GENETIC STUDIES IN SOME COWPEA (*VIGNA UNGUICULATA* (L) WALP.) VARIETIES IN GHANA

by

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D E D I C A T E D

to

DR. E.T. BLAY - who taught me Genetics

and

PROF. E.V. DOKU - who taught me Plant Breeding

DECLARATION

I solemnly declare that, except for references to the works of other researchers which have been duly cited, this work is the result of my own original research and that this thesis either in whole or in part has not been presented for another degree elsewhere.

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ABSTRACT

Variation in some growth and yield characteristics were studied in 16 local and exotic cowpea varieties grown in the country. Planting was done at three different times of the year representing three seasons. The characters studied were: days to 80% germination, days to 50% flowering, average dry weight per plant at 50% flowering, number of nodules per plant at 50% flowering, percent effective nodulation, number of branches per plant, number of peduncles per branch, number of pods per peduncle, pod length, number of seeds per pod, 100-seed weight, days to 50% pod maturity, grain yield per plant, grain yield per plot, resistance towards cowpea mosaic virus (CMV) and shattering in the field. Separate experiments were also conducted to test variability in harvest index, resistance to bruchids in storage and ease of cooking the dry seeds without using tenderizers.

Analysis of variance indicated that the varieties differed significantly from one another in respect of all the characters studied. Variety-season interactions also varied significantly for most characters studied.

Among the yield-influencing factors, only 100-seed weight and harvest index showed significant correlations with grain yield.

Percent crossability was variable among six varieties used as parents in heritability studies of some quantitative traits. There was also selective genotypic cross compatibilities among the varieties

used.

Narrow sense heritabilities determined for 100-seed weight, seeds per pod, pod length, branches per plant, peduncles per branch and pods per peduncle were 80.0%, 74.0%, 70.0%, 68.0%, 30.0% and 22.0% respectively.

Heterosis in the F_1s for yield-influencing characters was determined at both mid- and better-parent levels. All crosses showed heterotic response exceeding 100% for pods per peduncle and grain yield per plant at both levels.

Hundred-seed weight and harvest index were found to be of higher selective value than other yield-influencing factors in cowpea improvement.

None of the varieties tested fitted the description of an ideal cultivar suitable for recommendation to farmers in the country. In order to get a proven variety, it was suggested that hybridization be used to combine all desirable characters into a single compound or multiple cross variety.

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HARRY MENSAH AMOATEY

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LIST OF ABBREVIATIONS

A.D.	Anno Domini (Latin) - dating from the birth of Christ
Anon.	Anonymous
A.R.S.	Agricultural Research Station
B.C.	Before Christ
cm	centimetre
cm^2	square centimetre
C-S	C-shaped
d.f.	degrees of freedom
DFF	days to 50% first flowering
DMP	days to 50% pod maturity
et al	et alii (Latin) - and other people
F.	frequency (variance ratio)
F_1	first filial generation
Fig.	figure
g	gram
IITA	International Institute of Tropical Agriculture
J-S	J-shaped
kg/ha	kilograms per hectare
m	metre
ml	millilitre
M.S.S.	mean sum of squares

LIST OF ABBREVIATIONS (Contd.)

n-1	number of varieties less one
^{o}C	degree Celsius
P.I.	Plant introduction
r	coefficient of correlation
spp	species
S.S.	sum of squares
Subsp.	subspecies
V.	*Vigna*
var.	variety

CHAPTER I

INTRODUCTION

Cowpea is a leading pulse crop in Ghana (Guerts, 1959 cited by Doku, 1970a). It is cultivated throughout the country except in the forest regions where production is limited by the high incidence of pests and diseases and excessive vegetative growth at the expense of grain production, arising from the high rainfall and relative humidity (Aryeetey, 1971; Doku, 1976; Quashie-Sam, 1984).

The crop serves multiple purposes on peasant holdings where it features in mixed- and relay-cropping systems, usually planted long after the cereals and root crops have established. Grain production is an obvious target in this case while other equally important benefits such as protection of the soil by its vegetative cover and enhancement of soil fertility through nodulation are often overlooked.

There is currently a wealth of varieties in the country, both local and exotic. These exhibit marked variations in several characteristics (Doku, 1970a). Yields are usually low, attributable to various reasons including the following:

(i) heavy biotic pressures - particularly from insects and other pests which often attack the plant throughout its life cycle and the seeds in storage.

(ii) poor soil physical and chemical properties.

(iii) cultivation under stress conditions of inadequate soil moisture and excessively high temperatures.

(iv) low plant populations, dictated by the common practice of growing the crop in association with cereals and/or root crops in the traditional farming system.

(v) planting of locally adapted but low yielding cultivars.

(vi) inadequate management practices and plant protection.

(vii) sub-optimal planting dates.

Methods which may be adopted to reverse this situation include choice of the most suitable environment and planting time, application of improved agronomic practices, and the use of improved seed through breeding. For continuous high yields, the crop's environment must be maintained at a certain optimal level through improved agronomic practices. In the face of unstable environmental conditions, the breeding of cultivars for improved performance appears to be the only stable method of increasing yields. This has also been pointed out by Martin and Leonard (1970).

Currently going on in the country, is a programme by the Grains Development Board aimed at developing high yielding varieties which will not only be resistant to the major diseases and insect pests, but also have wide adaptation to the various agro-ecological zones of the country (Asafo-Adjei, 1984). Seed quality and other "Consumer preferred" characteristics are also being considered. As many local and introduced varieties as can be obtained are being drawn upon for use in this programme to facilitate rapid progress. For example, the introduction of elite lines from IITA in Nigeria and elsewhere provides material that could be used through conventional breeding programmes, to incorporate specific desirable characteristics into otherwise well-adapted local varieties.

The importance of genetic diversity in choosing parents in breeding programmes has been emphasized by several workers, especially for eliciting improvements in complex quantitative traits such as grain yield. The more diverse the parents, the greater are the chances of obtaining higher amount of heterotic expression in F_1s and broad spectrum of variability in segregating generations (Harrington, 1940; Murty, 1965; Joshi and Dhawan, 1966; Murty and Anand, 1966).

However, the presence of high genetic diversity in a population _per se_ may not be adequate to effect improvement over existing cultivars. Maurya and Singh (1977) suggested, therefore that in a breeding programme, parents which show both high yielding potential and a wide genetic diversity are likely to yield superior segregates within a short period. In addition, such parents must also show high combining ability in order to obtain heterosis.

The study is aimed at the following:

(i) Ascertaining the nature and magnitude of genetic diversity present in some cowpea varieties grown in the country.

(ii) Determining the correlations among some quantitative traits and heritabilities of economically important traits in potential parents.

(iii) Identifying varieties which may be selected as parents in a hybridization programme towards effecting improvements over existing cultivars in characters such as earliness, nodulation, growth habit and grain yield.

CHAPTER II

LITERATURE REVIEW

1. Cultivation and Economic Importance

Cowpea (*Vigna unguiculata* (L) Walp) is widely distributed throughout the tropics and subtropics. The bulk of it is produced in Africa, with Asia, Europe, North and Central America contributing small amounts only (Doughty and Walker, 1982).

In West Africa it is grown in association with cereals - millet, sorghum and maize - in traditional agricultural systems (Smithson, 1979). Rachie and Roberts (1974) stated that Nigeria, Niger, Burkina Fasso (Upper Volta), and Senegal grow cowpea for the market, but they are also widely grown as a subsistence crop for home use in nearly all African countries south of the Sahara.

Cowpea is easily the leading pulse crop in Ghana (Doku, 1976; Asafo-Adjei, 1984). It is grown in all the agro-ecological zones. The greatest production, however occurs in the savanna areas and forest fringes. The heavy rainfall and high relative humidity experienced in the forest regions, especially during the major season, tend to limit grain production by encouraging excessive vegetative growth and promoting incidence of pests and diseases (Aryeetey, 1971; Doku, 1976; Quashie-Sam, 1984). Production is principally at the peasant level where it features in mixed- and relay-cropping system, usually planted long after the cereals and root crops have established. This shifts the flowering period to the end of the rainy season and pods mature on residual soil moisture under the relatively favourable conditions of the early dry season.

A large number of varieties both local and exotic (introduced from IITA and elsewhere) are employed in cowpea cultivation in Ghana. These varieties exhibit marked variations in several characteristics (Doku, 1970a). Yields are very low, usually ranging between 100-250 kg/ha (Asafo-Adjei, 1984), compared with values such as 400-600 kg/ha for other parts of the tropics and 1000-3000 kg/ha for the subtropics.

The crop, however, is used extensively in the home and features, though not prominently in the traditional farming system. The mature dried cowpea seeds with protein content ranging from 22% to 35% provide a readily available and less expensive source of protein for most people in Ghana. In the Northern and Upper Regions, the young tender leaves are eaten as vegetable (Irvine, 1974). Cowpea may also be used as a fodder for livestock and as green manure or cover crop for soil conservation. As a nodulating legume, atmospheric nitrogen is fixed in the root nodules of the plant, providing supplementary nitrogen for growth. In addition, the residual effects of nitrogen fixed by cowpeas on subsequent crops have been confirmed to be advantageous. Cowpeas are thus among a number of grain legumes widely used in rotation systems (Cobbley and Steele, 1976 and Rachie, 1985).

Cowpeas cultivated in Ghana are mainly utilized as a food grain. Consumption is widespread as the crop is not a taboo to any known ethnic groups in the country. A wide cross-section of the population eat cowpeas in one form or the other frequently. The contention in the literature (Munro, 1966; Williams, 1974; Anon, 1983 and Rachie, 1985) that cowpeas or legumes in general are low prestige food, is certainly not applicable to Ghana. In a preliminary study of consumer preferences for cowpea varieties in the Volta Region of Ghana, Dovlo (1975), mentioned a number of local dishes prepared from the crop, some of them highly relished.

2. Origin and History

The precise origin of cowpeas is not known as most authors (Irvine, 1974; Steele, 1978; Purseglove, 1981; Doughty and Walker, 1982) mentioned either Africa or Asia. However, Faris (1965) and Doku (1976) are of the view that the crop is native to Africa.

Cobbley and Steele (1976) and Simmonds (1976) further argue that the earliest cultivars in Africa may have evolved in cultivation with sorghum and pearl millet in the cereal farming of the West African zone, where they are now a principal grain legume. The International Board for Plant Genetic Resources also considers that cowpeas originated from West Africa (IBPGR, 1976). Ng and Marechal (1985) mentioned work done on more than 10,000 accessions of world cowpea collections held at IITA which revealed that germ-plasm accession from Nigeria, Niger, Burkina Fasso and Ghana showed greater diversity than those from East Africa. These studies suggest West Africa as the primary centre of domestication. There is a profusion of wild and weedy species in

Nigeria prompting Rachie and Roberts (1974) to specify that country as the probable origin of the crop.

However, archeological reports cited by Ng and Marechal (1985) indicate that cowpea remains carbon dated 1450-1400 BC, discovered from Kintampo rockshelter in Central Ghana is the oldest archeological evidence of cowpea, with the remains carbon dated AD 100 reported from Nkope in Malawi being the second oldest.

3. Taxonomy of Various Species

Vigna is a very large and immensely variable genus comprising a number of distinct plant forms. There is considerable controversy over the classification and nomenclature of these distinct forms.

Some authorities consider that all cowpeas belong to the wild botanical species *Vigna unguiculata* (L.) Walp. All cultivars are lumped under this species as they inter-cross readily producing fertile hybrids. According to this view, *V. sescuipedalis* and *V. sinensis* are synonymous to *V. unguiculata* (Purseglove, 1981).

Smithson (1979) cited other classificatory work which recognizes five subspecies of *V. unguiculata* as follows:

Subsp. *unguiculata*, the cultivated type of the African savannahs.

Subsp. *cylindrica*, the catjang, a fodder and grain type from India.

Subsp. *sesquipedalis*, the yardlong or asparagus bean of India, Southeast Asia and China.

Subsp. *dekindtiana* and *mensensis*, the wild and weedy forms of Africa, putative progenators of the cultivated forms.

Other workers recognize three distinct species (Puresglove, 1981), namely: Vigna cyclindrica (L) Skeels: This is the catjang cowpea, which is cultivated in Africa but is more common and has more cultivars in Asia.

Vigna sesquipedalis (L) Fruw: This is the asparagus pea or yardlong bean mostly grown for its immature pods and is most widely cultivated in the Far East, but it is also recorded in Africa.

Vigna unguiculata (L) Walp: This is the common cowpea with most cultivars in Africa, where the crop is more highly specialized.

In this work, the third classification is adopted. By Vigna unguiculata, therefore, reference is made solely to the species indigenous to Africa, which probably originated from the West African Savanna zone where it is most adapted.

4. Botany

Cowpea (Vigna unguiculata (L) Walp. is the most important cultivated species of the genus Vigna, family Leguminosae and subfamily Papilionoideae. It is a warm-season, annual herbaceous plant referred to by various names in different localities. In West Africa it is generally referred to as beans.

There are at least four easily recognized plant types - erect, semi-erect, prostrate (trailing) and climbing. Although these differences are mostly genetic, reduced light contributes to vinyness. Growth habit ranges from indeterminate to semi-determinate, but the plant typically continues to blossom and produce seed for an extended period (Litzenberger, 1974). The non-viny types tend to be more determinate in blooming habit than the viny types, which continue to bloom when the first pods are ripe, and repeated harvests are necessary to keep pace with ripening pods.

Cobbley and Steele (1976) described the plant as a glabrous annual herb with a strong, deep taproot from which arise many branches, ramifying the surface soil. Several smooth and spherical nodules are formed on the roots, usually more numerous on the taproot than on the laterals. It has a trifoliate leaf, with the terminal leaf often larger than the laterals. Leaflets are ovate and usually entire with an acute apex, though sometimes slightly lobed and lanceolate. The leaf petiole is stout and grooved, ranging between 5-15 cm in length.

