PHENOTYPIC AND GENOTYPIC CORRELATIONS IN COWPEA (Vijgna unguiculata (L.) Walp)

By

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DECLARATION

I hereby declare that this thesis is a documentation of my research findings. It has not been presented before in any application for a higher degree.

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CERTIFICATION

This thesis entitled "Phenotypic and genotypic correlations in cowpea (Vigna unguiculata (L.) Walp)" by Aminu Abdu Zaria meets the regulations governing the award of the Degree of Master of Science of Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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To Master Muhammad Faisal, my son. His birth at the critical point on this work provided the impetus that saw it to a successful completion.

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ABSTRACT

Studies were carried out to determine phenotypic, genotypic and environmental correlations between number of pods/plant, number of seeds/plant, yield/plant, days to flowering, number of seeds/pod and seed size using three intervarietal crosses of cowpea. Another objective was to determine heritability and mode of inheritance of each of the six characters. The experiments were conducted in 1984 and 1985 at Samaru (11° 11'N. 7° 38'E, altitude 636m). Three varieties, three F1 hybrids and their corresponding F2S were space-planted in 4 replications of a randomized complete block design (RCED) for the evaluations.

Heritability estimates in the broad sense were very high for pods/plant, seeds/plant and seed size. There were positive and consistent correlations between pods/plant with seeds/plant and yield; seeds/plant and yield/plant and yield/plant with seed size. The characters, pods/plant, seeds/plant and seed size were positively correlated with yield and exhibited transgressive segregation. This shows their value in indirect selection to improve yield, especially when using pure-line selection.

Polygenic inheritance for these characters was indicated by unimodality in the F_2 distribution of the crosses in both years. Complementary gene effects, as evidenced by skewness of all F2 distributions, were also indicated.

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CHAPTER 1

INTRODUCTION

Cowpea (*Vigna unguiculata* (L.) Walp) is an important grain legume in Nigeria. The majority of the world cowpea crop is grown in tropical Africa, and Nigeria is the largest producer with about two-third of the world production (Moody, 1973). Cowpea is an important source of cheap plant protein because it is about 22-29 per cent in crude protein content (Aryeetey, 1971; Steckle, 1975). It forms part of the diet of most Nigerians because of the high cost of animal protein. The dry seeds are prepared and eaten in many forms such as 'moin-moin', 'akara', or boiled. The leaves, stems and hulls are also good livestock feed.

Yayock and Asenime (1977) estimated that over eighty per cent of the total cowpea produced in Nigeria are grown in the northern part within latitude 10°N to 15°N by small scale farmers who intercrop it with other crops especially millet and sorghum. Its yield averaged about 180kg/ha (Watson, 1964). Thus the farmers' field yields are very low due to a number of production constraints such as the use of unimproved photosensitive local types, insect pests, low plant population and diseases.

Cowpea is a predominantly self-pollinated crop and studies so far have shown that it responds to yield improvement through selection. Research results have shown that yields of 1500-1800kg/ha are possible if improved varieties of cowpea are grown as a sole crop and adequately protected against diseases and insect pests (Anonymous, 1975b).

Yield is a very important trait in crops. In breeding to increase the inherent yielding ability of a crop, the selection criterion may be yield directly or indirectly through its components. Thus in initiating an improvement programme for cowpea yield, selection of superior genotypes may be based on phenotypic appearances which may be subject to fluctuating environmental factors. The knowledge of genotypic and phenotypic correlations that exist between characters in a segregating population is thus important if progress is to be made in selecting superior genotypes from the population. Most characters of economic importance, such as yield, are complex in inheritance, difficult to select for directly and involve several related characters. The correlations that exist between such characters are not only of interest from a theoretical point of inheritance of the characters, but of practical value in indirect selection. Therefore an understanding of the correlations between yield

components and their associations with yield as well as the heritability of each character is necessary for the intelligent choice of breeding procedures for the breeding of high-yielding varieties. The main objective of the present study is to investigate the correlations among yield components and the association between each and yield. A second objective is to investigate the heritability and mode of inheritance of the yield components.

CHAPTER 2

REVIEW OF LITERATURE

2.1 Phenotypic (r_{ph}) and Genotypic (r_g) Correlations of Yield and Yield Components

Correlation studies give the nature and magnitude of association of characters. Therefore the knowledge of correlation coefficients is very useful in plant breeding for indirect selection of characters that show low heritability and/or are difficult to measure (Cuatero and Cubero, 1982). Direct selection based on the phenotypic performance of yield, a polygenically controlled complex character, is usually not very effective and reliable but that based on its components could be more effective (Waldia et al., 1980).

Kheradnam and Niknejad (1974) reported yield to be significantly and positively correlated with seed size (100-seed weight) (0.330), number of seeds per pod (0.540), number of clusters per plant (0.420), number of pods per plant (0.820) and insignificantly but positively correlated with number of branches per plant and concluded that for yield improvement in cowpea, number of pods per plant and number of seeds per pod have selection value equal to seed yield per plant, whereas seed size and number of clusters per plant

have less selection value. Singh et al. (1982) reported significant positive correlations between grain yield per plant and days to flowering (0.404), cessation of flowering (0.405), days to maturity (0.434), plant height (0.517), number of pods per plant (0.639), pod length (0.341), number of grains per pod (0.670) and seed size (0.433). They concluded that in cowpea, pods per plant, grains per pod and seed size were the important yield components.

Highly significant positive correlations in cowpea between seed yield and pods per plant, seeds per pod and seed size in the F_2 were reported by Virupakshappa et al. (1980). They pointed out that while the strength of correlations between seed yield and pods per plant of the backcross 1 (BC_1) was more than that of the F_2, no correlation was found between seed yield and seed size. The magnitude of correlation between seed yield and seeds per pod remained the same in all the three generations. The correlations between pods plant and seed size and seeds per pod were not significant in any generation. The strength of association between seed size and seeds per pod varied with the generation. While there were significant positive correlations in the F_2 and BC_2 the association was negligible in BC_1.

Pandita et al. (1982) reported that yield per plant had the highest genotypic and phenotypic coefficients of variation and that a wide range of variation occurs for yield per plant, days to flowering and plant height in cowpea. A wide range of phenotypic variability for all yield components, a high genetic coefficient of variability for branches per plant, pods per plant, yield per plant and peduncle length in cowpea were found by Trehan et al. (1970). They reported that grain yield per plant was significantly and positively correlated with peduncle length and concluded that selection and improvement for characters such as peduncle length, pods per plant and yield per plant can be based on phenotypic performance.

Singh and Mehndiratta (1969) found an appreciable expected genetic advance for number of clusters of pods per plant (48.11%), seed size (51.96%), pod number (31.59%), pod length (27.69%), and yield (27.57%) in cowpea. Seed

yield was found to be significantly correlated with number of pods per plant (r_{ph} = .434), seeds per pod (r_{ph} = 0.555, r_g = 0.923) and seed size (r_{ph} = 0.399, r_g 0.388). Seed size was positively correlated with number of seeds per pod (r_{ph} = 0.374, r_g = 0.608) but was negatively correlated with number of pods per plant (r_{ph} = -0.445, r_g = -0.612). There were also high correlations between number of pods per plant and days to flowering (r_{ph} = 0.683, r_g = 0.746). Deku (1970) reported significant associations between yield per plant and number of pods per plant (r_{ph} = 0.692, r_g = 0.599) and fruiting period (r_{ph} = 0.692, r_g = 0.822) and a non-significant negative correlation between seed size and number of pods per plant (r_{ph} = -0.215, r_g = -0.256) in cowpea.

Significant and positive phenotypic correlations of pod length with seed size (0.450) and number of seeds per pod (0.730) in the F_2 of a cowpea cross were reported by Aryeetey and Laing (1973). Number of seeds per pod was significantly and negatively correlated with seed size (-0.350) whereas number of pods per plant was non-significantly and positively correlated with number of seeds per pod (0.060) and non-significantly and negatively

correlated with seed size (-0.119). They also reported significant positive genotypic associations of yield per plant with number of pods per plant (0.890), number of seeds per pod (0.970) and seed size (0.970) in a non-segregating population of twenty-two cowpea varieties. They reported that number of pods per plant was consistently correlated with yield but concluded that because of its low heritability it may only be used as a preliminary selection criterion while the final selection is based on yield itself. Working with cowpea varieties, Bliss et al. (1973) reported significant and negative correlations between number of pods per plant and seed size (r_{ph} = -0.740, r_g = -1.360) and number of seeds per pod (r_{ph} = -0.010, r_g = 0.020). The correlation between seeds per pod and seed size was also negative and non-significant (r_{ph} = -0.290, r_g = -0.310) according to them.

In urd bean (Vigna mungo (L.) Hepper), Waldia et al. (1980) reported that phenotypic correlations were significant and positive between seed yield per plant and number of clusters per plant (r_{ph} = 0.510, r_g = 0.674) and number of pods per plant (r_{ph} = 0.897, r_g = 0.640). The latter two

characters were also positively associated with each other (r_{ph}= 0.913, r_g= 0.736). Seed size, though not significant, was positively correlated with yield (r_{ph} = 0.170, r_g = 0.274). Number of branches per plant was found to be positively and significantly correlated with number of clusters (r_{ph} = 0.322, r_g = 0.373) and positively and insignificantly with pods per plant (r_{ph} = 0.211, r_g = 0.101). Pods per plant was positively but insignificantly correlated with seed size (r_{ph} = 0.003, r_g = -0.114). In general, genotypic values were higher than the corresponding phenotypic values for twelve character combinations and they concluded that enironmental factors adversely affected the expression of the phenotypic associations.

In twenty-eight F_1 hybrids involving twelve varieties of blackgram (Phaseolus mungo L.), Sagar and Lal (1979) observed a significant and positive genotypic correlation of yield with all yield components except number of seeds per pod. Muthiah and Sivasubramanian (1981) also found pod number and cluster number to be positively correlated with each other and with all other yield components except seed size in blackgram. They concluded that pod yield (weight) and pod number were the most

important traits determining seed yield per plant. In soyabean (Glycine max (L.) Merrill), Kuun et al. (1974) reported seed yield to be positively correlated with seed size but negatively correlated with days to flowering, maturation period and plant height. In soyabean, Hanway (1956) also observed positive correlation of seeds per pod and seed size with yield. Weber and Moorthy (1952) noted consistent significant and positive correlations between yield and maturity, period from flowering to maturity, height and seed size in three F_2 generations of soyabean. Relatively high positive correlations were found between flowering time and maturity date in all the three F_2 populations. They also reported that, in general, genotypic correlations were larger than phenotypic correlations.

Yassin (1973) reported that yield/plot was significantly and positively correlated with number of pods/plant (r_{ph}=0.859, r_g= 0.986) and yield per plant (r_{ph} = 0.584, r_g = 0.763) but negatively and significantly correlated with seed size (r_{ph} = -0.715, r_g =-0.773) in field beans (Vicia faba L.). Number of pods per plant and seed size were significantly but negatively correlated (r_{ph} = -0.890, r_g = -0.940). Significant and positive correlation between seed yield per plant with weight of pods per plant (r_{ph} = 0.940) and with

number of pods per plant (r_{ph} = 0.950) in field beans were also observed by Salem (1982). He noted significant and positive correlations between number of seeds per pod and pod length (r_{ph} = 0.730) and between number of seeds per pod and seed size (r_{ph} = 0.920) and concluded that these components could be used to improve seed yield indirectly.

