VARIABILITY AND HETEROSIS IN COWPEA (*VIGNA UNGUICULATA* (L) WALP.) ACCESSIONS FROM FOUR REGIONS OF GHANA

By

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DECLARATION

I do hereby declare that, except for references to 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

Forty-five cowpea accessions, randomly selected from cowpea germplasm from four cowpea-growing regions of Ghana, namely, Upper East, Upper West, Northern and Eastern Regions, were characterized and evaluated at the Plant Genetic Resources Unit of the Crops Research Institute at Bunso with the objective to determine the range of variability in the samples with respect to vegetative, inflorescence and fruit characters. The variability in the samples was used to initiate hybridization among some selected accessions from the collection. Subsequently heterosis was determined for flowering and maturity dates and yield and yield components in four crosses among the selected accessions with the view to improving the yield.

Large variability was observed in most of the qualitative characters, particularly growth habit, twining tendency, plant and pod pigmentation, raceme position, pod attachment to peduncle and flower colour of the germplasm. The accessions differed significantly in their days to flowering and maturity, peduncle length, number of peduncles per plant, number of pods per plant, pod length, number of seeds per plant, 100-seed weight and grain yield per plant. There were also significant between- and within-region differences in these characters.

Heterosis for pods per plant and grain yield per plant in all the four crosses was positive and high. This was particularly so for grain yield per plant for the cross between accessions 87/27 and 87/157 in which heterosis was about 130%.

The possibility of using accessions 87/27 and 87/157 for future improvement programmes of the crop is discussed based on their performance in this work.

1. INTRODUCTION

Cowpea is one of the most important legumes in Ghana. It has been assigned first priority for germplasm collection and conservation in West Africa by the International Board for Plant Genetic Resources (IBPGR, 1981) since West Africa is regarded as centre of domestication and diversity of the crop (Steele, 1976; Steele and Mehra, 1980).

Cowpea is a widespread and popular food legume in Ghana and it is imperative that the landraces of the crop be collected and conserved. Landraces of cowpea and their wild relatives are well adapted to their local environment and it may be necessary to use these adaptive traits in breeding programmes. These traits include resistance to pests and diseases, adaptation to poor soils and tolerance to drought and heat stresses.

In recent years, cowpea improvement has been intensified by research institutions with the result that improved varieties are being turned out quite rapidly. These improved varieties may tend to replace the well adapted local varieties. Furthermore the frequent bushfires in the cowpea-growing areas may destroy several cowpea varieties together with their wild relatives. Genetic erosion in the crop may also be caused by development activities like the construction of dams, roads and townships (Chang et al., 1972).

The collection and conservation of germplasm are important to safeguard against the loss of the species due to genetic erosion and for use in cowpea improvement programmes. Collecting a large diversity of a crop provides a broad genetic base to satisfy the needs of future breeding programmes.

When germplasm has been assembled, it is necessary that it is characterized and evaluated using appropriate descriptors. In this respect, both qualitative and quantitative characters are evaluated. Such data are documented and supplied to plant breeders together with the germplasm when requests for breeding materials are made.

Though several cowpea germplasm expeditions have been carried out in Ghana, the collection is by no means complete. More expeditions are required to fill in gaps still existing in the collections. There is the need to ensure that majority of existing landraces in Ghana are present in the germplasm assembled at the genetic resources centres.

The objective of this study was to assemble, characterize and evaluate the genetic diversity in a collection of cowpea genotypes from four cowpea-growing areas in Ghana and furthermore, to initiate hybridization among some selected accessions from the collection and to estimate some genetic parameters in the hybrid populations. The magnitudes of these genetic parameters will indicate the potential for making improvements in the populations.

2. LITERATURE REVIEW

2.1 Origin and distribution of cowpea

Cowpea, *Vigna unguiculata* (L) Walp., is an important pulse crop in tropical Africa. It is reported to have originated from West Africa (Faris, 1963; Rachie and Rawal, 1976; Smithson, Redden and Rawal, 1980) and most probably in Nigeria, where wild and weedy species abound (Rawal, 1973; Rachie and Rawal, 1976; Steele, 1976).

Most of the world's production is in Africa and major producing countries are Nigeria, Burkina Faso, Niger, Ghana, Kenya and Uganda (Dovlo *et al*., 1976; Rachie and Rawal, 1976; Steele and Mehra, 1980; Rachie, 1985). Other producing countries outside Africa include, United States of America (USA), (Brazil, India, Sri Lanka, Burma and Bangladesh (Rachie, 1985). The crop is also cultivated in the Mediterranean region and the Carribean islands (IITA, 1983).

2.2 Economic importance of cowpea

Dry cowpea seeds have protein content ranging from 18 to 29% (IITA, 1983). Hence, it is a cheap source of protein in the diet. An increase in the production of cowpea will therefore help to reduce the incidence of protein malnutrition in children, especially in the rural areas of developing countries.

Cowpea is consumed in many different ways. The young shoots, leaves and even roots are used as pot herb in most parts of Africa (IITA, 1982). The tender young leaves are eaten in the northern parts of Ghana (Asafo-Adjei, 1986) and elsewhere in Africa as vegetables (Dovlo et al., 1976; Grubben, 1977). In the USA the canning and freezing of immature pods for food is very important (IITA, 1982; Purseglove, 1968). Cowpea may also be used as a fodder for livestock and as green manure (Dovlo et al., 1976).

Cowpea is most often eaten with cereals to enhance the protein value of the latter which are sometimes deficient in sulphur-containing amino acids (Dovlo et al., 1976). The bulk of the seed is cooked and eaten in West Africa (Dovlo, 1976).

2.3 Cowpea cultivation in Ghana

The cultivation of cowpea in Ghana is widespread. It is grown mainly in the savannah and the transitional zones. There is some amonunt of cultivation in the forest zone too. Indeed, it can be grown throughout the country (GGDP, 1990).

Cowpea cultivation in Ghana has been done mainly by peasant farmers who intercrop it with cassava, sorghum, millet and yams. The peasant farmers usually use local varieties which vary widely in various characters. Commercial cowpea farming involving large areas of sole cowpea is on a rapid increase in Ghana.

2.4 Constraints to cowpea production

Several factors militate against the production of cowpea in Ghana. Both biotic and abiotic factors contribute to this (IITA, 1982). Some of these factors are discussed below.

i. Planting materials - the planting materials used by peasant farmers are mostly locally adapted landraces which are generally low-yielding (Rachie and Rawal, 1976; IITA, 1983).

ii. Climate - this is characterized by unfavourable conditions like insufficient, poorly distributed or excessive rainfall, inadequate insolation and extreme temperatures (Rachie, 1985).

iii. Soils - which are usually poor in physical and chemical properties and have low fertility due to deficiency in organic matter and often unfavourable microbiological conditions (Rachie, 1985).

iv. Pests - cowpea production is greatly hampered by several pests which attack various parts of the plant especially, thrips which attack flowers, pod-sucking pests like *Maruca*, storage bruchid and *Striga*, the plant parasite of the crop (Singh and Jackai, 1985).

v. Disease - several disease-causing organisms like virus, fungi, nematodes and bacteria cause a drastic reduction in the yield of cowpea (Emechebe and Shoyinka, 1985).

vi. Storage loss - the storage weevil, *Callosobruchus maculatus* causes high rates of post-harvest losses which begin in the field and continue in the shelled seeds in storage (Singh and Jackai, 1985).

vii. Inadequate management practices - low plant densities which arise from the common practice of growing the crop in association with other crops, sub-optimal planting dates and little or no insecticidal and weed control methods lead to reduction in yield (Rachie, 1985).

2.5 Cowpea collecting exploration in Ghana

In Ghana the set-up mandated to engage in plant genetic resources activities is the Plant Genetic Resources Unit (PGRU) of the Crops Research Institute (CRI) based at Bunso in the Eastern Region. Systematic collection of cowpea germplasm in Ghana started in 1976 (Adansi and Holloway, 1980; Bennett-Lartey, 1988). The first collection of cowpea germplasm in Ghana was carried out in 1976 by a team of experts from the Genetic Resources Unit (GRU) of the International Institute of Tropical Agriculture (IITA) (GRU, 1976). The number of cultivated cowpea (*Vigna unguiculata*) and wild cowpea species collected were 111 and 32 respectively (GRU, 1976). The wild *Vigna* species collected included *V. reticulata*, *V. racemosa*, *V. pubigera* and *V. paludosa*.

In 1977 a team from the PGRU, Bunso followed up the 1976 collection. The team collected 48 accessions of cowpea from areas the 1976 team could not visit (Bennett-Lartey, 1986). In 1978 a team from the GRU of IITA and the Faculty of Agriculture of the University of Ghana, Legon also collected 38 accessions from the Northern, Upper and Brong Ahafo Regions of Ghana (Adansi and Holloway, 1978; GRU, 1978; Perez, 1978).
Between October, 1982 and February, 1983, there was a multicrop germplasm collecting mission in Ghana by the PGRU. In this expedition 61 accessions of cowpea were collected from all regions of Ghana except the Greater Accra and Western Regions (Bennett-Lartey, 1983; Holloway, 1983). Between October and December 1987, 71 accessions of cultivated cowpea were collected in four cowpea-growing regions of the country, namely, Northern, Upper East, Upper West and Eastern Regions by PGRU.
One hundred and nineteen accessions of wild cowpea species were also collected in all regions of Ghana except the Greater Accra, Eastern and Western Regions between 1987-89 (Bennett-Lartey, 1990; 1991).

Though there is a great diversity in the cowpea found in the savanna zones of Ghana, the diversity is not up to what is found in the savanna zones of Nigeria (GRU, 1976).

2.6 Preliminary characterization and evaluation

For collected plant genetic resources to be useful certain basic information has to be available on them. The provision of this basic information is considered the responsibility of the curator of the gene-bank. This work includes the basic morphological description of the accessions. This is usually done at the time of multiplication of the seeds or other planting materials using standardized crop descriptors (Howes, 1981).

Preliminary characterization consists of recording characters which are highly heritable and which can be easily scored visually and will be exposed in most environments (Howes, 1981; IBPGR, 1983). Some of these data can be collected in the field with the collection, otherwise they can be collected during multiplication of the germplasm.

Characterization data are useful because they can be used for identification purposes and they are a good guide for the future use of the material. Since such characters are heritable they will be reliable and constant. Examples of preliminary characterization data are flower colour, fruit size and fruit colour.

Preliminary evaluation consists of recording a limited number of additional agronomic traits thought desirable by a consensus of users of the particular crop (Howes, 1981). These characters are capable of visual assessment but not in all environment. Some of these descriptors may be recorded at the same time as characterization. Examples of such data are reaction to diseases and pests, and resistance or tolerance to environmental stresses.

2.7 Further characterization and evaluation

Beyond the basic descriptive work carried out on a collection are a range of other characters of interest to breeders (Chapman, 1989). These include stress tolerance, disease and pest resistances, and quality characters. Evaluation for many of these traits is outside the ability or resources of most curators. It is the responsibility of the users of a collection and may require specialized laboratory or greenhouse work and the assistance of an expert familiar with the specific character and procedure for testing (Howes, 1981; Chapman, 1989).

2.8 Characterization and evaluation of cowpea

Standardized characterization and evaluation data should be readily available on plant genetic resources. In this respect the International Board for Plant Genetic Resources (IBPGR) has produced standard descriptors for cowpea (IBPGR, 1983). The descriptors contain information necessary for recording passport, characterization and preliminary evaluation data for cowpea germplasm.

Several workers have worked on the characterization and evaluation of cowpea. Faris (1963) collected both cultivated and wild cowpea from all over the world and he characterized them on the basis of morphological traits. Doku (1970) characterized 7 local and 32 introduced cowpea cultivars on morphological characters including 100-seed weight, pod length, number of pods per plant, time from germination to maturity, weight of nodules per plant, seed yield per plant, number of seeds per pod and time from germination to flowering. Scientists at the Genetic Resources Unit of the International Institute of Tropical Agriculture have characterized the cowpea germplasm collected from all over the world and have produced a catalog of information on cowpea (Porter, 1973; Porter *et al.*, 1974). A similar catalog has been produced from the data on Botswana cowpea germplasm (deMooy, 1984). Cowpea germplasm collected in Ghana in 1982 and 1983 have also been characterized and evaluated (Bennett-Lartey, 1984).

2.9 Variability in cowpea collections

Abifarin (1984) defines variability as the state or quality of being variable. In plant breeding, variability refers to the presence of genotypically different individuals.

Cultivated species are usually variable and cowpea is no exception (Ng and Maréchal, 1985). Ng and Maréchal (1985) attributed the variability in cultivated species to artificial selection under diverse environments. As a result of characterization and evaluation carried out on cowpea germplasm, wide variability has been observed in several characters of the crop.

