.90	4.49	2.20	.306	.099	3.83	1.25	2.300	
	46	92	257	32.0	34.3	865	4799	3.97	3.10	1.28
		13.50	5.36	2.03	.274	.109	3.86	1.54	.550	
24	47	101	295	26.5	48.6	1330	6593	3.70	2.90	1.28
		12.70	4.70	2.19	.278	.102	3.75	1.39	.650	
	48	92	300	36.0	22.4	688	3533	3.33	2.72	1.22
		13.45	4.50	2.06	.277	.092	3.70	1.24	1.215	

APPENDIX TABLE 3 (CONTINUED).

F2(4)	F3(4)	D.FL PROT.	HT. P/K	P/PL LYS.	P/HT LYS.S	K/P LYS/K	G.Y. OIL	K.HT. OIL/K	K.V. C.EG.	K.D.
25	49	80	225	36.0	42.7	1160	6337	3.75	2.95	1.27
		11.70	4.41	2.13	.249	.094	4.01	1.51	1.035	
	50	86	232	35.0	46.0	1126	6905	4.13	3.10	1.33
		12.20	5.06	2.12	.258	.107	4.09	1.70	.725	
26	51	90	297	23.5	61.2	1315	6187	3.38	2.58	1.31
		12.30	4.16	2.01	.247	.084	3.58	1.21	1.335	
	52	96	265	32.0	47.4	1343	6462	3.53	2.88	1.22
		12.00	4.24	2.11	.253	.089	3.26	1.16	.660	
27	53	108	305	22.0	31.3	998	2963	3.15	2.70	1.16
		13.85	4.33	2.03	.292	.088	3.35	1.07	.220	
	54	100	305	23.0	36.3	1253	3486	2.95	2.40	1.23
		14.05	4.13	2.02	.285	.084	3.50	1.02	.325	
28	55	99	255	30.5	29.8	813	4043	3.78	3.00	1.26
		14.65	5.56	1.91	.280	.106	3.75	1.42	.700	
	56	102	267	24.5	30.3	799	3201	3.80	2.95	1.29
		12.75	4.84	2.01	.258	.098	4.64	1.84	.470	
29	57	83	275	35.5	29.6	738	4446	4.00	3.10	1.29
		13.80	5.54	1.95	.268	.107	3.45	1.38	.875	
	58	84	232	36.0	45.0	1053	7116	4.27	3.35	1.27
		12.70	5.43	1.93	.244	.104	3.92	1.67	1.045	
30	59	76	170	38.5	27.5	1087	4562	4.06	3.40	1.20
		12.50	5.08	1.85	.232	.094	3.42	1.39	.805	
	60	103	302	37.0	24.7	817	3927	3.02	2.58	1.17
		11.70	3.53	2.22	.260	.079	3.59	1.09	1.750	
31	61	99	295	22.0	37.1	1032	3516	3.66	2.88	1.27
		12.25	4.53	2.00	.243	.089	4.23	1.58	.955	
	62	96	267	25.0	43.2	1089	4474	3.83	3.05	1.26
		13.15	5.10	2.03	.264	.101	3.72	1.46	.310	
32	63	89	230	32.0	22.9	493	3172	4.72	3.80	1.24
		14.00	6.64	2.06	.238	.137	3.03	1.44	.600	
	64	89	222	29.5	29.7	669	3761	4.54	3.50	1.30
		13.40	6.16	2.00	.266	.122	3.33	1.52	.380	

APPENDIX TABLE 3 (CONTINUED).

F2(4)	F3(4)	D.FL PROT.	HT. P/K	P/PL LYS.	P/WT LYS.S	K/P LYS/K	G.Y. OIL	K.WT. OIL/K	K.V. C.EC.	K.D.
33	65	90	265	26.5	29.6	709	3262	4.38	3.45	1.27
		14.85	6.54	2.04	.303	.133	4.37	1.93	.445	
	66	105	285	32.0	28.8	907	4121	3.20	2.55	1.26
		12.00	3.89	2.36	.284	.092	3.64	1.17	1.390	
34	67	105	265	24.0	30.8	973	3176	3.16	2.53	1.31
		12.65	4.01	1.91	.243	.077	3.44	1.09	.300	
	68	108	320	31.5	32.6	1090	4573	2.91	2.30	1.27
		13.40	3.91	2.11	.283	.081	3.24	.96	.855	
35	69	98	275	22.5	44.9	1282	4162	3.50	2.75	1.27
		12.75	4.47	2.08	.266	.093	3.97	1.39	.215	
	70	99	250	18.0	43.7	1265	3409	3.47	2.75	1.26
		11.65	4.04	2.07	.241	.083	3.26	1.13	.710	
36	71	101	305	29.0	47.8	1669	5965	2.80	2.22	1.26
		11.35	3.18	2.20	.250	.069	2.97	.84	.335	
	72	100	300	30.0	35.8	1026	4510	3.46	2.75	1.26
		13.70	4.81	2.08	.284	.098	3.73	1.36	.325	
37	73	92	260	20.0	20.8	489	1799	4.25	3.30	1.29
		13.25	5.64	1.99	.264	.112	3.39	1.45	.440	
	74	93	267	34.0	31.5	763	4530	4.26	3.40	1.25
		13.70	5.88	2.00	.272	.116	3.36	1.44	.710	
38	75	91	280	19.5	62.8	1616	5259	3.92	3.10	1.27
		13.05	5.16	1.99	.257	.100	3.57	1.39	.455	
	76	109	315	27.5	20.6	743	2425	2.72	2.25	1.21
		14.10	3.88	2.25	.316	.086	2.46	.69	.425	
39	77	79	207	33.5	34.7	849	5067	4.10	3.30	1.24
		12.60	5.17	2.02	.252	.103	3.05	1.25	1.460	
	78	84	247	40.5	44.5	1097	7747	4.07	3.20	1.27
		12.75	5.20	1.95	.250	.102	4.54	1.85	1.245	
40	79	98	295	27.5	28.6	828	3247	3.61	2.85	1.26
		13.90	5.06	2.07	.287	.103	3.43	1.25	.445	
	80	94	295	23.0	39.1	964	3796	4.17	3.25	1.28
		14.05	5.90	2.06	.288	.120	3.76	1.58	.510	