Significant and positive correlations between days to flowering and pods per plant (r_{ph} = 0.340, r_g = 0.740), seeds per pod (r_{ph} = 0.250, r_g = 0.670) seeds per plant (r_{ph} = 0.380, r_g = 0.900) and yield per plant (r_{ph} = 0.250, r_g = 0.610) were obtained by Pandey and Gritton (1975) in peas (Pisum sativum L.). Pods per plant was significantly and positively correlated with seeds per plant (r_{ph} = 0.910, r_g = 0.940) and yield per plant (r_{ph} = 0.440, r_g = 0.180) whereas seeds per pod was associated with seeds per plant (r_{ph} = 0.470, r_g = 0.410) and yield per plant (r_{ph} = 0.530, r_g = 0.580). They also found yield per plant to be positively associated with seeds per plant (r_{ph} = 0.600, r_g = 0.380).

2.2 Heritability and Mode of Inheritance of Yield Components.

Heritability is a function of the character as well as the environment and the population, thus heritability estimate applies to a character in a specific situation or condition. Its most important value lies in its predictive role in expressing the reliability of the phenotypic value as a measure of the breeding value. A high heritability estimate, especially the narrow sense heritability (NSH), in a character indicates that selection could improve the character.

Grain yield in cowpea is to a large extent determined by its yield components, number of pods per plant, number of seeds per pod and average seed size or 100-seed weight (Singh and Mehndiratta, 1970, Aryeetey and Laing, 1973). Lelej i (1975) reported that in a cross between large and small seeded parents in cowpea, small seeds appeared to be partially dominant and that broad-sense estimates of heritability (BSH) for seed size ranged from 49% to 82%. He pointed out that selection for seed size would be very effective starting from the F_2 generation and that there is transgressive segregation for small

seeds. He also reported that fewer number of seeds was partially dominant over larger number of seeds and that there was a transgressive segregation for fewer number of seeds and estimates of broad sense heritability for number of seeds ranged between 16% to 83%.

Singh and Mehndiratta (1969) reported high heritability for seed size (95.90%), days to flowering (88.79%), days to maturity (78.90%), number of clusters per plant (50.51%), number of pods per plant (56.07%), pod length (80.45%) and number of grains per pod (64.17%). Likewise, Kheradnam and Niknejad (1974) reported that heritability values in cowpea were 75.00% for seed size, 64.00% for number of seeds per pod, 47.00% for number of clusters per plant, 44.00% for number of pods per plant, 35.00% for yield per plant and 15.00% for number of branches per plant. Trehan et al. (1970) obtained medium values of heritability for all yield components and high genetic coefficient of variation for the traits, number of branches per plant, number of pods per palnt, yield per plant and peduncle length. Genetic advance as per cent of mean value was highest for number of pods per plant. They

concluded that selection and improvement for peduncle length, number of pods per plant and yield per plant can be based on phenotypic performance.

Broad sense heritability estimates were reported by Aryeetey and Laing (1973) to be 60.70% for pod length, 47.80% for number of seeds per pod, 63.00% for seed size and 28.20% for number of pods per plant and narrow sense estimates of hertability for the characters were, 60.30% for pod length, 37.80% for number of seeds per pod, 37.40% for seed size and 19.80% for number of pods per plant. They pointed out that selection for pod length, number of seeds per pod and seed size was likely to be successful because of their fairly high narrow sense heritability estimates. Because of the low narrow sense estimate of heritability for number of pods per plant, it is apparent that selection for this character will be difficult as high environmental influence would be a problem. Doku (1970) found high broad sense estimates of heritability for the characters, seed size (78.13%), mean number of pods per plant (93.50%) and mean seed weight per plant (80.35%). Phenotypic coefficients of variation for the characters were 25.76%, 47.24% and 45.19%, respectively. He reported genotypic coefficients of variation for the three

characters as, seed size (24.65%), mean number of pods per plant (46.68%) and mean seed weight per plant (44.03%).

Fery (1985), in a review of the genetics of cowpea, remarked that reported heritability estimates were highly erratic but that the averages for the various characters were, 53.10% for number of pods per plant, 52.80% for number of seeds per pod, 45.55% for number of seeds per plant, 45.00% for yield per plant, 48.30% for days to flowering and 67.80% for seed size. The ranges for the characters were, 7.00-98.90% for number of pods per plant, 9.60-98.90% for number of seeds per pod, 35.80-55.30% for number of seeds per plant, 12.00-80.80% for yield per plant, 3.80-94.30% for days to flowering and 3.80-98.90% for seed size. From a cowpea cross between small and large seeded parents, Drabo et al. (1984) reported that the broad and narrow sense heritability estimates for seed size were 85.10 ± 5.30% and 75.40 ± 18.60%, respectively. Seed size was inherited quantitatively and small seed size was partially dominant to large seed size.

In a heritability study of seed size in three crosses of chickpea (Cicer arietinum L.), it was reported that the narrow sense estimate of heritability in a cross,

large x large, was 50,00%, in small x small, was 30.00% and in large x small, was 85.00% (Anonymous, 1975a). These high heritability values indicate that seed size is a highly heritable trait and that selection could improve the character. Medhi et al. (1980) found high broad sense estimates of heritability for the characters, seed size (99.43%), seed yield per plant (99.19%), seeds per pod (98.90%), effective branches per plant (89.23%) and clusters per plant (90.38%) in green gram (Vigna radiata (L.) Wilczek). They noted an association between high heritability estimates and high corresponding values of expected genetic advance for number of effective branches bearing pods, number of clusters per plant, seeds per pod, seed size and seed yield per plant. This is an indication of predominance of additive gene action and that mass selection based on phenotypic value can be useful for improving these characters. On the other hand, the high heritability estimates for days to flowering (94.37%) and days to maturity (96.19%) in conjunction with the low expected genetic advance, they reported, indicate the predominance of non-additive gene effects. They concluded that judicious application of pure-line selection may prove effective in improving these two characters in green gram. Yassin (1973) reported that broad

sense heritability estimates for three characters were, 28.70% (yield per plant), 54.70% (pods per plant) and 93.70% (seed size) in field beans (Vicia faba L.).

CHAPTER 3

MATERIALS AND METHODS

3.1 Experimental Materials

Cowpea (*Vigna unguiculata* (L.) Walp) varieties originating from diverse backgrounds were used in this study. Their origin and brief descriptions are as follows:

P_1: K59. This variety was released by the National Cereals Research Institute (N.C.R.I.), Ibadan (now Badeggi), Nigeria. It is upright in growth habit and has brown medium seeds. It has a rough seed coat and is photo-insensitive and high yielding.

P_2: Tvx3000. A small seeded variety originating from the International Institute of Tropical Agriculture (I.I.T.A.), Ibadan, Nigeria. It is aphid-resistant and has smooth white seed coat with a brown eye. It is semi-upright in growth habit and photo-insensitive.

P_3: Kano 1696. An improved local variety released by the Institute for Agricultural Research (I.A.R.), Samaru, Zaria, Nigeria; spreading in growth habit, photosensitive and high yielding. It has large white seeds with prominent black eyes and rough seed coats.

3.2 Experimental Methods

Crosses were made in the field at Samaru during the 1983 growing season among the three parent materials. The F_1 hybrids were advanced to the F_2 generation during the 1983/84 off-season under irrigation. The resulting nine populations, made up of the three parents, three F_1 hybrids and three F_2 progenies were evaluated in this study. The materials were planted at the Institute for Agricultural Research farm at Samaru (11^{o} 11'N, 7^{o} 38'E, altitude 686m) in July of 1984 and 1985.

3.3 Experimental Design

In both years, the design was a Randomized Complete Block Design (RCBD) with 4 replicates. In 1984, plots were 4 rows, for the parental materials; 1 row, for the F_1 hybrids; and 6 rows for the F_2 generations. Single seeds were spaced 60cm apart on 6m long ridges 75cm apart.

In 1985, parental plots were 4 rows, the F_1 hybrids were treated like the parental materials; and the F_2 plots consisted of 10 rows. Spacing within and between ridges were as in 1984.

3.4 Cultural Practices

Single superphosphate was broadcast at the rate of 200kg/ha. The land was then ploughed, harrowed and ridged. Dimethoate (Rogor 40EC) and cypermethrin (Cymbush 10EC) were applied at the rate of 1 l/ha each at weekly intervals at the commencement of flowering until maturity in order to control insect pests. The fungicides, benlate and dithane M-45 were applied three times at the rate of 15g and 62.5g/10 l of water, respectively, for the control of fungal diseases. The insecticides and fungicides were mixed for the sprays. Weeding was done as often as was necessary.

3.5 Data Collection

Twenty plants were randomly selected across replications (5plants from each replication) in the parentals and F_1 hybrids whereas all individuals in the segregating generations (F_2s) were utilized. Data were collected on single plant basis on the following six characters:-

(i) Number of pods per plant (NPPP) - Taken as the total number of fully-formed ripe pods at harvest.

(ii) Number of seeds per plant (NSPP) - The total number of well-formed seeds after threshing the harvested pods for each plant.

(iii) Yield per plant (YP) - Weight (grams) of seed per plant.

(iv) Days to flowering (DTF) - Number of days from sowing to the day the first flower opened for each plant.

(v) Number of seeds per pod (NSPD) - This was obtained by dividing the total number of seeds per plant (ii) by the total number of pods per plant (i).

(vi) Seed size - weight (in grams) of 100-seeds calculated as

$$\frac{\text{Yield per plant (iii)}}{\text{Number of seeds per plant (ii)}} \times \frac{100}{1}$$

3.6 Statistical Analysis

Individual plant data were used in the computations for each character. Data were not analyzed by the conventional ANOVA method. Data from each replication were pooled and population parameters (means, standard deviation, variances, covariances and coefficient of variation) were calculated for each generation without taking replication effect into consideration. This was

because the analyses of variance done on each of the three different groups (parentals, F_1s and F_2s), on plot basis, showed that replication effect was not significant in most of the characters. Data from each year were analyzed separately and for the combined analysis, data for the two years were simply pooled.

F_2 genotypic variance and covariance for each character studied in each cross were calculated by subtracting the environmental variance and covariance from the total F_2 variance and covariance. The cube root of the product of parental and F_1 variances and covariances was used as the best estimate of both environmental variance and covariance (Weber, 1950, Weber and Moorthy, 1952). This was on the assumption that environmental variances and covariances based on non-segregating generations may be equivalent to those in a segregating generation.

The F_2 phenotypic variances for two characters, A and B and the covariance between A and B may be represented symbolically as follows:-

$$\sigma^2_{A_{F_2}} = \sigma^2_{A_G} + \sigma^2_{A_E}$$

$$\sigma^2_{B_{F_2}} = \sigma^2_{F_G} + \sigma^2_{B_E}$$

$$COV_{AB_{F_2}} = COV_{AB_G} \times COV_{AB_E}$$

where

$\sigma^2_{A_{F_2}}$ and $\sigma^2_{B_{F_2}}$ = total F_2 variance observed in characters A and B, respectively.

$\sigma^2_{A_G}$ and $\sigma^2_{A_E}$ = genotypic and environmental variances, respectively, of character A.

COV_{AB_G} and COV_{AB_E} = genotypic and environmental covariances, respectively, between characters A and B.

$\sigma^2_{B_G}$ and $\sigma^2_{B_E}$ = genotypic and environmental variances, respectively, of character B.

$\sigma^2_{A_E}$, $\sigma^2_{B_E}$ and COV_{AB_E} = environmental portions (calculated from parental and F_1 values.)

(Weber and Moorthy, 1952).