Dovlo (1976) reported the presence of many different grain colour in cowpea found in Ghanaian markets. Working on a world collection of cowpea at IITA, Porter *et al.* (1974) observed variability in several characters including growth habit, twining tendency, days to flowering and maturity, eye colour and pattern and susceptibility to insect pests and diseases.

deMooy (1984; 1985) also found variability in several characters in 108 accessions of Botswana cowpea germplasm. These characters included terminal leaflet length and width, peduncle length, pod length, number of pods per plant and number of seeds per pod. Amoatey (1987) working with cowpea accessions from Ghana and Nigeria found variability in seed size, seed colour, pod length, number of seeds per pod, 100-seed weight and grain yield. Doku (1970) observed variability in weight of nodules per plant in 39 Ghanaian and exotic cowpea varieties he studied.

2.10 Cowpea improvement

Evaluated cowpea germplasm has proved very useful in crop improvement programmes against known pests and diseases. The cowpea B301 from Botswana was found to be resistant to the plant parasite *Alectra vogelii* in evaluations in Botswana. It was subsequently used in *Striga* trials in Burkina Faso, Mali, Niger and Nigeria and was found to be resistant. Similarly B301 which is a smooth-seeded variety of about 70 days maturity is being used in breeding programmes in Nigeria for its drought resistance characteristics (IITA, 1988a).

Several cowpea lines including TV 3236 with adaptability and high yields have been used to breed improved varieties like IT 845-2246-4 which has resistance against aphids, thrips and the storage weevil (IITA, 1988b). An IITA cowpea germplasm TVu 2027 is known to be moderately resistant to the bruchid storage insect (*Callosobruchus maculatus*) (Singh and Jackai, 1985) and this was the only accession out of 10,000 found to have resistance to this pest (Jackai and Singh, 1991). This accession has been the basis of the bruchid resistance in all improved cowpea varieties from IITA (Singh and Jackai, 1985). Research at the University of Durham revealed a biochemical factor which made cowpea meal toxic to the bruchid larvae and thereby conferring resistance in TVu 2027 (Baker, 1978).

Desirable traits in cowpea germplasm have been used in the improvement of other crops by the use of genetic engineering techniques. A gene from the IITA-bred cowpea TVu 2027 which inhibits insect trypsin has been transferred into a tobacco plant by British plant scientists at the Plant Breeding Institute, Cambridge, U.K. (Anon, 1988). The gene encodes a protein that is a natural inhibitor of insect trypsin which helps the tobacco plant to resist insect pests.

Wild cowpea germplasm has also been found to possess high levels of resistance to insect pests. Sources of high levels of resistance to cowpea coreid bug, *Clavigralla tomentosicollis* and cowpea pod borer, *Maruca testulalis* have been identified from the IITA germplasm collections of *Vigna vexillata* (TVNu 72 and TVNu 73) (IITA, 1988b; Jackai and Singh, 1991). Though so far no successful cross has been possible between *V. vexillata* and *V. unguiculata*, there is the possibility that the barriers in the hybridization of wild and cultivated cowpea may be overcome using in-vitro methods (IITA, 1988b).

Lately, the major thrust within the cowpea research programme has been to develop genotypes with high and stable potential and favourable characteristics such as resistance to some diseases and insects (Ng, 1982), early (60 days) and medium (75-80 days) maturity, grain, vegetable and fodder types; and different seed sizes, coat texture and colours for various consumer preferences (IITA, 1988b).

In Ghana cowpea improvement has been intensified since 1979 with the inception of the Ghana Grains Development Project (GGDP) (Asafo-Adjei, 1986). This increased research activity in co-operation with IITA and the Canadian International Development Agency (CIDA) has led to the release of several improved varieties of cowpea (Wobil, 1986). Examples of the improved and high yielding varieties of cowpea recently released in Ghana are Soronko, Amantin, Asontem and Vallenga with medium (75-80 days) to very early (60-65 days) maturity (GGDP, 1990).

2.11 Heterosis and crop improvement

Heterosis is defined as the increased development or expression of one or more characters of hybrid plants above that of the parents (Abifarin, 1984). The characters could be vigour, growth, size, yield, earliness and improved general fitness characteristics such as resistance to disease, lodging and drought. The character so expressed is usually more than the average of the two parents. Heterosis is also termed hybrid vigour.

Several theories have been put forward to explain the genetic basis of heterosis. According to Briggs and Knowles (1967), there are the over-dominance, dominance and epistasis theories. The overdominance or heterozygosity theory has resulted from the fact that theoretically heterozygotes for a single gene difference are superior to either of the two homozygotes.

This superiority is attributed to the metabolic advantage of the gene product produced by two different kinds of alleles rather than only one kind (Strickberger, 1985). In the dominance theory, dominant alleles contribute equally to heterosis and the recessive alleles do not and therefore dominance is assumed to be complete and expressed in the hybrid. It has been postulated that epistasis, which includes complementary, inhibiting and duplicate gene interactions, may be a cause of heterosis even though no direct evidence to that effect has been cited (Briggs and Knowles, 1967). According to Burton (1968), heterosis is thought to have resulted from the combined action and interactions of allelic and non-allelic factors and is usually closely and positively correlated with heterozygosity.

Heterosis is usually measured with reference to either the midparent value or the higher parent value (Laosuwan and Atkins, 1977). Heterosis in which an expressed character of a hybrid is beyond the range of either parent is termed heterobeltiosis

(Abifarin, 1984). Both heterosis and heterobeltiosis can be computed from the following equations.

$$\text{Heterosis (\%)} = (\bar{F}_1 - MP) / MP \times 100$$

$$\text{Heterobeltiosis (\%)} = (\bar{F}_1 - HP) / HP \times 100$$

where $\bar{F}_1$, MP and HP are the means for the F_1, midparent and higher parent respectively (Laosuwan and Atkins, 1977).

In practice the problems a hybrid breeder would have to resolve have been enumerated by Simmonds (1979) as follows:

1) isolating numerous inbred lines;
2) testing combinations of inbreds to identify excellent ones;
3) devising short-cut methods of testing inbreds without resort to crossing everything by everything and
4) developing methods of making hybrid seed on commercial scale.

Weber _et al_. (1970) also argued that for a highly self-fertilizing species two requirements should be satisfied for successful commercial production of F_1 hybrids. First, there must be heterosis for seed yield and, second an economical large-scale method of making hybrids must be found. Kheradnam _et al_. (1975) concluded that the production of hybrid seed for cowpea could be commercially advantageous, if large-scale methods of emasculation and crossing were developed for this species. The discovery or development of male sterility would facilitate hybrid seed production in cowpea (Rachie and Rawal, 1976).

Several workers have observed heterosis for yield and yield components in such crops as cowpea (Kheradnam at al., 1975), soybean (Paschal and Wilcox, 1975), safflower (Yazdi-Samadi et al., 1975), potato (Tarn and Tai, 1977) and Indian mustard (Singh, 1973).

3. MATERIALS AND METHODS

3.1 Exploration and collection of cowpea germplasm

A cowpea germplasm collecting mission was carried out in four cowpea-growing regions of Ghana, namely Northern, Upper East, Upper West and Eastern Regions. Collection started in October, 1987 and ended in December, 1987. The collection sites of the germplasm are indicated in Fig.1. Collections were made in towns and villages (Appendix), from farmers' fields, home gardens, farm stores and markets. All collections were landraces. Materials collected were pods and seeds. Seed samples of the collected accessions are shown in Fig.2. Passport data were collected with the germplasm (Appendix). A total of 71 accessions of cowpea germplasm were collected in the four regions.

3.2 Seed multiplication, characterization and preliminary evaluation

Forty-five accessions of the cowpea germplasm were randomly selected for this study with representative accessions from each region.

Seeds from the 45 accessions were sown in the field for seed multiplication, characterization and preliminary evaluation. The seeds were sown at a spacing of 90cm x 90cm using three seeds per hill on plots 4.5m by 1.8m.. The seedlings were thinned to one per stand one week after seedling emergence. There were two rows per

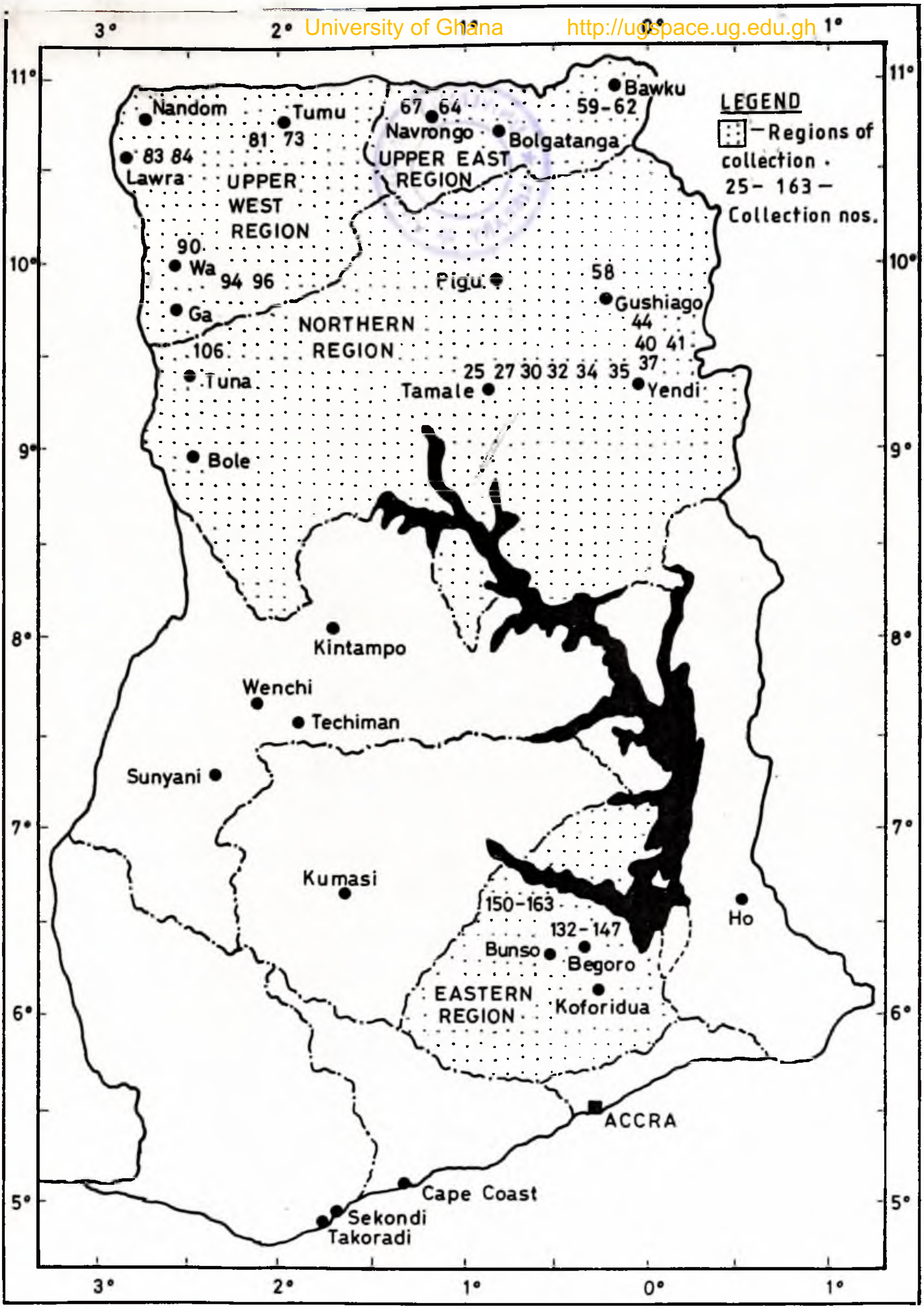

FIG. 1. COWPEA GERMPLASM COLLECTION SITES (SHADED REGIONS) IN GHANA IN 1987.

Fig. 2 Seed samples of cowpea germplasm collected in four regions of Ghana in 1987.

five plants per row. There was no replication because of the small number of seed samples.

Characterization and preliminary evaluation data collected at this stage were on vegetative, inflorescence and fruit characters based on the standard descriptors for cowpea (IBPGR, 1983). Mature pods were collected from all accessions for further studies.

3.2.1 Characterization of vegetative characters

i. Growth habit: - The accessions were classified at six weeks after planting (WAP) into erect, semi-erect, intermediate, semi-prostrate or prostrate.

ii. Growth pattern: - The plants were classified as determinate or indeterminate at six WAP.

iii. Twining tendency: - Classification was based on the intensity of twining. It could be absent, slight or intermediate.

iv. Plant pigmentation: - Pigmentation of the vegetative parts was recorded at six WAP. The options were no pigmentation (green), very slight, moderate or extensive pigmentation.

v. Plant hairiness: - The absence or presence of hairs on stems, leaves and pods were recorded as glabrescent or hirsute respectively.