The flowers are large and showy, commonly white or purple in colour but some varieties produce yellow flowers, with a standard petal 2-3 cm across. They occur in alternate pairs on a long axillary peduncle 2-30 cm long with large extrafloral nectaries between each pair of flowers. Though many flowers may be produced in each inflorescence, only few (usually 2-4) produce fruit, as the rest are shed. Cowpea flowers are cleistogamous, ensuring a high degree of inbreeding, thereby producing homogenous pure lines. Insect activity and weather conditions, however, may induce crossing between 1-10%

(Purseglove, 1968; Rachie and Roberts, 1974; and Steele, 1976). The pods are cylindrical and show many variations in size, conformation, length and number of seeds (Irvine, 1976). Seed characteristics are also very variable. Seed size ranges from 0.20 - 1.20 cm long. The seeds may be globular to kidney-shaped: smooth or wrinkled, with a wide range of colours - white, buff (cream), red (maroon), brown or black to variously spotted, speckled or marbled (Purseglove, 1981). Some varieties have a darker coloured spot on the hilum often called the "eye". With this range in varietal characteristics it is possible for the plant breeder to select plants to combine desired growth habit and yield with seed characteristics readily acceptable in specific localities.

5. Genetics and Breeding

Cowpea has been the subject of genetic research since the beginning of this century (Fery, 1985). Although most of the earlier work was conducted in the United States, much of the current research effort is in the African and Asian countries where most of the world's cowpeas are produced and where the crop has the greatest potential for alleviating food shortage. A total of 158 specific genes have been identified in the cowpea. Additionally, many quantitatively inherited traits have been studied in the past two decades, and more than 225 heritability estimates published, (Fery, 1985).

Cowpea is basically a self-pollinating crop. It is a diploid with a relatively short life cycle. The large flowers and untwisted keels of the cowpea make it one of the easiest legumes to emasculate and pollinate. These properties render it a convenient crop for plant breeding and genetics research. The crop has chromosome number 2n = 22. Available evidence indicates that inter-specific hybridization with other Vigna or Phaseolus species has so far not been possible. However, it is easy to make inter-varietal crosses; the source of heterosis for a number of traits as reported by Agble, (1972); Premsekar and Raman, (1972); Ojomo, (1974); Erskine and Khan, (1978); and Bhaskaraiah *et al.* (1980).

The development of population improvement schemes for self-pollinated crops and the possibility of hybrid seed production have stimulated the search for male sterility and other out-crossing mechanisms to facilitate hybridization procedures in cowpea. Fery (1985) stated that four recessive genes causing genetic male sterility have been identified by researchers.

6. Breeding Objectives and Programmes

The major objective of Cowpea breeding in the Tropics is to develop improved varieties to fit the various ecological zones. These varieties must have wide adaptation, acceptable seed qualities, resistance to diseases and pests, improved plant type and high yield potential (Anon., 1972).

The number and complexity of cowpea breeding methods continue to grow with the advancement of science. Conventional breeding methods include the assembly and evaluation of germplasm, inter-mating of parental stocks, selection of elite recombinants, and testing in preliminary, advanced and uniform yield trials. In addition, more specific techniques such as multiple crossing, back crossing and recurrent selection are sometimes employed to transfer specific desirable traits from one genome to a better adapted one. These methods are further augmented by more sophisticated techniques such as chromosome engineering, mutation breeding and inter-specific crossing whenever appropriate and feasible ([illegible] Anon., 1972). In recent times, attempts are also being made to use the population improvement method where the mating system of the crop is altered and controlled by using the technique of male sterility.

Ebong (1970a,b) described a strategy for breeding cowpeas. He stressed the importance of assembling and maintaining collections of genetically diverse materials and breeding for (1) high yield, (2) acceptable seed quality, (3) day neutrality, (4) erect growth habit, (5) long peduncles (above foliage) and (6) resistance to diseases (anthracnose), seedling blights, stem rot, viruses, and leaf spots.

7. Genetic Diversity

Boughey (1973) mentioned two ways in which diversity or variability of members of a population of a single species may come about. It may originate from differences in the genetic complement, or genome of different individuals. This is known as genotypic or genetic variation. Variation may also be produced by exposure to different values for particular environmental parameters during the development of individuals possessing similar genomes. This type of variation is termed environmental variation and is not heritable. However, genotypic variation is heritable and when acted upon by selection pressures brings about evolution.

Simmonds (1962) distinguished three kinds of genetic variability in crop plants as follows:

1. Variability of adapted combinations (i) in the form of homozygous gene combinations exhibited as phenotypic differences between inbred lines or clones, or (ii) in the form of heterozygosity which is often stabilized in clones.
2. Variability developed from foreign genes - introductions, chance or deliberate, from other populations, and introgressions.
3. Variability developed in situ - the product of mutation, recombination, and selection.

Generally, advanced agricultures are characterized by a great increase in adaptation of species through selection, resulting in a narrowing of the genetic base. In any one area, therefore, the available collection of well-adapted breeding stocks is very small in relation to the variability of the crop as a whole. For example, whilst studying the variability of local and exotic varieties of cowpea in Ghana, Doku (1970a) worked on 39 varieties, but only a few are now employed in the breeding programme.

The importance of establishing a broad genetic base before embarking on a breeding programme for any crop has been emphasized by many workers. Such a collection carries virtually the whole load of the future adaptability (Simmonds, 1962). It is treasured by the breeder because it provides a stock of genetically diverse material which can be combined variously for specific purposes. In addition, the use of very diverse parents in a hybrization programme enhances the chances of obtaining higher amount of heterotic expression in F_1s and broad spectrum of variability in segregating generations (Harrington, 1940; Murty, 1965; Joshi and Dhawan, 1966; Murty and Anand, 1966).

8. Heritability

A trait is said to be inherited if it passes from parent to offspring through the action of genes. The heritability of such a trait is the proportion of observed variability (among a single species) due to heredity (Allard, 1960). It expresses the proportion of the total variance that is attributable to the average effects of genes, and this is what determines the degree of resemblance between relatives. But the most important function of heritability in the genetic study of metric characters is its predictive role, expressing the reliability of the phenotypic value as a guide to breeding value (Falconer, 1960).

Only the phenotypic values of individuals can be directly measured, but it is the breeding value that determines their influence on the next generation. Therefore, if the breeder chooses individuals to be parents according to their phenotypic values, his success in changing the characteristics of the population can be predicted only from a knowledge of the degree of correspondence between phenotypic values and breeding. This degree of correspondence is measured by the heritability - defined in the narrow sense as the ratio of additive genetic variance to phenotypic variance:

$$h^2 = \frac{V_A}{V_P}$$

Techniques for estimating the degree of heritability in crop plants reported in the literature (Warner, 1952; Briggs and Knowles, 1967) fall into three main categories as follows: Those based on:

a) parent - offspring regressions,

b) variance components from an analysis of variance, and

c) approximation of non-heritable variance from genetically uniform populations to estimate total genetic variance.

Other methods used by some workers are either combinations of two or more of the above or modifications thereof. The various methods, however, give different values when used in computing the heritability of a single trait.

Heritability estimates also vary from crop to crop and from season to season or year to year. In addition, broad or narrow sense heritability may be estimated, giving different values. Estimates of heritability for different varieties of the same crop may also give variable figures due to varietal differences. Heritability values are estimated separately for all heritable traits of the same crop and these also show a wide range of variation.

Heritability studies in the cowpea were first reported by Spillman (1911) investigating hilum colour. Smith (1956) investigated the inheritance of three seedcoat colour genes, whilst Brittingham (1950) worked on pod length and seed size. This was followed by extensive studies by Saunders (1952, 1959, 1960a,b,c) covering various traits of the crop. In his study of the inheritance of seed size, Sene (1968) obtained estimates of 71% and 80% for the heritability in the narrow and broad sense respectively. High heritability estimates were also obtained by Singh and Mehndiratta (1969) for grain yield, days to flowering, days to maturity and pod length. Results of work by Aryeetey and Laing (1973) indicated that narrow sense heritability estimates for number of pods per plant and pod length were 19.8% and 60.3% respectively. Heritability values estimated by Kheradnam and Niknejad (1974), Leleji (1975) and Erskine and Khan (1978) ranged between 15% and 81% for various traits.

Heritabilities of factors controlling agronomically important characters, especially those closely correlated with yield have much significance in plant breeding programmes. Such knowledge, according to several workers (Robinson et al, 1949; Mahler, 1965; Kheradnam and

Niknejad, 1974), is important to the breeder as it indicates the possibility and extent to which improvement is possible through selection.

9. <u>Correlation</u>

As a polygenically controlled complex character, grain yield cannot be selected for by merely deducing from phenotypic performance. It can, however, be efficiently selected for by relying on data on yield components. Correlation studies are of great value in determining the association of grain yield with its components and also among the components (Waldia et al. 1980 and Singh et al. 1982). According to Aryeetey and Laing (1973), knowledge of the correlations among yield components and the association between each component and yield, together with an understanding of their mode of inheritance is necessary for the intelligent choice of breeding procedures for evolving high-yielding varieties.

Reports by Kheradnam and Niknejad (1974), Aryeetey and Laing (1973), and Singh et al. (1982) have consistently showed that yield is positively correlated with number of branches, pods and clusters per plant, and 100-seed weight. However, conflicting reports were given as regards the correlation between grain yield and other agronomic characters. Amongst themselves, these characters were either highly positively or negatively correlated. For instance, Doku (1970) observed that correlation coefficients between all characters and seed yield were negative except pod number and fruiting period which showed highly significant positive correlations with seed yield.

10. Heterosis

The superiority of a hybrid over the average performance of its parents is termed heterosis or hybrid vigour. It is manifest by increase in size, vigour, yield, earliness and improved general fitness characteristics such as resistance to disease, lodging, drought, etc. although hybrid vigour appears to be the main component used by many workers to identify it.

The cause of heterosis is not yet fully understood. However, three possible genetic causes have been postulated: partial to complete dominance, overdominance, and epistasis. From the point of view of a plant breeder, a basic issue is whether the best genotypes are homozygotes or heterozygotes. If overdominance is important, the best genotype is a heterozygote. With partial to complete dominance, the best genogype would be a homozygote and rather than capitalize on heterosis directly, Moll and Stuber (1974) have suggested that it might be desirable to isolate transgressive segregates.

Many investigators (Shull, 1952; Walton, 1971; Falconer, 1960) indicated that heterosis can be obtained when parent varieties have different origins (geographical and ancestral), but Harrington (1940) demonstrated the possibility of obtaining heterosis for intravarietal hybrids. He explained that when the genotypes of two parents differ sufficiently for the characters investigated, heterosis can be effected.

It is usual to measure heterosis with reference to the mid-parent value (Walton, 1971 and Suresh and Renu, 1975) given as

$$\% \text{ Heterosis} = \frac{F_1 - \left[\frac{P_1 + P_2}{2}\right]}{\left[\frac{P_1 + P_2}{2}\right]} \times 100$$

Where F_1 = Performance of offspring

P_1 = Performance of first parent

P_2 = Performance of second parent.

However, to be of potential value, a hybrid should be more profitable than the best available variety. This means that the hybrid should not only be superior to the mid-parent value, but should also be superior to the better parent. In consequence, some earlier workers (Marani, 1963; Miller and Marani, 1963; Marani, 1967 and 1968; and Meredith et al, 1970) preferred to distinguish between "heterosis" based on the mid-parent value and "useful heterosis" based on the better parent. Other workers (Shull, 1952; Leng, 1954; Hayes et al., 1955; Allard, 1960; Rao and Murty, 1970; Quinby, 1970; and Laing et al., 1972) simply evaluated heterosis in comparison with the better parent using the formular,

$$\text{Heterosis} = \frac{(F_1 - \text{better parent})}{\text{better parent}} \times 100$$

The level of heterosis obtained is therefore dependent upon whether it is measured with reference to the mid-parent value or to the better-parent value. Also, the realization of maximum desired heterosis in F_1 is dependent on the presence of suitable environment for its expression (Pfahler, 1966).

Heterotic reponse of yield and yield determining characters in the cowpea is of great significance with the discovery of male sterility genes in the crop as this will have a bearing on the breeding methodology.

11. Harvest Index

Harvest index is the most commonly advocated physiological parameter used as an estimator of yield potential in small grain cereals (McVetty and Evans, 1980). It has been employed successfully in the breeding of these cereals, leading to the creation of new dwarf, high-yielding, lodging-resistant varieties which can also tolerate high population densities.

Donald (1962) coined the term harvest index to describe the ratio of the economic yield (dry weight) to the biological yield (ie. total dry matter) of a crop. Its value is expressed in percentages as follows:

$$\text{Harvest Index} = \frac{\text{Economic Yield} \times 100}{\text{Biological Yield}}$$

In theory, the total yield of dry matter should include the roots. In practice, this may not be feasible in most cases. For this reason, it is often more convenient to derive the biological yield from the harvested dry matter, constituting the above-ground parts only. The harvest index of a variety varies with the environment, and also with the agronomic management of the crop.

In organizing improvement programmes for higher yields of pulses, Jain (1975) stressed the need to take into consideration the selection history of these crops. The stress conditions under which pulses have been cultivated for centuries has led to selection primarily for those characteristics which contribute to their establishment under these adverse conditions. It is therefore not accidental that many of these crops still retain a number of semi-wild characteristics such as a bushy and spreading growth habit, associated in many cases, with excessive vegetative growth, late maturity and toxic or other undesirable constituents in their seeds.

For a major production advance comparable to that obtained in the cereals in recent years, Jain (1975), suggested that the grain legumes must be bred for high yield together with a relatively short maturity duration, which can be fitted in a series of multiple-cropping patterns. These varieties will be expected to show an improvement in their plant type in the direction of a much higher harvest index.

12. <u>Bruchid Resistance</u>

Callasobruchus spp, pests of other pulses, cause extensive damage to seeds of cowpea throughout the year. Infestation usually occurs in the field and the insects, eggs and larvae are subsequently carried into the store. Total infestation of bulk seed can take place within few days and losses arising therefrom have been estimated to be in the range of 30-70% by the fifth month (Singh, 1977; Anon, 1980; Williams, 1980). C. maculatus and C. chinensis appear to be most important in W. Africa.

The adult female weevil lays its eggs on the dry pods or on the dry seeds of the crop, each laying up to ninety eggs. When the eggs hatch after about six days, the larvae enter and feed inside the seed. At optimum condition of 75% R.H. and 26°C, the development period is between 20-30 days. The adult emerges through an exit hole already prepared for it by the developing larva, and a new cycle of mating and egg laying begins almost immediately. The complete cycle takes about 40 days. Both adults and larvae feed on the seeds.