Broad sense heritability (BSH) estimates for the characters were calculated from F_2, parental and F_1 hybrid variances using the formulae suggested by Mahmud and Kramer (1951) and Weber and Moorthy (1952).

$$BSH = \frac{\sigma_{F_2}^2 - \sigma_E^2}{\sigma_{F_2}^2} \times 100$$

where

$$\sigma_{F_2}^2 = \sigma_G^2 + \sigma_E^2, \quad \sigma_E^2 = \sqrt[3]{\sigma_{P_1}^2 \times \sigma_{P_2}^2 \times \sigma_{F_1}^2}$$

Phenotypic (r_{ph}), genotypic (r_g) and environmental (r_e) correlation coefficients between a pair of characters, A and B, were computed using the equations given by Weber and Moorthy (1952).

$$\text{Phenotypic } r_{AB} = \frac{COV_{AB_{F_2}}}{\sqrt{\sigma_{A_{P_2}}^2 \times \sigma_{B_{F_2}}^2}}$$

$$\text{Genotypic } r_{AB} = \frac{COV_{AB_G}}{\sqrt{\sigma_{A_G}^2 \times \sigma_{B_G}^2}}$$

$$\text{Environmental } r_{AB} = \frac{COV_{A_{B_E}}}{\sqrt{\sigma_{A_E}^2 \times \sigma_{B_E}^2}}$$

Genetic (GCV), phenotypic (PCV) and environmental (ECV) coefficients of variation in the F_2 generation for each character were calculated by the formulae suggested by Burton (1952).

$$GCV = \frac{\sqrt{\sigma^2_{G_{F_2}}}}{\bar{X}} \times 100$$

$$PCV = \frac{\sqrt{\sigma^2_{F_2}}}{\bar{X}} \times 100$$

$$ECV = \frac{\sqrt{\sigma^2_{E_{F_2}}}}{\bar{X}} \times 100$$

where,

$\sigma^2_{G_{F_2}}$ = genotypic variance of a character in a particular F_2 generation.

$\sigma^2_{F_2}$ = total F_2 variance observed in a character.

$\sigma^2_{E_{F_2}}$ = environmental variance for a character obtained from parental and F_1 variances.

$\bar{X}$ = mean of a character.

Frequency distributions were obtained for all characters in the three crosses evaluated for each year separately. Indications of mode of gene action governing the inheritence of particular characters were shown by comparing the mean performances of the generations.

CHAPTER 4

RESULTS

4.1 Mean Performance

The mean values of the generations for number of pods per plant indicate that the F_1 was better than both parents in all the crosses in 1984, in one cross in 1985 and in all crosses evaluated when combined over the two years (Tables 1, 2 and 3, respectively). In all crosses in 1984, the F_1 value was higher than the mid-parent (MP) values. The F_1 values also exceeded the better parents in the three crosses. This indicates over-dominance of the better parent. This was also the case in the combined mean performances. However, in 1985, the F_1 values were higher than the mid-parent values in all three crosses but exceeded the better yielding parent in only two crosses, K59 x Tvx3000 and K59 x 1696. This again indicated over-dominance of the better yielding parent. In Tvx3000 x 1696 in 1985, the F_1 value was higher than the MP value but lower than the better parent, which indicates partial dominance of the better yielding parent. The F_2 mean values were lower than the corresponding F_1 means in all crosses in both years.

Table 1. Mean performance of four generations for six traits in three cowpea crosses in 1984.

Cross	Genera-tion	Character* NPPP	NSPP	YP(g)	DTF	NSPD	SS(g)	N
K59	P_1	35.9±2.6	382.6±25.2	39.8±2.5	46.8±0.9	10.9±0.4	10.5±0.3	20
x	P_2	33.3±2.0	384.1±26.9	23.7±1.6	43.8±0.8	11.5±0.4	6.3±0.3	20
Tvx3000	MP	34.6	383.4	31.8	45.3	11.2	8.4	
	F_1	62.7±1.8	668.5±21.9	66.5±2.7	43.5±0.8	10.7±0.2	9.9±0.3	20
	F_2	38.3±1.2	422.7±13.6	35.6±0.4	49.2±0.4	11.2±0.1	8.5±0.1	205
	$LSD_{(0.05)}$	8.4	86.9	8.1	2.1	1.2	0.7	
K59	P_1	35.9±2.6	382.6±25.2	39.8±2.5	46.8±0.9	10.9±0.4	10.5±0.3	20
x	P_2	48.1±3.0	517.0±37.0	98.1±9.2	62.8±2.1	10.7±0.3	18.6±0.8	20
1696	MP	42.0	449.8	69.0	54.8	10.8	14.6	
	F_1	80.2±3.5	824.0±37.5	124.1±6.0	50.0±0.8	10.3±0.2	15.1±0.4	20
	F_2	34.5±1.5	382.4±15.9	56.8±2.3	52.0±0.5	11.4±0.1	15.2±0.2	182
	$LSD_{(0.05)}$	19.6	200.3	35.4	7.1	0.8	1.9	
Tvx3000	P_1	33.3±2.0	384.1±26.9	23.7±1.6	43.8±0.8	11.5±0.4	6.3±0.3	20
x	P_2	48.1±3.0	517.0±37.0	98.1±9.2	62.8±2.1	10.7±0.3	18.6±0.8	20
1696	MP	40.7	450.6	60.9	53.3	11.1	12.5	
	F_1	68.2±2.1	725.1±28.2	79.0±3.7	47.0±0.7	10.6±0.3	10.9±0.4	20
	F_2	38.8±1.2	429.5±13.0	40.1±1.3	49.8±0.4	11.3±0.1	9.4±0.1	206
	LSD(0.05)	12.1	153.2	28.7	5.3	1.6	1.9	

* NPPP - Number of pods per plant; NSPP - Number of seeds per plant; $YP_{(g)}$ - Yield per plant in grams; DTF - Number of days to flowering; NSPD - Number of seeds per pod; $SS_{(g)}$ - Seed size (100-seed weight) in grams.

Table 2: Mean performance of four generations for six traits in three cowpea crosses in 1985.

Cross	Genera-tion	Character* NPPP	NSPP	$YP_{(g)}$	DTF	NSPD	$SS_{(g)}$	N
K59	P_1	48.0±2.5	496.0±27.0	55.4±3.2	46.4±1.0	10.3±0.9	11.2±0.3	20
x	P_2	35.5±2.4	361.8±24.5	23.5±1.6	45.8±0.6	10.2±0.3	6.6±0.8	20
Tvx3000	[illegible]	41.8	428.9	39.5	46.1	10.3	8.9	
	F_1	66.4±1.4	747.7±19.8	70.7±2.3	43.9±0.3	11.3±0.2	9.5±0.2	20
	F_2	46.1±1.2	488.8±13.7	45.7±1.3	53.3±0.3	10.5±0.1	9.4±0.1	308
	$LSD_{(0.05)}$	8.1	102.2	11.7	1.8	1.0	0.8	
K59	P_1	48.0±2.5	496.0±27.0	55.4±3.2	46.4±1.0	10.3±0.9	11.2±0.3	20
x	P_2	63.6±2.3	611.6±32.7	119.0±7.9	62.5±1.4	9.6±0.3	19.4±0.6	20
1696	[illegible]	55.8	553.8	87.2	54.5	10.0	15.3	
	F_1	67.6±1.9	695.2±21.7	109.6±3.7	51.9±0.7	10.3±0.2	15.8±0.3	20
	F_2	40.7±1.0	396.1±10.1	57.9±1.6	54.3±0.3	9.8±0.1	14.7±0.2	359
	$LSD_{(0.05)}$	8.3	91.5	19.7	4.1	0.9	1.8	
Tvx3000	P_1	35.5±2.4	361.8±24.5	23.5±1.6	45.8±0.6	10.2±0.3	6.6±0.8	20
x	P_2	63.6±2.3	611.6±32.7	119.0±7.9	62.5±1.4	9.6±0.3	19.4±0.6	20
1696	[illegible]	49.6	486.7	71.3	54.2	9.9	13.0	
	F_1	58.9±2.9	639.4±34.4	70.3±4.0	46.9±0.8	10.9±0.3	11.0±0.2	20
	F_2	38.3±1.0	386.8±10.1	55.5±2.0	51.4±0.3	10.1±0.1	14.0±0.1	371
	$LSD_{(0.05)}$	10.8	106.0	16.3	4.4	1.2	1.3	

* NPPP - Number of pods per plant; NSPP - Number of seeds per plant; $YP_{(g)}$ - Yield per plant in grams;
DTF - Number of days to flowering; NSPD - Number of seeds per pod; $SS_{(g)}$ - Seed size (100 - seed weight) in grams.

Table 3: Mean performance of four generations for six traits in three cowpea crosses combined over two years.

Cross	Genera-tion	Character* NPPP	NSPP	YP(g)	DTF	NSPD	SS(g)	N
K59	P_1	42.0±1.1	439.3±10.8	47.6±1.2	46.6±0.2	10.6±0.1	10.8±0.1	40
x	P_2	34.4±0.9	372.9±10.2	23.6±0.6	44.8±0.2	10.9±0.1	6.4±0.1	40
Tvx3000	MP	38.2	406.1	35.6	45.7	10.8	8.7	
	F_1	64.7±1.5	708.1±18.7	68.6±1.7	43.7±0.3	11.0±0.1	9.7±0.1	40
	F_2	42.3±0.9	455.3±9.9	40.6±0.9	51.3±0.3	10.8±0.1	8.9±0.1	513
	LSD(0.05)	8.0	84.9	9.0	1.5	0.8	0.4	
K59	P_1	42.0±1.1	439.3±10.8	47.6±1.2	46.6±0.2	10.6±0.1	10.8±0.1	40
x	P_2	55.8±1.0	564.3±11.4	108.5±2.6	62.6±0.5	10.1±0.1	19.0±0.2	40
1696	MP	48.9	501.8	78.1	54.6	10.4	15.0	
	F_1	73.9±1.7	759.6±17.6	116.8±2.9	50.9±0.3	10.3±0.1	15.4±0.3	40
	F_2	37.0±0.8	380.4±8.6	55.7±1.3	52.0±0.3	10.4±0.1	14.6±0.1	541
	LSD(0.05)	10.0	93.5	13.9	2.4	0.5	1.1	
Tvx3000	P_1	34.4±0.9	372.9±10.2	23.6±0.6	44.8±0.2	10.9±0.1	6.4±0.1	40
x	P_2	55.8±1.0	564.3±11.4	108.5±2.6	62.6±0.5	10.1±0.1	19.0±0.2	40
1696	MP	45.1	468.6	66.1	53.7	10.5	12.7	
	F_1	63.6±1.4	682.2±17.2	74.6±2.0	46.9±0.3	10.7±0.1	11.0±0.1	40
	F_2	40.4±0.7	404.9±8.0	47.4±1.1	50.4±0.2	10.2±0.1	11.8±0.1	577
	LSD(0.05)	6.8	79.9	8.3	2.4	0.9	1.1	

*NPPP - Number of pods per plant; NSPP - Number of seeds per plant; $YP_{(g)}$ - Yield/plant in grams; DTF - Number of days to flowering; NSPD - Number of seeds per pod; $SS_{(g)}$ - Seed size (100-seed weight) in grams.

The same trend in performance is exhibited for number of seeds per plant. The F_1 means were higher than the parental means in all crosses in both years. The F_1 values also exceeded both the MP values and better parents in all crosses in the two years individually, and when combined. Over-dominance is therefore suggested for this character in all crosses.