3.2.2 Characterization of inflorescence and fruit characters

i. Raceme position: - The position of the flowers in relation to the canopy was recorded when the peduncles were at full length. Racemes were either held above the canopy, in the upper canopy or throughout the canopy.

ii. Pod attachment to penducle: - This was evaluated at the mature green stage. The options were erect, 30-90 degrees inclination or pendant.

iii. Immature pod pigmentation - Pattern of pigmentation on green pods was recorded. The options were none, pigmented tip, pigmented sutures, pigmented tips and sutures, splashes of pigment and uniformly pigmented.

iv. Flower colour: - Main flower colours identified were purple and white based on the Methuen Handbook of colour (Methuen, 1981).

3.3 Further characterization and evaluation

Harvested seeds from each of the 45 accessions were sown in the field for further characterization and evaluation in May, 1988. Seeds of each accession were planted at three seeds per hill in a randomized complete block design with three replications. The seedlings were thinned to one per hill at one week after seedling emergence leaving ten plants per plot for each accession. Both vegetative and reproductive characters were studied.

3.3.1 Vegetative characters

i. Hypocotyl length: - The hypocotyls of five seedlings per plot were randomly measured 14 days after planting (DAP) and the mean of the five taken.

ii. Terminal leaflet length and width: - The widths at the widest points and the lengths of the terminal leaflets of ten leaves per plant for five plants per plot were randomly measured at six WAP and the mean taken.

iii. Number of branches: - The mean number of branches per plant from a random sample of five plants per plot was recorded six WAP.

iv. Number of nodes on main stem: - The mean number of nodes per plant from five randomly selected plants per plot was recorded six WAP.

3.3.2 Inflorescence, fruit and seed characters

i. Days to flowering: - Number of days from sowing to when 50% of the plants had flowered was recorded.

ii. Standard length: - The mean of the lengths of 30 freshly opened, randomly selected standard petals from five plants per plot was measured.

iii. Calyx lobe length: - The mean of the lengths of 30 randomly selected calyx lobes from five plants per plot was measured.

iv. Days to maturity: - The number of days from sowing to the stage when 50% of the plants had mature pods was recorded.

v. Number of racemes per plant: - The mean number of racemes from five randomly selected plants per plot was recorded.

vi. Peduncle length: - The mean length of penducles from five randomly selected plants per plot was measured.

vii. Number of peduncles per plant: - The mean number of peduncles per plant from a random sample of five plants per plot was recorded.

viii. Number of pods per plant: - The mean number of mature pods from five randomly selected plants per plot was recorded.

ix. Pod length: - The mean length of pods on five randomly selected plants per plot was measured.

x. Number of seeds per pod: - The mean number of seeds from pods harvested from five randomly selected plants per plot was recorded.

xi. 100-seed weight: - The weight of a sample of 100 seeds at 12% moisture content was measured.

xii. Grain yield per plant: - The mean grain yield from five randomly selected plants per plot was recorded.

The same five randomly selected plants per plot were used for the above characters, besides the flowering and maturity dates.

3.4 Heterosis studies

Five accessions of cowpea possessing contrasting flowering and maturity dates, number of pods per plant, pod length and grain yield per plant, were selected, based on the results of previous studies, for heterosis. The objectives of the studies were:

1) to produce plants with combined early maturity and large number of seeds.
2) to combine large number of seeds per pod and large seeds,
3) to produce plants which have large number of seeds per plant combined with large seeds and
4) to produce plants with high seed yield.

The characteristics of the parental accessions are shown in Table 1. The selected accessions were planted in April, 1990 in single rows in the field at different times to synchronize flowering periods.

The crosses made were as follows:

i. 87/56 x 87/94

ii. 87/35 x 87/157

iii. 87/27 x 87/35

iv. 87/27 x 87/157

Table 1. Some characteristics of cowpea parental accessions used in heterosis studies.

Cowpea accessions	Days to flower	Racemes per plant	Days to maturity	Pod length (cm)	Pods per plant	Seeds per pod	100-seed wt.(g)	Grain yield per plant (g)
87/27	40	56.0	62	17.1	32.0	16.1	11.8	46.9
87/35	49	50.7	69	13.2	4.7	8.1	15.2	17.9
87/56	39	63.7	57	13.7	28.3	11.3	9.6	29.1
87/94	42	45.3	60	15.1	23.3	12.3	10.7	28.2
87/157	47	49.7	66	15.6	44.7	15.6	9.3	36.9

Crosses and their reciprocals were made according to the method developed at IITA by Rachie, Rawal and Franckowiak (1975). Emasculation was done in the evening and crosses were made early in the morning. Mature pods were harvested as soon as they began to dry. Pods from identical crosses as well as those from parental plants were harvested separately.

The parents designated P1 and P2 and their F1's were planted in a randomized complete block design with three replications in

August, 1990 for the heterosis studies. Five randomly selected plants per plot were used to evaluate the following yield components: days to flowering, days to maturity, pods per peduncle, pods per plant, pod length, seeds per pod, 100-seed weight and grain yield per plant. Backcrosses to both parents (BC1 and BC2) were made from the remaining F1's and parents. Pods from each backcross were harvested separately and bulked. Heterosis was estimated by the formula of El-Hosary and Nawar (1984).

$$\text{Heterosis (\%)} = (\overline{F}_1 - MP)/(MP) \times 100$$

where $\overline{F}_1$ and MP are the means of the F1 and the midparent, respectively.

3.5 Statistical Analysis

Further characterization and evaluation data recorded were subjected to analysis of variance. First the data on accessions from all regions were analysed as a whole. The data were further analysed on within- and between-region basis.

4. RESULTS

4.1 Characterization and preliminary evaluation data on vegetative characters.

4.1.1 Growth habit

Figure 3 shows the growth habit of cowpea germplasm from four regions of Ghana. The three main growth habits shown by the cowpea germplasm were intermediate, semi-prostrate and prostrate. Germplasm from the Upper East Region showed only the semi-prostrate habit whereas germplasm from the Upper West, Northern and Eastern Regions showed all the three types of growth habits. For each region the semi-prostrate type formed the majority of the accessions. This was followed by the prostrate and intermediate types, respectively.

4.1.2 Twining tendency

The twining tendency exhibited by the cowpea germplasm under study is shown in Fig. 4. Three categories of twining tendency were found; no twining, slight twining and intermediate twining. All accessions collected in the Upper East Region showed no twining. Accessions collected in the Upper West Region showed two categories of twining tendency; none and slight. Majority of the accessions showed slight twining. Most of the accessions from the Northern Region showed no twining. This was followed by slight and intermediate twining in that order. Accessions from

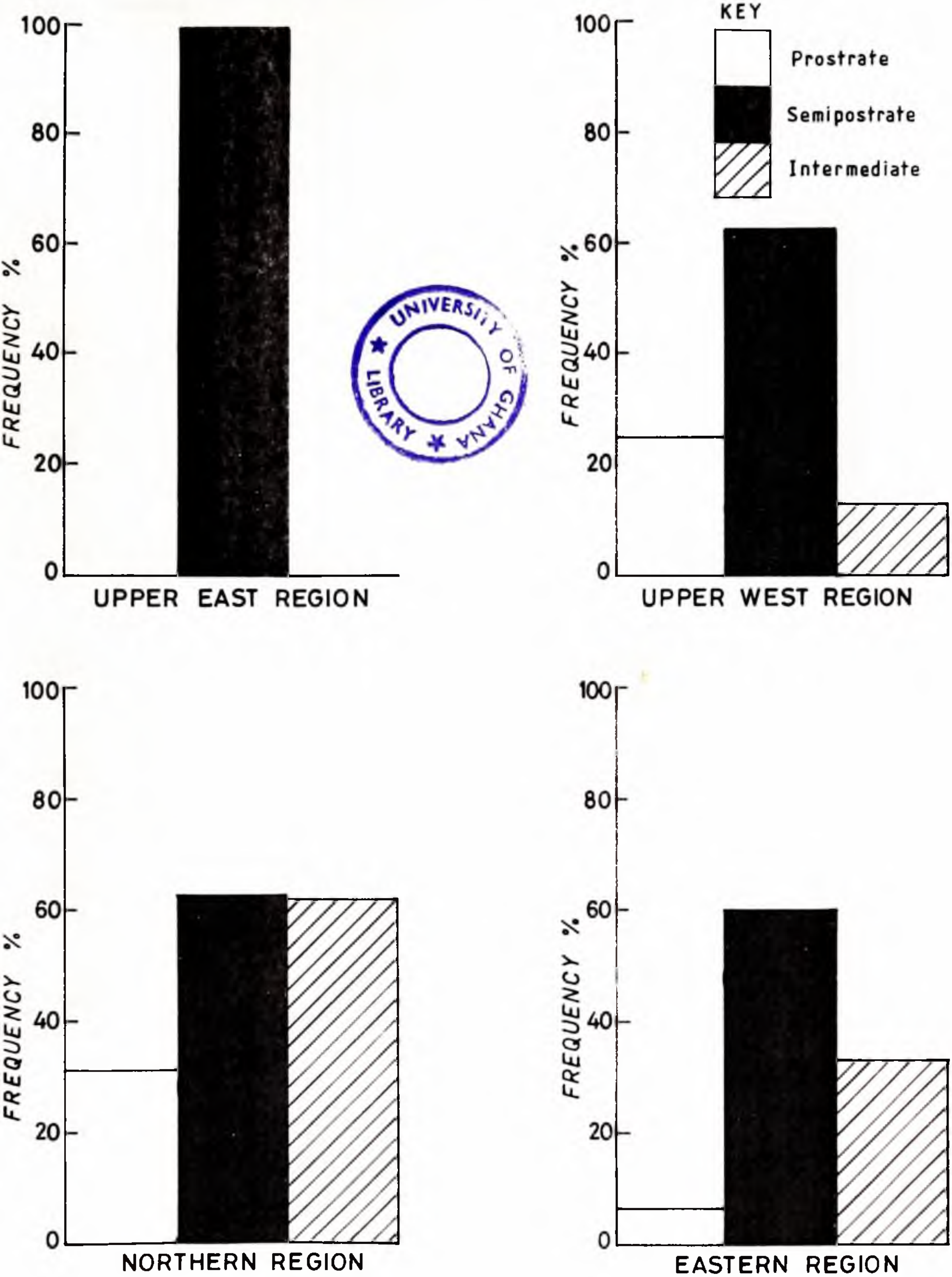

Fig. 3 . Growth habit of Cowpea germplasm from four Regions of Ghana .

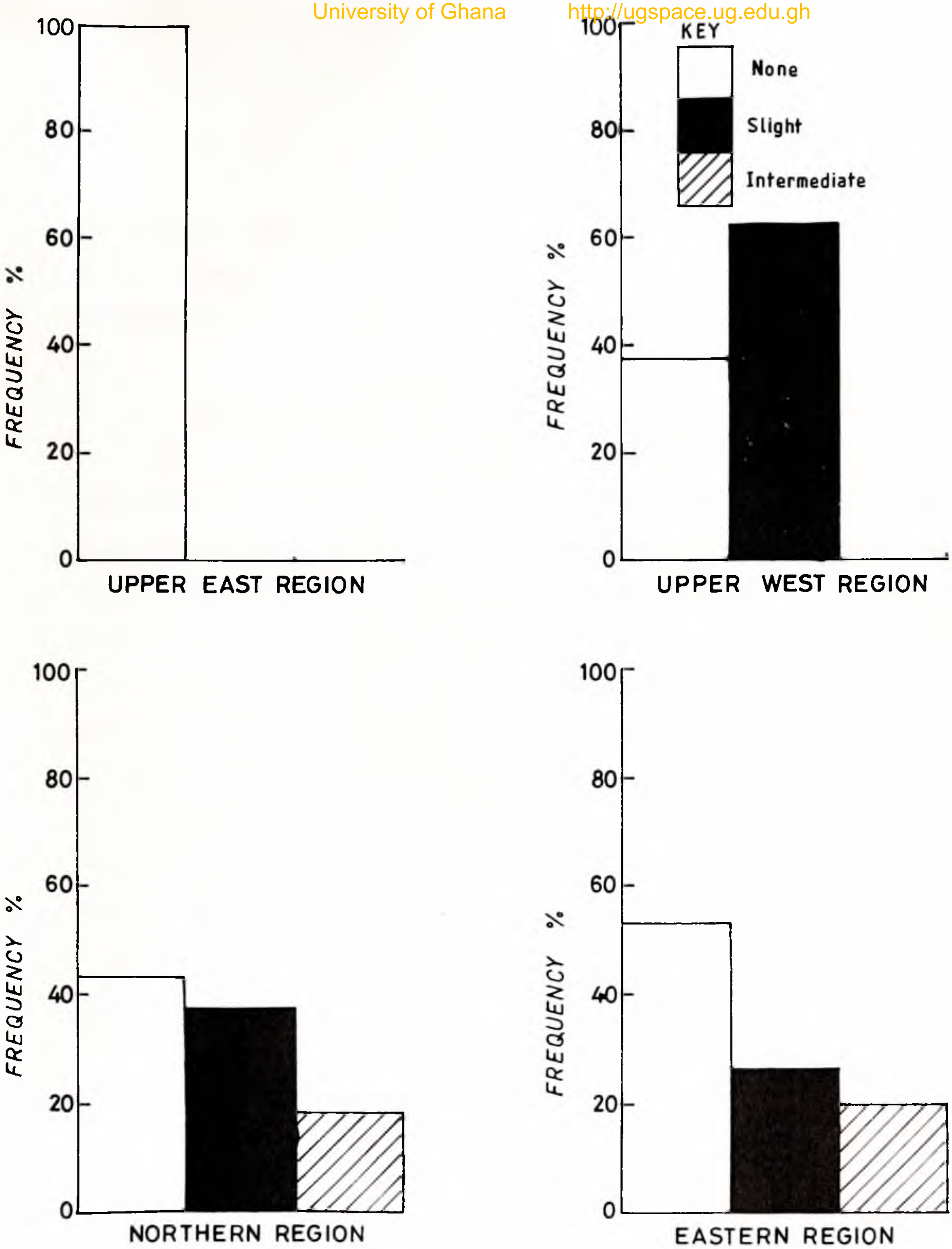

Fig. 4 . Twining tendency of cowpea germplasm from four Regions of Ghana .

the Eastern Region showed a similar trend as those from the Northern Region. Generally majority of all accessions showed no twining and the least showed intermediate twining.