APPENDIX TABLE 3 (CONTINUED).

F2(4)	F3(4)	D.FL PROT.	HT. P/K	P/FL LYS.	F/WT LYS.S	K/F LYS/K	G.Y. OIL	K.WT. OIL/K	K.V. C.EQ.	K.D.
41	81	95	255	33.0	35.8	1072	5066	3.42	2.60	1.31
		13.15	4.56	2.21	.287	.099	4.72	1.65	1.025	
	82	98	280	31.0	37.3	1123	4973	3.33	2.55	1.31
		12.60	4.21	2.09	.262	.087	4.83	1.62	1.525	
42	83	78	215	43.5	26.5	619	4962	4.28	3.25	1.32
		14.10	6.03	1.88	.263	.113	3.73	1.60	1.170	
	84	93	280	22.5	38.5	1074	3335	4.05	3.20	1.25
		13.55	5.55	1.95	.261	.104	3.22	1.33	.410	
43	85	102	310	25.0	36.6	1087	3940	3.38	2.65	1.28
		14.00	4.75	2.17	.303	.102	4.04	1.38	.160	
	86	101	315	35.0	32.0	943	4708	3.33	2.60	1.28
		12.10	4.11	1.99	.239	.080	3.50	1.18	.225	
44	87	78	270	33.0	44.1	978	6098	4.53	3.47	1.30
		12.85	5.84	1.88	.241	.109	3.81	1.73	.355	
	88	85	280	41.5	28.7	800	4853	3.60	2.75	1.49
		13.25	4.76	1.85	.243	.088	4.01	1.45	2.905	
45	89	99	295	21.0	37.4	1178	3316	3.24	2.50	1.29
		13.25	4.31	1.89	.249	.080	3.55	1.16	.355	
	90	101	315	16.5	32.7	1026	2320	3.23	2.52	1.28
		13.35	4.31	2.20	.294	.094	3.83	1.23	1.000	
954 086		86	215	35.7	28.7	545	4321	5.32	4.15	1.28
		14.09	7.51	1.81	.254	.135	3.28	1.75	.697	
IS 2319		93	277	30.2	49.3	1398	5953	3.57	2.80	1.27
		13.84	4.96	2.18	.300	.107	5.33	1.86	.478	
NK 300		84	200	41.6	43.4	1900	7658	2.31	1.79	1.29
		10.12	2.35	2.11	.213	.049	3.32	.77	3.668	

APPENDIX TABLE 4. MEANS OF ALL CHARACTERS OVER TWO LOCATIONS FOR ALL ENTRIES IN POPULATION 4.+

F2(4)	F3(4)	D.FL PROT.	HT. P/K	P/PL LYS.	F/WT LYS.S	K/F LYS/K	G.Y. OIL	K.WT. OIL/K	K.V. C.EC.	K.D.
1	1	85	290	26.0	26.0	1219	2931	2.12	1.60	1.32
		14.30	3.03	2.16	.319	.065	4.38	.93	4.665	
	2	91	305	27.5	33.6	1570	3972	2.15	1.70	1.27
		13.30	2.86	2.29	.304	.066	3.62	.78	5.995	
2	3	97	277	28.5	32.0	1095	4009	2.90	2.20	1.32
		11.00	3.19	2.25	.247	.071	3.13	.91	2.710	
	4	98	290	20.5	30.7	1228	2692	2.47	1.90	1.30
		12.45	3.08	2.33	.290	.071	3.17	.79	.405	
3	5	86	260	28.0	51.1	1716	6129	2.96	2.27	1.31
		12.25	3.63	1.82	.223	.067	3.23	.96	.880	
	6	102	275	29.5	34.6	1532	4136	2.25	1.70	1.32
		10.90	2.45	2.40	.261	.059	3.14	.70	4.135	
4	7	102	345	37.0	20.1	1121	3193	1.84	1.35	1.35
		12.15	2.24	2.22	.269	.049	3.11	.58	3.500	
	8	99	330	25.5	27.3	1340	3015	2.04	1.60	1.27
		12.75	2.61	2.30	.293	.060	3.69	.75	5.790	
5	9	89	310	37.0	28.2	1312	4590	2.13	1.60	1.33
		14.55	3.10	1.88	.273	.058	4.64	.99	4.655	
	10	84	295	24.0	44.8	1370	4745	3.28	2.50	1.31
		12.25	4.00	1.98	.244	.079	3.45	1.12	2.890	
6	11	99	313	24.5	26.9	1742	2819	1.54	1.22	1.26
		15.05	2.31	1.91	.287	.044	4.78	.74	4.895	
	12	98	320	29.0	21.5	1656	2629	1.31	1.00	1.31
		14.40	1.89	2.07	.297	.039	4.79	.63	.270	
7	13	105	350	36.5	18.4	1004	2842	1.84	1.40	1.31
		11.70	2.15	2.28	.267	.049	3.58	.66	2.570	
	14	105	300	31.5	23.9	1012	3241	2.36	1.85	1.28
		11.85	2.80	2.03	.240	.057	3.19	.75	4.010	
8	15	93	265	25.5	43.2	1653	4906	2.61	1.95	1.34
		13.10	3.42	1.89	.248	.064	3.58	.94	.560	
	16	95	235	44.0	22.0	927	4168	2.36	1.90	1.25
		13.05	3.08	2.14	.279	.066	3.52	.83	.400	