The mean performances of the various generations for yield per plant show that the F_1 was higher than both the MP and higher yielding parent in crosses 1 & 2 in 1984 and in the cross, K59 x Tvx3000 in 1985 but exceeded only the MP but was closer to the higher parent in one cross in 1985 (K59 x 1696). In Tvx3000 x 1696 in 1985, the F_1 was lower than the MP but higher than the lower yielding parent: this suggests partial dominance of the higher yielding parent. The former case is suggestive of over-dominance in two crosses, K59 x Tvx3000 and K59 x 1696 in 1984 as well as partial dominance of the higher yielding parent in Tvx3000 1696. Over-dominance is also apparent in K59 x Tvx3000 in 1985 while partial dominance of the higher yielding parent is seen in the remaining two crosses. For the combined mean performances, the F_1 was higher than the MP in all crosses, was higher than the better

yielding parent in K59 x Tvx3000 and K59 x 1696, suggesting over-dominance but lower than the higher yielding parent in Tvx3000 x 1696, suggesting partial dominance of the higher yielding parent. F_2 mean values for yield per plant were lower than their corresponding F_1 means in both years and when combined.

The trend in the performances of the various generations for days to flowering is such that the F_1 was intermediate between the two parents in all the crosses evaluated in both years and when combined. In all crosses in both years, and when combined, the F_1 was lower than the MP value but closer to the earlier flowering parent. This shows that early flowering is partially dominant over late flowering. The means of the F_2 generally increased when compared to the F_1 means in all crosses in both years and when combined. The F_2 and F_1 means were similar to the MP suggesting that gene action for this character is primarily additive.

The mean values of the generations for number of seeds per pod indicate that the F_1 was intermediate between the two parents in most of the crosses,

although the differences in the means of the three parents used in this study were not statistically significant. F_1 means in 1984 were lower than the MP values but closer to the parent with lesser number of seeds in all three crosses. This is suggestive of partial dominance of fewer number of seeds over larger number of seeds per pod. In 1985 and in the combined mean performances, however, the F_1 was higher than the MP in crosses 1 & 3. Over-dominance of larger number of seeds per pod is indicated in K59 x Tvx3000 and Tvx3000 x 1696 and complete dominance of larger number of seeds in K59 x 1696 in 1985. The combined mean performances show that the F_1 was larger than MP values but closer to the larger parent in two crosses (1& 3). This indicates that larger number of seeds per pod is partially dominant over fewer number of seeds. F_2 mean values were higher than their corresponding F_1 means in all crosses in 1984 but lower than the F_1 means in 1985 and when combined for the two years, suggesting the role of epistatic gene effects for this character.

The trend in the performances of the generations for seed size shows that the F_1 was intermediate between the two parents in both years. F_1 means were also higher than the MP values in K59 x Tvx3000 and

K59 x 1696 in both years. In all crosses in both years, F_1 means were closer to the larger seeded parent, which indicates partial dominance of the larger seeded parent.

In the characters, number of pods per plant, number of seeds per plant, yield per plant and seed size, the F_1 means exceeded the arithmetic MP values. This means that the F_1 hybrids exhibited heterosis for these characters.

4.2 Frequency Distributions

The results for number of pods per plant indicate that the F_1 distributions have surpassed the parentals in all the crosses evaluated in both years (Table 4). The F_2 distribution is unimodal in all crosses in both years and exhibited positive skewness (towards the parent with lesser pods). There was transgressive segregation in all crosses in both directions in the two years.

Table 5 shows the distribution of number of seeds per plant. The F_1 distribution exceeded the better parent in all crosses in both years.

Table 4: Frequency distribution of number of pods/plant in three cowpea crosses in 1984 and 1985.

Cross		Year	Classes of number of pods															N	Mean	S.D.	C.V.(%)
			1-9	10-18	19-27	28-36	37-45	46-54	55-63	64-72	73-81	82-90	91-99	100-108	109-117	118-126	127-135				
	P_1	1984		2	4	4	5	4	1									20	35.9	11.7	32.59
		1985			1	2	5	6	5	1								20	48.0	11.1	23.12
K59	P_2	1984			5	9	4	2										20	33.3	9.0	27.03
x		1985		1	3	6	6	4										20	35.5	10.8	30.42
Tvx3000	F_1	1984						2	7	8	3							20	62.7	8.1	12.92
		1985							6	10	4							20	66.4	6.2	9.34
	F_2	1984	5	21	38	34	51	17	18	10	8	2	1					205	38.3	18.0	47.00
		1985	1	18	35	50	48	62	41	20	19	7	1	4	-	1	1	308	46.1	20.6	44.69
	P_1	1984		2	4	4	5	4	1									20	35.9	11.7	32.59
		1985			1	2	5	6	5	1								20	48.0	11.1	23.12
K59	P_2	1984			2	2	4	6	3	3								20	48.1	13.6	28.27
x		1985					1	2	8	6	3							20	63.6	10.2	16.04
1696	F_1	1984						2	2	2	6	3	2	2	1			20	80.2	15.7	19.58
		1985						2	5	7	5	1						20	67.6	8.7	12.87
	F_2	1984	7	32	40	28	22	26	12	5	4	3	1	2				182	34.5	20.2	58.55
		1985	6	29	63	62	66	53	36	22	13	5	1	3				359	40.7	19.0	46.68

Table 4: (Cont'd)

Cross		Year	Classes of number of pods															N	MEAN	S.D	C.V(%)
			1-9	10-18	19-27	28-36	37-45	46-54	55-63	64-72	73-81	82-90	91-99	100-108	109-117	118-126	127-135				
	P_1	1984			5	9	4	2										20	33.3	9.0	27.03
		1985		1	3	6	6	4										20	35.5	10.8	30.42
Tvx3000	P_2	1984			2	2	4	6	3									20	48.1	13.6	28.27
x		1985					1	2	8	6	3							20	63.6	10.2	16.04
1696	F_1	1984						2	4	8	3	3						20	68.2	9.6	14.08
		1985				2	1	2	5	8	2							20	58.9	13.1	22.24
	F_2	1984	1	14	37	42	53	34	7	12	2	1	1	-	-	1	1	206	38.9	17.3	44.47
		1985	4	40	65	85	61	53	28	17	9	2	5	2				371	38.3	18.5	48.30

Table 5: Frequency distribution of number of seeds per plant in three cowpea crosses in 1984 and 1985.

Cross	Year	Classes of number of seeds																N	MEAN	S.D	C.V(
		23-121	122-220	221-319	320-418	419-517	518-616	617-715	716-814	815-913	914-1012	1013-1111	1112-1210	1211-1309	1310-1408	1409-1507	1508-1606				
	P_1 1984		1	6	3	8	2											20	382.6	112.6	29.1
	1985		1	1	2	7	6	2	1									20	496.0	120.7	24.
K59	P_2 1984		2	5	6	4	2	1										20	384.1	120.4	31.
x	1985		2	6	6	4	2											20	361.8	109.4	30.
Ty-3070	F_1 1984					1	5	9	3	1	1							20	668.5	98.0	14.
	1985							10	5	4	1							20	747.7	88.5	11.
	F_2 1984	5	27	37	38	42	21	21	6	5	2	1						205	422.7	195.0	46.
	1985	10	28	46	43	62	41	30	23	11	9	-	1	-	2	2		308	488.8	235.2	48.
	P_1 1984		1	6	3	8	2											20	382.6	112.6	29.
	1985		1	1	2	7	6	2	1									20	496.0	120.7	24.
K59	P_2 1984		1	1	2	8	1	5	1	1								20	517.0	165.6	32
x	1985				1	3	9	4	2	-	-	1						20	611.6	146.1	23
1696	F_1 1984						3	2	6	2	3	4						20	824.0	166.9	20
	1985					1	3	7	8	1								20	695.2	97.2	13
	F_2 1984	11	38	37	28	23	20	12	5	4	1	2	1					182	382.4	214.0	55
	1985	18	49	79	71	65	31	21	15	4	3	2	1					359	396.1	192.0	48

Table 5: (Cont'd)

Cross		Year	Classes of number of seeds																N	MEAN	S.D	C.V.(%)
			23-121	122-220	221-319	320-418	419-517	518-616	617-715	716-814	815-913	914-1012	1013-1111	1112-1210	1211-1309	1310-1408	1409-1507	1508-1606				
	P_1	1984		2	5	6	4	2	1										20	384.1	120.4	31.35
		1985		2	6	6	4	2											20	361.8	109.2	30.24
Tvx3000	P_2	1984		1	1	2	8	1	15	1	1								20	517.0	165.6	32.03
x		1985				1	3	9	4	2	-	-	1						20	611.5	146.1	23.89
1696	F_1	1984					2	3	4	6	4	1							20	725.1	126.2	17.40
		1985				2	2	4	6	2	4								20	639.4	153.7	24.04
	F_2	1984	2	14	39	48	54	27	8	8	3	1	-	-	-	1	-	1	206	429.5	186.8	43.49
		1985	15	64	78	78	65	33	15	8	6	5	3	1					371	386.8	194.7	50.34

Trangressive segregates in both directions were apparent in all crosses in both years. The F_2 distributions were wide, unimodal and positively skewed.

Results for yield per plant are presented in Table 6 and indicate that the distribution of the F_1 was intermediate between the two parents in Tvx3000 x 1696 but similar to that of the higher yielding parent in K59 x Tvx3000 and K59 x 1696. The F_2 distributions were positively skewed in all crosses in both years and transgressed the lower yielding parent in one cross, K59 x 1696, in 1984; transgressed the higher yielding parent in two crosses, K59 x Tvx3000 and Tvx3000 x 1696 in 1985 but only the lower yielding parent in K59 x 1696 in the same year. In both years, the F_2 distributions were unimodal and positively skewed.

Table 7 shows the frequency distribution of number of days to flowering in the three crosses studied. The F_1 distribution is similar to the earlier flowering parent in cross, K59 x 1696 but to the later flowering parent in K59 x Tvx3000 in 1984. In 1985, the distribution is almost intermediate between the two parents. The spread of the F_2 distribution fell within the parental extremes in

Table 6. Frequency Distribution of Yield per plant(g) in Three Cowpea Crosses in 1984 and 1985

Cross		Year	Class Centre(g) 9	24	39	54	69	84	99	114	129	144	159	174	189	204	219	N	Mean	S.D	C.V.(%
	P_1	1984		4	8	8												20	39.8	11.2	28.14
		1985		1	4	10	3	2										20	55.4	14.3	25.81
K59	P_2	1984	1	16	3													20	23.7	7.2	30.38
x		1985	4	15	1													20	23.5	7.2	30.64
Tvx3060	F_1	1984				10	8	1	1									20	56.5	12.1	18.20
		1985				4	11	4	1									20	70.7	10.3	14.57
	F_2	1984	23	65	63	41	8	5										205	35.6	16.9	47.47
		1985	26	67	80	73	32	18	5	2	3	2						308	45.7	23.7	51.86
	P_1	1984		4	8	8												20	39.8	11.2	28.14
		1985		1	4	10	3	2										20	55.4	14.3	25.81
K59	P_2	1984		1	-	4	2	4	2	1	1	2	2					20	98.1	41.2	42.00
x		1985				1	-	4	1	8	1	1	3	-	-	-	1	20	119.0	35.1	29.50
1696	F_1	1984				1	-	2	2	3	5	4	3					20	124.1	26.9	21.68
		1985						2	7	3	8							20	109.6	16.5	15.05
	F_2	1984	10	34	37	32	23	15	17	7	6	1						182	56.8	31.0	54.58
		1985	10	60	71	83	51	44	10	15	8	4	1	-	2			359	57.9	30.53	52.7

Table 6. (Cont'd)

Cross		Year	Class Centre(g) 9	24	39	54	69	84	99	114	129	144	159	174	189	204	219	N	Mean	S.D	C.V.(%
	P_1	1984	1	16	3													20	23.7	7.2	30.38
		1985	4	15	1													20	23.5	7.2	30.64
Tvx3000	F_2	1984		1	-	4	2	4	2	1	1	2	2					20	98.1	41.2	42.00
x		1985				1	-	4	1	8	1	1	3					20	119.0	35.1	29.5
1696	F_1	1984				2	6	6	6									20	79.0	26.9	20.76
		1985			2	6	5	4	3									20	70.3	16.5	25.60
	F_2	1984	10	69	60	45	18	2	-	1	-	1						206	40.1	31.0	45.64
		1985	16	71	81	84	54	33	16	6	4	3	4	1				371	55.5	30.53	71.17

Table 7: Frequency distribution of number of days to flowering in three cowpea crosses in 1984 and 1985.