4.1.3 Plant pigmentation

Figure 5 shows the frequencies of various plant pigmentation types in the germplasm collected. Five categories of plant pigmentation were observed. Accessions from the Upper East and Upper West Regions showed none, very slight or moderate pigmentation. In each of these regions, accessions with very slight pigmentation were in the majority. This was followed by moderate pigmentation and no pigmentation in that order. Accessions from the Northern Region were all pigmented and showed four categories of pigmentation, namely, very slight, moderate, intermediate and extensive. Similarly accessions from the Eastern Region were all pigmented with most accessions showing slight pigmentation. This was followed by moderate and intermediate pigmentation in that order.

4.1.4 Other vegetative characters

All the cowpea accessions studied showed indeterminate growth pattern and none had hairs on stem, pods or leaves.

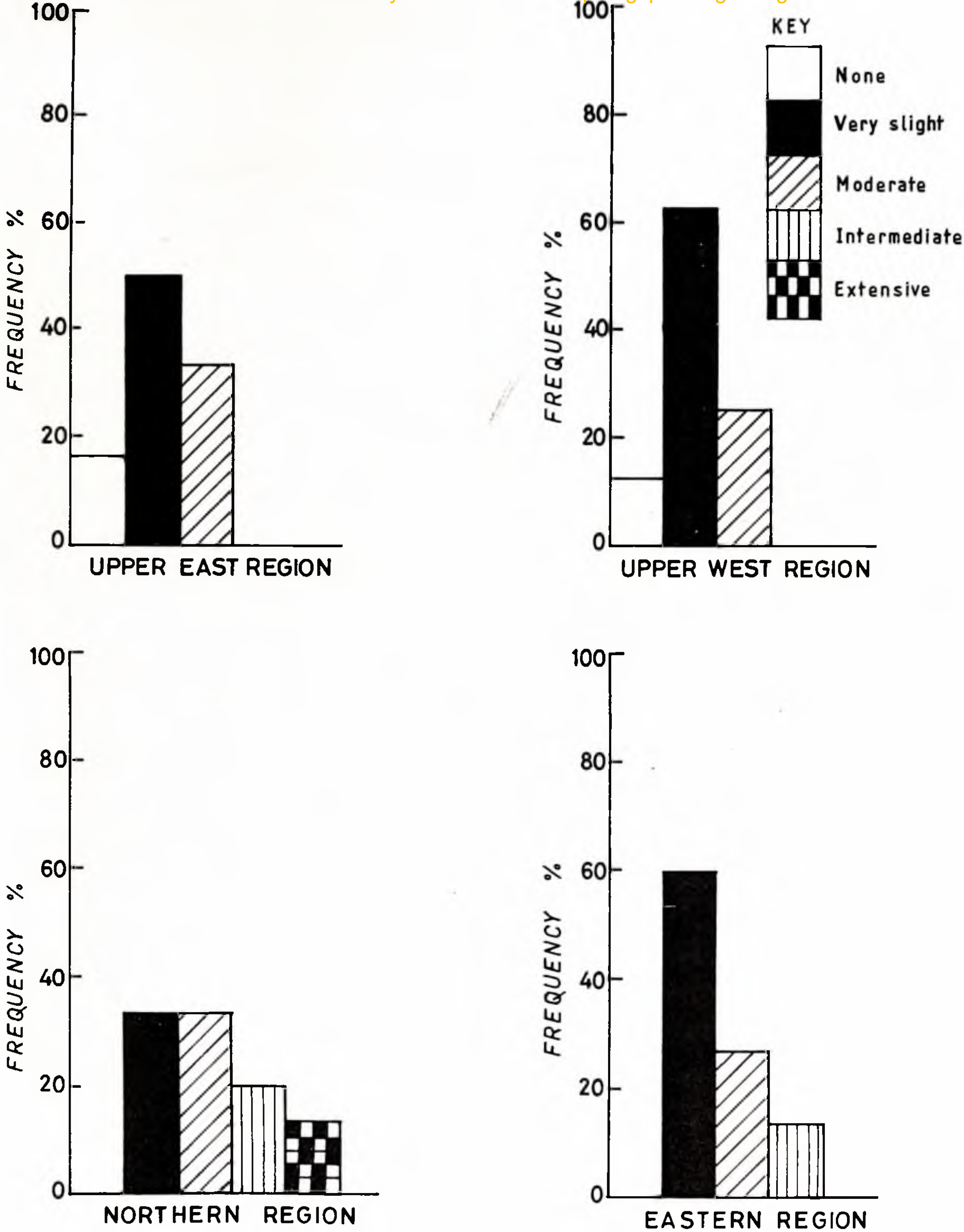

Fig. 5. Plant pigmentation of cowpea germplasm from four Regions of Ghana.

4.2 Characterization and preliminary evaluation data on flower and fruit characters

4.2.1 Flower colour

Figure 6 shows the distribution of flower colour of the cowpea germplasm . All the accessions from the Upper East Region had white flowers. Most (81-88%) of the accessions from Upper West, Northern and Eastern regions had purple flowers and the remainder of the accessions from these regions had white flowers.

4.2.2 Raceme position

The types of raceme positions exhibited by the cowpea germplasm are shown in Fig. 7. Three types of raceme positions were observed; the racemes were mostly held above the canopy, they were held in the upper canopy or they were found throughout the canopy. The general trend shown by accessions from the four regions is that most of the racemes were mostly above the canopy. This was followed by the racemes being found in the upper canopy and then the racemes being throughout the canopy.

4.2.3 Pod attachment

Figure 8 shows types of pod attachment in the cowpea germplasm . Two conditions were observed: the condition in which the pod was inclined 30-90 degrees from erect and the condition in which the pod was pendant. Majority of accessions from each region had the pendant type of pod attachment.

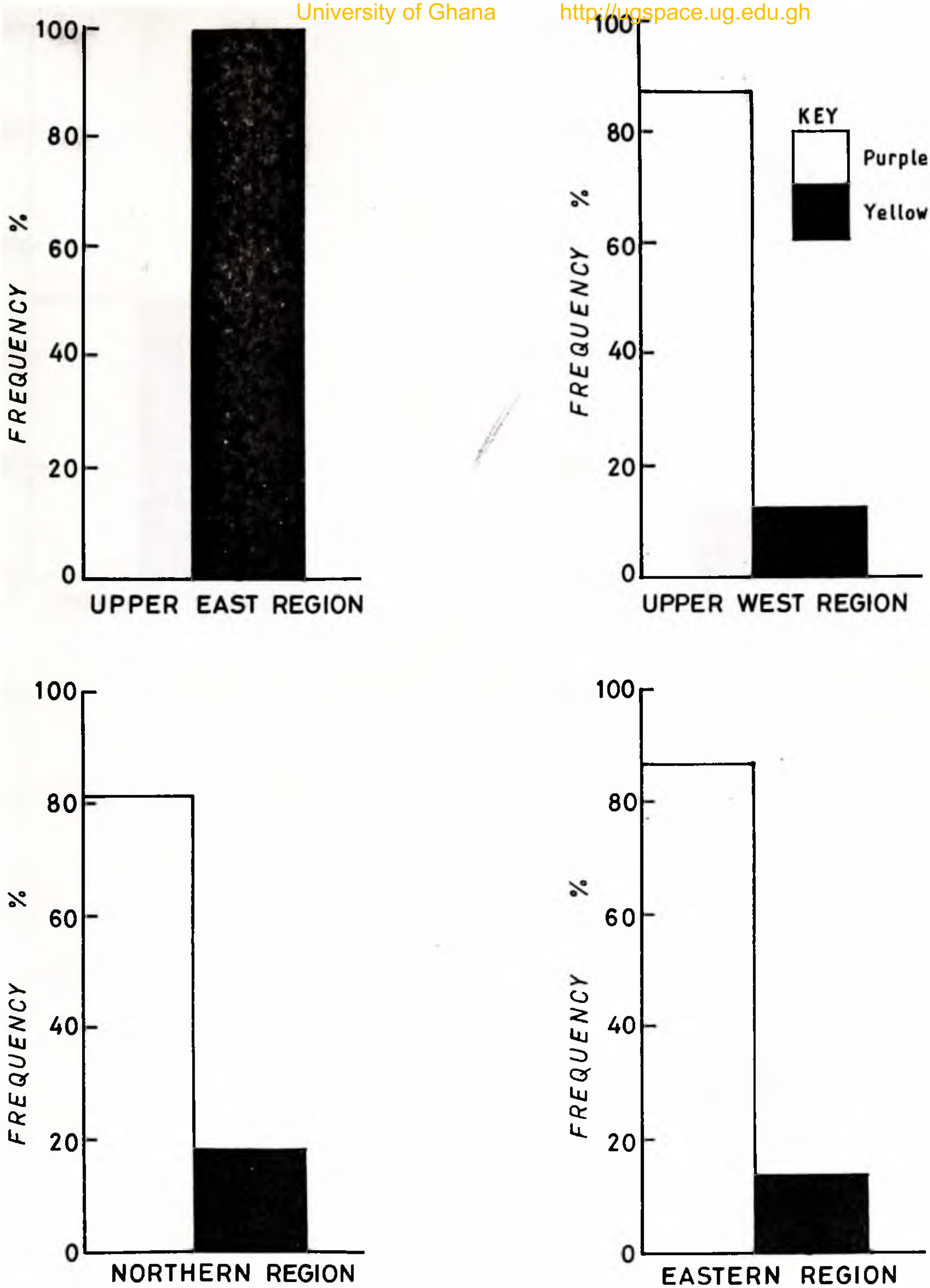

Fig. 6. Flower colour of cowpea germplasm from four Regions of Ghana.

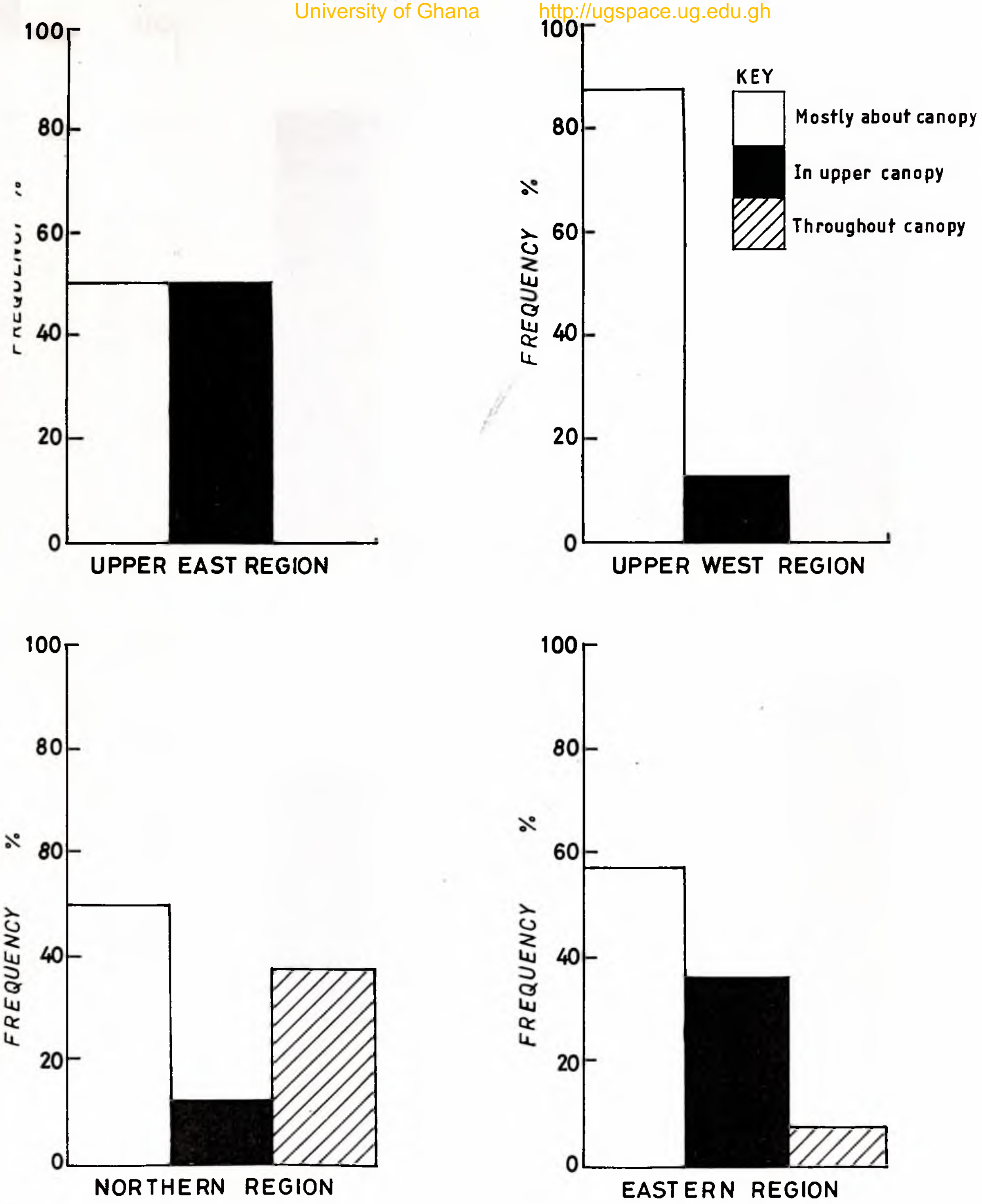

Fig. 7 . Raceme position of cowpea germplasm from four Regions of Ghana .