Although fumigation with methyl bromide effectively controls bruchids, the concern of breeders is to obtain varieties naturally resistant to these insects to forestall the hazard of chemical toxicity, especially with illiterate farmers.

There is evidence that cowpea susceptibility to Callosobruchus spp differs from one variety to another. Preferential selection by bruchids for seed of a particular variety as food or site for oviposition and subsequent development is controlled by several factors including size, colour and coat texture (Nwanze and Horber, 1975; 1976; Nwanze et al. 1975; Osuji, 1976; and Vir, 1980). However, complete resistance to infestation appears to be a rare trait, difficult to observe among existing cultivars.

Singh (1977) screened cowpea germplasm consisting of 7,000 cultivars at the world centre, for resistance against C. maculatus (F) in storage. Only one cultivar, TVu 2027 from the entire collection was resistant to this pest. The trait was subsequently demonstrated to be associated with above normal levels of trypsin inhibitor in the seeds of this variety. The trait had earlier on been indicated to be recessive and digenically inherited (Anon., 1974).

13. Selection

Selection is one of the oldest procedures used for crop improvement. During the process individual plants or groups of plants are sorted out from mixed populations. Selection can be natural or artificial and is possible only if there is variation. It acts as a sieve in favour of the well-adapted strains and varieties. Present-day plants, according to Sinha and Sinha (1980) are quite different from the earliest ones because they have evolved as a result of variation and selection.

The individuals comprising a species differ in many ways. Those that possess certain features which prove useful for their survival and reproduction are considered better adapted. They are naturally selected over the others if there is competition for factors of survival in the environment (Mettler and Gregg, 1969). Artificial selection on the other hand is the result of conscious decision by man to keep the progeny of one parent in preference to others. The two together have complemented each other in the evolution of crop plants and are responsible for the characters observed on the plants today.

The plant breeder's objective in a selection programme is the improvement of the aggregate of all characters that constitute "general worth" (Simmonds, 1976), as usually more than one trait is of interest economically. Selection, therefore, is often applied to several traits simultaneously.

Yield components of selective value in the cowpea include number of pods per plant, number of seeds per pod and 100-seed weight (Doku, 1970a; Ebong, 1972; Aryeetey and Laing, 1973). Breeding for high yield in the crop would necessarily involve selecting for high heritability of these characters in potential parents, alongside yield stabilizing factors such as resistance to disease, insects, non-shattering pods and photoperiod insensitivity. For selection based on yield components to be effective, Aryeetey and Laing (1973) stressed the need for such components to be highly heritable, strongly genotypically correlated with yield and finally among themselves, the components should be positively correlated.

Whilst studying heritability estimates and correlations of yield components in cowpea, Kheradnam and Niknejad (1974) observed that a highly heritable character may not, in any way, be correlated with yield and conversely a yield-correlated character may not be highly heritable. They, therefore, preferred the use of the product of the two parameters to represent a more reliable relative selective value of different characters. It was concluded from their studies that, for yield improvement in cowpea, number of pods per plant and number of seeds per pod have selective value equal to seed yield per plant, whereas 100-seed weight and number of clusters per plant have less selective value and number of branches per plant has no selective value.

Furthermore, Jain (1975), emphasized the indispensability of high harvest index in breeding for the realization of the full genetic potential of a crop for grain yield. Basing his argument on the remarkable improvements in yield obtained by plant breeders with respect to cereal breeding, he conjectured that reconstructing the plant type in favour of higher harvest index would be associated with a determinate and compact growth habit, and relative insensitivity to photoperiodic conditions. Such determinate variety according to him would obviously show reduced dry matter production on per plant basis, but this can often be compensated for by response to increased plant populations.

CHAPTER III

MATERIALS AND METHODS

1. Project Site

Two sites were used for the experiment. These were Sinna's Garden, University of Ghana, Legon and the Experimental Field of the Department of Biology, Food and Agriculture of the National Nuclear Research Institute at Kwabenya. The former had served, over several years, as a museum and supported various crops grown for demonstration to Agricultural Science students of the Faculty. The latter is a newly developed experimental site and the plots used for the second and third trials had not supported cowpea in the previous three years. Incidence of pests and diseases here was lower. The soils at the two locations belong to Toje series and Papao series respectively (Brammer, 1960).

2. Cowpea Varieties and Sources

Sixteen cowpea varieties of diverse genetic backgrounds obtained from three seed centres in the country were used for this investigation. They included both local and exotic varieties and were accessioned as follows:

Accn. No.	Name	Origin	Source of Seed
1	Accra Market No.1	Ghana	Crop Science Dept.
2	Accra Market No.2	"	"
3	Adua Ayera	"	"
4	Dark Mottled	"	"

Accn. No.	Name	Origin	Source of Seed
n5	Ex. Ada	Ghana	Crop Science Dept.
6	Gbeho	"	"
7	Ife Brown	Nigeria (IITA)	"
8	Kaase Market Black Eye	Ghana	"
9	Kaase Market Brown Eye	"	"
10	Legon Brown	"	"
11	Legon Prolific	"	"
12	Legon Red	"	"
13	P.I. 1239	USA (U.S.D.A.)	"
14	TVX 1834	Nigeria (IITA)	Ghana Seed Company
15	TVX 1999-02E	"	A.R.S. Kpong
16	Westbred	USA (U.S.D.A.)	Crop Science Dept.

3. Evaluation of Yield and Genetic Diversity

Three field trials were conducted to ascertain the nature and extent of genetic variation in the sixteen varieties of cowpea. Three different growing seasons of the year were chosen as follows:

1st Trial (season) ..... Jan., 1985 - April/May, 1985

2nd Trial (season) ..... May, 1985 - Aug./Sept., 1985

3rd Trial (season) ..... Sept., 1985 - Dec./Jan., 1985/86

The Randomized Complete Block design was used with three replications in the first trial and four replications in the second and third trials. A plot size of 4.80m x 2.40m was used and a spacing of 0.8m x 0.40m. This accommodated 36 plants/plot in three rows of 12 plants/row.

4. Harvest Index Determination

A pot experiment was conducted in Sinna's Garden for the determination of Harvest Index. Three seeds were sown per pot and thinned out to two per pot two weeks after germination. Each variety had two pots and there were three replications. The plants were watered as and when nesessary until maturity period.

All leaves, floral parts, stems and pods from the two plants in each pot were carefully picked just before abscission or pod dehiscence and dried in an oven at 70°C for 72 hours and carefully weighed. Harvest Index was calculated from the cummulative weights obtained for seed yield and total biological yield as follows:

$$\text{Harvest Index} = \frac{\text{Seed Yield} \times 100\%}{\text{Total Biological Yield}}$$

5. Insect Resistance Determination

A cage experiment was set up to determine the resistance of the various varieties against the storage insect *Callosobruchus maculatus*. Sixteen petri dishes containing 100 seeds of each variety were placed at equidistances from an infested source in the centre of the cage. Cages were closed and left to stand undisturbed for 5, 10, 15, 20, 25, 30, 35, and 40 days respectively before scoring for insect damage on the seeds. All seeds which outwardly appeared undamaged at the time of scoring were split open with a knife.

All seeds which visibly showed holes bored into them or contained larvae when split open were considered damaged and the percent damage was calculated based on this criterion. There were three replicates for each test period.

6. Determination of Cooking Time

The cooking times for the sixteen varieties of cowpea were determined as follows. The varieties were put into four groups as follows: 4 white, 4 red, 4 brown, 4 mottled. Each colour group was tested separately on a different day to eliminate stimulus error due to colour differences. The actual test was preceded by a preliminary study to give an idea of the cooking times of the varieties.

250 g of dried seed of each variety was first soaked in half a litre of water for 12 hours and boiled in half litre of water using an electric hot plate. Timing was started at the onset of boiling and there were three replicates for each test. Samples were taken out at different intervals (30, 40, 50, and 60 minutes) for testing. These were labelled and arranged randomly to avoid biasing due to sequential arrangement.

The degree of cooking was determined by the resistance the boiled seed gave when pressed in-between the thumb and fore-finger. Panelists evaluated doneness of seeds boiled for different periods.

A bean was considered "done" or well-cooked when it mashed easily and smoothly upon pressing and rubbing between the thumb and fore-finger.

A panelist recorded his judgement on a graduated scale as follows:

1.= Very hard, ie. does not appear to have been cooked at all

2 = Hard, ie. under-cooked

3 = Quite hard, ie. partially cooked

4 = Soft, ie. just well-cooked

5 = Too soft, ie. over-cooked.

7. Heritability and Crossability Studies

Narrow sense heritabilities for some quantitative traits were studied by making crosses and reciprocal crosses on chosen pairs of potential parents with essentially contrasting characters. One variety, Kaase market black eye was crossed with three different parents, each cross representing a different pair of contrasting character. There were 8 combinations represented by the following crosses and their reciprocals. The crosses were made according to the method developed by Rachie et al, (1975).

Kaase market black eye	x	Accra market No. 2
Kaase market black eye	x	Legon brown
Kaase market black eye	x	Dark mottled
TVX 1843	x	Ex. Ada.

The characteristics of the parental lines used are summarized in Table 1.

The crosses were made on plants grown in the open (in Sinna's Garden). Parent populations planted in single rows were sown at different times to synchronize flowering periods. Crosses were made

TABLE 1: QUANTITATIVE CHARACTERS OF PARENTS USED IN HERITABILITY STUDIES

PARENTAL VARIETY	DFF (days)	DFM (days)	Branch Length (m)	Leaf Area (cm^2)	Pod Length (cm)	Seeds /Pod	Pods/ Peduncle	Peduncles/ Branch	Branches/ Plant	100-seed Weight (g)	Grain Yield Per PLANT (g)
Kaase Market Black Eye	57.00	90.00	2.54	185.86	14.90	12.90	0.79	6.50	7.00	14.93	53.13
Accra Market No. 2	33.00	58.00	1.74	123.59	17.55	15.40	1.63	4.00	6.50	7.91	51.62
Legon Brown	36.00	56.00	2.48	347.45	20.95	15.50	0.86	11.00	7.25	12.31	30.86
Dark Mottled	29.00	49.00	1.01	121.80	12.80	9.90	1.52	4.50	6.50	9.70	42.69
Ex. Ada	33.00	60.00	1.64	124.30	16.26	12.00	1.17	6.00	6.00	20.05	83.61
TVX 1834	35.00	58.00	2.20	215.75	18.55	16.80	0.38	9.25	5.75	14.17	48.11
Mean	37.17	61.83	1.94	186.46	16.84	13.75	1.06	6.88	6.50	13.18	51.67
S.E. Mean ±	4.09	5.85	0.86	35.90	1.17	1.06	0.19	1.12	0.23	1.75	7.19

S.E. Mean = Standard error of mean

in the morning and evening. Unsuccessful crosses shrivelled and dropped off few days after crossing. A count of all stalks bearing labels was used in computing crossability among the varieties chosen.

Pods from identical crosses were harvested and bulked. F_1 seeds from these were later sown in the field (Sinna's Garden) together with the parents in single row plantings to evaluate relative performances. Regression of F_1 data on parental data provided the basis for computing heritabilities.

8. Leaf Area Determination

Leaf area was determined by establishing a relationship between leaf area and leaf weight (Chang, 1974). For this, ten fully grown leaves of approximately the same age (each picked as the fifth leaf counting from the growing tip of a primary branch), were taken for each variety and weighed. Punches of known diameters were used to take samples of circular portions of the leaves and then weighed. Total area of a whole leaf was thus extrapolated from the area/weight ratios obtained for the circular portions.

9. Cultural Practices

For the three field trials and parental populations used for the crosses and in the performance test, three seeds were sown per hill and thinned out to one per hill two weeks after germination. F_1 seeds used in the comparison/performance test, however, were sown singly to economize on the small number obtained from the successful crosses.

Following planting, each plot was weeded thrice using a hoe, to control weeds. Supplementary water was provided as and when necessary by using sprinklers and watering cans.

The second field trial (May-Aug./Sept., 1985) coincided with the major rainy season. As such infestation from insects, mainly aphids (Aphis craccivora) and ladybird beetles (Epilachna varivestis) was severe. A single application of Cymbush at a concentration of 2 ml per litre was employed to control the pests. All plantings done in Sinna's Garden were also sprayed.

Pods were harvested once a week (as they matured) and over a period of six weeks to cater for the late-maturing and indeterminate fruiting types. After taking measurements on pod length, pods were dried in the sun for 2-3 days to ease threshing. The number of seeds per pod was counted during threshing.

10. Data Collection

Data were collected on the following plant characteristics:

PHYSIOLOGICAL CHARACTERISTICS

1. Days to 80% germination - Number of days from sowing to 80% seedling emergence.
2. Days to 50% flowering - Number of days from date of 80% seedling emergence to date of 50% onset of flowering.

3. Days to 50% maturity - Number of days from 80% seedling emergence to date of 50% pod maturity.

4. Number of nodules per plant at 50% flowering - A total count of number of nodules on main and lateral roots. Four plants were carefully uprooted for this purpose.

5. Percent effective nodules - A ratio of actively fixing nodules to total number of nodules. This was determined by splitting open with a blade all nodules and counting those whose cores showed pink/reddish coloration.

6. Disease resistance score - A visual appraisal of varietal resistance to CMV as exhibited by mottling of the leaves. A rating of 1 (no symptoms of the disease) through 5 (total destruction from the disease) was used.

7. Shattering resistance score - Numerical rating was done based upon visual appraisal on 4 plants. Rating was done when 95% of the pods were mature, where 1 = no shattering to 5 = over 50% shattering.

REPRODUCTIVE CHARACTERISTICS

1. Number of branches per plant - The mean number of branches per plant from a random sample of 5 plants chosen from the middle row of each plot.

2.	Number of peduncles per plant	-	The mean number of peduncles on all branches of the five plants selected at random from the middle row of each plot.
3.	Number of pods per peduncle	-	The mean number of pods per peduncle was obtained by considering all peduncles on all branches of the five plants randomly selected from the middle row.
4.	Pod length	-	The mean measurement taken on ten randomly selected dry pods harvested from the middle row of each plot.
5.	Number of seeds per pod	-	The mean number of seeds threshed from ten randomly selected dry pods harvested from five randomly selected plants from the middle row of each plot.
6.	100 seed weight	-	The weight of a sample of 100 clean, whole and well-formed seeds.
7.	Grain yield per plot	-	Total grain yield from five randomly selected plants from the middle row of each plot multiplied by a factor of 36/5 since there were 36 plants per plot.