+See page 98 for identification of column headings and any other abbreviations.

APPENDIX TABLE 4 (CONTINUED).

F2(4)	F3(4)	D.FL PROT.	HT. P/K	P/FL LYS.	P/HT LYS.S	K/P LYS/K	G.Y. OIL	K.WT. OIL/K	K.V. C.EC.	K.D.
9	17	90	307	34.5	36.3	1239	5405	2.92	2.17	1.35
		14.00	4.09	1.87	.261	.077	3.87	1.13	.455	
	18	86	280	32.0	36.8	1498	5130	2.45	1.88	1.31
		13.85	3.39	1.71	.237	.058	4.39	1.08	5.165	
10	19	86	295	22.5	43.1	1899	4157	2.28	1.70	1.34
		14.35	3.27	1.95	.280	.064	4.54	1.03	7.365	
	20	99	290	27.0	34.3	1341	4069	2.55	1.90	1.34
		13.10	3.34	2.10	.275	.070	4.04	1.03	6.535	
11	21	89	288	28.5	30.4	1539	3600	1.98	1.48	1.34
		13.95	2.75	1.79	.250	.049	4.94	.91	4.815	
	22	91	245	22.5	45.0	2033	4349	2.21	1.72	1.28
		11.45	2.54	2.16	.248	.055	3.84	.85	.900	
12	23	86	285	34.5	22.7	755	3349	3.00	2.30	1.30
		13.60	4.08	1.95	.264	.079	4.04	1.21	1.890	
	24	93	325	29.0	32.0	1144	3998	2.81	2.15	1.31
		13.45	3.77	1.79	.241	.068	3.72	1.04	3.260	
13	25	98	280	30.5	23.6	1305	3004	1.83	1.38	1.33
		11.55	2.11	2.41	.277	.051	3.47	.64	7.250	
	26	90	195	27.5	24.0	892	2802	2.71	2.08	1.31
		13.55	3.67	1.80	.244	.066	3.66	.99	1.040	
14	27	88	285	35.0	37.5	1431	5631	2.63	1.95	1.35
		13.00	3.42	2.06	.268	.070	4.43	1.17	4.555	
	28	94	310	21.5	36.3	1714	3333	2.13	1.63	1.31
		14.30	3.05	1.82	.260	.055	4.64	.99	4.015	
15	29	90	305	27.0	36.2	1503	3832	2.35	1.77	1.32
		14.60	3.44	2.08	.301	.070	4.92	1.16	3.495	
	30	102	313	34.5	24.0	1193	3587	2.01	1.55	1.30
		12.15	2.44	2.23	.271	.054	3.86	.77	4.830	
16	31	85	315	38.0	30.5	1134	5020	2.70	2.05	1.32
		14.45	3.91	1.91	.276	.075	4.41	1.20	3.190	
	32	86	290	40.5	31.7	1200	5013	2.65	2.05	1.29
		13.00	3.43	1.90	.248	.065	4.28	1.14	3.370	

APPENDIX TABLE 4 (CONTINUED).