Cross		Year	Class Centres 32	37	42	47	52	57	62	67	72	77	N	Mean	S.D.	C.V.(%)
	F_1	1984			6	9	3	2					20	46.8	4.0	8.55
		1985		1	6	6	6	1					20	46.4	4.5	9.70
K59	P_2	1984		3	7	9	1						20	43.8	3.8	8.68
x		1985			6	13	1						20	45.8	2.9	6.33
Tvx3000	F_1	1984		1	11	7	1						20	43.5	3.4	7.82
		1985			14	4	1	1					20	43.9	4.0	9.11
	F_2	1984		2	41	82	47	19	10	4			205	49.2	6.0	12.20
		1985		1	20	66	104	56	50	9	2		308	53.3	6.1	11.45
	P_1	1984			6	9	3	2					20	46.8	4.0	8.55
		1985		1	6	6	6	1					20	46.4	4.5	9.70
K59	P_2	1984				1	4	3	2	3	5	2	20	62.8	9.5	15.13
x		1985					3	1	11	-	5		20.	62.5	6.1	9.76
1696	F_1	1984			1	10	5	4					20	50.0	3.7	7.40
		1985				4	12	4					20	51.9	3.0	5.78
	F_2	1984		4	22	38	54	39	20	3	2		182	52.0	6.6	12.69
		1985		1	23	49	93	121	65	7			359	54.3	5.8	10.68

Table 7: (Continued)

Cross		Year	Class Centres 32	37	42	47	52	57	62	67	72	77	N	Mean	S.D	C.V.(%)
	F_1	1984		3	7	9	1						20	43.8	3.9	8.68
		1985			6	13	1						20	45.8	2.9	6.33
Tvx3000	F_2	1984				1	4	3	2	3	5	2	20	62.8	9.5	15.13
		1985					3	1	11	-	5		20	62.9	6.1	9.76
x																
1696	F_1	1984			3	13	3	1					20	47.0	3.3	7.02
		1985			5	11	3	1					20	46.9	3.4	7.25
	F_2	1984	1	5	31	70	50	32	14	3			206	49.8	6.0	12.05
		1985		1	42	92	122	83	27	4			371	51.4	5.5	10.70

cross, K59 x 1696 in both years and in cross, Tvx3000 x 1696 in 1985 and showed unimodality in all crosses in both years. The F_2 distributions were almost normal and transgressed the late flowering parent in one cross (K59 x Tvx3000) in both years, and the early flowering parent in 1984 (Tvx3000 x 1696).

Table 8 shows the frequency distributions of number of seeds per pod. The F_1 is similar to one or both parents in all crosses in both years. The F_2 distribution is unimodal and positively skewed in all the crosses in both years. It transgressed the parent with fewer number of seeds in all crosses in 1985 and the parent with larger number of seeds in one cross (K59 x 1696) in 1984.

For seed size (Table 9), the results indicate that the F_1 distribution is similar to the larger seeded parent in two crosses (K59 x 1696 and Tvx3000 x 1696) in both years. The spread of the F_2 distribution fell within the parental extremes in the cross, medium x small (K59 x Tvx3000) and also in the cross, small x large (Tvx3000 x 1696) in the two years. Transgressive segregation was suggested in the cross, medium x large (K59 x 1696) for large seed size in 1984 and for small seed size in 1985. Unimodality and skewness in the F_2 distribution were apparent in all crosses in both years.

Table 8: Frequency distribution of number of seeds per pod in three cowpea crosses in 1984 and 1985.

Cross		Year	Classes of number seeds 4-6	7-9	10-12	13-15	16-18	19-21	N	Mean	S.D	C.V.(%)
	P_1	1984		3	14	2	1		20	10.9	1.7	15.60
		1985		2	18				20	10.3	0.8	7.77
K59	F_2	1984			16	3	1		20	11.5	1.8	15.65
x		1985		4	15	1			20	10.2	1.2	11.76
Tvx3000	F_1	1984		4	16				20	10.7	0.9	8.41
		1985			18	2			20	11.3	1.0	8.85
	F_2	1984		11	162	29	3		205	11.1	1.5	13.51
		1985	4	67	204	32	1		308	10.5	1.6	15.24
	P_1	1984		3	14	2	1		20	10.9	1.7	15.60
		1985		2	18				20	10.3	0.8	7.77
K59	P_2	1984		5	14	1			20	10.7	1.4	13.08
x		1985		12	7	1			20	9.6	1.2	12.50
1696	F_1	1984		2	17	1			20	10.3	0.8	7.77
		1985		2	18				20	10.3	0.8	7.77
	F_2	1984		9	131	36	5	1	182	11.3	1.7	15.04
		1985	6	155	184	14			359	9.8	1.4	14.29

Table 8: (Continued)

Cross		Year	Classes of number of seeds 4-6	7-9	10-12	13-15	16-18	19-21	N	MEAN	S.D	C.V(%)
	F_1	1984			16	3	1		20	11.5	1.8	15.65
		1985		4	15	1			20	10.2	1.2	11.76
Tvx3000	P_2	1984		5	14	1			20	10.7	1.4	13.08
x		1985		12	7	1			20	9.6	1.2	12.50
1696	F_1	1984		3	16	1			20	10.6	1.2	11.32
		1985		1	17	2			20	10.9	1.5	13.76
	F_2	1984		6	166	31	3		206	11.2	1.4	12.50
		1985	1	11?	204	23	1		371	10.1	1.5	14.85

Table 9: Frequency distribution of seed size in three cowpea crosses in 1984 and 1985.

Cross		Year	Class Centre (g/100 seeds) 5	8	11	14	17	20	23	26	29	N	MEAN	S.D.	C.V(%)
	P_1	1984		3	15	2						20	10.5	1.1	10.48
		1985			18	2						20	11.2	1.1	9.82
K59	P_2	1984	12	8								20	6.3	1.2	19.05
x		1985	7	13								20	6.6	0.8	12.12
Tvx3000	F_1	1984		10	9	1						20	9.9	1.5	15.15
		1985		11	9							20	9.5	0.8	8.42
	F_2	1984	21	137	44	2	1					205	8.5	1.6	18.82
		1985	11	157	121	19						308	9.4	1.8	19.15
	P_1	1984		3	15	2						20	10.5	1.1	10.48
		1985			18	2						20	11.2	1.1	9.82
K59	P_2	1984			2	1	9	2	5	1	1	20	18.6	3.8	20.43
x		1985				1	6	7	6			20	19.4	2.6	13.40
1696	F_1	1984			2	9	9					20	15.1	1.9	12.58
		1985			1	7	12					20	15.8	1.3	8.23
	F_2	1984		3	21	83	61	18	2	1	1	182	15.2	2.9	19.08
		1985	2	13	62	147	101	24	8	2		359	14.7	3.1	21.09

Table 9: (Cont'd)

Cross		Year	Class Centre (g/100 seeds) 5	8	11	14	17	20	23	26	29	N	Mean	S.D.	C.V(%)
	P_1	1984	12	8								20	6.3	1.2	19.05
		1985	7	13								20	6.6	0.8	12.12
Tvx3000	P_2	1984			2	1	9	2	5	1		20	18.6	3.8	20.43
x		1985				1	6	7	6			20	19.4	2.6	13.40
1696	F_1	1984		2	15	2	1					20	10.9	1.7	15.60
		1985		1	17	2						20	11.0	0.9	8.18
	F_2	1984	3	118	73	11	-	-	1			206	9.4	2.0	21.28
		1985	2	4	67	224	66	8				371	14.0	2.1	15.00

4.3 Measures of Variability

Table 10 shows phenotypic, genotypic and environmental variances whereas Table 11 presents phenotypic, genotypic and environmental coefficients of variation for the six characters under study in the F_2 generations of the three cowpea crosses used. Very high variances and coefficients of variation are associated with the characters, number of pods per plant, number of seeds per plant and yield per plant in all the crosses in both years. The other three characters, days to flowering, number of seeds per pod and seed size have comparatively lower variances and coefficients in both years, individually, and when combined. In general, the differences between genotypic and phenotypic coefficients of variation were small for most of the characters. In 1984, the cross, Tvx3000 x 1696 recorded a negative variance for the character, seeds per pod, and although this is theoretically impossible, it was included for completeness. It was also not possible to determine the genotypic coeficient of variation here because of the negative variance.

The three F_2 populations have similar variances and coefficients of variation for five characters namely, number of pods per plant, number of seeds per plant, days to flowering, number of seeds per pod and seed size in both years. The magnitude of variation for yield per plant was such that the cross, small x large (Tvx3000 x 1696) was much more variable than the other

Table 10: Phenotypic, genotypic and environmental variances in the F_2 generations of three cowpea crosses in 1984 and 1985.

Trait	Year	Variances								
		K59 x Tvx3000			K59 x 1696			Tvx3000 x 1696		
		Pheno-typic	Geno-typic	Environ-mental	Pheno-typic	Geno-typic	Environ-mental	Pheno-typic	Geno-typic	Environ-mental
Number of pods/plant	1984	322.77	232,91	89.86	409.70	225.93	183.77	297.67	186.29	111.38
	1985	423.31	341.39	81.92	359.38	260.99	98.40	340.99	213.84	127.15
	Combined	397.17	301.80	95.37	384.20	197.44	186.76	325.07	181.53	143.54
Number of seeds/plant	1984	38018.25	25931.40	12086.85	45798.31	24489.49	21308.82	34686.96	16389.01	18497.95
	1985	55337.29	44238.55	11098.75	36880.59	22556.54	14324.05	37925.38	19712.93	18212.45
	Combined	49378.35	36409.90	12968.45	39843.23	18531.71	21311.53	37199.45	17909.50	19289.96
Yield/ plant	1984	284.89	186.91	97.98	962.59	427.03	535.56	336.15	49.03	287.12
	1985	559.67	455.07	104.63	932.06	522.97	409.11	1561.93	1286.35	275.58
	Combined	473.64	360.64	113.00	940.83	371.12	569.70	1178.06	889.07	288.99
Days to flowering	1984	35.36	21.56	13.80	43.63	16.47	27.16	36.17	12.16	24.01
	1985	37.18	23.43	13.75	33.71	14.93	18.78	30.60	15.38	15.23
	Combined	40.44	26.31	14.14	38.20	14.64	23.56	33.11	13.04	20.07
Number of seeds/pod	1984	2.17	0.18	1.99	2.87	1.33	1.54	1.98	-0.08	2.06
	1985	2.65	1.70	0.95	2.03	1.15	0.88	2.14	0.52	1.62
	Combined	2.54	0.86	1.68	2.87	1.53	1.34	2.38	0.28	2.10
seed size	1984	2.46	0.94	1.52	8.39	4.40	3.99	4.02	0.22	3.80
	1985	3.08	2.28	0.80	9.71	7.24	2.47	4.19	2.67	1.52
	Combined	3.02	1.60	1.22	9.31	5.94	3.37	9.02	6.38	2.64

Table 11: Phenotypic, genotypic and environmental coefficients of variation for six traits in the F_2 generations from three cowpea crosses in 1984 and 1985.