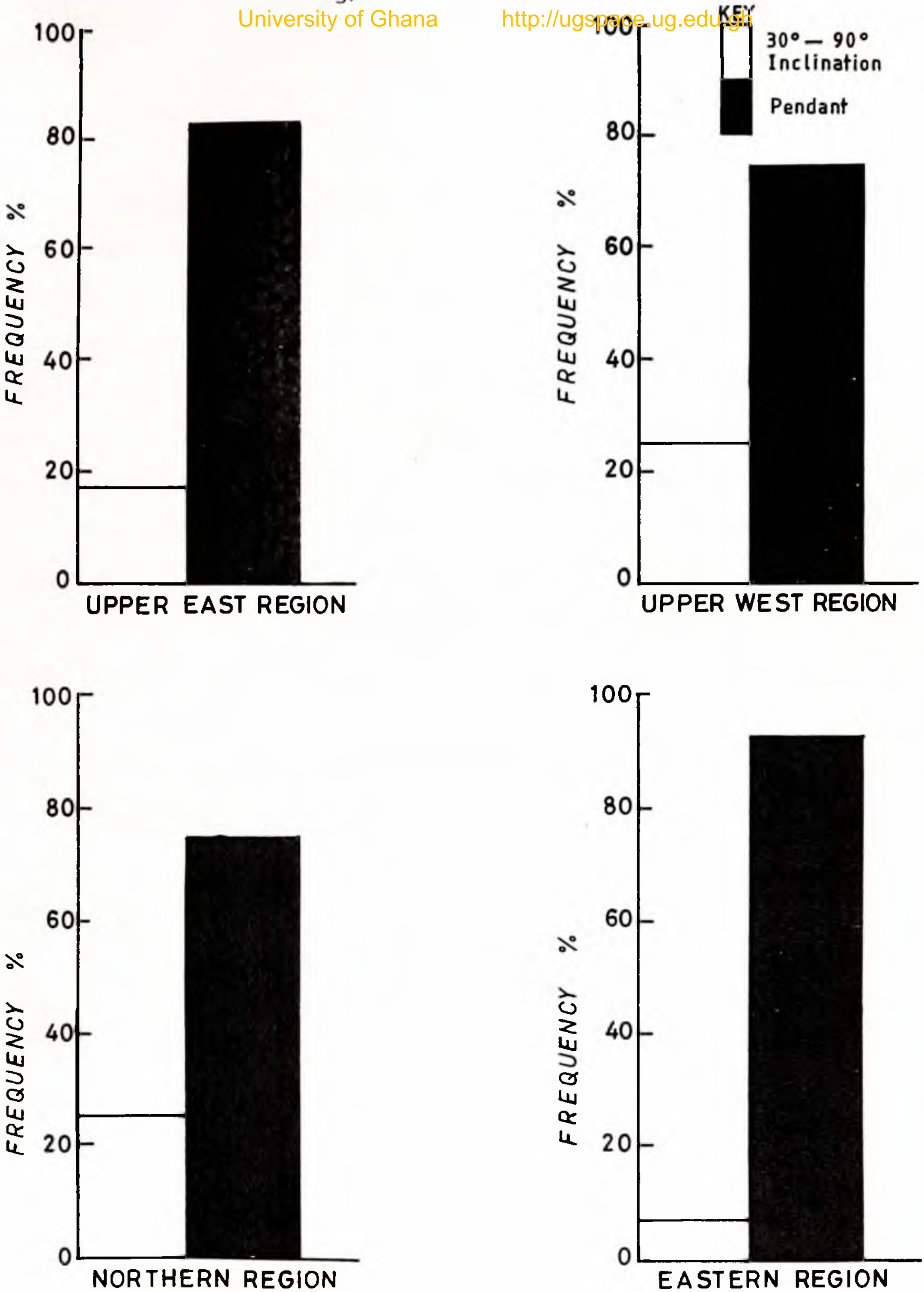

Fig. 8. Pod attachment of cowpea germplasm from four Regions of Ghana.

4.2.4 Immature pod pigmentation

Figure 9 shows the patterns of immature pod pigmentation observed in the cowpea germplasm. Six patterns of pigmentation were observed in the immature pods. About 17-42% of accessions from all regions showed no pigmentation in their immature pods. Immature pod pigmentation observed in accessions from the Upper West Region was quite similar to that observed in accessions from the Upper East Region. Both did not have accessions with pigmented tips and those with pigmented tips and sutures. Accessions from the Northern Region had representation in all six categories of pigmentation patterns.

4.3 Further characterization and evaluation data on Vegetative characters

4.3.1 Hypocotyl length

The hypocotyl lengths of the cowpea germplasm are shown in Table 2. The hypocotyl lengths of all the germplasm under study ranged from 14.3 to 27.3mm. Though there were no significant differences between the means of the hypocotyl length of the cowpea germplasm as a whole, and between-region, there were significant within-region differences in the hypocotyl lengths of the germplasm from the Northern and Eastern Regions but no significant differences in the hypocotyl lengths of those from the Upper East and Upper West Regions. The coefficient of

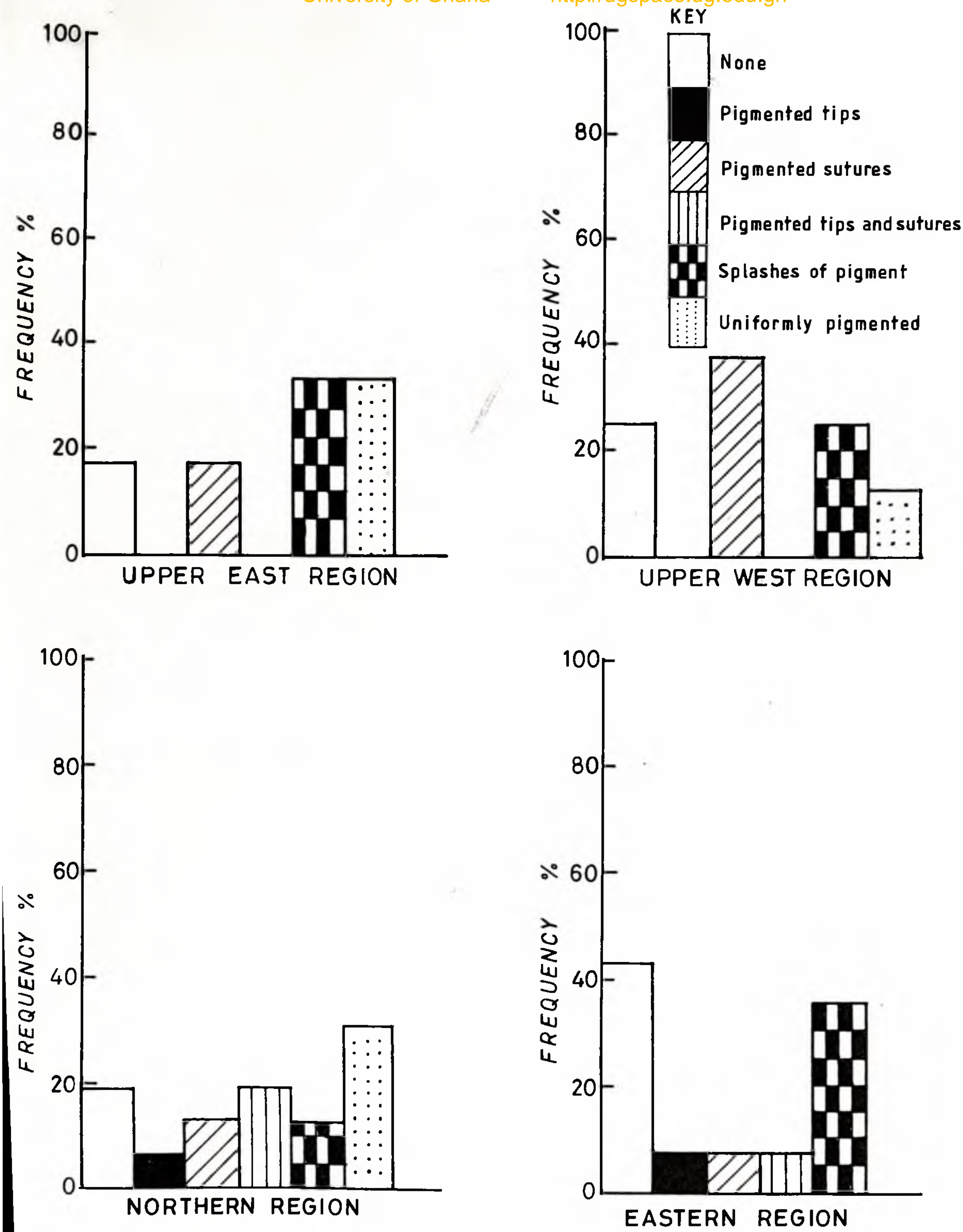

Fig. 9. Immature pod pigmentation of cowpea germplasm from four Regions of Ghana.

variation for hypocotyl lengths of the germplasm from the Upper East and Upper West Regions were high (>20%). This may be due to the fact that the number of accessions obtained from the two regions were low.

4.3.2 Number of nodes on main stem

The number of nodes on the main stem of cowpea germplasm collected from four regions of Ghana is shown in Table 3. The number of nodes on the main stem ranged from 11.3 to 18.7. There were large differences in the number of nodes on the main stem for the accessions from all four regions. However, differences both between and within regions were not significant.

4.3.3 Number of branches per plant

The number of branches per plant of the cowpea germplasm collected from four regions of Ghana is shown in Table 4. The number of branches ranged between 7.3 and 10.0 with accessions from each region averaging about 8 to 9 branches per plant.

Table 2. Ranges, means and coefficients of variation for hypocotyl length (mm) of cowpea germplasm from four regions of Ghana.

Region	No. of Accs.	Range	Mean+	Coeficient of Variation (%)
Northern	16	14.3-24.0	19.8	14.7
Upper East	6	15.0-23.0	19.3	20.2
Upper West	8	17.7-25.0	20.7	22.2
Eastern	15	16.3-27.3	21.0	15.3

Table 3. Ranges, means and coefficients of variation for the number of nodes on the main stem of cowpea germplasm from four regions of Ghana.

Region	No. of Accs.	Range	Mean+	Coefficient of Variation (%)
Northern	16	13.0-18.7	15.7	17.9
Upper East	6	14.7-18.0	15.8	12.9
Upper West	8	11.3-17.0	14.1	25.8
Eastern	15	12.7-17.0	14.7	22.9

+Mean differences not significant (P>0.05)

There were no significant between-region differences in the number of branches per plant. Similarly there were no significant within-region differences in this character.

4.3.4 Terminal leaflet length and width

The terminal leaflet lengths of the cowpea germplasm are shown in Table 5. The terminal length ranged from 6.8cm to 12.8cm. Both the shortest and longest leaflet lengths were from the Northern Region collection. There were significant differences among the accessions for the terminal leaflet length. There were also significant between-region differences in this character. There were significant within-region differences in the terminal leaflet length in the accessions from the Northern and Eastern Regions whereas there was none in those from the Upper East and Upper West Regions.