F2(4)	F3(4)	D.FL PROT.	HT. P/K	P/PL LYS.	P/HT LYS.S	K/P LYS/K	G.Y. OIL	K.HT. OIL/K	K.V. C.EC.	K.D.
17	33	84	295	47.0	26.8	1268	5569	2.11	1.60	1.32
		13.70	2.89	2.02	.277	.059	5.05	1.07	4.570	
	34	88	305	41.0	26.5	1218	4984	2.35	1.75	1.34
		14.00	3.30	1.95	.273	.064	4.82	1.14	5.670	
18	35	86	295	27.5	40.9	1746	4842	2.35	1.70	1.38
		13.25	3.13	1.99	.262	.062	4.34	1.02	2.990	
	36	90	295	37.0	27.5	1334	4310	2.07	1.52	1.36
		14.90	3.08	1.92	.286	.059	5.16	1.07	4.550	
19	37	106	310	25.5	23.3	1013	2535	2.30	1.70	1.35
		12.70	2.94	2.19	.277	.064	3.66	.85	2.495	
	38	102	315	29.0	32.8	1447	3826	2.25	1.75	1.28
		12.25	2.76	2.09	.256	.057	3.48	.79	3.790	
20	39	88	265	32.0	34.7	1415	4693	2.46	1.85	1.33
		14.15	3.48	1.94	.274	.067	4.32	1.06	4.000	
	40	86	310	39.5	36.6	1360	6150	2.69	2.00	1.34
		14.15	3.79	1.87	.264	.071	4.06	1.09	4.540	
21	41	86	270	31.5	29.6	1352	4129	2.19	1.60	1.37
		12.30	2.69	2.00	.246	.054	4.06	.89	3.475	
	42	88	267	36.0	26.5	1204	4097	2.20	1.65	1.33
		13.10	2.88	1.96	.257	.057	3.75	.82	3.205	
22	43	100	325	30.5	38.2	1556	5044	2.48	1.90	1.30
		11.85	2.92	2.31	.274	.067	3.43	.85	3.600	
	44	86	260	39.0	29.7	1347	5005	2.21	1.65	1.34
		14.55	3.22	1.98	.288	.064	4.62	1.02	3.550	
23	45	86	300	35.5	32.3	1489	4631	2.19	1.60	1.37
		14.95	3.27	1.74	.260	.057	5.06	1.11	4.440	
	46	91	270	43.5	26.4	1133	4762	2.53	1.88	1.35
		13.15	3.32	1.95	.255	.065	3.84	.97	.670	
24	47	85	280	40.0	22.2	896	3796	2.48	1.85	1.34
		15.20	3.76	2.03	.309	.076	5.31	1.32	3.060	
	48	89	305	29.5	28.5	932	3746	3.05	2.40	1.27
		13.70	4.18	2.22	.305	.093	4.12	1.26	5.225	

APPENDIX TABLE 4 (CONTINUED).

F2(4)	F3(4)	D.FL PROT.	HT. P/K	P/FL LYS.	F/WT LYS.S	K/F LYS/K	G.Y. OIL	K.WT. OIL/K	K.V. C.EC.	K.D.
25	49	92	315	26.0	52.5	2365	5765	2.23	1.70	1.31
		14.05	3.13	1.81	.255	.057	4.96	1.11	2.480	
	50	87	290	26.0	36.3	1706	3979	2.13	1.65	1.29
		14.45	3.07	1.93	.270	.057	4.91	1.05	.370	
26	51	91	295	26.0	26.3	1194	2737	2.27	1.67	1.35
		13.35	3.05	1.99	.264	.060	4.14	.95	2.205	
	52	89	290	35.0	28.0	1248	4198	2.27	1.67	1.36
		13.90	3.16	1.99	.276	.063	4.35	.99	3.345	
27	53	83	250	47.0	31.2	925	6400	3.40	2.58	1.32
		12.05	4.12	2.28	.274	.093	3.64	1.24	.325	
	54	83	288	33.0	30.1	1106	4282	2.73	2.05	1.33
		11.85	3.25	2.22	.264	.073	3.47	.95	.335	
28	55	84	270	40.0	40.1	1363	6443	2.97	2.30	1.29
		14.05	4.18	1.81	.255	.076	4.29	1.28	.485	
	56	85	232	35.0	23.1	721	3484	3.21	2.47	1.30
		11.50	3.69	1.84	.212	.068	3.06	.98	2.040	
29	57	88	320	31.0	34.4	1248	4766	2.75	2.02	1.36
		16.30	4.48	1.74	.284	.078	4.61	1.27	.565	
	58	96	322	21.5	38.0	1712	3508	2.22	1.60	1.39
		15.45	3.43	1.79	.276	.061	4.55	1.02	.265	
30	59	93	335	35.5	33.7	1205	5173	2.80	2.08	1.35
		12.25	3.43	2.18	.267	.075	4.13	1.16	1.820	
	60	88	305	32.0	29.6	973	4102	3.05	2.30	1.33
		13.95	4.25	1.86	.259	.079	3.66	1.11	.135	
31	61	93	335	35.0	32.7	1487	4900	2.22	1.65	1.34
		14.15	3.16	1.97	.278	.062	4.20	.95	5.725	
	62	88	275	22.0	59.0	1639	5571	3.60	2.77	1.30
		12.65	4.56	2.27	.297	.104	3.49	1.26	3.305	
32	63	92	302	37.5	18.6	738	3015	2.61	2.00	1.30
		13.25	3.60	2.04	.261	.068	4.35	1.13	5.045	
	64	99	295	39.0	21.3	916	3643	2.33	1.75	1.33
		12.35	2.89	2.25	.277	.064	4.32	1.00	5.780	

APPENDIX TABLE 4 (CONTINUED).