8. Grain yield per plant	-	The mean grain yield from five randomly selected plants from the middle row of each plot.
9. Harvest Index	-	Computed as the ratio of grain yield per plant to total Biological Yield.
10. Storage insects resistance score	-	Percent damage caused by insects to seeds in storage as manifest by holes bored into the seeds or the presence of larvae in apparently undamaged seeds when they were split open.

MORPHOLOGICAL CHARACTERISTICS

1. Dry weight per plant at 50% flowering	-	The average dry weight of four randomly selected plants carefully uprooted from the middle rows. Plants were dried in an oven at 80°C for 48 hours.
2. Plant growth habit	-	Visual appraisal of the growth characteristics of the plants as to whether it is erect or not.
3. Seed coat colour	-	The colour of the seed as determined by matching against standard horticultural colour charts as found in Exotica Horticultural Color Guide (E.H.C.G.), (Graf, 1963).

CHAPTER IV

RESULTS AND DISCUSSIONS

1. Growth and Yield Characteristics

Uniform germination was recorded for all varieties in all three field trials. In experiments one and three plantings were followed by rain two and four days respectively. Eighty percent germination was recorded for all varieties on the fifth and sixth day respectively. In experiment two, 80% germination was observed on the seventh day following sowing.

No statistical analysis was carried out for data collected on germination. Data collected on other characters were, however, subjected to analysis of variance. For convenience, only three out of four replications in each of the second and third trials were considered for the statistical analysis as trial one had only three replications.

The varieties differed highly significantly ($P<0.01$) in respect of all characters investigated except average dry weight per plant at 50% flowering (Appendix 1). Seasonal variation was also highly significant ($P<0.01$) in respect of days to 50% flowering, average dry weight per plant at 50% flowering, number of nodules per plant at 50% flowering, percent effective nodulation, number of branches per plant, number of peduncles per branch, pod length, number of seeds per pod, 100-seed weight, resistance towards shattering, and days to 50% pod maturity. Seasonal differences in grain yield per plant were significant ($P<0.05$). Variety-season interaction gave highly significant (P 0.01) differences in respect of days to 50% flowering, number of nodules per plant at 50% flowering, percent effective nodulation, pod length, 100-seed weight, incidence of the Cowpea Mosaic Virus (CMV), grain yield per plant and grain yield per plot (Appendix 1).

The sixteen varieties used in these studies were of diverse origin. The highly significant differences observed for most characters investigated is an indication of their genetic diversity. Doku (1970a) observed great genetic diversity in 39 local and exotic varieties of cowpea grown in Ghana.

Three main growth habits were observed in the varieties used in this study. These were erect, semi-erect and spreading growth habits. Most local varieties exhibited spreading growth habit whilst the exotic ones were either erect or semi-erect (Table 4). Doku 1970a) observed that most local varieties exhibited prostrate growth habit typical of unimproved landraces.

All varieties gave higher dry matter per plant at flowering during the second planting (May-August/September). This coincided with the major rainy season and the favourable weather conditions contributed to extra vegetative growth.

Seasonal variation in nodulation is explained by seasonal differences in soil conditions. All varieties produced more nodules in the major rainy season (i.e. second planting) than in the other seasons. Percent effective nodulation was also higher for the second planting season. Earlier workers (Wilson, 1931; Masefield, 1952; 1957; 1961; and Doku, 1970b) reported that nodulation is enhanced by soil moisture.

Philpotts (1967) reported that high soil temperatures reduced nodule formation and development.

Plants which were severely infected by the cowpea Mosaic Virus (CMV) typically showed leaf distortion, blistering, reduction in nodal length (stunting) and a high level of flower drop. Legon Red, Legon Prolific and Gbeho showed very severe signs of the incidence of the disease.

The seasonal variation in yield is explained by differences in weather conditions during the three seasons. Yields in the second planting with higher humidity and its attendant high incidence of pests were lower than in the first and third plantings. Laguda (1980) observed that exotic cowpea varieties planted in June gave lower yields than when planted in October due to pest damage. Grain yield also appeared to have been sacrificed for the higher vegetative growth observed during the second season. Ex-Ada was consistently the highest yielder for all three seasons, whilst Legon Prolific, Legon Red and Legon Brown were the poorest yielders in the first, second and third trials respectively. Legon Prolific and Legon Red showed severe signs of virus infection in the field, a factor contributing to their poor yields. Singh and Singh (1985) reported a reduction in the number of flowers, pods, seed output, seed size, pod size, pod weight and seed weight in cowpeas due to virus infection. Reduction in yield of 13-87% due to virus infection was reported by Kaiser and Mossahebi (1975), whilst other workers (Chant, 1960; Glimer et al., 1974 and

Shoyinka, 1974) reported that reduction in yield due to cowpea yellow mosaic virus ranged between 60% and 100%.

Two local varieties, Kaase Market Black Eye and Kaase Market Brown Eye, appeared to be photoperiod sensitive. Flowering and fruiting in these varieties were delayed during the second field trial (May-August/September) which coincided with longer daylengths (Fig. 1).

2. Genetic Variability

Tables 2 and 3 give the overall means and coefficients of variation respectively in 15 quantitative traits of the varieties investigated, while variability in qualitative traits is presented in Table 4.

A wide range of variability was observed for the quantitative traits studied. High coefficients of variation were recorded for grain yield per plot, grain yield per plant, number of pods per peduncle, 100-seed weight, harvest index, number of nodules per plant, percent effective nodules, branch length and diameter of spread. Number of peduncles per branch, number of primary branches per plant and days to 50% first flowering showed only moderate variation, whereas number of seeds per pod, pod length and days to 50% pod maturity had low coefficients of variation.

The varieties also showed great variability in several qualitative traits. For convenience, however, three classes only were recognized for each of the variation in plant growth habit, maturation period, flowering/fruit habit and pod conformation. Spreading growth habit as

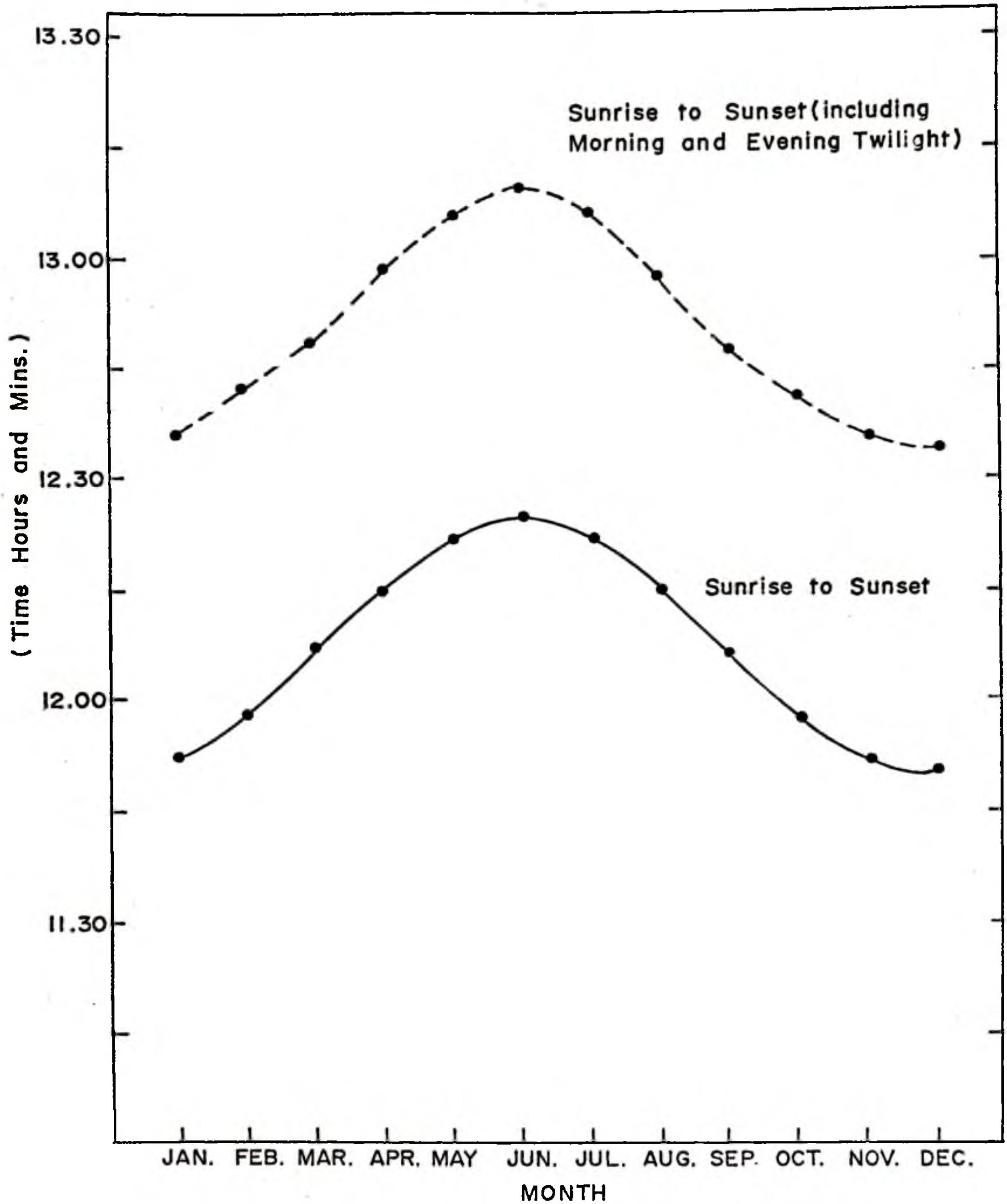

FIG. 1. DAYLENGTH AT LEGON (05° 36' LAT.)

TABLE 2: OVERALL MEANS OF SOME QUANTITATIVE CHARACTERS

VARIETIES	DFF (days)	DFM (days)	Nodules / Plant	Effect Nodules/ Plant (%)	Branch Length (cm)	Diameter of Spread (m)	Pod Length (cm)	100-Seed Weight (g)	Branches/ Plant	Peduncles/ Branch	Pods / Peduncle	Seeds/ Pod	Grain Yield / Plant (g)	Grain Yield / Plot (kg)	Harvest Index (%)
1. AM No. 1	43.00	62.13	29.27	26.20	57.54	0.79	15.85	9.55	5.83	2.71	1.99	13.63	39.63	1360.99	30.33
2. AM No. 2	41.00	58.33	23.98	25.55	70.60	1.06	16.96	9.35	5.41	2.17	2.06	14.31	31.95	1116.95	23.85
3. Adua Ayera	43.27	63.00	22.82	29.21	70.69	1.01	15.70	9.23	6.22	2.83	1.58	12.93	32.03	946.48	19.70
4. Dark Mottled	37.11	59.25	15.97	23.24	68.35	1.29	13.27	10.48	6.70	3.56	1.31	11.50	35.05	1095.54	38.59
5. Ex. Ada	39.18	64.00	22.03	24.68	83.57	1.31	15.87	20.03	6.43	3.79	1.22	10.08	63.03	2060.52	25.99
6. Gbeho	50.09	67.63	16.14	19.49	55.88	1.00	15.33	12.91	6.00	3.35	1.09	12.91	32.22	1034.29	13.78
7. Ife Brown	41.91	64.38	20.26	17.65	43.79	0.89	13.46	15.19	5.30	4.60	1.07	10.14	39.25	1290.17	35.93
8. K.M. Black Eye	48.18	75.65	12.38	12.44	72.61	1.28	16.82	18.04	6.61	3.63	0.77	12.78	38.78	1205.15	29.34
9. K.M. Brown Eye	51.00	75.00	12.70	8.55	49.97	0.97	15.85	18.55	7.50	3.73	0.67	12.20	45.45	1384.18	30.05
10. Legon Brown	48.55	69.75	31.09	26.19	54.69	0.86	17.67	13.57	5.43	3.69	0.65	11.24	20.08	718.50	17.62
11. Legon Prolific	44.00	67.75	22.18	20.73	68.88	1.25	14.18	10.26	7.20	3.73	0.62	11.85	24.42	790.31	26.54
12. Legon Red	48.09	67.75	18.86	17.86	25.25	1.92	18.51	12.77	5.43	3.75	0.67	12.28	30.74	978.78	10.73
13. PI 1239	48.55	68.88	11.77	12.94	99.03	1.81	16.99	12.15	6.41	3.38	0.87	13.75	31.46	995.85	18.21
14. TVX 1843	40.45	65.88	22.18	20.76	40.78	0.78	17.19	16.87	5.39	3.28	0.98	13.60	37.49	1171.77	31.09
15. TVX 1999-02E	43.36	65.25	11.43	7.35	35.69	0.76	14.33	13.78	5.64	3.92	1.17	13.24	46.36	1539.66	31.93
16. Westbred	38.36	61.38	22.36	25.18	55.13	0.90	13.94	10.25	6.51	3.31	1.31	12.76	36.93	1272.33	22.98

TABLE 3: VARIABILITY IN SOME QUANTITATIVE TRAITS

QUANTITATIVE TRAIT	Range	Mean ($\bar{X}$)	Standard Deviation (SD, ±)	Coefficient of Variation (CV,%)
1. Grain yield per plot (kg/ha.)	718.50 - 2060.52	1185.09	318.98	26.92
2. Grain yield per plant (g)	20.08 - 63.03	36.55	9.80	26.81
3. No. of seeds per pod	10.08 - 14.31	12.45	1.24	9.92
4. No. of pods per peduncle	0.65 - 2.06	1.15	0.42	36.92
5. No. of peduncles per branch	2.17 - 4.60	3.46	0.56	16.07
6. No. of primary branches per plant	5.30 - 7.50	6.13	0.68	11.13
7. 100-seed weight (g)	9.23 - 20.03	13.31	3.53	26.49
8. Pod length (cm)	13.27 - 18.51	15.75	1.57	9.97
9. Harvest Index (%)	10.73 - 38.59	25.42	7.86	30.92
10. Days to 50% first flowering (DFF)	37.17 - 51.00	43.94	4.43	10.08
11. Days to 50% pod maturity (DPM)	59.25 - 75.63	66.00	4.91	7.44
12. No. of nodules per plant	11.43 - 31.09	19.71	5.98	30.34
13. Percent effective nodules	7.35 - 29.21	19.88	6.64	33.40
14. Branch length (cm)	35.69 - 125.25	65.78	22.71	34.52
15. Diameter of spread (m)	0.76 - 1.92	1.12	0.35	31.25

used in this classification includes plants with trailing, creeping, or climbing growth characteristics. The local varieties appeared to be mostly spreading types, with long- or medium-term maturation periods. While a few were clearly determinate in flowering/fruiting behaviour, most of them flowered and fruited over protracted periods especially in the presence of water, nesessitating repeated harvests. These wild/semi-wild characteristics may have contributed to their being favoured by local peasants. In the mixed cropping systems of these farmers, the trailing, late-maturing varieties play the role of cover crops, their decayed vegetative parts and nodules enriching the soil to the benefit of companion crops, while repeated harvests ensure supply over a longer period and the small quantities gathered per harvest are easier to handle without storing for long periods. In contrast, the exotic varieties showed more of improved plant characteristics. Spreading growth habit, late maturity and indeterminate flowering/fruiting habit were not noticeable in any of them. These results agree with those obtained by Doku (1970a) whilst working on 39 local and exotic varieties of cowpea.