		Coefficients of variation in percentage								
		K59 x Tvx3000			K59 x 1696			Tvx3000 x 1696		
	Year	Pheno-typic	Geno-typic	Environ-mental	Pheno-typic	Geno-typic	Environ-mental	Pheno-typic	Geno-typic	Environ-mental
Number of pods/plant	1984	46.91	39.85	24.75	58.67	43.57	39.29	44.47	35.18	27.20
	1985	44.63	40.08	19.63	46.58	39.69	24.37	48.21	38.18	29.44
	Combined	46.63	40.31	22.66	50.78	36.40	35.40	46.71	34.90	31.04
Number of seeds/plant	1984	46.13	44.84	26.01	55.96	40.92	38.17	43.49	29.81	31.67
	1985	48.13	43.03	21.55	48.48	37.92	30.22	50.35	36.30	34.89
	Combined	48.30	41.47	24.75	51.26	34.96	37.49	48.10	33.37	34.64
Yield/ plant	1984	47.41	38.40	27.80	54.62	36.38	40.74	45.72	17.46	42.26
	1985	51.77	46.68	22.38	52.73	39.50	34.93	71.21	64.62	29.91
	Combined	52.19	45.54	25.49	53.07	33.33	41.29	70.05	60.85	34.69
Days to flowering	1984	12.09	9.44	7.55	12.70	7.80	10.02	12.08	7.00	9.84
	1985	11.44	9.08	6.96	10.69	7.12	7.98	10.76	7.63	7.59
	Combined	12.30	9.92	7.27	11.55	7.15	9.07	11.33	7.11	8.82
Number of seeds/pod	1984	13.15	3.79	12.60	14.86	10.12	10.89	12.45	—*	12.70
	1985	15.50	12.42	9.28	14.54	10.89	9.57	14.48	7.14	12.60
	Combined	14.76	8.59	12.00	16.45	12.01	11.24	14.66	5.04	13.80
Seed size	1984	18.45	11.41	14.46	19.06	13.80	13.14	21.33	4.99	20.77
	1985	18.67	16.06	9.52	21.20	18.30	10.69	14.62	11.67	8.81
	Combined	19.28	14.91	12.27	20.48	16.36	12.32	24.22	20.37	13.10

* = Square root of a negative number.

two crosses followed by the cross, medium x large (K59 x 1696). The cross, medium x small (K59 x Tvx3000) was least variable for this character. Evironmental variation was more pronounced in 1984 than it was in 1985 and comparatively higher coefficients of variation are associated with the characters, number of pods per plant, number of seeds per plant and yield per plant in F_2 plants.

4.4 Heritability

Estimates of heritability (broad sense) in percentage and the ratios of environmental to total phenotypic variance are presented in Table 12. Heritability in this study indicates the extent to which the expression of a character is under genic control. It was calculated as the percentage genotypic variance of the total F_2 variance.

Heritability estimates in 1984 were in general lower than those obtained in 1985. This is reflected in larger ratios of environmental variance to total phenotypic variance for all characters in 1984. The heritablity for each character in each cross in 1985 was in close agreement except in number of seeds per pod. In 1984, heritability estimates were erratic in yield per plant, number of seeds per pod and seed size. The cross, small x large (Tvx3000 x 1696) produced a negative heritability for the character, seeds per pod in 1984. Although this is

Table 12: The ratios of genotypic (σ_g^2) i.e. broad-sense heritability (BSH) estimates and environmental (σ_e^2) variance to total phenotypic variance (σ_{ph}^2) for six characters in each of three cowpea crosses in 1984 and 1985.

Character	Year	[illegible] x Tvx3000		F59 x 1696		Tvx3000 x 1696		Average for th crosses	
		σ_g^2/σ_{ph}^2	σ_e^2/σ_{ph}^2	σ_g^2/σ_{ph}^2	σ_e^2/σ_{ph}^2	σ_g^2/σ_{ph}^2	σ_e^2/σ_{ph}^2	σ_g^2/σ_{ph}^2	σ_e^2/σ_{ph}^2
		(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
Number of pods/plant	1984	72.16	27.84	55.15	44.85	62.58	37.42	63.30	36.7
	1985	80.65	19.35	72.62	27.38	62.71	37.29	71.99	28.0
	Combined	75.99	24.01	51.39	48.61	55.84	44.16	61.07	38.9
Number of seeds/plant	1984	68.21	31.79	53.47	46.53	46.98	53.02	56.22	43.7
	1985	79.94	20.06	61.16	38.84	51.99	48.01	64.36	35.6
	Combined	73.74	26.26	46.51	53.49	48.14	51.86	56.13	43.8
Yield/ plant	1984	65.61	34.39	44.36	55.64	14.59	85.41	41.52	58.4
	1985	81.31	18.69	56.11	43.89	82.36	17.64	73.26	26.7
	Combined	76.14	23.86	39.45	60.55	75.47	24.53	63.69	36.3
Days to Flowering	1984	60.97	39.03	37.75	62.25	33.62	66.38	44.11	55.8
	1985	63.02	36.98	44.29	55.71	50.26	49.74	52.52	47.4
	Combined	65.06	34.96	38.33	61.67	39.38	60.62	47.59	52.4
Number of seeds/pod	1984	8.29	91.71	46.34	53.66	-4.04	104.04	16.86	83.1
	1985	64.15	35.85	56.65	43.35	24.30	75.70	48.37	51.6
	Combined	34.86	66.14	53.31	46.69	11.77	88.23	33.31	66.6
Seed size	1984	38.21	61.79	52.44	47.56	5.47	94.53	32.04	67.9
	1985	74.03	25.97	74.56	25.44	63.72	36.28	70.77	29.2
	Combined	59.60	40.40	63.80	36.20	70.73	29.27	64.71	35.2

theoretically impossible, it was calculated for completeness. It is possible that the total variance observed in 1984 for this character was due to environmental effects and their interaction with genotypes.

In 1984, number of pods per plant exhibited the highest estimates of heritability among the three crosses studied with the highest value (72.16%) obtained in the cross, K59 x Tvx3000. The three crosses averaged 63.30% for this character. For number of seeds per plant, heritability ranged from 46.98% in the cross, small x large to 68.21% in the cross, medium x small with an average of 56.22%. The heritability of yield/plant in F_2 plants seemed to be erratic in this year but averaged 41.52%. Days to flowering is also moderately inherited as shown by the 1984 figures with an average for the crosses of 44.11%. A highly erratic trend was again observed in seeds per pod where it ranged from -4.04% to 46.34% and averaged 16.86%. This means that seeds per pod is highly influenced by environmental factors. Likewise, seed size also depicted erratic BSH estimates with an average of 32.04% and a range of 5.47 - 52.44%. The ratios of environmental to total F_2 phenotypic variances in

1984 for yield per plant, days to flowering, number of seeds per pod and seed size exceeded 50.00% indicating a strong influence of environment on the expression of these characters in F_2 plants.

Heritability values were comparatively higher in 1985. The highest estimate was in yield per plant which averaged 73.26% and ranged from 56.11% to 82.36%. Number of pods per plant averaged 71.99%, number of seeds per plant, 64.36%, days of flowering, 52.52%, number of seeds per pod, 48.37% and seed size, 70.77%. The average ratios of environmental to total F_2 phenotypic variances for the six characters are, (a) number of pods/plant, 28.01%, (b) number of seeds/plant, 35.64%, (c) yield/plant, 26.74%, (d) days to flowering, 47.48%, (e) seeds per pod, 51.63%, and (f) seed size, 29.23%. Thus in 1985, the characters, days to flowering and number of seeds/pod were moderately influenced by the environment.

Heritability values from the combined analysis show that four characters are highly heritable, namely, pods/plant (61.07%), seeds/plant (56.13%), yield/plant (63.69%) and seed size (64.71%). Moderate values were recorded in days to flowering (47.59%) and seeds/pod (33.31%). Conversely, the ratios of

environmental to total F_2 phenotypic variance were highest in the latter two characters but lower in the former ones.

4.5 Phenotypic (r_{ph}), Genotypic (r_g) and Environmental (r_e) Correlations.

Tables 13, 14 and 15 show the phenotypic, genotypic and environmental correlation coefficients between six characters in 1984, 1985 and in the combined set of data, respectively. In general, genotypic correlations were higher than the corresponding phenotypic correlations for most character combinations in both years in all the three crosses used in this study.

In 1984, pods/plant was highly and positively correlated with seeds/plant and yield/plant in all the three crosses. Its phenotypic correlation with days to flowering, seeds/pod and seed size was negative and significant in K59 x Tvx 3000 and Tvx 3000 x 1696 and only with seeds/pod and seed size in K59 x 1696. The genotypic correlations were similar and of high magnitude in K59 x Tvx 3000 and K59 x 1696. Number of seeds/plant was highly and positively correlated with yield/plant in all crosses. It was insignificantly correlated with

Table 13: Phenotypic, genotypic and environmental correlation coefficients between characters in the F_2 generation from three cowpea crosses in 1984.

	Correlation Coefficients								
	K59 x Tvx3000			K59 x 1696			Tvx3000 x 1696		
	Pheno-typic	Geno-typic	Environ-mental	Pheno-typic	Geno-typic	Environ-mental	Pheno-typic	Geno-typic	Fr me
Number of pods/plant and									
Number of seeds/plant	0.966**	1.006	0.873**	0.977**	1.024	0.921**	0.965**	1.069	0.
Yield/plant	0.880**	0.978	0.671**	0.917**	1.035	0.811**	0.862**	1.404	0.
Days to flowering	-0.132*	-0.303	0.209**	0.046	0.421	-0.277**	-0.014	-0.346	0.
Number of seeds/pod	-0.155*	-0.935	0.140*	-0.284**	-0.737	0.181**	-0.238**	(——)+	0.
Seed size	-0.060	0.146	-0.331**	-0.155*	-0.423	0.156*	-0.032	0.374	-0.
Number of seeds/plant and									
Yield/plant	0.926**	0.990	0.799**	0.944**	0.996	0.902**	0.898**	1.303	0.
Days to flowering	-0.108	-0.214	0.085	-0.007	0.329	-0.288**	-0.021	0.259	-0.
Number of seeds/pod	0.067	0.865	-0.252**	-0.113	-0.609	-0.218**	0.003	(——)+	0.
Seed size	-0.047	0.167	-0.300**	-0.152*	-0.467	0.201**	-0.034	-1.453	0.
Yield/plant and									
Days to flowering	-0.072	-0.166	0.092	0.014	-0.131	0.115	-0.032	0.327	-0.
Number of seeds/pod	0.075	-0.174	0.205**	-0.091	-0.432	0.192**	0.013	(——)+	0.
Seed size	0.288**	0.668	-0.102	0.121	0.485	-0.220**	0.380**	1.576	0.
Days to flowering and									
Number of seeds/pod	0.111	0.982	-0.178*	-0.204**	-0.670	0.131*	-0.013	(——)+	0.
Seed size	0.076	0.105	0.052	0.063	-0.127	0.219**	-0.022	1.143	-0.
Number of seeds/pod and									
Seed size	-0.022	0.284	-0.096	0.053	0.349	-0.236**	-0.017	(——)+	0.

*,** Denote significance at 0.05 and 0.01 level, respectively; + = square root of a negative number.

Table 14: Phenotypic, genotypic and environmental correlation coefficients between characters in the F_2 generation from three cowpea crosses in 1985.