F2(4)	F3(4)	D.FL PROT.	HT. P/K	P/FL LYS.	F/HT LYS.S	K/F LYS/K	G.Y. OIL	K.HT. OIL/K	K.V. C.EC.	K.D.
33	65	94	240	29.5	36.1	1253	4629	2.89	2.25	1.30
		12.95	3.78	2.13	.275	.080	3.38	.96	1.420	
	66	98	227	39.0	19.0	804	3385	2.32	1.80	1.29
		11.40	2.66	2.52	.286	.067	3.71	.87	4.655	
34	67	93	227	43.0	28.5	1126	5216	2.52	1.82	1.38
		12.60	3.19	1.98	.250	.063	3.67	.93	3.155	
	68	85	282	24.5	45.2	1331	4853	3.41	2.65	1.29
		12.90	4.40	1.99	.257	.088	3.35	1.14	1.645	
35	69	97	245	20.5	27.5	1202	2526	2.25	1.70	1.32
		12.70	2.88	2.56	.324	.073	3.59	.82	4.495	
	70	98	290	29.0	31.0	1426	3884	2.22	1.67	1.32
		11.95	2.66	2.50	.299	.066	3.27	.73	6.655	
36	71	80	220	25.5	32.4	1273	3559	2.55	1.95	1.31
		13.85	3.52	1.92	.267	.068	3.89	.99	.715	
	72	94	265	26.5	35.4	1462	2054	2.45	1.90	1.29
		13.35	3.31	2.11	.280	.069	3.87	.96	2.140	
37	73	99	280	18.5	29.7	1169	2537	2.45	1.82	1.34
		11.00	2.68	2.61	.286	.069	2.88	.72	5.935	
	74	98	295	25.0	32.8	1303	3555	2.42	1.75	1.38
		14.15	3.43	2.07	.293	.071	4.21	1.02	.435	
38	75	91	305	45.5	34.2	1433	6731	2.39	1.80	1.33
		14.20	3.39	2.09	.297	.071	4.79	1.15	6.735	
	76	89	295	39.5	31.5	1356	5074	2.35	1.52	1.60
		14.50	3.42	1.91	.275	.065	4.54	1.07	3.835	
39	77	89	297	39.0	18.2	818	3028	2.25	1.70	1.33
		15.10	3.41	1.79	.270	.061	4.69	1.06	4.170	
	78	100	285	27.0	22.7	1300	2621	1.73	1.35	1.28
		12.25	2.13	2.39	.291	.050	3.18	.63	3.860	
40	79	95	290	29.0	31.6	1377	3940	2.65	1.98	1.34
		14.30	3.80	1.98	.283	.075	4.10	1.09	.325	
	80	90	300	26.0	48.0	1988	5356	2.42	1.82	1.32
		13.00	3.14	2.24	.290	.070	4.15	1.00	4.360	

APPENDIX TABLE 4 (CONTINUED).

F2(4)	F3(4)	D.FL PROT.	HT. P/K	P/FL LYS.	P/WT LYS.S	K/P LYS/K	G.Y. OIL	K.WT. OIL/K	K.V. C.EC.	K.D.
41	81	87	290	23.0	50.6	1768	5005	2.88	2.20	1.31
		11.35	3.27	2.03	.231	.066	3.34	.96	.690	
	82	90	295	37.5	39.6	1442	3954	2.77	2.05	1.35
		13.10	3.64	2.20	.286	.079	3.94	1.10	1.745	
42	83	93	280	40.5	36.8	1542	6417	2.38	1.82	1.31
		12.10	2.89	2.08	.250	.060	3.88	.93	.345	
	84	93	272	35.0	33.6	1525	4943	2.22	1.60	1.39
		12.10	2.69	2.26	.274	.061	3.75	.84	2.755	
43	85	89	267	33.5	35.3	1546	4764	2.34	1.75	1.34
		13.55	3.19	2.15	.290	.068	4.67	1.09	4.045	
	86	88	240	39.5	31.1	1339	4850	2.38	1.83	1.31
		11.60	2.78	2.33	.268	.064	3.93	.95	2.880	
44	87	88	295	25.5	43.0	1852	4633	2.32	1.70	1.36
		13.95	3.24	2.10	.293	.068	4.75	1.10	3.220	
	88	88	285	39.5	35.0	1456	5786	2.42	1.60	1.58
		14.60	3.55	1.91	.278	.067	4.60	1.12	2.475	
45	89	95	242	27.5	28.2	1033	3533	2.66	2.05	1.31
		13.30	3.57	2.20	.293	.078	3.38	.90	.705	
	90	95	255	41.0	31.1	1223	5453	2.54	1.92	1.32
		11.15	2.84	2.39	.265	.068	3.16	.80	6.200	
IS 0628		86	179	35.8	30.4	801	4711	3.83	2.92	1.31
		11.44	4.38	2.06	.235	.090	2.54	98	.435	
IS 1210		86	286	35.0	32.4	1621	4859	2.00	1.50	1.34
		14.84	2.96	1.89	.280	.056	5.34	1.07	4.827	
NK 300		85	200	40.6	40.9	1774	7096	2.33	1.75	1.32
		10.41	2.43	2.05	.212	.049	3.34	.78	2.864	

APPENDIX TABLE 5
PHENOTYPIC CORRELATIONS BETWEEN ALL POSSIBLE PAIRS
OF 17 CHARACTERS AMONG F2(4) AND F3/2(4)
IN POPULATION 1.+