Slightly curved (i.e. J-shaped) was the predominant pod conformation observed in the varieties as compared to straight or highly curved (i.e. C-shaped) pods. Pod colour was also very variable, ranging over eight botanic colours whilst seed coat colour showed the greatest variability. Apart from the easily discernible uniform single colours such as ivory, rest, flesh, brown, cardinal red, ivory white, light brown and garnet

TABLE 4: QUALITATIVE CHARACTERISTICS OF 16 COWPEA VARIETIES

VARIETY	Plant Growth Habit	Maturation Period	Flowering/ Fruiting Habit	Pod Conformation	Pod Colour	Seed Coat Colour
1. AM No. 1	Semi-erect	Medium	Determinate	Slightly curved(J-S)	Salmon	Cardinal Red
2. AM No. 2		Early			Maroon	"
3. Adua Ayera		Medium	Semi-determinate		Salmon	'
4. Dark Mottled		Early	Determinate	'	Dark maroon	Maroon/Rust (SP)
5. Ex. Ada	Spreading	Medium	"	Highly curved (C-S)	Chestnut brown	Chocolate/Light Brown (Mt)
6. Gbeho	Semi-erect	Late	Indeterminate	Slightly curved(J-S)	Salmon	Chocolate/Brown (Mt)
7. Ife Brown	Erect	Medium	Determinate	Straight	Ivory pink	Flesh
8. K.M. Black Eye	Spreading	Late*	Semi-determinate	Highly curved (C-S)	Cream	Ivory white
9. K.M. Brown Eye		Late*	"		Cream	Ivory white
10. Legon Brown			Indeterminate	Slightly curved(J-S)	Salmon	Brown
11. Legon Prolific	"	"	"		Flesh	Ivory
12. Legon Red	'	'		"	Maroon	Garnet lake
13. PI 1239	'	'	Semi-determinate	"	Flesh	Chocolate/Rust (Mt)
14. TVX 1843	Semi-erect		'	Straight	Peach pink	Rust
15. TVX 1999-02E	Erect	"		Straight	Ivory pink	Light Brown
16. Westbred	Erect	Medium	Semi-determinate	Slightly curved(J-S)	Ivory pink	Ivory

* Photoperiod sensitive Sp: Speckled Mt: Mottled

lake, there were also various shades of mottling or speckling involving maroon or chocolate colour on rust, brown or light brown backgrounds in some varieties. No correlation was observed between pod colour and seed coat colour.

3. Harvest Index

Harvest index for the varieties ranged from 10.73% in Legon Red, a late-maturing, local variety with spreading growth habit to 38.59% in Dark Mottled, another local variety with semi-erect growth habit. Dark Mottled gave the least number of days to flowering and maturity of the 16 varieties tested. Significant differences were found among cultivars with respect to harvest index (Table 5). Generally, higher harvest indices were recorded for erect and semi-erect varieties than for the spreading types.

Jain (1975) recorded harvest indices in the ranges of 8.70% to 21.40% and 20.00% to 30.00% in some pigeon pea and chick pea varieties respectively as compared to 36.19% - 40.98% in wheat. He attributed the low yield of grain legumes to poor harvest index rather than total biological yield. Singh *et al*., (1980) also observed that harvest indices in varieties of mungbean, (*Vigna radiata*), urd bean (*Vigna mungo*) and pigeon pea (*Cajanus cajan*) were in the ranges 23-47%, 17-30% and 17-29% respectively. For effective improvement in grain yield of grain legumes, he suggested that emphasis be put on breeding varieties for high harvest index, alongside other factors.

TABLE 5: MEAN GRAIN YIELD PER PLOT. MEAN HARVEST INDEX, MEAN DAYS TO MATURITY AND GROWTH HABIT

VARIETY	Grain Yield Per Plot in kg/ha.	Harvest Index (%)	Maturity Duration (days)	Growth Habit
1. A.M. No. 1	1360.99bcd	30.33cd	62.13cde	S. Erect
2. A.M. No. 2	1116.95defgh	23.85efg	59.38e	S. Erect
3. Adua Ayera	946.48hi	19.70gh	63.00cde	S. Erect
4. Dark Mottled	1095.54efgh	38.59a	59.25e	S. Erect
5. Ex Ada	2060.52a	25.99def	64.00cde	Spreading
6. Gbeho	1034.29fgh	13.78ij	67.63bcd	S. Erect
7. Ife Brown	1290.17cde	35.93ab	64.38cde	Erect
8. K.M. Black Eye	1205.15cdefg	29.34cde	75.63a	Spreading
9. K.M. Brown Eye	1384.18bc	30.05cd	75.00ab	Spreading
10. Legon Brown	718.50j	17.62hi	69.75abc	Spreading
11. Legon Prolific	790.31ij	26.54cde	67.75bcd	Spreading
12. Legon Red	978.78ghi	10.78j	67.75bcd	Spreading
13. P.I. 1239	995.85ghi	18.21hi	68.88abcd	Spreading
14. TVX 1843	1171.77cdefgh	31.09bcd	65.88cde	S. Erect
15. TVX 1999-02E	1539.66b	31.93bc	65.25cde	Erect
16. Westbred	1272.33cdef	22.98fgh	61.38de	Erect

Means in the same column followed by the same subscript are not significantly different by Duncan's Multiple Range test (5%).

Fig. 2 shows the relationship between grain yield and harvest index in the varieties investigated. The highest harvest index was observed for Dark Mottled, an erect, early-maturing local variety with determinate flowering/fruiting habit. Ex-Ada, a local, early-maturing, spreading variety which recorded the highest grain yield gave relatively low harvest index. Ife Brown, TVX 1843, TVX 1999-02E and Westbred, all exotic varieties with erect or semi-erect growth habits gave high yields and high harvest indices. Accra Market No. 1 (an erect, local variety), Kaase Market Black Eye and Kaase Market Brown Eye (both spreading local varieties) also behaved similarly. For a high-yielding, spreading variety such as Ex-Ada with low harvest index, further improvement in yield could be elicited by reconstructing the morphological frame of the plant in such a way that the total dry matter produced is more efficiently partitioned between grains and vegetative parts. A compact plant form would be most desirable towards this end as this would permit higher plant populations per unit area.

4. Cooking Period

Highly significant differences were observed among varieties for time to cook the dry beans (soaked overnight) without using tenderizers. Consumer preference for level of softness also differed highly significantly for all four test periods.

Table 6 shows that most varieties required to be boiled for between fifty minutes and an hour to soften enough for human consumption.

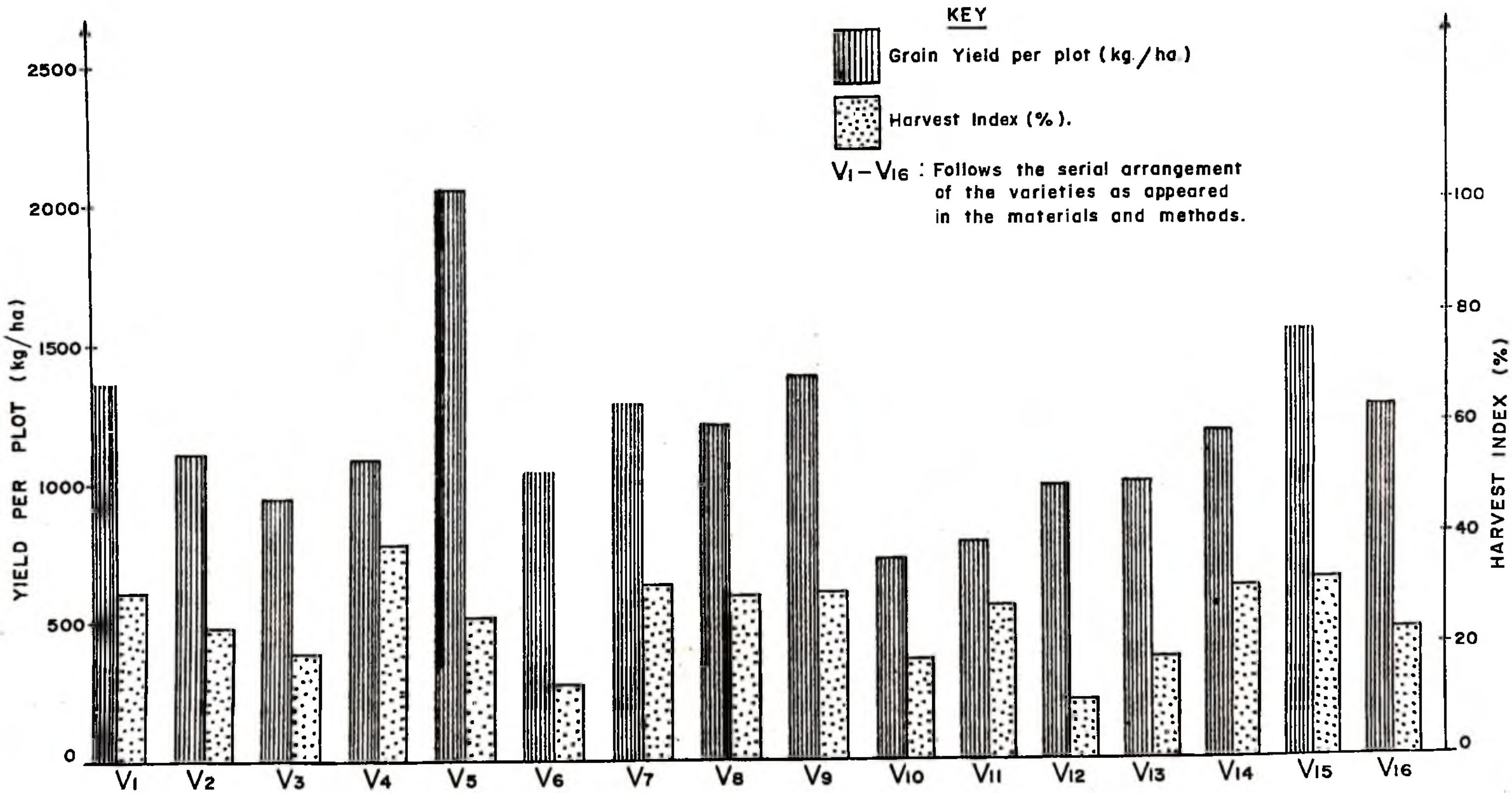

FIG. 2. GROUP BAR GRAPH INDICATING VARIETAL VARIATION IN GRAIN YIELD AND HARVEST INDEX.

TABLE 6: MEANS OF VALUES SCORED BY EIGHT JUDGES FOR COOKING PERIOD

VARIETY	Period of cooking (minutes)			
	30.00	40.00	50.00	60.00
1. A.M. No. 1	3.00 bcde	3.54 de	4.04 cde	4.04 cd
2. A.M. No. 2	2.92 cdef	3.42 f	4.00 cde	4.09 cd
3. Adua Ayera	3.00 bcde	3.58 de	3.92 def	3.96 d
4. Dark Mottled	2.71 ef	3.50 ef	4.00 cde	4.38 b
5. Ex. Ada	3.49 a	4.25 ab	4.34 ab	4.17 bcd
6. Gbeho	3.25 ab	3.75 cde	3.96 cdef	3.88 d
7. Ife Brown	3.25 ab	4.29 a	4.50 a	4.71 a
8. K.M. Black Eye	2.63 f	3.38 ef	3.92 def	4.00 cd
9. K.M. Brown Eye	2.67 ef	3.38 ef	3.75 ef	3.92 d
10. Legon Brown	3.17 abcd	3.62 de	3.79 def	4.29 bc
11. Legon Prolific	2.42 g	2.75 g	3.67 f	3.58 e
12. Legon Red	3.17 abcd	3.96 bc	4.21 bc	4.17 bcd
13. PI 1239	2.87 cdef	3.33 f	3.25 g	3.46 e
14. TVX 1843	3.21 abc	3.83 cd	4.08 cd	4.13 bcd
15. TVX 1999-02E	3.00 bcde	3.79 cde	3.67 f	4.08 cd
16. Westbred	2.71 ef	3.08 f	3.67 f	3.46 e

Means in the same column followed by the same subscript are not significantly different by Duncan's Multiple Range test.

Six varieties required to be boiled for more than an hour whilst two varieties, Ife Brown and Ex Ada required only forty minutes. Ex -Ada had relatively large seeds (100-seed weight = 20.03 g) with smooth seed coat. Five out of six varieties requiring more than an hour for cooking were small-seeded with smooth seed coats whilst the last one (Kaase market brown eye), had wrinkled large seeds. Degree of softness of seeds after one hour of boiling was positively correlated (r = 0.276) with 100-seed weight, though not significantly. The results, however, showed no clear trend relating seed coat colour and period required for cooking as beans from each colour group (brown, mottled, red, and white) could or could not be cooked within an hour.

It is apparent from these results that a number of factors interplay to determine the time required to cook cowpea seeds, though larger-seeded varieties generally took shorter time than smaller-seeded varieties. Selecting for high 100-seed weight in any breeding programme will conform with consumer expectations as it may ease cooking of the dried bean.