	Correlation Coefficients								
	K59 x Tvx3000			K59 x 1696			Tvx3000 x 1696		
	Phenotypic	Genotypic	Environmental	Phenotypic	Genotypic	Environmental	Phenotypic	Genotypic	Environmental
Number of pods/plant and									
Number of seeds/plant	0.950**	0.974	0.850**	0.961**	1.020	0.862**	0.965**	1.032	0.88
Yield/plant	0.874**	0.904	0.748**	0.875**	1.002	0.681**	0.670**	0.674	0.72
Days to flowering	-0.270**	-0.461	0.272**	0.053	0.212	-0.173**	0.006	0.090	-0.10
Number of seeds/pod	0.089	0.087	0.100*	-0.040	0.014	-0.142**	-0.001	-0.219	0.18
Seed size	-0.021	-0.060	0.113*	-0.014	0.055	-0.206*	0.001	0.130	-0.22
Number of seeds/plant and									
Yield/plant	0.924**	0.933	0.888**	0.904**	0.916	0.889**	0.690**	0.649	0.9
Days to flowering	-0.264**	-0.516	0.374**	0.073	0.060	0.091*	0.009	0.165	-0.15
Number of seeds/pod	0.351**	0.357	0.356**	0.200**	-0.011	0.501**	0.233**	0.076	0.38
Seed size	0.002	0.013	-0.036	-0.024	-0.099	0.135*	-0.002	-0.105	0.11
Yield/plant and									
Days to flowering	-0.238**	-0.486	0.419**	0.117*	0.569	-0.336**	0.041	0.003	0.1
Number of seeds/pod	0.339**	0.345	0.346**	0.169**	-0.121	0.543**	0.162**	0.065	0.38
Seed size	0.344**	0.371	0.255**	0.349**	0.350	0.366*	0.208**	0.196	0.2
Days to flowering and									
Number of seeds/pod	-0.060	0.008	-0.179*	0.040	-0.130	0.214**	0.009	0.495	-0.2
Seed size	-0.007	0.147	-0.347**	0.093*	-0.134	0.451**	0.219**	0.195	0.2
Number of seeds/pod and									
Seed size	0.094*	0.087	0.111*	-0.014	0.087	-0.212**	0.018	0.374	-0.2

*,** Denote significance at 0.05 and 0.01 level, respectively.

Table 15: Phenotypic, genotypic and environmental correlation coefficients betwee characters in the F_2 generation from three cowpea crosses combined over two years.

	Correlation Coefficients								
	K59 x Tvx3000			K59 x 1696			Tvx3000 x 1696		
	Pheno-typic	Geno-typic	Environ-mental	Pheno-typic	Geno-typic	Environ-mental	Pheno-typic	Geno-typic	En me
Number of pods/plant and									
Number of seeds/plant	0.955**	0.985	0.867**	0.960**	1.016	0.909**	0.961**	1.047	0.8
Yield/plant	0.877**	0.926	0.722**	0.882**	1.006	0.791**	0.661**	0.627	0.7
Days to floweri[illegible]	-0.143**	-0.249	0.108*	0.076*	-0.123	0.238**	-0.003	-0.179	0.1
Number of seeds/pod	-0.031	0.018	-0.101*	-0.186**	-0.230	-0.137**	-0.063	-0.029	-0.0
Seed size	0.016	0.113	-0.195**	-0.072*	-0.230	0.142**	-0.017	-0.093	0.1
Number of seeds/plant and									
Yield/plant	0.922**	0.949	0.843**	0.917**	0.938	0.906**	0.658**	0.570	0.8
Days to floweri[illegible]	-0.150**	-0.310	0.213**	0.047	-0.284	0.291**	-0.016	0.202	-0.1
Number of seeds/pod	-0.222**	0.605	-0.194**	0.052	0.263	-0.159**	0.182**	-0.318	0.1
Seed size	0.023	0.108	-0.151**	-0.071*	-0.238	0.135**	-0.087*	-0.301	0.2
Yield/plant and									
Days to floweri[illegible]	-0.097*	-0.218	0.194**	0.081*	0.024	0.117**	0.051	0.186	-0.1
Number of seeds/pod	0.205**	0.256	0.188**	0.056	-0.094	0.186**	0.041	-0.361	0.1
Seed size	0.364**	0.440	0.218**	0.273**	0.197	0.371**	0.311**	0.326	0.2
Days to flowering and									
Number of seeds/pod	-0.056	-0.070	-0.047	-0.132**	-0.219	-0.061	-0.046	-0.660	0.1
Seed size	0.101*	0.062	0.168**	0.066	-0.269	0.421**	0.185**	0.502	-0.1
Number of seeds/pod and									
Seed size	0.004	-0.184	0.169**	0.044	0.210	-0.190**	-0.254**	-1.231	0.1

*,** Denote significance at 0.05 and 0.01 level, respectively.

the other characters in all crosses except in K59 x 1696 where its correlation with seed size was negative but significant. The correlation between yield/plant and seed size was positive and significant in all the three crosses. Its association with other characters was not significant. The correlation of days to flowering with seeds/pod was significant but negative in K59 x 1696. Its correlation with seed size was not significant in all the crosses. Number of seeds/pod was negatively but insignificantly correlated with seed size in K59 x Tvx3000 and Tvx3000 x 1696 but positively though insignificantly in K59 x 1696. Nine genotypic associations were either greater than +1 or less than -1 across the three crosses. In small x large, five genotypic associations were not determinable because they resulted in square root of negative variances. Environmental correlations were in general significant for most of the character combinations in the three crosses.

A similar trend was observed in 1985. Pods/plant was highly associated with seeds/plant and yield/plant in all the three crosses. Its phenotypic and genotypic associations with all other characters were not significant. Number of seeds/plant was

highly correlated with yield/plant in the crosses. However, its phenotypic and genotypic correlations with days to flowering were negative and significant in K59 x Tvx3000 but positive though insignificant in the other two crosses. It was positively correlated with seeds/pod in K59 x Tvx3000 and Tvx3000 x 1696. Its association with seed size was negative though insignificant in K59 x 1696 and Tvx3000 x 1696 but positive and insignificant in K59 x Tvx3000. The character, yield/plant was significantly and positively correlated with seeds/pod and seed size in all crosses but in K59 x 1696 its positive phenotypic association with seeds/pod came with an insignificant and negative genotypic one. Again yield/plant was positively associated with days to flowering in K59 x 1696 and Tvx3000 x 1696 but negatively in K59 x Tvx3000. Days to flowering was erratically associated with seeds/pod in the crosses. Its phenotypic association with seed size was insignificant in K59 x 1696 and Tvx3000 x 1696. Number of seeds/pod was positively associated with seed size in K59 x Tvx3000 and Tvx3000 x 1696 but the associations were not significant. Environmental correlations were significant for almost all character combinations in the three crosses studied. In this year, only three genotypic correlations exceeded +1 and all genotypic associations were determinable.

The correlations of the six characters from the combined (pooled) analysis are similar to those of 1984 and 1985. The number of pods/plant was positively and significantly associated with seeds/plant and yield/plant in all crosses. Its association with days to flowering was negative in K59 x 1696 and Tvx3090 x 1696, both at phenotypic and genotypic levels. Again, it was negatively associated with seed size at both levels in two crosses (K59 x 1696 and Tvx3000 x 1696). Number of seeds/plant was again positively and highly correlated with yield/plant in all crosses but its association with days to flowering was not consistent. It was positively correlated with seeds/pod in all the three crosses whereas it was negatively associated with seed size in two crosses (K59 x 1696 and Tvx3000 x 1696) and the association was positive though insignificant in K59 x Tvx3000. Yield/plant on the other hand was consistently associated with seed size in all crosses and the association was positive and significant. It was positively associated with days to flowering in K59 x 1696 and Tvx3000 x 1696 but negatively in K59 x Tvx3000. Its association with seeds/pod was positive in K59 x Tvx3000 at both phenotypic and genotypic levels and only at phenotypic level in K59 x 1696 and Tvx3000 x 1696. These associations were insignificant. Days to flowering

was negatively correlated with seeds/pod in all crosses; and its phenotypic association with seed size was positive in all the three crosses. The association between seeds/pod and seed size was positive at the phenotypic level in K59 x Tvx3000 and K59 x 1696 but negative in Tvx3000 x 1696. The genotypic associations here were negative in K59 x 1696 and Tvx3000 x 1696 but positive in K59 x 1696. All genotypic associations were determinable here and only four exceeded +1 or were less than -1.

CHAPTER 5

DISCUSSION

Most reports on heritable and non-heritable relationships and the correlations of characters in cowpea were based on homozygous populations. But, these reports, based on a number of fixed genotypes may have limitations in extrapolation with regards to genotypes in segregating populations of inter-varietal crosses. The variations occurring in segregating populations are attributable to three main sources; namely, additive genetic effects, non-additive effects due to dominance and interaction of non-allelic genes, and environmental effects. But phenotypic fluctuations may occur from combinations of all of these types of variations. Furthermore, since the breeder is concerned with selecting superior genotypes, but of necessity must choose individuals from their phenotypic expressions in a segregating population, estimates of genotypic and phenotypic variances and covariances as well as correlations between characters are needed. Results from the present study were obtained from segregating populations of cowpea and would provide an insight into the variability and correlations of characters in such populations.

5.1 Mean Performance

The present study indicates the occurrence of heterosis for the character pods/plant. This is in agreement with the reports of Kheradnam et al. (1975) and Mak and Yap (1977). Over-dominance of larger number of pods over fewer number is also suggested by the results. This is in contrast to the report of Aryeetey and Laing (1973) who observed partial dominance of large number of pods and additive gene action for the character.

In seeds/plant, heterosis was apparent. Over-dominance of higher number of seeds over lesser number is suggested by the results.

Yield/plant also exhibited heterosis, over-dominance and partial dominance for this character. Kheradnam et al. (1975) and Mak and Yap (1977) also reported heterosis for this character. The former authors reported 52.50% for heterosis while the latter authors observed a low percentage for heterosis (2.80%). Ojomo (1974) speculated that heterotic response for yield was due to the effect of dominance or epistasis.

For days to flowering, the results obtained indicate partial dominance of early flowering over late flowering. The reports of Roy and Richharia (1948), Brittingham (1950), Ojomo (1971) and Mak and Yap (1980) are in agreement with this observation. However, the reports of Mackie (1939) and Capinpin and Irabagon (1950) contrasted this observation suggesting that late flowering was dominant over early flowering. A comparison of F_1 and F_2 means with the arithmetic mid-parent in this study suggests that gene action for days to flowering was primarily additive. This is in agreement with the reports of Kheradnam and Niknejad (1971), Lal et al. (1975), Tikka et al. (1976), Mak and Yap (1977) and Zaveri et al. (1980). Conversely, the report of Trehan et al. (1970) suggested that earliness was conditioned by effects other than additive gene action. This study failed to detect heterosis for earliness. But Tikka et al. (1976) and Erskine and Khan (1978) reported heterosis for earliness.

In relation to the character, seeds/pod, the present results are inconclusive. Partial dominance (in all crosses in 1984), complete dominance and over-dominance were also shown. Leleji (1975) reported that fewer number of seeds was partially

dominant over larger number of seeds. This was in contrast to Aryeetey and Laing (1973) who reported partial dominance of high over low number of seeds/pod.

The present study shows that F_1 seed size was intermediate between parents. This is in agreement with the report of Aryeetey and Laing (1973), Drabo et al. (1984) and the observation of Fery (1985). Partial dominance of heavier seeds was observed in contrast to the reports of Aryeetey and Laing (1973), Mackie (1946), Leleji (1975), and Mak and Yap (1980). However, the report of Drabo et al. (1984) is in agreement with the present finding.