	HT. 2	P/PL 3	P/HT 4	K/P 5	G.Y. 6	K.HT. 7	K.V. 8	K.D. 9	PROT. 10	P/K 11	LYS. 12	LYS.S 13	LYS/K 14	OIL 15	OIL/K 16	C.EC. 17
1	.590**	-.374*	-.159	.170	-.331*	-.673**	-.663**	-.203	-.199	-.630**	.454**	.305*	-.553**	.113	-.589**	.045
	.375**	-.013	-.335*	.065	-.351*	-.385**	-.369*	.010	-.014	-.353**	.188	.174	-.325*	-.194	-.488**	-.148
2		-.407**	.334*	.546**	.090	-.537**	-.584**	.236	-.322*	-.536**	.362**	.005	-.514**	.196	-.134	.169
		-.138	-.005	.261	-.159	-.495**	-.508**	.216	-.017	-.451**	.225	.305*	-.391**	.314*	-.548**	.374**
3			-.447**	-.534**	.341*	.249	.244	.009	.183	.252	-.163	.066	.248	-.026	.168	-.056
			-.282	-.198	.445**	-.060	-.103	.165	-.031	-.069	.085	.036	-.058	.028	.196	-.036
4				.862**	.641**	.016	-.107	.160	-.277	-.087	.009	-.408**	-.102	.231	.157	.139
				.771**	.229	.135	.123	-.123	-.214	-.026	.019	-.149	.031	.229	.251	.005
5					.448**	-.475**	-.491**	.056	-.426**	-.527**	.181	-.376**	-.558**	.247	-.262	.266
					.515**	-.132	-.487**	.009	-.268	-.568**	.238	.007	-.517**	.382**	-.221	.287
6						.195	.156	.275	-.227	.064	-.018	-.335*	.081	.215	.255	.018
						.216	.383	-.032	-.249	-.054	.066	-.220	-.036	.346*	.326	.084
7							.990**	.163	.443**	.948**	-.449**	.050	.960**	.047	.841**	-.256
							.984**	-.213	.197	.926**	-.243	-.085	.947**	-.272	.742**	-.371*
8								.025	.466**	.953**	-.447**	.087	.963**	.012	.813**	-.246
								-.362**	.202	.916**	-.221	-.047	.944**	-.318*	.697**	-.369*
9									-.096	.083	-.091	-.259	.069	.242	.268	-.103
									-.087	-.220	-.086	-.224	-.284	.345*	.026	.099
10										.698**	-.747**	.491**	.551**	.241	.482**	-.113
										.543**	-.693**	.320*	.297**	.107	.221	.115
11											-.612**	.210	.955**	.113	.934**	-.243
											-.465**	.048	.922**	-.223	.791	-.278
12												.203	-.365*	-.218	-.465**	.106
												.457**	-.097	-.021	-.223	.042
13													.324*	.082	.386	-.024
													-.004	.092	-.014	.224
14														.054	.813**	-.254
														-.227	.727**	-.275
15															.571**	.375*
															.433**	.531**
16																-.041
																-.006

Upper values are for $F_2(4)$ and
Lower values are for $F_{3/2}(4)$.

* Significant at .05 level ** Significant at .01 level

See page 98 for identification of column headings and any other abbreviations.

APPENDIX TABLE 6
PHENOTYPIC CORRELATIONS BETWEEN ALL POSSIBLE PAIRS
OF 17 CHARACTERS AMONG F2(4) AND F3/2(4)
IN POPULATION 2.+

	HT. 2	P/PL 3	P/WT 4	K/P 5	G.Y. 6	K.WT. 7	K.V. 8	K.D. 9	PROT. 10	P/K 11	LYS. 12	LYS.S 13	LYS/K 14	OIL 15	OIL/K 16	C.EC. 17
1	.617**	-.545**	.209	.187	-.179	-.113	.055	-.372*	-.234	-.121	.313*	.221	.145	.032	.026	-.231
	.289*	-.392**	.177	.226	-.095	.129	-.031	-.138	-.272	-.202	.526**	.312*	.021	-.110	-.401**	.087
2		-.386**	.208	.223	-.060	-.095	-.082	-.066	-.139	-.143	.031	-.062	-.073	-.132	.143	-.291
		.041	-.066	-.018	-.027	.083	.040	.213	-.129	-.028	.177	.014	.171	.091	-.562**	-.174
3			-.527**	-.412**	.122	-.058	-.066	.087	-.090	-.086	.060	-.033	-.117	-.068	-.109	.218
			-.525**	-.444**	.274	.031	-.164	.357*	.301	.198	-.233	.149	.071	.209	.157	-.164
4				.898**	.755**	-.191	-.102	.049	-.072	-.202	-.056	-.169	-.212	.015	-.149	-.109
				.879**	.639**	-.077	-.244	.100	-.632**	-.434**	.308*	-.522**	-.291	.040	-.149	.347*
5					.734**	-.574**	-.565**	.139	-.133	-.521**	-.012	-.164	-.503**	.025	-.455**	.087
					.542**	-.513**	-.508**	.154	-.689**	-.745**	.399**	-.474**	-.602**	.122	-.342*	.066
6						-.283	-.293	.172	-.236	-.341*	.060	-.258	-.355*	.003	-.245	.066
						-.066	-.130	.377	-.426**	-.291*	.164	-.378**	-.208	.210	-.093	.357*
7							.986**	-.215	.089	.851**	-.036	.116	.822**	.003	.839**	-.039
							.982**	-.065	.256	.808**	-.203	.083	.811**	-.178	.666**	.056
8								-.374*	.082	.836**	-.016	.144	.839*	-.054	.764**	-.015
								-.277	.273	.805**	-.171	.140	.821*	-.134	.654**	.059
9									.010	-.165	-.117	-.216	-.177	.325*	.135	-.134
									-.179	-.157	-.109	-.338*	-.216	.014	.063	.109
10										.594**	-.691**	.266	.221	.177	.185	-.074
										.773**	-.754**	.469**	.366*	.008	.249	-.328*
11											-.386**	.238	.777**	-.084	.753**	-.069
											-.588**	.338*	.757**	.112	.591**	-.156
12												.491**	.134	.027	-.021	.085
												.196	-.064	.057	-.134	.272
13													.510**	.282	.257	-.004
													.447**	.028	-.112	-.073
14														.199	.772**	-.100
														-.185	.536**	.018
15															.574**	-.085
															.593**	.143
16																-.064
																.134