5. Bruchid Resistance

Virtually no visible damage was done to seeds of all varieties up to the fifteenth day after introduction of insects. When split open, however, most such seeds contained larvae in various stages of development. By the twentieth day, exit holes were visible on a few seeds indicating that emergence of adults had started.

Sampling at 5-day intervals showed varietal differences in susceptibility to infestation by Callosobruchus spp. These differences were, however, obliterated after the thirtieth day as most varieties recorded 100% infestation (Fig. 3). This is explained by increased insect activity following the emergence of new adults.

Initially, lower levels of infestation were recorded for varieties with small and/or rough-coated seeds than for those with large and/or smooth-coated seeds. A count of the number of eggs laid on seeds of the various varieties five days after introduction of insects showed highly significant differences among varieties. More eggs were laid on larger seeds than on smaller ones. Rough-coated seeds also had fewer eggs than smooth-coated seeds.

Varieties with large seeds were preferred for oviposition by the insects probably because they provided a larger surface area compared to those with small seeds. Seeds with smooth coat texture provided a non-obstructive surface, also preferred by the insects for oviposition. Subsequently, higher rates of infestation were recorded for varieties whose seed characteristics fall under these descriptions than for those with small and/or wrinkled seeds. Ife Brown, an elite line from IITA with medium seed size (100-seed weight = 15.19 g) and highly wrinkled seed coat consistently showed the lowest rates of infestation throughout the experiment (Fig. 3).

Earlier workers (Nwanze and Horber, 1975; Nwanze et al., 1975; and Nwanze and Horber, 1976) have observed that the cowpea weevil readily distinguishes between rough- and smooth-seeded varieties, preferring the

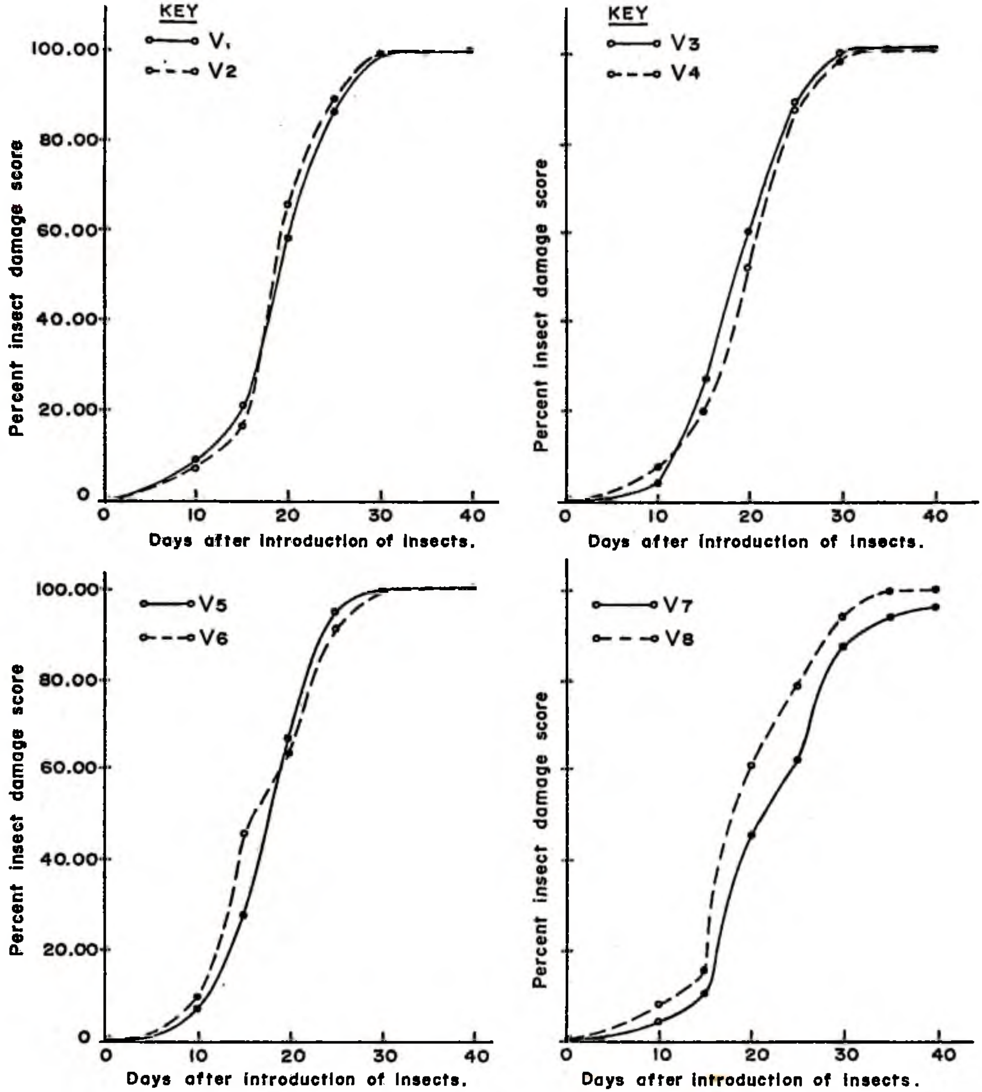

Fig. 3. Relation between percent damage caused to seeds and days after introduction of insects.

Footnote: V1 – V8 follows the Serial arrangement of the Varieties as appeared in the materials and methods.

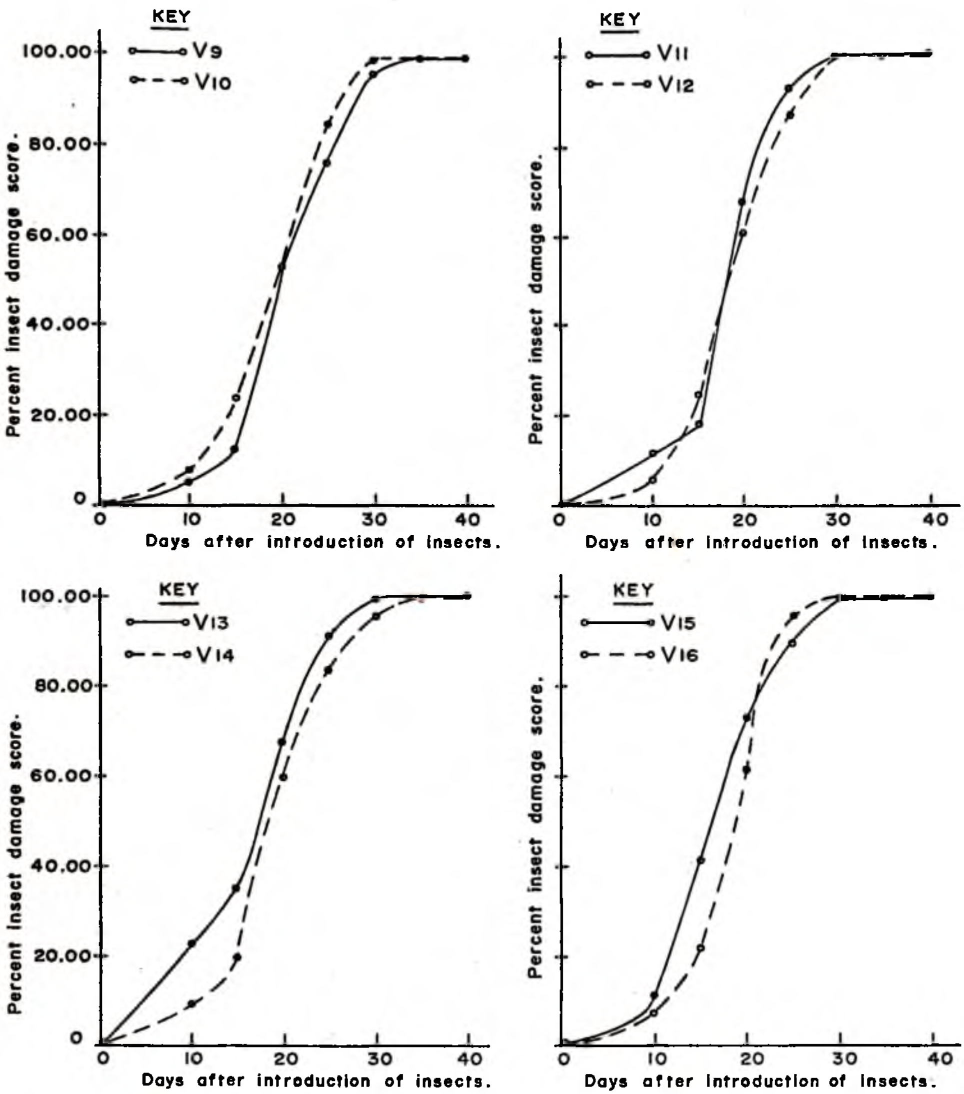

Fig. 3 cont'd. Relation between percent damage caused to seeds and days after introduction of insects.

Footnote: V9 — V16 follows the Serial arrangement of the Varieties as appeared in the materials and methods.

latter as sites for oviposition. They also noted that large-seeded varieties provided larger surface area for oviposition and were therefore preferred to small-seeded varieties. Further, Vir (1980) observed that C. maculatus preferred brightly coloured, smooth seeds with large volume for oviposition. He also noted that egg-laying was minimum on seeds with wrinkled coats.

The results of this investigation, however, gave no indication of the influence of seed coat colour on ovipositional behaviour or selection of feeding sites by bruchids as infestation on colour basis showed no clear trend. Differences in preference for oviposition were reflected in the levels of infestation recorded up to the twenty-fifth day. All varieties, however, became heavily infested by the thirtieth day. It appeared therefore that of the varieties tested, once oviposition had taken place the seeds had no intrinsic mechanism for halting infestation.

6. Correlation Studies

The results of correlation studies for seed yield with its components and among the components in the 16 varieties are presented in Table 7. Seed yield per plant showed positive correlations with pods per peduncle, peduncles per branch, branches per plant (not significant), 100-seed weight and harvest index (significant) but negative correlations (not significant) with seeds per pod, pod length, days from sowing to 50% first flowering and days to 50% pod maturity.

TABLE 7: CORRELATION COEFFICIENTS AMONG 10 CHARACTERS IN COWPEA

	Yield/ Plant	Seeds/ Pod	Pods/ Peduncle	Peduncles Branch	Branches/ Plant	100-Seed Weight	Pod Length	Harvest Index	DFF	DFM
Yield/Plant	-	-0.261	0.136	0.204	0.165	0.616*	-0.205	0.513*	-0.304	-0.046
Seeds/Pod			0.403	-0.734**	-0.131	-0.420	0.329	-0.208	0.141	-0.087
Pods/Peduncle				-0.725**	-0.280	-0.567*	-0.167	0.139	-0.556*	-0.815**
Peduncles/Branches					0.105	0.541*	-0.307	0.239	0.146	0.418
Branches/Plant						0.125	-0.337	0.180	0.123	0.350
100-Seed Weight							0.200	0.208	0.231	0.601*
Pod Length								-0.601*	0.500*	0.375
Harvest Index									-0.524*	-0.181
DFF										0.819**
DFM										-

* Indicates significance at 5% level of test (r > 0.497)

** Indicates significance at 1% level of test (r > 0.623)

Harvest index was positively correlated with four other characters apart from grain yield per plant though not significantly and negatively correlated with another four, significant in the cases of pod length and days from sowing to 50% first flowering.

Highly significant negative correlations were observed for the associations between seeds per pod and peduncles per branch, pods per peduncle and peduncles per branch, and between pods per peduncle and days from sowing to 50% pod maturity. The association between days to 50% onset of flowering and days to 50% pod maturity was positive and highly significant.

These results, in some aspects, agree with those of earlier workers. Doku (1970a) found seed yield to be positively correlated with pod number per plant and fruiting period but negatively correlated with other characters. Aryeetey and Laing (1973) also found yield to be positively correlated with number of pods per plant, number of seeds per pod, and 100-seed weight but negatively correlated with pod length whilst Erskine and Khan (1978) also observed positive correlations with pods per plant and seeds per pod only. All yield components, except number of branches per plant were positively correlated with yield in another study by Kheradnam and Niknejad (1974). Lagudah (1980) also observed positive correlations between grain yield and number of pods per plant, number of seeds per pod, and 100-seed weight, the association not statistically significant in the case of seeds per pod. In a study involving fifty genotypes, Singh _et al_., (1982) observed positive correlations between all eight plant characters investigated and grain yield, the association between grain yield and plant height, pods per plant and number of grains per pod being highly significant.

It is evident from this study and those of other workers that grain yield in the cowpea may be improved by selecting for 100-seed weight, harvest index, peduncles per branch, branches per plant and pods per peduncle, in decending order of importance. That grain yield is negatively correlated with both days to 50% onset of flowering and 50% pod maturity indicates that the selected plant should also be early-maturing.

7. Crossability

The results of pod set from crosses and reciprocal crosses made between six of the varieties provided information on the expected ease of hybridization between them. Table 8 shows the percent crossabilities calculated from the number of successes recorded as against the total number of crosses made.

Crossability values of 11.63% and 6.67% obtained for the crosses Ex Ada (m.p.) x TVX 1843 (f.p.) and TVX 1843 (m.p.) x Ex Ada (f.p.) respectively indicate that in a cross involving the two varieties, either of them could be used as the male or female parent. However, with TVX 1843 as female parent crossability was nearly twice as high as when it was used as the pollinator, indicating its preferability as female parent rather than male parent in crosses with Ex Ada. Floral parts of TVX 1843 were generally larger than those of Ex Ada.

TABLE 8: PERCENT CROSSABILITIES

HYBRID	No. of Crosses Made	Successes Recorded	% Pod Set
Ex. Ada (m.p.) x TVX 1843 (f.p.)	43	5	11.63
TVX 1843 (m.p.) x Ex. Ada (f.p.)	45	3	6.67
KMBE (m.p.) x L.B. (f.p.)	44	3	6.82
L.B. (m.p.) x KMBE (f.p.)	54	0	0.00
KMBE (m.p.) x AM No. 2 (f.p.)	42	1	2.38
AM No. 2 (m.p.) x KMBE (f.p.)	58	0	0.00
KMBE (m.p.) x DM (f.p.)	45	6	13.33
DM (m.p.) x KMBE (f.p.)	40	0	0.00

m.p. - male parent; f.p. - female parent.
DM - Dark Mottled; AM No.2 - Accra Market No.2
L.B. - Legon Brown; KMBE - Kaase Market Black Eye

The low pod set in the TVX 1843 (m.p.) x Ex Ada (f.p.) crosses could be attributed to the inability of pollen tubes developed from Ex Ada pollen to travel the longer length of the styles of TVX 1843 flowers to the ovary for fertilization to take place.