The terminal leaflet width ranged from 3.8cm to 8.6cm (Table 6). Again the extremes are from the Northern Region collection. The 45 accessions showed significant differences with respect to their terminal leaflet width. There were however no significant differences between the regions in the terminal leaflet width of the cowpea germplasm. Significant differences were observed in the terminal leaflet width within each region except the Upper East Region.

Table 4. Ranges, means and coefficients of variation for the number of branches per plant of cowpea germplasm from four regions of Ghana.

Region	No. of Accs.	Range	Mean+	Coefficient of Variation (%)
Northern	16	7.3-9.3	8.6	10.9
Upper East	6	7.7-9.3	8.4	12.2
Upper West	8	7.3-9-3	8.4	12.7
Eastern	15	7.6-10.0	8.7	9.7

+Mean differences not significant (P>0.05)

Table 5. Ranges, means and coefficients of variation for the terminal leaflet length (cm) of cowpea germplasm from four regions of Ghana.

Region	No. of Accs.	Range	Mean+	Coefficient of Variation (%)
Northern	16	6.8-12.8	8.6	10.9
Upper East	6	8.3-10.8	9.5	16.1
Upper West	8	7.6-9.8	8.7	14.1
Eastern	15	7.8-11.1	9.9	8.8

+Mean differences significant. LSD(5%) = 0.8

4.4 Further characterization and evaluation data on inflorescence, fruit and seed characters

4.4.1 Days to flowering

The number of days to 50% flowering in the cowpea germplasm is shown in Table 7. The days to 50% flowering ranged from 31 days in accessions from Northern and Upper West Regions to 72 days in accessions from Upper East Region. There were significant differences both between- and within-regions with respect to flowering date. Accessions from Northern and Upper West Regions averaged 38 days from sowing to flowering. The coefficients of variation were relatively small ranging from 3.5% to 7.2%.

4.4.2 Peduncle length

The peduncle lengths of the cowpea germplasm collected from four regions of Ghana are shown in Table 8. The peduncle lengths ranged between 15.0cm and 41.3cm, indicating large differences in the peduncle lengths of the germplasm. However there were no significant differences between the regional means of peduncle lengths. There were significant within-region differences in the peduncle lengths of the germplasm from the Northern and Upper West Regions whilst there were small differences in those from the Upper East and Eastern Regions.

4.4.3 Peduncles per plant

Table 9 shows the number of peduncles per plant of the cowpea germplasm studied. The number of peduncles per plant ranged between 10.0 and 14.3. There were significant differences between the accessions with respect to the number of peduncles per plant. However on regional basis, there were no significant differences in the number of peduncles per plant. Accessions from each region, with the exception of Upper East Region, showed no significant intra-regional differences.

Table 6. Ranges, means and coefficients of variation for the terminal leaflet width (cm) of cowpea germplasm from four regions of Ghana.

Region	No. of Accs.	Range	Mean+	Coefficient of Variation (%)
Northern	16	3.8-8.6	5.1	14.0
Upper East	6	4.4-5.8	5.2	16.3
Upper West	8	4.4-6.8	5.7	11.2
Eastern	15	4.2-7.6	6.2	10.5

+Mean differences not significant (P>0.05)

Table 7. Ranges, means and coefficients of variation for the number of days to flowering of cowpea germplasm from four regions of Ghana

Region	No. of Accs.	Range	Mean+	Coefficient of variation (%)
Northern	16	31-51	38	3.5
Upper East	6	37-72	52	7.2
Upper West	7	31-54	38	6.6
Eastern	12	36-50	49	4.2

+Mean differences significant LSD (5%) = 5

Table 8. Ranges, means and coefficients of variation for peduncle length (cm) of cowpea germplasm from four regions of Ghana.

Region	No. of Accs.	Range	Mean+	Coefficient of variation (%)
Northern	16	15.0-41.3	27.4	12.8
Upper East	4	28.1-34.1	30.6	18.7
Upper West	7	15.8-35.2	29.4	16.7
Eastern	12	27.5-38.9	32.4	14.6

+Mean differences not significant (P>0.05)

Table 9. Ranges, means and coefficients of variation for the number of peduncles per plant of cowpea germplasm from four regions of Ghana.

Region	No. of Accs.	Range	Mean+	Coefficient of variation (%)
Northern	16	10.3-11.7	11.0	4.6
Upper East	4	10.0-12.3	11.3	2.1
Upper West	7	10.0-14.3	11.8	4.6
Eastern	12	10.3-12.0	11.3	5.1

+Mean differences not significant ($P>0.05$)

4.4.4 Number of racemes per plant

Table 10 shows the number of racemes per plant of the cowpea germplasm. Accessions from the Northern Region showed the widest range of about 42 to 64 racemes per plant. There were significant differences in the number of racemes produced by the different accessions. There were no between-region differences in the number of racemes per plant of the accessions. Similarly, there were no significant differences between the accessions within each region.

4.4.5 Standard length and calyx lobe length

The standard lengths and calyx lobe lengths of cowpea germplasm are shown in Tables 11 and 12 respectively. No significant differences were observed in those two characters in the germplasm studied whether between-region or within-region.

4.4.6 Days to maturity

The number of days to 50% maturity of cowpea germplasm is shown in Table 13. The earliest were accessions from Northern and Upper West Regions (57 days) and the latest were from Upper East and Upper West Regions (83 days). Significant differences were observed in the number of days to maturity of the cowpea germplasm.

There were also significant differences in the maturity period when the germplasm were considered on regional basis. With the exception of the Eastern Region, the accessions from the other regions showed significant differences within each region. The coefficients of variation were rather small being about 2% in the Upper West Region to about 6% in the Upper East Region.

4.4.7 Pods per plant and pod length

The number of pods per plant of cowpea germplasm is shown in Table 14. The number of pods per plant ranged from 3.0 to 44.7. Significant differences were observed in the accessions as a whole.

Table 10. Ranges, means and coefficients of variation for the number of racemes per plant of cowpea germplasm from four regions of Ghana.

Region	No. of Accs.	Range	Mean+	Coefficient of variation (%)
Northern	16	41.7-63.7	50.2	16.6
Upper East	4	42.0-59-7	52.8	12.1
Upper West	7	43.7-61.0	50.1	18.2
Eastern	12	45.0-56.7	51.1	13.3

+Mean differences not significant (P>0.05).

Table 11. Ranges, means and coefficients of variation for the standard length (mm) of cowpea germplasm from four regions of Ghana.

Region	No. of Accs.	Range	Mean+	Coefficient of variation (%)
Northern	16	15.0-20.0	18.0	10.2
Upper East	4	18.3-20.0	18.7	10.9
Upper West	7	16.7-20-0	18.6	10.0
Eastern	12	16.7-20.0	17.2	9.3

+Mean differences not significant (P>0.05)

Table 12. Ranges, means and coefficients of variation for the calyx lobe length (mm) of cowpea germplasm from four regions of Ghana.

Region	No. of Accs.	Range	Mean+	Coefficient of variation (%)
Northern	16	3.7-5.0	4.6	9.0
Upper East	4	4.3-4.7	4.4	9.3
Upper West	7	4.3-5.0	4.5	9.6
Eastern	12	4.0-5.0	4.5	9.4

+Mean differences not significant (P>0.05)

Table 13. Ranges, means and coefficients of variation for the number of days to maturity of cowpea germplasm from four regions of Ghana.

Region	No. of Accs.	Range	Mean+	Coefficient of variation (%)
Northern	16	57-80	66	3.3
Upper East	4	68-83	76	5.7
Upper West	7	57-83	64	2.2
Eastern	12	64-72	68	4.9

+Mean differences significant LSD (5%) = 1.3

and also between the regions with respect to the number of pods per plant. Within each region there were significant differences in the accessions except the Upper East Region. Upper East Region had the lowest range of 2.3 to 14.0 pods per plant. The coefficient of variability for each region was very high.

Pod length of the cowpea germplasm ranged from 8.3 to 17.5cm (Table 15). Significant differences were observed in the pod length of the germplasm. Similarly, there were significant between- and within-region differences in the germplasm.

4.4.8 Seeds per pod and 100-seed weight

The number of seeds per pod of the cowpea germplasm is shown in Table 16. The number of seeds per pod of the cowpea germplasm ranged from 7.7 to 16.4, while the regional means ranged from 9.1 to 11.5. There were significant differences in the number of seeds per pod of the accessions studied. Comparing the germplasm on regional basis, there were significant differences among the regions and also significant differences in the accessions within each region.

The 100-seed weight of the cowpea germplasm ranged between 6.7g and 21.4g (Table 17). There were significant differences between the accessions in 100-seed weight. There were also differences among the regions in 100-seed weight of the germplasm. With the exception of the Northern Region, there were significant differences in the accessions within each region with respect to 100-seed weight. Seed weight was fairly uniform within the regions except for the Upper East Region where it ranged from 100-seed weight of 7.7 to 21.4g. The coefficients of variation were relatively small.

Table 14. Ranges, means and coefficients of variation for the number of pods per plant of cowpea germplasm from four regions of Ghana.

Region	No. of Accs.	Range	Mean+	Coefficient of variation (%)
Northern	16	3.0-39.0	16.2	41.2
Upper East	4	2.3-14.0	6.3	58.1
Upper West	7	4.3-29.7	17.0	41.8
Eastern	12	8.7-44.7	27.2	29.9

+Mean differences significant. LSD (5%) = 4.1

Table 15. Ranges, means and coefficients of variation for the pod length (cm) of cowpea germplasm from four regions of Ghana.

Region	No. of Accs.	Range	Mean+	Coefficient of variation (%)
Northern	16	9.2-17.3	12.3	4.3
Upper East	4	9.6-15.2	12.7	4.8
Upper West	7	8.3-15.2	12.9	4.1
Eastern	12	12.4-17.5	14.3	5.5

+Mean differences significant LSD (5%) = 0.9

Table 16. Ranges, means and coefficients of variation for the number of seeds per pod of cowpea germplasm from four regions of Ghana.

Region	No. of Accs.	Range	Mean+	Coefficient of variation (%)
Northern	16	7.7-16.4	10.6	6.7
Upper East	4	8.0-10.3	9.1	6.2
Upper West	7	8.0-13.5	11.5	6.9
Eastern	12	8.7-15.6	10.9	8.0

+Mean differences significant. LSD (5%) = 0.8

Table 17. Ranges, means and coefficients of variation for 100-seed weight (g) of cowpea germplasm from four regions of Ghana.

Region	No. of Accs.	Range	Mean+	Coefficient of variation (%)
Northern	16	8.7-11.9	10.0	3.1
Upper East	4	7.7-21.4	14.9	2.6
Upper West	7	8.2-13.6	9.8	3.9
Eastern	12	6.7-14.0	9.4	4.5

+Mean differences significant. LSD (5%) = 0.3

4.4.9 <u>Grain yield per plant</u>

The grain yield per plant of the cowpea germplasm is shown in Table 18. The range of grain yield per plant was between 2.1 and 46.9g. There were significant differences in the grain yield per plant of the cowpea accessions. The regions also differed significantly from one another with respect to their grain yield per plant. Except the Eastern Region, the accessions within each region showed differences in grain yield per plant. The coefficient of variation observed for each of the regions was very high

4.5 Heterosis estimates in selected crosses

Table 19 shows the mean values for the parents, F1 hybrids as well as midparent heterosis (%) of yield and yield components of four crosses involving some selected cowpea accessions. There were significant differences (P>0.05) between the F1´s and the parental values of the characters studied. The F1´s were the same as the midparent for days to flowering and days to maturity in two crosses but earlier than the midparent in the other two.

The F_1´s were intermediate between the parents in two of the crosses and higher than the midparental values in the other two for pods per peduncle, pod length and 100-seed weight. For number of seeds per pod the F1´s were intermediate between the parents in three out of the four crosses and was higher than the midparent in one cross. Midparent heterosis was very high and positive in both number of pods per plant and grain yield per plant in all four crosses. This was particularly so for grain yield per plant for the crosses 87/27 x 87/157 where heterosis was about 130%.

Table 18. Ranges, means and coefficients of variation for grain yield per plant (g) of cowpea germplasm from four regions of Ghana.

Region	No. of Accs.	Range	Mean+	Coefficient of variation (%)
Northern	16	2.1-46.9	18.5	32.5
Upper East	4	3.2-18.8	8.2	53.5
Upper West	7	4.7-35.6	19.4	44.1
Eastern	12	18.5-36.8	27.5	29.6

+Mean differences significant. LSD (5%) = 12.0

Table 19. Performance of parents and their F1's and midparent heterosis (%) in four crosses among some selected cowpea accessions.