Upper values are for $F_2(4)$ and
Lower values are for $F_{3/2}(4)$.

* Significant at .05 level ** Significant at .01 level

+See page 98 for identification of column headings and any other abbreviations.

APPENDIX TABLE 7
PHENOTYPIC CORRELATIONS BETWEEN ALL POSSIBLE PAIRS
OF 17 CHARACTERS AMONG F2(4) AND F3/2(4)
IN POPULATION 3.+

	WT. 2	P/PL 3	P/WT 4	K/P 5	G.Y. 6	K.WT. 7	K.V. 8	K.D. 9	PROT. 10	P/K 11	LYS. 12	LYS.S 13	LYS/K 14	OIL 15	OIL/K 16	C.EO. 17
1	.759** .732**	-.699** -.170	-.154 -.143	.179 .023	-.632** -.154	-.731** -.684**	-.585** -.656**	-.419** -.109	.264 -.081	-.521** -.603**	.476** .438**	.641** .284*	-.420** -.496**	-.325* -.257	-.644** -.516**	-.590** -.464
2		-.542** -.052	.009 -.181	.346* -.142	-.759** -.220	-.744** -.652**	-.192 -.644**	.181 -.087	-.608** .050	.458** -.512**	.475** .292*	-.540** .278*	-.237 -.455**	-.663** -.334*	-.312* -.472**	.084
3			-.181 -.344*	-.325* -.295	.573** .307*	.460** -.142	.426** -.143	.343* .081	-.079 -.038	.373* -.128	-.288* .071	-.325* .005	.317* -.127	.376* -.062	.517** -.113	.555** .233
4				.847** .889**	.664** .729**	-.056 .284	-.094 .242	.166 .102	-.628** -.316*	-.310* .099	.083 -.143	-.501** -.383**	-.342* .071	-.025 .258	-.036 .265	.011 -.288
5					.438** .667**	-.536** -.112	-.553** -.138	-.033 .158	-.646** -.367*	-.727** -.236	.331* -.046	-.312* -.346*	-.732** -.278*	-.175 .032	-.429** -.083	-.178 -.214
6						.264 .112	.199 .071	.425** .119	-.623** -.380**	-.030 -.072	-.073 .061	-.635** -.339**	-.064 -.070	.275 .174	.357* .136	.382* .156
7							.983** .984**	.275 -.062	.139 .190	.909** .909**	-.526** -.437**	-.333 -.187	.864** .844**	.268 .475**	.773** .341**	.349* -.261
8								.116 -.187	.117 .215	.897** .908**	-.479** -.429**	-.285* -.162	.868** .845**	.156 .392**	.691** .783**	.332* -.272
9									-.067 -.098	.210 .093	-.403** -.139	-.406** -.185	.088 .148	.101 .384**	.537** .176	.344* .354*
10										.507** .577**	-.359* -.255	.611** .609**	.442** .546**	.071 .025	.113 .141	-.221 -.197
11											-.593** -.481**	.027 .005	.937** .925**	.264 .395**	.717** .752**	.213 -.265
12												.515** .576**	-.278 -.124	-.365** -.113	-.55 ** -.332*	-.237 .238
13													.183 .357*	-.247 -.060	-.357* -.115	-.399** .091
14														.165 .425**	.624** .735**	.145 -.201
15															.811* .86[illegible]*	.30[illegible]* .[illegible]34
16																.40[illegible]** -.138

Upper values are for $F_2(4)$ and
Lower values are for $F_{3/2}(4)$.

* Significant at .05 level ** Significant at.01 level

+See page 98 for identification of column headings and any other abbreviations.