Whilst K.M.B.E. proved unsuitable for use as the female parent in crosses with three of the varieties (Table 8) it could be employed successfully in their reciprocal crosses when used as the pollen parent. Indeed, crosses between K.M.B.E. (m.p.) and D.M. (f.p.) produced the highest number of pods (6) with a crossability of 13.33%, whilst 6.82% and 2.38% were obtained for similar crosses with Legon Brown and A.M. No. 2 respectively in which it served as the pollinator. The inability of K.M.B.E. to set pods following cross combinations with other varieties serving as pollinators could be due to the very delicate attachment of the flower to the pedicel (noticed during emasculation). Disturbance during mechanical manipulation could have led to the abscission of the flowers and therefore no successful pod setting.

It is clear from the results of this study that there is parental selectivity among cowpea varieties when used as males and females in different cross combinations. In studies on parental selectivity as a factor affecting success in cowpea crossing, Mishra et al., (1985) observed highly selective genotypic cross compatibilities among varieties with crossability ranging between 0-30%. They ascribed such genotypic or parental selectivity in crosses to inherent genotypic differences for cross compatibility, preferential union of male and female gametes and extra-chromosomal effects of the seed parent in pod development.

The results obtained in the parent study may have been influenced by other variables such as

(i) unequal number of crosses made - as a result of poor flower production in some varieties - and

(ii) number of fruits already borne on the female parent - these served as better physiological sinks able to outcompete new and weaker sinks (mechanically manipulated flowers) for the supply of nutrients and water, leading to the abscission of the latter.

8. Heritability Estimates

Narrow sense heritabilities determined by regressing offspring data on data of pollen parent were 80.0, 74.0, 70.0, 68.0, 30.0 and 22.0% for 100-seed weight, seeds per pod, pod length, branches per plant, peduncles per branch and pods per peduncle respectively.

The heritability values obtained from this study are in agreement with results obtained by Aryeetey and Laing (1973), and Kheradnam and Niknejad (1974). Sene (1968) also obtained estimates of 71.0% and 80.0% for heritability of seed size in the narrow and broad sense respectively. In this study, however, heritability of branches per plant was estimated at 68.0%, a sharp constrast to the low estimate of 15.0% obtained by Kheradnam and Niknejad (1974).

Generally, these results imply that for yield improvement in the cowpea, 100-seed weight, seeds per pod, pod length and branches per plant are important traits to be considered as they have higher selective values than the other yield components.

9. Heterosis

Table 9 compares F_1 data collected for several characters to parental values, while estimates of heterosis for the same characters are indicated in Table 10.

Both mid- and better-parent heterosis were observed for all crosses with respect to pods/peduncle. These exceeded 100% in all cases. There was no clear-cut trend in the heterotic response of the crosses to the following yield determining factors: pod length, seed per pod, peduncles per branch, branches per plant and 100-seed weight, as some showed both mid- and better- parent heterosis, only mid-parent heterosis, or no heterosis at all for one or more of these characters. However, all crosses showed very high response (exceeding 100%) to grain yield per plant for both mid- and better- parent heterosis, reflecting the complementary effects of these factors in determining grain yield.

Ramanujam et al., (1964), Singh et al., (1973), and Gowda and Bahl (1976) reported heterosis for grain yield and pods per plant in chickpea. Average heterotic response for some seven chickpea crosses investigated by Mandal and Bahl (1979) were 18.92% for grain yield, 10.72% for

TABLE 9: VEGETATIVE AND REPRODUCTIVE CHARACTERISTICS OF F_1 COMPARED WITH PARENTAL VALUES

PARENTS/HYBRIDS	DFF (days)	DFM (days)	Branch Length (m)	Leaf Area (cm^2)	Pod Length (cm)	Seeds/ Pod	Pods/ Peduncle	Peduncles /Branch	Branches /Plant	100-Seed Weight (g)	Grain Yield Per Plant (g)
1. AM No.2	33.00	58.00	1.74	123.59	17.55	15.40	1.63	4.00	6.50	7.91	51.62
2. Ex. Ada	33.00	60.00	1.64	124.30	16.26	12.00	1.17	6.00	6.00	20.05	83.61
3. D.M.	29.00	49.00	1.01	121.80	12.80	9.90	1.52	4.50	6.50	9.70	42.69
4. L.B.	36.00	56.00	2.48	347.45	20.95	15.50	0.86	11.00	7.25	12.31	130.86
5. K.M.B.E.	57.00	90.00	2.54	185.86	14.90	12.90	0.79	6.50	7.00	14.93	53.13
6. TVX 1843	35.00	58.00	2.20	215.75	18.55	16.80	0.38	9.25	5.75	14.17	48.11
1. K.M.B.E. x AM No.2	36.00	58.00	1.62	150.70	18.84	16.70	2.85	5.50	6.50	8.00	136.12
2. K.M.B.E. x L.B.	38.00	69.00	2.69	351.99	18.90	13.93	2.67	10.00	8.00	14.80	440.37
3. K.M.B.E. x D.M.	31.00	58.00	0.92	331.01	15.81	14.02	3.18	4.00	6.50	9.74	112.90
4. Ex. Ada x TVX 1843	30.00	64.00	3.15	312.72	20.71	15.48	3.25	8.25	7.50	16.74	381.10
5. TVX 1843 x Ex. Ada	33.00	62.00	2.56	279.06	16.29	12.36	2.20	9.17	5.67	21.50	303.97

TABLE 10: ESTIMATES OF HETEROSIS (%)

HYBRIDS/PARENTS	DFF (days)	DFM (days)	Branch Length (cm)	Leaf Area (cm^2)	Pod Length (cm)	Seeds/ Pod	Pods/ Peduncle	Peduncles /Branch	Branches /Plant	100-Seed Weight (g)	Grain Yield Per Plant (g)
K.M.B.E. x D.M.	31.00	58.00	0.92	331.01	15.81	14.02	3.18	4.00	6.50	9.74	112.90
P_1 (K.M.B.E.)	57.00	90.00	2.54	185.86	14.90	12.90	0.79	6.50	7.00	14.93	53.13
P_2 D.M.	29.00	49.00	1.01	121.80	12.80	9.90	1.52	4.50	6.50	9.70	42.69
Mid-parent heterosis	27.91	16.55	48.17	115.18	14.15	22.98	169.49	-27.27	-3.70	-34.76	135.65
Better-parent heterosis	-6.90	-18.37	8.91	78.10	6.11	41.62	102.55	-38.46	-7.14	-37.76	112.50
K.M.B.E. x AM No.2	36.00	58.00	1.62	150.70	18.84	16.70	2.85	5.50	6.50	8.00	136.12
P_1 (K.M.B.E.)	57.00	90.00	2.54	185.86	14.90	12.90	0.79	6.50	7.00	14.93	53.13
P_2 (AM No.2)	33.00	58.00	1.74	123.59	17.55	15.40	1.63	4.00	6.50	7.91	51.62
Mid-parent heterosis	20.00	22.00	24.30	-2.60	16.08	18.02	135.54	4.76	-3.70	-29.95	159.87
Better-parent heterosis	-9.09	0.00	-6.90	-18.92	7.35	8.44	74.85	-15.39	-7.14	-46.42	156.20
K.M.B.E. x L.B.	38.00	69.00	2.69	351.09	18.90	13.93	2.67	10.00	9.00	14.80	440.37
P_1 (K.M.B.E.)	57.00	90.00	2.54	185.86	14.90	12.90	0.79	6.50	7.00	14.93	53.13
P_2 (L.B.)	36.00	56.00	2.48	347.45	20.95	15.50	0.86	11.00	7.25	12.31	130.86
Mid-parent heterosis	18.28	5.48	7.17	32.00	5.41	-1.90	221.69	14.29	12.20	8.66	378.66
Better-parent heterosis	-5.56	-23.21	5.91	1.31	-9.79	-10.13	210.47	-9.09	10.34	-0.87	236.50

Table 10 Cont'd: Estimates of Heterosis (%)

HYBRIDS/PARENTS	DFF (days)	DFM (days)	Branch Length (cm)	Leaf Area (cm^2)	Pod Length (cm)	Seeds/Pod	Pods/Peduncle	Peduncles/Branch	Branches/Plant	100-Seed Weight (g)	Grain Yield Per Plant (g)
Ex. Ada x TVX 1843	30.00	64.00	3.15	312.72	20.71	15.48	3.25	8.25	7.50	16.74	381.10
P_1 (Ex. Ada)	33.00	60.00	1.64	124.30	16.26	12.00	1.17	6.00	6.00	20.05	83.61
P_2 (TVX 1843)	35.00	58.00	2.20	215.75	18.55	16.80	0.38	9.25	5.75	14.17	48.11
Mid-parent heterosis	11.76	-8.48	64.06	83.92	18.98	7.50	316.67	8.20	27.64	-16.51	478.65
Better-parent heterosis	9.09	-10.35	43.18	44.95	11.64	-7.86	177.78	-10.81	25.00	-2.16	355.81
TVX 1843 x Ex. Ada	33.00	62.00	2.56	279.06	16.29	12.36	2.20	9.17	5.67	21.51	303.97
P_1 (TVX 1843)	35.00	58.00	2.20	215.75	18.55	16.80	0.30	9.25	5.75	14.17	48.11
P_2 (Ex. Ada)	33.00	60.00	1.64	124.30	16.26	12.00	1.17	6.00	6.00	20.05	83.61
Mid-parent heterosis	2.94	-5.09	33.33	64.12	-6.41	-14.17	197.97	20.25	-3.49	25.72	361.54
Better-parent heterosis	0.00	-6.90	16.36	29.34	-12.18	-26.43	88.03	-0.87	-5.50	7.28	263.56

primary branches, 4.74% for pods per plant and 3.97% for branches per plant.

Mid- and better-parent heterosis for branch length was high for the cross Ex Ada (spreading) x TVX 1843 (semi-erect), intermediate for its reciprocal cross, TVX 1843 (semi-erect) x Ex Ada (spreading), and low for K.M.B.E. (spreading) x L.B. (spreading) whilst K.M.B.E. (spreading x A.M. No. 2 (semi-erect) and K.M.B.E. (spreading) x D.M. (semi-erect) showed no heterotic response to branch length. These observations may be due to degree of genetic divergence in the varieties used. Ex Ada (local variety) and TVX 1843 (exotic variety) represent two geographically and probably genetically divergent parents. That F_1s from crosses and reciprocal crosses between the two generally showed high heterosis for all traits studied should be expected. However, Ex Ada, K.M.B.E., D.M., L.B., and A.M. No. 2 are all of local origin. Inability of their inter-varietal crosses to show appreciable heterosis for some of the traits investigated indicates that their genotypes do not differ sufficiently for those traits.

The three crosses involving K.M.B.E. showed only mid-parent heterosis in the range of 5.48 - 27.91% for both days to 50% flowering and 50% pod maturity. Ex Ada x TVX 1843 showed low heterotic response of 11.76% and 9.09% for mid- and better-parent heterosis respectively with regard to earliness of flower initiation, but no heterosis in respect of earliness of pod maturation. The reciprocal cross exhibited a 2.94% mid-parent heterosis only, for earliness to flower initiation but no heterosis for earliness to pod maturation.

On account of the results obtained, exploitation of heterosis in the breeding programme of cowpea appears attractive, limited only by the labour-intensive nature of mass production of F_1 as seed for commercial distribution.

CHAPTER V

SUMMARY AND CONCLUSIONS

Summary

Three field experiments were conducted at different times of the year, spanning January, 1985 to January, 1986, to determine the extent of genetic variability in growth characteristics and yield among 16 cowpea varieties. Separate experiments were conducted to test variability in harvest index (i.e. grain-straw ratio calculated on dry weight basis), resistance to bruchids in storage and ease of cooking without using tenderizers.

Data collected were subjected to basic statistical analysis relevant to genetic studies.

Based on the results obtained, six promising varieties with essentially contrasting characters were selected for making crosses used in estimating heritabilities of economically important yield components. Heterotic responses in the F_1s to these characters was also estimated as a guide to their selective values in future breeding programmes. The ease of crossing between the pairs of parents was also assessed.

The 16 varieties of cowpea used in these studies exhibited a wide range of variability in several traits, both quantitative and qualitative.

Most yield-influencing characters, except 100-seed weight and harvest index either negatively correlated with seed yield per plant or positively correlated, but not significantly. Hundred-seed weight and harvest index showed positive significant correlations with seed yield per plant.

In spite of the apparent complexity of characters determining the time required to cook cowpeas, larger-seeded varieties generally took shorter time than smaller-seeded varieties.

Seeds of all varieties were eventually infested and damaged by bruchids in storage. However, larger-seeded varieties were preferred and thus stored poorly in comparison with smaller-seeded ones.

Percent crossability was variable among the pairs of parents used. Kaase market black eye could not be used successfully as a female parent because the delicately attached pedicel easily fell off after mechanical manipulation.

Narrow sense heritabilities determined for yield components showed that 100-seed weight, seeds per pod, pod length and number of branches per plant, in that order, were of higher selective value than other yield components.

F_1 values for yield-influencing factors showed varying levels of heterosis over both mid- and better-parental values. The complementary effects of these factors in contributing to grain yield was evidenced by the fact that heterotic response for grain yield at both levels far exceeded 100% in all crosses, giving enough cause to advocate for the exploitation of heterosis in cowpea breeding programmes.

Conclusions

With the range in variability in varietal characteristics observed it is possible for the plant breeder to select plants with the specific desirable characteristics for use in future breeding programmes.

Improvement in seed yield could be elicited by selecting for high 100-seed weight and high harvest index as evidenced from the correlation studies. Reductions in flowering and maturity times should be expected alongside, as these characters were negatively correlated with seed yield. Selecting for high 100-seed weight in a breeding programme will also be compatible with consumer expectations as it will ease cooking of the dried beans.