CROSS	Popn. and % Het'sis	Days to flower-ing	Days to matu-rity	Pods per ped-uncle	Pods per plant	Pod length (cm)	Seeds per pod	100-seed weight (g)	Grain yield per plant (g)
	87/157 (P1)	47	66	2.1	24.7	15.9	14.7	10.1	37.2
I	87/35 (P2)	50	68	1.4	14.2	12.8	8.0	15.9	17.9
	F1	49	66	1.9	26.1	14.3	11.4	12.8	38.1
	% Heterosis	0	-2.0	8.5	34.1	-0.3	0.4	-1.5	38.2
	87/27 (P3)	39	56	1.3	18.2	17.0	16.4	12.3	36.9
II	87/35 (P2)	49	70	1.5	15.1	13.5	8.2	15.6	19.0
	F1	43	64	1.8	29.1	17.3	10.5	16.6	51.2
	% Heterosis	-2.2	1.5	28.5	74.7	13.4	-14.6	18.9	83.1
	87/56 (P4)	39	56	1.5	23.2	13.1	11.8	9.6	26.1
III	87/94 (P5)	43	66	1.5	23.1	15.3	13.5	10.8	33.6
	F1	41	64	2.0	36.5	14.9	13.0	11.4	54.2
	% Heterosis	0	4.9	33.3	57.6	4.9	2.7	11.7	81.2
	87/27 (P3)	41	58	1.9	15.4	17.9	15.8	11.4	2.7
IV	87/157 (P1)	46	66	2.3	40.3	15.4	15.6	8.6	54.2
	F1	42	61	2.2	50.8	19.1	16.7	10.9	93.3
	% Heterosis	-2.3	-1.6	4.7	82.4	14.7	6.3	9.0	129.8

5. DISCUSSION

5.1 Variability in qualitative characters in cowpea germplasm

There was a wide range of variability in most of the qualitative characters of the cowpea germplasm, especially, in seed colour, plant, flower and pod pigmentation, growth habit, pod attachment, raceme position and twining tendency. Ng and Maréchal (1985) observed a large diversity in cowpea germplasm accessions from Ghana in collections at IITA.

The seed colours in the present collection ranged from white, red, brown to black with intermediate colours between these extremes, as well as mottled colours. Earlier collectors in the same regions recorded similar variability in seed coat colour in cowpea germplasm (Dovlo, 1976; Holloway,1983). Seed coat colour plays an important role in the consumer preference of cowpea in Ghana. White or cream is the most preferred colour for several dishes because it is quick-cooking and has a pleasant flavour, brown and mottled are preferred when rice or maize is cooked together with cowpea and red for stews (Dovlo, 1976).

There are indications that the white or cream cowpea types may be more susceptible to pests and diseases both as plants in the field and as seeds in storage than the other colour types. There is evidence for preferential selection by bruchids for seeds of a particular variety as food or site for oviposition and subsequent development based on factors like size, seed colour and seed coat texture (Osuji, 1976). Amoatey (1987) observed that bruchids preferred large and smooth seeds to small and wrinkled seeds for oviposition. He however did not observe any trend in the ovipositional behaviour of bruchids based on seed colour. Research efforts are being made to incorporate desirable seed characteristics like white, creamy-white or light colours into improved strains to suit consumer preferences for seed colour (Rachie and Rawal, 1976).

Pigmentation on the stem and pods ranged from green to purple and the flowers were either white or purple with the latter being more predominant. Ezueh and Nwoffiah (1984) also observed white and purple flowers in cowpea accessions in Nigeria and the purple types were in the majority. Fery (1985) recognized four principal flower colours in cowpea, namely, dark, pale, tinged and white and related these to the concentration of anthocyanin in the flower parts. The dark flowers contain a high concentration of anthocyanin in all of the principal flower parts, pale flowers contain small amounts in the wings, tinged flowers have a faint narrow band of pigmentation along the outer edge of the standard, and white flowers have no anthocyanin. Flower colour has been associated with seed-coat colour (Harland, 1919). Generally, dark to pale flowers are characteristic of cultivars with pigmented seeds whereas white flowers are characteristic of cultivars with white or cream seed coats (Fery, 1985).

Growth habit is a very important factor in the cropping system of cowpea in Ghana. The range of growth habits in cowpea germplasm is from the climbing types to the erect types. There are also intermediate, semi-prostrate and prostrate types. The present collection had the intermediate, semi-prostrate and prostrate types. Most landraces exhibit the prostrate and climbing types (Doku, 1970; Rachie and Rawal, 1976). Rachie and Rawal (1976) observed that the prostrate types are used by peasant farmers in mixed cropping as they can cover the ground quickly and thereby suppress weeds. Climbing types climb companion crops which act as live stake.

The intermediate, semi-prostrate and prostrate types of cowpea formed the majority of the accessions characterised at IITA by Porter et al. (1974). However, deMooy (1985) working on cowpea germplasm from Botswana observed that majority of genotypes displayed the erect or semi-erect habits followed by the semi-prostrate. The production of cowpea in Botswana may be more recent than in Nigeria or Ghana hence the predominance of the erect and semi-erect types in that country. It is an objective of recent cowpea improvement programmes to breed the erect and semi-erect types of cowpea for the mono-culture cultivation of the crop, and prostrate, creeping and climbing types for the mixed cropping system (Rachie and Rawal, 1976).

Steele and Mehra (1980) observed that landraces of cowpea are usually indeterminate and determinate types are rare. In characterization and preliminary evaluation work at IITA, almost all the accessions of cowpea studied showed the indeterminate pattern (Porter et al., 1974). It seems that over the years, peasant farmers have selected the indeterminate types to suit their farming systems and to ensure continuous production over a long period within the season. Similarly, the presence of hairs in cultivated cowpea accessions is a rare feature. Hairs are known to be present in some wild cowpea types and this is an important diagnostic feature between the cultivated and some wild species (Steele and Mehra, 1980).

Twining in landraces of cowpea is desirable to the peasant farmer who intercropped these types with cereals like millet and sorghum. Rachie and Rawal (1976) observed that twining types used by peasant farmers have lower performance than the erect and semi-erect types. Rachie and Rawal (1976) have proposed the breeding of erect and climbing strains for associated cropping.

Majority of the accessions collected had racemes mostly above the canopy. It is more desirable to have racemes above the canopy than in the upper canopy or throughout the canopy because that position facilitates harvesting of the mature pods. Porter et al. (1974) observed that accessions with racemes throughout the canopy were the commonest among 4,000 accessions that they studied.

Steele and Mehra (1980) observed that pods of cultivated cowpea are mostly pendant whereas those of wild cowpea are mostly erect, that is directed vertical to the peduncle. Porter et al. (1974) on the other hand observed that in most of the accessions they studied, the pods were inclined 30-90°.

5.2 Variability in quantitative characters in cowpea germplasm

The cowpea germplasm collected from four cowpea-growing regions of Ghana revealed large variability in quantitative characters. Much variability was observed in the leaf size of the cowpea germplasm. Terminal leaflet length and width ranged from 6.8 to 12.8cm and 3.8 to 8.6cm respectively. This implies that there is a wide range of leaflet sizes from small to large. In a similar work at IITA, terminal leaflet lengths and widths had ranges of 7 to 20cm and 4.5 to 14.5cm respectively (Porter et al., 1974) whilst in another work in Botswana these traits ranged from 5.4 to 14.5cm and 3.0 to 7.8cm respectively (deMooy, 1985). The accessions studied by Porter et al. (1974) had the widest ranges in both terminal leaflet length and width. This was followed by those studied by deMooy (1985) and those in the present study. This could be attributed to the number of accessions studied in each case: Porter et al. (1974) worked with 4,000 accessions, deMooy (1985) worked with 108 accessions whilst in the present work there were 45 accessions. Another factor which could have influenced the variability of the accessions is the scope of the collections. The collections in Porter et al. (1974) were from all over the world, those in deMooy (1985) were from throughout Botswana and those in this study were from four cowpea-growing regions of Ghana.

The leaves of cowpea play an important role in the utilization of the crop. Cowpea is grown throughout the tropics as leaf vegetable, pulse, fodder and as a cover crop (Steele and Mehra, 1980). The young leaves are used as spinach in the northern part of Ghana (Asafo-Adjei, 1986). It has been observed that if the tender green leaves are plucked before the reproduction phase begins, the plant continues to produce new leaves (IITA, 1982). This characteristic in cowpea makes it a useful spinach, fodder and cover crop (Purseglove, 1968; Steele and Mehra, 1980; Asafo-Adjei, 1986). The greater the size of the leaflets of cowpea, the more suitable they are for use as spinach, fodder and cover crop. The leaflets of cowpea are mostly ovate in shape but forms with narrow hastate leaves have been bred (IITA, 1977) to improve light penetration deeply into the leaf canopy and thereby improve yields (Steele and Mehra, 1980).

The cowpea germplasm collected exhibited much variability in their flowering dates; the range was 31 to 72 days. There was variability both between and within regions. Though most accessions flowered, a few remained vegetative throughout the period of the experiment (March-July, 1988). The types which did not flower were from the Upper West, Upper East and Eastern Regions. All the accessions from the Northern Region flowered.

Amoatey (1987) working on 16 accessions from Ghana and Nigeria observed days to flowering to range between 37 and 51 days while at IITA the range for over 4,000 accessions was from 33 to 84 days (Porter et al., 1974). In Botswana, the range for 108 accessions was 38 to 41 days (deMooy, 1985). It appears that the accessions that did not flower within the period of the experiment were probably late types, since farmers grow them also for their seed. Wien and Summerfield (1980) and Steele and Mehra (1980) observed that onset of flowering of local varieties of cowpea may be ascribed to photoperiod control which also depends on the latitude of origin of the germplasm and the variation in day and night temperature.

No significant differences were observed in both the standard length and the calyx lobe length of the cowpea germplasm but significant differences were observed in the number of racemes per plant. The sizes of standard and calyx have been used to distinguish between Vigna species and subspecies (Verdcourt, 1970). Total yield will depend on the number of racemes, the number of flowers per raceme and more importantly, the fertility or the ratio of pods to flowers. Many flowers and immature pods abort (Summerfield and Wien, 1980; Summerfield et al., 1985). This abortion in the flowers and immature pods has been attributed to warm or cool air, dry atmospheric conditions, water stress, abnormalities in pollen formation, poor pollen germination and arrested pollen tube elongation (Summerfield and

Wien, 1980). Also implicated in the abortion of flowers is the abscission-causing insect, Megalurothrips (Summerfield *et al.*, 1985).

The variability in the number of days to maturity was closely related to the variability in the number of days to flowering. Accessions which flowered early also matured early. Doku (1970) further observed that for a good yield, flowering period must be short to enable most of the plant's energy material to be diverted into seed and pod development and that the longer the pod and seed development take the better for seed yield.

The number of pods per plant averaged 2 to 45. Several factors, both biotic and abiotic could have influenced the variability observed in the number of pods per plant. Since the accessions were collected from diverse locations with varied ecological conditions, their transfer to Bunso, in the forest area might have affected the yield of some of them. Viral diseases were observed in some accessions especially those from the Upper East Region and this could also have affected the yield. Amoatey (1987) found in a study of local and exotic cowpeas that varieties which were very severely affected by virus had a very poor yield. Furthermore, landraces of cowpea naturally have low seed yield (Rachie and Rawal, 1976). In a characterization of cowpea germplasm from Botswana, a range of 1 to 99 was observed for the number of pods per plant and majority of the accessions had low production levels (deMooy, 1985).

The accessions differed significantly in peduncle length and the number of peduncles per plant. The range of peduncle length was 15.0 to 41.3cm whilst that of number of peduncles per plant was 10.0 to 14.3. There is normally one peduncle per node. However, there are some genetic stocks with multiple peduncles (Rachie and Rawal, 1976). The length of the peduncle determines the position of pod in relation to the canopy. There is a rare West African variety of cowpea called Vigna unguiculata textilis with long peduncles (<60cm) which are used for fibre (Ng and Marechal, 1985; IITA, 1988c). The pods of this variety are reported to be small and upright with small, smooth seeds (Ng and Maréchal, 1985). Long peduncles appear to be a disadvantage to pod and seed production in cowpea. Dry matter, and its partitioning into useful products like pods and seeds is diverted into the long peduncles (Rachie and Rawal, 1976). There were therefore research efforts to breed for shortened peduncle (Rachie and Rawal, 1976). deMooy (1985) observed a range of 4 to 36cm for peduncle length in cowpea germplasm from Botswana.

Much variability was observed in pod length of the cowpea germplasm which ranged from 8.3 to 17.5cm. Pod length is a very important diagnostic feature between cultivated and wild cowpea species (Verdcourt, 1970). Steele and Mehra (1980) observed that pod length ranges from 4cm in some wild subspecies to 12 to 20cm in subsp. unguiculata, and one metre in subsp. sesquipedalis. In a world collection of cowpea germplasm, Porter et al. (1974) observed the range of 7.1 to 41.7cm for pod length.

The cowpea germplasm exhibited variability in the number of seeds per pod. There was both between-region and within-region variability. The range was 8 to 16. Both the accessions with the lowest number of seeds per pod and those with the highest were collected from the Northern Region. Amoatey (1987) observed a positive correlation between number of seeds per pod and pod length. In this study, accessions which had the shortest pods also had the lowest number of seeds per pod. Similarly, accessions with the longest pods also had the highest number of seeds per pod. Research efforts are directed at producing long pods (Rachie and Rawal, 1976). Amoatey (1987) observed a range of 10 to 14 seeds per pod whilst deMooy (1985) observed a range of 2 to 16.