APPENDIX TABLE 8
PHENOTYPIC CORRELATIONS BETWEEN ALL POSSIBLE PAIRS
OF 17 CHARACTERS AMONG F2(4) AND F3/2(4)
IN POPULATION 4.+

	HT. 2	P/PL 3	P/HT 4	K/P 5	G.Y. 6	K.HT. 7	K.V. 8	K.D. 9	PROT. 10	P/K 11	LYS. 12	LYS.S 13	LYS/K 14	OIL 15	OIL/K 16	C.EG. 17
1	.339* .359*	-.280 .073	-.431** -.238	-.169 .013	-.554** -.252	-.445** -.385*	-.411** -.359*	-.166 -.031	-.281 -.434**	-.565** -.557**	.498** .527**	.223 .157	-.375* -.301*	-.326* -.351*	-.681** -.614**	.092 .229
2		-.087 .072	-.018 .124	.135 .376*	-.375 .047	-.252 -.314*	-.291 -.303*	.250 .029	.375* .011	-.061 -.247	-.087 .102	.313* .132	-.117 -.244	.320* .478	.079 -.232	.239 .368*
3			-.300* -.565**	-.410** -.482**	.481** .328**	.152 -.282	.143 -.309*	.104 .187	-.106 .122	.109 -.170	-.151 -.005	-.260 .123	.035 -.211	.081 .297*	.227 .319	.106 .144
4				.757** .793**	.639** .509**	.354* .519**	.308* .537**	.089 -.048	.142 -.155	.399** .366*	-.356* -.034	-.248 -.208	.279 .429**	.135 -.232	.439** .317*	-.261 -.185
5					.356* .362*	-.322* -.084	-.358* -.348	.271 -.154	.353* -.049	-.178 -.146	-.293 .058	.038 -.068	-.321* -.114	-.453* -.029	.326 -.176	-.088 -.139
6						.419** .289*	.357* .284*	.371* -.078	.053 -.040	.429** .236	-.366* -.115	-.340* -.197	.300* .212	.165 .050	.513** .351*	-.102 .154
7							.988** .981**	-.082 -.175	-.249 -.159	.873** .835**	-.138 -.180	-.415** -.293*	.887** .869**	-.392** -.331*	.615** .521**	-.319* -.374*
8								-.230 -.352*	-.296* -.098	.837** .798**	-.089 -.128	-.412** -.272	.874** .862**	-.436** -.363*	.564** .578**	-.332* -.331
9									.358* .211	.099 -.036	-.307* -.235	.051 -.065	-.354 -.201	.368* .194	.251 -.331	.139 -.140
10										.245 .491**	-.610** -.731**	.401** .325*	-.369 .111	.796** .787**	.456** .584**	.178 -.263
11											-.439** -.536**	-.216 -.049	.853** .832**	-.011 .122	.847** .853**	-.208 -.485**
12												.475** .396**	.085 .032	-.536** -.479**	-.553** -.501**	.231 .309*
13													.050 .193	.299* .376*	-.111 .147	.454** .215
14														-.267 -.141	.633** .692**	-.114 -.361*
15															.468** .511**	.385* .254
16																-.061 -.318*

Upper values are for $F_2(4)$ and
Lower values are for $F_{3/2}(4)$.

Significant at .05 level ** Significant at .01 level

ee page 98 for identification of column headings and any other abbreviations.

F2(4)	=	F_2 subpopulations in the 4th generation
F3/2(4)	=	F_3 subpopulations within F_2 subpopulations in the 4th generation
D.FL	=	Days to flower
HT.	=	Plant height in cm
P/PL	=	Panicles per plot
P/WT	=	Panicle weight in grams
K/P	=	Kernels per panicle
K.WT.	=	Kernel weight (in grams/100 kernels)
K.D.	=	Kernel density
P/K	=	Mg of protein per kernel
LYS.S	=	Percent lysine of sample
OIL	=	Percent oil
G.Y.	=	Grain yield (kg/ha)
K.V.	=	Kernel volume (in c.c./100 kernels)
PROT.	=	Percent protein
LYS.	=	Percent lysine of protein
LYS/K	=	Mg of lysine per kernel
OIL/K	=	Mg of oil per kernel
C.EQ.	=	Catechin equivalent value

VITA

VITA

Samwiri Ziryabareba Mukuru was born in December 1939 at Kigata, Kigezi, District, Uganda, East Africa to Andereya and Yoniya Mukuru. He completed his primary and secondary education at Kigezi High School and Ntare Secondary School respectively. He received the B.Sc honors degree in Botany and Zoology from Makerere University, Kampala, Uganda (then a College of the University of East Africa) in April 1968.

He was employed by the East African Agriculture and Forestry Research Organization as a Research Officer (trainee) at Serere Research Station in Uganda from July 1968 until September 1969 when he was given a leave of absence and a Rockefeller Foundation Scholarship to pursue graduate studies towards the M.S. and Ph.D. degrees at Purdue University, West Lafayette, Indiana, United States. His M.S. research was conducted under the direction of Dr. R. C. Pickett and in June 1971 he was awarded an M.S. degree in Agronomy. In the summer of 1971 he began his Ph.D. research under the direction of Dr. J. D. Axtell and completed the requirements for the Ph.D. degree in September 1973.

He and his wife, Connie, have two sons, Allan and Andrew.

He is a member of Gamma Sigma Delta, American Society of Agronomy and Crop Science Society of America.