Any attempt to select for small-seeded varieties as a way of reducing seed damage by bruchids in storage may not only contradict current breeding objectives but may also prove ineffective. The large numbers of such seeds required per unit weight may in the long run provide a much larger surface area for oviposition by the insects and hence subsequent development and damage to the seeds. In this regard, the ultimate choice of breeders appears to be for varieties with size compatible with breeding objectives and consumer preferences, and possessing intrinsic characteristics conferring resistance to the cowpea weevil, **probably** a deterrent seed coat and/or reduced nutritional value to the insect.

An ideal variety for incorporation in the multiple- and mixed-cropping systems common with peasant agriculture in the country, and also suitable for cultivation in monocultures should be one which is erect, early maturing, with determinate flowering and fruiting habits. Such a variety should also be able to withstand stress conditions in the field, nodulate freely and be a very high yielder of good quality seeds.

In the present studies, no single variety combined high yielding ability with all the desirable traits. However, two local and three exotic varieties may be recommended for use in future improvement programmes based on their performances. These are Ex Ada, Kaase market black eye, TVX 1843, Ife brown and TVX 1999-02E. Kaase market black eye may be replaced by Kaase market brown eye as their characters are similar. The two varieties are, however, photoperiod sensitive (requiring shorter days to trigger flowering and fruiting) and could be treated with mutagens with a view of obtaining mutants which will be photoperiod insensitive.

In order to get a proven variety, hybridization may be used to combine all desirable characters into a single compound or multiple cross variety.

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APPENDIX 1: ANALYSIS OF VARIANCE TABLES

EXPERIMENTS 1-3: GROWTH AND YIELD CHARACTERISTICS

1. Days to 50% Flowering

Source of Variation	d.f. (n-1)	S.S.	M.S.S.	Observed F	Required F	
					5%	1%
Total	143	5234.22	36.60			
Varieties	15	2759.19	183.95	35.93**	1.80	2.27
Blocks	6	13.72	2.29	0.45	2.21	3.04
Season	2	604.01	302.01	58.99**	3.11	4.89
Var. x Season	30	1396.69	46.56	9.09**	1.60	1.95
Error	90	460.61	5.12			

2. Average dry Weight Per Plant At 50% Flowering

Source of Variation	(d.f. (n-1)	S.S.	M.S.S.	Observed F	Required F	
					5%	1%
Total	143	37058.01	259.15			
Varieties	15	6.89	0.46	0.01	1.80	2.27
Blocks	6	273.31	45.55	0.16	2.21	3.04
Season	2	7955.18	3977.59	13.27**	3.11	4.89
Var. x Season	30	2552.52	85.04	0.29	1.60	1.95
Error	90	26270.11	291.89			

3. No. of Nodules Per Plant at 50% Flowering

Source of Variation	d.f. n-1)	S.S.	M.S.S.	Observed F	Required F	
					5%	1%
Total	143	15371.86	37.57			
Varieties	15	5151.19	343.41	8.27**	1.80	2.27
Blocks	6	796.46	132.74	3.20**	2.21	3.04
Season	2	1218.26	609.13	14.66**	3.11	4.89
Var. x Season	30	4466.37	509.47	12.26**	1.60	1.95
Error	90	3739.58	41.55			

Note: * Significant at 5% level ** Significant at 1% level

4. Percent Effective Nodulation

Source of Variation	d.f. (n-1)	S.S.	M.S.S.	Observed F	Required F 5%	Required F 1%
Total	143	30117.16	210.61	4		
Varieties	15	3572.81	238.19	4.32**	1.80	2.27
Blocks	6	469.51	78.25	1.42	2.21	3.04
Season	2	3875.37	1937.69	35.15**	3.11	4.89
Var. x Season	30	17238.68	574.62	10.43**	1.60	1.95
Error	90	4960.79	55.12			

5. No. of Branches Per Plant

Source of Variation	d.f. (n-1)	S.S.	M.S.S.	Observed F	Required F 5%	Required F 1%
Total	143	305.17	2.13			
Varieties	15	70.65	4.71	2.82**	1.80	2.27
Blocks	6	8.69	1.45	0.87	2.21	3.04
Season	2	46.01	23.01	13.78**	3.11	4.89
Var. x Season	30	29.68	0.99	0.59	1.60	1.95
Error	90	150.14	1.67			

6. No. of Peduncles Per Branch

Source of Variation	d.f. (n-1)	S.S.	M.S.S.	Observed F	Required F 5%	Required F 1%
Total	143	112.50				
Varieties	15	25.12	1.67	3.64**	1.80	2.27
Blocks	6	1.15	0.19	0.41	2.21	3.04
Season	2	19.05	9.53	20.72**	3.11	4.89
Var. x Season	30	25.93	0.86	1.87*	1.60	1.95
Error	90	41.25	0.46			

Note: * Significant at 5% level ** Significant at 1% level

7. <u>No. of Pods Per Peduncle</u>

Source of Variation	d.f. (n-1)	S.S.	M.S.S.	Observed F	Required F	
					5%	1%
Total	143	34.08	0.24			
Varieties	15	26.05	1.74	24.86**	1.80	2.27
Blocks	6	0.10	0.02	0.29	2.21	3.04
Season	2	0.07	0.04	0.57	3.11	4.89
Var. x Season	30	1.97	0.07	1.00	1.60	1.95
Error	90	5.89	0.07			

8. <u>Pod Length</u>

Source of Variation	d.f. (n-1)	S.S.	M.S.S.	Observed F	Required F	
					5%	1%
Total	143	603.40	4.22			
Varieties	15	347.68	23.18	20.70**	1.80	2.27
Blocks	6	4.96	0.83	0.74	2.21	3.04
Season	2	69.30	34.65	30.94**	3.11	4.89
Var. x Season	30	80.39	2.68	2.39**	1.60	1.95
Error	90	101.07	1.12			

9. <u>No. of Seeds Per Pod</u>

Source of Variation	d.f. (n-1)	S.S.	M.S.S.	Observed F	Required F	
					5%	1%
Total	143	834.26	5.83			
Varieties	15	237.34	15.82	10.84**	1.80	2.27
Blocks	6	7.04	1.17	0.80	2.21	3.04
Season	2	378.42	189.21	129.60**	3.11	4.89
Var. x Season	30	80.02	2.67	1.83*	1.60	1.95
Error	90	131.44	1.46			

Note: * Significant at 5% level ** Significant at 1% level

10. 100-Seed Weight

Source of Variation	d.f. (n-1)	S.S.	M.S.S.	Observed F	Required F 5%	Required F 1%
Total	143	2052.78	14.36			
Varieties	15	728.13	48.54	42.21**	1.80	2.27
Blocks	6	0.96	0.16	0.14	2.21	3.04
Season	2	117.87	58.94	51.25**	3.11	4.89
Var. x Season	30	1102.42	36.75	31.96**	1.60	1.95
Error	90	103.41	1.15			

11. CMV Resistance Score

Source of Variation	d.f. (n-1)	S.S.	M.S.S.	Observed F	Required F 5%	Required F 1%
Total	143	111.97	0.78			
Varieties	15	39.53	2.64	6.14**	1.80	2.27
Blocks	6	0.35	0.06	0.14	2.21	3.04
Season	2	0.26	0.13	0.30	3.11	4.89
Var. x Season	30	32.85	1.10	2.56**	1.60	1.95
Error	90	38.98	0.43			

12. Shattering Resistance Score

Source of Variation	d.f. (n-1)	S.S.	M.S.S.	Observed F	Required F 5%	Required F 1%
Total	143	106.97	0.75			
Varieties	15	57.75	7.50	23.44**	1.80	2.27
Blocks	6	0.39	0.07	0.22	2.21	3.04
Season	2	10.68	5.34	16.69**	3.11	4.89
Var. x Season	30	9.54	0.32	1.00	1.60	1.95
Error	90	28.61	0.32			

Note: * Significant at 5% level ** Significant at 1% level

13. Days to 50% Pod Maturity

Source of Variation	d.f. (n-1)	S.S.	M.S.S.	Observed F	Required F	
					5%	1%
Total	143	12151.94	84.98			
Varieties	15	3579.83	238.66	2.66**	1.80	2.27
Blocks	6	13.54	2.26	0.03	2.21	3.04
Season	2	2165.04	1082.52	12.06**	3.11	1.95
Var. x Season	30	1892.73	63.09	0.70	1.60	1.95
Error	90	8077.05	89.75			

14. Grain Yield Per Plant

Source of Variation	d.f. (n-1)	S.S.	M.S.S.	Observed F	Required F	
					5%	1%
Total	143	36204.96	253.18			
Varieties	15	18325.19	1221.17	13.46**	1.80	2.27
Blocks	6	5.54	0.92	0.01	2.21	3.04
Season	2	678.73	339.37	3.74*	3.11	4.89
Var. x Season	30	9028.98	300.97	3.32**	1.60	1.95
Error	90	8166.52	90.74			

15. Grain Yield Per Plot

Source of Variation	d.f. (n-1)	S.S.	M.S.S.	Observed F	Required F	
					5%	1%
Total	143	3.482×10^7	2.435×10^5			
Varieties	15	1.692×10^7	11.280×10^5	12.55**	1.80	2.27
Blocks	6	0.004×10^7	0.067×10^5	0.07	2.21	3.04
Season	2	0.042×10^7	2.100×10^5	2.34	3.11	4.89
Var. x Season	30	0.935×10^7	3.117×10^5	3.47**	1.60	1.95
Error	90	0.809×10^7	0.899×10^5			

Note: * Significant at 5% level ** Significant at 1% level

EXPERIMENT 4: SEED SOFTNESS AFTER VARIOUS PERIODS OF BOILING

1. 30 Minutes

Source of Variation	d.f. (n-1)	S.S.	M.S.S.	Observed F	Required F	
					5%	1%
Total	127	34.87	0.27			
Varieties	15	9.81	0.65	3.82*	1.77	2.23
Blocks	7	7.57	1.08	6.35*	2.11	2.83
Error	105	17.49	0.17			

2. 40 Minutes

Source of Variation	d.f. (n-1)	S.S.	M.S.S.	Observed F	Required F	
					5%	1%
Total	127	49.12	0.39			
Varieties	15	18.80	1.25	7.35**	1.77	2.23
Blocks	7	12.15	1.74	10.24*	2.11	2.83
Error	105	18.18	0.17			

3. 50 Minutes

Source of Variation	d.f. (n-1)	S.S.	M.S.S.	Observed F	Required F	
					5%	1%
Total	127	40.40	0.32			
Varieties	15	10.68	0.71	5.07**	1.77	2.23
Blocks	7	14.70	2.10	15.00**	2.11	2.83
Error	105	15.02	0.14			

4. 60 Minutes

Source of Variation	d.f. (n-1)	S.S.	M.S.S.	Observed F	Required F	
					5%	1%
Total	127	49.03	0.39			
Varieties	15	12.78	0.85	6.54**	1.77	2.23
Blocks	7	22.36	3.19	24.54**	2.11	2.83
Error	105	13.39	0.13			

Note: * Significant at 5% level ** Significant at 1% level

EXPERIMENT 5: BRUCHID DAMAGE TO SEEDS IN STORAGE***

1. Number of Eggs Laid Per Seed at 5 Days

Source of Variation	d.f. (n-1)	S.S.	M.S.S.	Observed F	Required F 5%	Required F 1%
Total	63	58.85	0.93			
Varieties	15	53.25	3.55	29.58**	1.90	2.48
Blocks	3	0.25	0.08	0.67	2.82	4.27
Error	45	5.35	0.12			

2. Infestation at 10 Days

Source of Variation	d.f. (n-1)	S.S.	M.S.S.	Observed F	Required F 5%	Required F 1%
Total	63	3514.13	55.78			
Varieties	15	2337.41	155.83	6.53**	1.90	2.48
Blocks	3	102.14	34.05	1.43	2.82	4.27
Error	45	1074.58	23.88			

3. Infestation at 15 Days

Source of Variation	d.f. (n-1)	S.S.	M.S.S.	Observed F	Required F 5%	Required F 1%
Total	63	3667.46	58.21			
Varieties	15	2265.84	151.06	6.70**	1.90	2.48
Blocks	3	86.82	28.94	1.28	2.82	4.27
Error	45	1014.80	22.55			

4. Infestation at 20 Days

Source of Variation	d.f. (n-1)	S.S.	M.S.S.	Observed F	Required F 5%	Required F 1%
Total	63	3002.97	47.67			
Varieties	15	1373.15	91.54	2.62**	1.90	2.48
Blocks	3	60.47	20.16	0.58	2.82	4.27
Error	45	1569.35	34.87			

Note: ** Significant at 1% level

*** Data transformed using the arcsin transformation

5. Infestation at 25 Days

Source of Variation	d.f. (n-1)	S.S.	M.S.S.	Observed F	Required F	
					5%	1%
Total	63	1365.69	21.53			
Varieties	15	603.78	40.25	2.46*	1.90	2.48
Blocks	3	16.70	5.57	0.34	2.82	4.27
Error	45	736.20	16.36			

6. Infestation at 30 Days

Source of Variation	d.f. (n-1)	S.S.	M.S.S.	Observed F	Required F	
					5%	1%
Total	63	827.83	12.93			
Varieties	15	229.83	15.32	1.25	1.90	2.48
Blocks	3	47.47	15.82	1.29	2.82	4.27
Error	45	550.54	12.23			

7. Infestation at 35 Days

Source of Variation	d.f. (n-1)	S.S.	M.S.S.	Observed F	Required F	
					5%	1%
Total	63	1027.26	21.07			
Varieties	15	291.21	19.41	1.33	1.90	2.48
Blocks	3	76.78	25.59	1.75	2.82	4.27
Error	45	659.28	14.65			

8. Infestation at 40 Days

Source of Variation	d.f. (n-1)	S.S.	M.S.S.	Observed F	Required F	
					5%	1%
Total	63	482.32	9.24			
Varieties	15	125.08	8.34	1.10	1.90	2.48
Blocks	3	15.64	5.21	0.69	2.82	4.27
Error	45	341.60	7.59			

Note: * Significant at 5% level ** Significant at 1% level

EXPERIMENT 6: HARVEST INDEX

Source of Variation	d.f. (n-1)	S.S.	M.S.S.	Observed F	Required F	
					5%	1%
Total	47	4595.52	97.78			
Varieties	15	2778.07	185.20	3.94**	2.01	2.70
Blocks	2	406.55	203.28	4.32*	3.32	5.39
Error	30	1410.91	47.03			

Note: * Significant at 5% level ** Significant at 1% level