Significant differences were observed in the 100-seed weight of the cowpea germplasm. The range was 6.7 to 21.4g. Accessions from the Eastern Region had the lowest 100-seed weight whilst the accessions which had the highest were from the Upper East Region. Steele and Mehra (1980) observed that the weight of 100 seeds varies from 1g in some wild forms to 34g in rare cultivars. Amoatey (1987) had a range of 9.2 to 20.0g for 100-seed weight for 16 cowpea accessions he studied.

Much variability was found in the grain yield per plant of the cowpea accessions. The range was 2.1 to 46.9g per plant. Both the accessions with the lowest and highest grain yield per plant were from the Northern Region. Generally the region with highest mean grain yield per plant was the Eastern Region whilst the Upper East had the lowest. Amoatey (1987) had a range of 20.1 to 63.0g per plant for seed yield. The wide range of variability in the grain yield per plant of the accessions may be due to the reasons already advanced for the number of pods per plant.

A wide range of variability was observed in the 17 quantitative characters studied as shown by their coefficients of variation. Very high coefficients of variation were recorded for number of pods per plant and grain yield per plant. High coefficients of variation were recorded for hypocotyl length, nodes on main stem, main branches per plant, terminal leaflet length and width, number of branches per plant, calyx lobe length, standard length, peduncle length, number of racemes per plant and number of seeds per pod. Characters which had low coefficients of variation were days to 50% flowering, peduncles per plant, days to 50% maturity, pod length, number of seeds per pod and 100-seed weight. Amoatey (1987) observed similar coefficients of variation as those in the present study. He found that coefficients of variation for grain yield per plant and number of pods per peduncle were high whereas those for number of peduncles per branch, days to 50% flowering, days to 50% maturity, number of seeds per pod and pod length were low. Similarly, Opoku-Asiama (1978) observed that days to flowering and maturity were the least variable in a study of bambara groundnut accessions. Opoku-Asiama (1978) also observed that the observed variation in the agronomic characters associated with yield in bambara groundnut is largely under genetic control as evidenced by their high heritability estimates.

The current trend in cowpea research is to produce types which mature early (60 days) and are high yielding (Singh and Rachie, 1985). The cowpea-breeding programme at IITA has focused on breeding for preferences in different regions, resistance against insect pests and diseases and for extra-early and bushy-type varieties (Singh and Ntare, 1985). It is desirable to develop useful plant types with preferred qualities to suit farmers' specific situations (Rachie and Rawal, 1976).

5.3 Heterosis for maturity date, yield and yield components

An essential factor in breeding for heterosis is to breed hybrids which are more productive than the best available cultivars. Several cowpea accessions have been characterized in this study from which five accessions were selected for crosses for heterosis studies on yield and yield components based on some desirable traits they had. Accession 87/157 from the Eastern Region had a high number of pods per plant and high grain yield per plant; 87/35 from the Northern Region had large white seeds and high 100-seed weight; 87/27 from the Northern Region had desirable traits which include long pods, high number of seeds per pod and high grain yield per plant; accessions 87/94 from the Upper West Region and 87/56 from the Northern Region had high seed yield and early maturity respectively.

Heterosis for yield is a very important economic consideration in breeding. In this study all the hybrids of the four crosses showed midparent heterosis for grain yield per plant. The heterosis for grain yield per plant ranged from 38.2 to 129.8%, the highest being found in the cross 87/27 x 87/157. This should be expected since the parents in this cross were among accessions with the highest grain yield per plant.

Another trait in which the crosses had high heterosis was number of pods per plant. The range of heterosis in this trait was 34.1 to 82.4%. Cross 87/127 x 87/157 once again had the highest heterosis. Both accessions 87/27 and 87/157 normally produced high number of pods per plant therefore their hybrids showed significant heterosis for number of pods per plant.

All the four crosses showed positive midparent heterosis for number of pods per peduncle. The range for this trait was 4.7 to 33.3%. The highest midparent heterosis for number of pods per peduncle occurred in the cross 87/56 x 87/94.

Three crosses out of four had positive midparent heterosis for pod length. The range for these crosses was 4.9 to 14.7%. The cross which showed the highest heterosis for pod length was once again 87/27 x 87/157. The parents in this cross were among the accessions with the longest pods. It is therefore not surprising that their hybrids had longer pods than the midparent.

There were three crosses with positive midparent heterosis for number of seeds per pod. However, the values for the heterosis were all low. The range was 0.4 to 6.3%. The accessions 87/27 and 87/157 had the highest number of seeds per pod and the cross between the two accessions fortunately also produced the highest midparent heterosis for the trait.

Three crosses had positive midparent heterosis for 100-seed weight whilst one had negative. The range for the positive heterosis was 9.0 to 18.9%. The cross with the highest heterosis for this trait was 87/27 x 87/35. Accession 87/35 had large seeds with high 100-seed weight and therefore influenced the 100-seed weight of the hybrid of the cross 87/27 x 87/35.

Heterosis was either negative, positive but low, or nil in the four crosses for days to flowering and days to maturity. Two crosses had zero heterosis and two had negative heterosis for days to flowering. The implication is that the hybrids with zero heterosis flowered at the same time as their midparents whereas the hybrids with negative heterosis flowered earlier than their midparents. The two crosses in which the hybrids flowered earlier than the midparents were 87/27 x 87/35 and 87/27 x 87/157 and those in which the hybrids flowered at the same time as the midparents were 87/157 x 87/35 and 87/56 x 87/94. Similarly, two hybrids had negative midparent heterosis whilst two had positive heterosis for days to maturity. This means that the two crosses which had negative heterosis matured earlier than their midparents whilst those with positive heterosis matured later than their midparents. The two crosses in which the hybrids matured earlier than the midparents were 87/157 x 87/35 and 87/27 x 87/157 whilst those in which the hybrids matured later were 87/27 x 87/35 and 87/56 x 87/94.

In this study, seed yield showed the highest midparent heterosis among other yield components. This shows the tendency for the hybrids to produce more seeds than the average of the parents or even than the higher parent. Similar observations were made by Yazdi-Samadi et al. (1975) for safflower, Singh (1973) for Indian mustard, Paschal and Wilcox (1975) for soybean, Tarn and Tai (1977) for potato species and Kheradnam et al. (1975) for cowpea.

Kheradnam et al. (1975) therefore concluded that the commercial production of hybrid seed for cowpeas could be advantageous if large scale methods of emasculation and crossing were developed for this species. The discovery of male sterility in cowpea at IITA permits rapid and efficient crossing by both insects and by hand (Rachie et al., 1975) and this could be exploited to facilitate hybrid seed production in the crop.

Spacing in this study (90cm x 90cm) was greater than the recommended spacing for commercial cowpea production in order to minimize competition within and between accessions and also to facilitate the recording of data for individual plants.

6. SUMMARY AND CONCLUSIONS

6.1 Summary

Cowpea germplasm collected from four cowpea-growing regions of Ghana in 1987 were studied at Bunso to determine the amount of variability in vegetative and reproductive characters among 45 randomly selected accessions.

The accessions exhibited variability in such qualitative characters as growth habit, twining tendency, plant, flower and pod pigmentation, raceme position and pod attachment to the peduncle. Variability was also exhibited in such quantitative characters as terminal leaflet length and width, days to flowering and maturity, peduncle length and number of peduncles per plant, number of racemes per plant, number of pods per plant, pod length, number of seeds per pod, 100-seed weight and grain yield per plant.

Based on the results obtained from the variability studies five cowpea accessions with contrasting or similar flowering and maturity dates, number of pods per plant, pod length and grain yield per plant, were selected for heterosis studies. Crosses were made between the selected accessions. The parents and their F_1 hybrids were planted and evaluated over one season.

High and positive midparent heterosis was observed for pods per plant and grain yield per plant in all crosses. Heterosis for the grain yield for the cross 87/27 x 87/157 was about 130%.

6.2 Conclusions

Both between- and within-region variability was observed in various qualitative and quantitative characters in the cowpea germplasm collected from the four regions of Ghana.

Majority of the accessions from all regions had the semi-prostrate growth habit, showed no twining, had slight plant pigmentation and had purple flowers.

All the accessions studied were indeterminate types. The racemes were mostly held above the canopy in most accessions from all regions.

In majority of accessions pod attachment to the peduncle was pendant.

Variability was observed in both terminal leaflet length and width of the cowpea accessions. The accession with both the longest and broadest terminal leaflet was from the Northern Region.

Accessions which flowered and matured earliest were from the Northern and Upper West Regions whereas those that flowered and matured latest were from the Upper East Region.

Generally accessions from the Eastern Region had the longest pods, the highest number of pods per plant and the highest grain yield per plant. Accessions from the Upper West and Upper East Regions had the highest number of seeds per pod and the highest 100-seed weight respectively.

The cross between accessions 87/27 and 87/157 gave the highest midparent heterosis for number of pods per plant, pod length, number of seeds per pod and grain yield per plant. It is recommended that these accessions could be used in future improvement programmes for grain yield on the basis of their performance in this work.

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APPENDIX

Passport data on cowpea germplasm collected from four regions of Ghana

Collector's No.	Local name	Ethnic Group	Name of Village	Region	Lat(N)	Long(W)	Colour of seeds	Source of sample
87/25	Sanji	Tingbani	Labaraga	North	0912	0151	Red	Farm store
87/27	"	Dagomba	Borterly	"	0925	0029	Mottled	"
87/30	"	Tingbani	Tua	"	0925	0027	Red	"
87/32	"	"	"	"	"	"	White	"
87/34	"	"	Sang	"	0924	0016	Red	"
87/35	"	"	"	"	"	"	White	"
87/37	"	Dagbani	Malzeri	"	0927	0001	Red	"
87/40	Isagi	Kombani	Tuwuwa	"	0944	0007	Dark brown	"
87/41	Ituo	"	"	"	"	"	White	"
87/44	Sanji sambli	Dagbani	Shaipo	"	0958	0038	Light	"
87/49	Sanji	Dagomba	Ziong	"	0931	0030	Red	"
87/52	Tua	"	"	"	"	"	White	"
87/555	Sanji	Dagbanle	Limoh	"	0935	0039	Red	"
87/56	"	"	"	"	"	"	Mottled	"
87/58	"	Kokomba	Duobunantor	"	1024	0007	Red	Garden
87/59	Nobega	Kusar	Manga	Upper East	1101	0015	White	"

APPENDIX (CONTD)

Collector's No.	Local Name	Ethnic Group	Name of Village	Region	Lat(N)	Long(W)	Col- of seeds	source of sample
87/60	Benga	Kusar	Bawku	Upper East	1103	0014	White	Field
87/61	Zarebum-nega	Busanga	Manga	"	1101	0015	Light brown	"
87/62	Zare	"	"	"	"	"	White	"
87/64	Tia	Nankani	Kandiga	"	1050	0150	"	"
87/67	Soone	Kasena	Navrongo	"	1054	0106	"	Mar-ket
87/73	Bonda	Sisala	Tumu	Upper West	1053	0159	Black	Farm store
87/81	Sona	"	Buoti	"	1047	0206	White	"
87/83	Bibita-kone	Dagarti	Nandom	"	1051	0042	Black	"
87/84	Napopog-be	"	"	"	"	"	Light brown	"
87/90	Dapiala	"	Sombo	"	1015	0233	Mottled	"
87/94	Bengeh	Wala	Kampaha	"	1002	0225	"	"
87/96	"	"	Mengweh	"	0959	0220	"	"
87/103	"	"	Ga	"	0952	0230	"	"
87/106	Achibe	Gonja	Tuna	North-ern	0929	0226	"	"
87/132	Asedua	Akim	Akora Darko	East-ern	0622	0024	Cream	"
87/133	"	"	"	"	"	"	White	"
87/134	"	"	"	"	"	"	Mottled	"

Collector's No.	Local name	Ethnic Group	Name of Village	Region	Lat(N)	Long(W)	Colour of seeds	Source of sample
87/135	Asedua	Akim	Akora Darko	Eastern	0622	0024	Red	Farm store
87/136	"	"	"	"	"	"	Brown	"
87/137	"	"	"	"	"	"	Red	"
87/138	"	"	"	"	"	"	Mottled	"
87/139	"	"	"	"	"	"	White	"
87/142	Yor	Krobo	"	"	"	"	Cream	"
87/147	Asedua	Akim	Ahomahamasu	"	0630	0017	Red	Market
87/150	Adua nsawa	Kwahu	Bepong	"	0636	0043	"	"
87/153	"	"	Asakraka	"	0639	0041	Brown/ Mottled	Farm store
87/156	"	"	Abene	"	0657	0057	White	"
87/157	"	"	"	"	"	"	Red	"
87/163	"	"	"	"	"	"	White	Mar ket