5.2 Frequency Distributions

Smoothness, apparent normality or unimodality of F_2 distribution can be used as evidence of polygenic inheritance provided that the major portion of the variance in the F_2 is genetic (Echekwu, 1983).

For number of pods/plant, the unimodality observed in the F_2 distribution in all the crosses in both years is evidence that this character is polygenically inherited. The skewness seen is probably due to the complementary effects of genes.

The F_2 distributions for seeds/plant also suggest polygenic inheritance as evidenced by unimodality in all the crosses in both years. The skewness shown by the F_2 distribution is again suggestive of the effect of complementary factors in the inheritance of this character.

The unimodality in the F_2 distributions of the character, yield/plant, suggests the role of polygenes in the inheritance of this character. Complementary factors seem to affect the expression of this character as shown by the skewness of the distributions in all the crosses in both years.

Polygenic inheritance is also indicated for days to flowering as evidenced by the unimodal distribution of F_2 in all the crosses evaluated in both years. However, the skewness seen in the F_2 distribution is again suggestive of the effect of complementary factors in the inheritance of this character.

The unimodality exhibited by the F_2 distribution for seeds/pod in all the crosses in both years infers the operation of polygenes in the inheritance of the character. The operation of complementary factors in the inheritance of seeds/pod is strongly indicated by the skewness of the F_2 distribution in all the crosse

In seed size, the unimodality shown by the F_2 distributions in all crosses in both years strongly indicates the role of polygenes in the inheritance of this character. Again, the skewness shown by the F_2 distribution in all crosses is suggestive of the part of complementary effects in the inheritance of this character.

Sene (1968), Aryeetey and Laing (1973), Leleji (1975) and Drabo et al. (1984) reported similar results i.e., unimodality of F_2 distributions or polygenic nature of inheritance for pods/plant, seeds/pod, seed size and yield/plant.

5.3 Measures of Variability

The results from this study show that very high variances and coefficients of variation are associated with the characters, number of pods per plant, number of seeds per plant and yield per plant whereas days to flowering, number of seeds per pod and seed size have comparatively lower variances and coefficients in all crosses in both years. This is in agreement with the reports of Singh and Mehndiratta (1969), Doku (1970), Trehan et al.(1970), Aryeetey and Laing (1973) and Erskine and Khan (1978).

5.4 Heritability

Heritability refers to the ratio of the genotypic to the total phenotypic variation. Estimates of

heritability are important to the plant breeder because this parameter determines progress from selection. Two types of estimates are recognized, broad and narrow sense. Broad sense heritability is the ratio of the total genetic variance to the phenotypic variance while narrow sense heritability is the ratio of the additive genetic (heritable portion) variance to the phenotypic variance. Because of their relative nature and differences in the accuracy of the methods used in their computations, the concept should be appropriately utilized. In this study, heritability is reported in the broad sense.

The results show that in general, 1984 heritability estimates were lower than those observed in 1985. A close look at the ratios of environmental variance (σ_e^2) to phenotypic variance (σ_{ph}^2) for the two years shows that the ratios were higher in the former than in the latter year. Thus environmental effects were more important in 1984. Obilana and Fakorede (1981) remarked that heritability was not a stable population parameter and tends to be higher at 'non-stress' relative to 'stress' environments. This is the case with the 1984 and 1985 estimates. 1984 was drier than 1985 and while cultural operations like spraying against insects and diseases and weeding were promptly carried out in 1985, it was not the case in 1984. Furthermore, harvesting was lately done in 1984 after most of the pods on the plants in crosses, K59 x Tvx3000 and

Tvx3000 x 1696 had shattered. This and the lack of significant differences between parental lines probably account for the very low estimates in seeds/pod recorded in the two crosses (8.2% and -4.04%, respectively). This also accounts for the erratic estimates for yield/plant in this year as well as my failure to calculate all genotypic correlations where seeds/pod was involved. In general, heritability estimates were moderate to high in both years.

The results showed that there were differences in heritabilities among crosses for all the characters studied as expected. These differences could be explained by varying number and type of genes carried by the parents involved in the crosses with respect to these characters. However, as was stated by Liang and Walter (1968), it is not totally unexpected since the performance of a parent's progeny would vary depending on the other parent variety in combination.

Broad sense heritability estimates reported in the literature for the characters considered in this study are highly inconsistent. Fery (1985) observed that the averages for the various characters in the literature were, 53.10% for pods/plant, 45.55% for seeds/plant, 45.00% for yield/plant, 48.55% for days to flowering, 52.80% for seeds/pod and 67.80% for seed size.

The ranges for the six characters according to him were; (1) 7.00% to 98.9% for pods/plant, (2) 35.80% to 94.30% for seeds/plant, (3) 12.00% to 80.80% for yield/plant, (4) 3.80 to 94.30% for days to flowering, (5) 9.60 to 98.90% for seeds/pod and (6) 3.80 to 98.90% for seed size. The estimates obtained in this study do not appear to be significantly different from these averages and also fell within the ranges for all characters.

5.5 Phenotypic, Genotypic and Environmental Correlations

In genetic studies two causes of correlation between characters are recognized, genetic and environmental. The genetic cause of correlation is chiefly pleiotropy and linkage which sometimes causes transient correlation. Negative correlations between important characters may lead to selection of cultivars with undesirable characters. If a negative association between characters is due to pleiotropic effects it would be very difficult to obtain the desired combinations, while if linkage is involved special breeding programmes are needed to break this linkage (Al-Jibouri et al. 1958, Pandey and Gritton, 1975). One such approach is to intercross segregating populations and another is the use of mutagenesis. The available evidence, however, is against pleiotropic action as a general explanation for correlated response of characters (Mather and Jinks, 1971).

Genotypic correlation coefficients provide a measure of genetic association between characters and thus help identify the more important as well as the lesser important characters to be considered in a breeding programme. Furthermore, since a suitable test of significance of the genotypic correlations is not available, their main usefulness is in their strengthening the interpretations based on phenotypic correlations (Pandey and Gritton, 1975).

Indirect selection of one character to improve another is based on the phenotypic correlation between characters of interest. But phenotypic and genotypic correlations may differ in magnitude and sign. One may be negative and the other positive or on the other hand one may be low and the other high . Selection for one of the characters here would result in greater changes in the other than would be expected if the genotypic correlation were assumed equal to the phenotypic correlation. This is based on the assumption that the differences indicated between genotypic and phenotypic correlations are true differences and not due to sampling variation alone (Johnson et al. 1955, Robinson et al. 1951). In this study environmental correlations were computed to provide an insight into the role of environment on the association of any two given characters.

In general, the results from this study indicate that genotypic correlations were higher than phenotypic correlations with few exceptions. This is in agreement with the findings of Johnson et al.(1955), Doku (1970), Aryeetey and Laing (1973), Waldia et al. (1980), Yunus and Paroda (1982) and Sharma (1984). This may mean that although there was a strong inherent association between the various characters, the phenotypic expression of the correlation was lessened under the influence of the environment (environmental correlations for most of the character combinations were quite high and significant and therefore support this observation).

In 1984, pods/plant was highly correlated with seeds/plant and yield/plant in all crosses. Number of seeds/plant was also consistently associated with yield/plant and likewise, yield/plant was correlated consistently with seed size in all crosses. The same trend was noticeable in 1985 and in the results from the combined (pooled) analysis. These correlations are in agreement with those reported by Trehan et al. (1970), Kheradnam and Niknejad (1974), Virupakshappa et al. (1980) and Singh et al. (1982). This means that indirect selection for these characters to improve yield would be effective. All other associations were either insignificant or such that

the magnitude and sign of the phenotypic and genotypic correlations were different and as such may not be useful in a selection programme.

The characters, pods/plant, seeds/plant, yield/plant, seeds/pod and seed size were inconsistently correlated with days to flowering, mostly in a negative direction. The implication of negative genotypic correlations between yield components and days to flowering means that indirect selection for earlines could lead to a reduction in yield. Number of pods/plant also appeared to be negatively correlated with seeds/pod and seed size - the implication is selecting for higher number of pods/plant would reduce seed size and seeds/pod. Inconsistence in the association of yield with number of seeds/pod indicates that indirect selection for number of seeds/pod may lead to a reduction in yield. The reports of Kheradnam and Niknejad (1974), Virupakshappa et al.(1980), Singh et al. (1982), among others, contrast the present finding.

The inconsistencies observed above probably arose because of genotype by environment interaction in F_2 plants. It is known that some genotypes perform differently under varying plant densities, i.e., some do best when closely planted but poorly when planted widely. This is true of two of the materials used for this study. The two are improved

non-photosensitive varieties bred for planting at very high densities as opposed to the other parent, Kano-1696, a photosensitive spreading type which does best at low planting densities. The observation of Johnson et al. (1955) that correlations based on plot basis were more consistent than those obtained on plant basis is pertinent here. It is also pertinent to state that most reports on correlations in cowpea and related crops were based on homozygous lines which were closely planted. This is probably the reason why results from such reports contrasted the present findings in most instances.

A few genotypic correlations exceeded +1 or were less than -1. Since such values are theoretically impossible, it must be concluded that these determinations were subjected to higher degree of experimental error and in addition, a small sample size might also have contributed towards such unexpected results (Van Vleck and Henderson, 1961; Pandey and Gritton, 1975). In 1984, all of the genotypic correlations involving seeds/pod were not determinable because they resulted in square root of a negative number. This was because a negative genotypic variance was recorded for seeds/pod in this year and might mean an absolute zero value for the genotypic correlations. Yassin (1973), Pandey and Gritton (1975) and Nwasike et al. (1983) also observed and reported this kind of effect.

CHAPTER 6

SUMMARY AND CONCLUSIONS

Studies were carried out at the Institute for Agricultural Research Farm, Samaru, in the 1984 and 1985 growing seasons to investigate correlations between yield and five other characters as well as the correlations among the characters. Three varieties, three F_1 hybrids and their corresponding F_2s were space-planted in 4 replications of a randomized complete block design (RCBD) for the evaluations.

The F_2 distributions indicated unimodality and transgressive segregation in most of the crosses in both years for the six characters studied. This is an indication of polygenic inheritance for these characters. Thus it is concluded that the parents differed in many genes, with sufficient plus and minus gene effects to account for the transgressive segregation in both directions. The skewness observed in the F_2 distributions for most of the characters suggest the role of complementary gene effects in the inheritance of the characters.

Heterosis was apparent in pods/plant, seeds/plant and yield/plant in this study, as was reported by

several workers. The presence of heterotic effects, no matter how small, is an indication of dominance gene action. Partial dominance and over-dominance were jointly or severally recorded for the three characters. The present results are inconclusive on heterosis and dominance gene effects in days to flowering, seeds/pod and seed size.

Broad sense heritability estimates in 1984 ranged from 16.86% to 63.30%, in 1985, the estimates ranged from 48.37% to 73.26%. These estimates were moderate to high, and 1985, a 'non-stress' year, recorded high values in all characters. The crosses, K59 x Tvx3000 and Tvx3000 x 1696 in 1984 had very low values in seeds/pod because of shattering in one of their parents (Tvx3000). This means that in genetic studies, parents should be chosen carefully in order to reduce variation from avoidable sources i.e., to provide better control over experimental error.

The results obtained in this study showed consistently high and significant correlations between pods/plant and seeds/plant and yield/plant; between seeds/plant and yield/plant and also between yield/plant and seed size in all the crosses. Pods/plant, seeds/plant and seed size had high heritabilities. It is therefore concluded that the three characters are the important yield components and could be selected for in order to improve yield while adopting the method of pure-line selection to improve yield.

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