GENETIC VARIABILITY IN COWPEA *Vigna unguiculata* (L.) Walp UNDER VARIOUS CROP MANAGEMENT SYSTEMS

BY

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DECLARATION

I hereby declare that this thesis has been written by me and that it is a record of my own research work. It has not been presented before in any previous application for higher degree.

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The above declaration is confirmed.

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CERTIFICATION

This thesis entitled 'GENETIC VARIABILITY IN COWPEA, Vigna unguiculata (L.) WALP UNDER VARIOUS CROP MANAGEMENT SYSTEMS' by Omonlara Adjadi meets the regulations governing the award of the degree of Master of Science of Ahmadu Bello University, Zaria and is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

This thesis is dedicated to my dear daughters, Eriyomi, Binoutiri and Modoukpè and husband, Djibril M. Abdoulaye for their love, care, patience and sacrifice.

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pray He spreads blessings on all the people working towards human progress generally and women well-being in particular. Amen.

ABSTRACT

Twelve cowpea ("Vigna unguiculata (L.) Walp) genotypes (ten breeding lines and two local checks) were evaluated on station under different crop management systems for the estimation of their variability, the interaction between genotype and some environmental components such as cropping patterns, pesticide spraying regime, locations and years. Ten of the twelve genotypes were also evaluated on-farm under the farmers' management systems at Gezawa and Minjibir local government areas in Kano State, Nigeria. The acceptability of the lines as crop and food by farmers was assessed. Considerable variation was observed for yield observed for yield and its components such as plant height, days to 50% flowering, days to maturity number of pods per plant, number of seeds per pod, 100-seed weight, fodder yield at harvest per plant and per hectare; dry fodder yield per plant and per hectare, number of Striga plants at harvest. Very wide range was observed for many traits on-station as well as on-farm. Breeding lines such as IT90K-59, IT89KD-374-57, IT86D-719, IT90K-277-2, IT89KD-391, IT89KD-355 and IT89KD-319 performed better than the local varieties across locations for most of the traits. IT89KD- 319, IT89KD-391, IT88DM-867-11 and IT89KD-355 performed as poorly as the local varieties under heavy infestation of the crop by Maruca testulalis, pod sucking bugs, scab, Septoria and Striga for days to 50% flowering, days to maturity, grain yield, number of pods per plant. The performance of the genotypes evaluated varied from one location to another.

Farmers' local varieties performed as good as some of the breeding lines such as IT89KD-374-57 and IT89KD-319 for 100-seed weight, IT86D-719 for grain yield, IT89KD-374-57 and IT86D-719 for pod length, IT86D-719 and IT89KD-391 for number of seeds per pods. Some of the cowpea test lines such as IT88DM-867-11, IT89KD-374-57 and IT90K-277-2 performed better than the farmers' local varieties and the local check 'Danlla' for grain yield per plant.

Significant differences were observed among locations and in the interactions between genotypes and locations; genotypes, locations, pesticide spraying regime and cropping pattern; pesticide spraying regime and year; genotypes and pesticide spraying regime and years for many of the traits. Variance components estimates were computed using a set of data combined over locations, and another set of data combined over

years. Genetic variance estimates had positive value for eleven traits out of thirteen for the data combined over years and for seven out of thirteen for the ones combined over locations. Most of the variance components estimates were associated with large standard errors. The negative variance components estimates were rather very small values than equal to zero.

Broad sense heritability estimates were calculated. The estimates obtained from the data combined over years and the data combined over locations had similar magnitude for plant height, days to 50% flowering and days to maturity. Differences in the heritability estimates obtained by the two approaches for traits such as number of pods per plant, 100-seed weight and grain yield could have been due to the differences, observed in the level of heterogeneity in the environments (locations and years).

The cowpea genotypes had no effect on the associated millet crop on-station even though 57% of the farmers reported an increase in the millet yield on their fields. A high proportion of farmers had a positive appreciation of the performance of the genotypes. They were acceptable and found suitable for cooking varied local dishes. The adoption of these breeding lines by farmers would increase the stability of grain production in their fields which are often under heavy attack by bacterial blight, aphids, thrips and other diseases to which these lines are resistant as against the local varieties which are susceptible. Farmers participation in varietal evaluation was found highly positive. Farmers wished that their involvement would be a permanent feature of the development of improved varieties.

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CHAPTER 1
INTRODUCTION

Cowpea, *Vigna unguiculata* (L.) Walp is a major food legume of considerable nutritional, agricultural, economic and overall general importance as source of food for man and animals (Okigbo, 1979). It is widely cultivated in Africa, its center of origin, Brazil, India and the United States of America for various purposes (Ng and Maréchal, 1985; Fery, 1985).

Cowpea is consumed by people in various forms such as fresh cowpea seeds, immature pods which are regular parts of people's diets in the United States of America (USA) and India, young shoots and leaves as spinach in East Africa and dry cowpea seeds, which are very important in West African daily diets. Akundabweni *et al.* (1986) reported that cowpea is grown for grain as well as fodder in parts of Sudan sahelian region where as a result of the long dry season, the availability of fodder for cattle and other animals can be an acute problem. Therefore, farmers use the dry cowpea seeds for human consumption but store the cowpea haulms for use as fodder in the dry season. When the dry season is a prolonged one, the price of cowpea fodder becomes almost close to its grain price. Therefore, both grain and fodder yields are very important in this region. Tarawali *et al.* (1995) reviewed the traditional farming systems using cowpea haulms as fodder in Asia, Australia and other regions. They reported that dry matter yields from selected cowpea lines grown at Kano, Nigeria were good with some exceeding 10t/ha.

Osho (1995) emphasized the role of cowpea in the improvement of food quality of many people whose food is mainly carbohydrates from roots, tubers and cereals. The dry grain of cowpea contains about 24% of protein (Dos Santos and Damon, 1987). Cowpea leaves are a good source of vitamins and minerals. The protein content ranges from 29 to 43% (dry weight basis) with a higher protein content in younger leaves, (Nielsen *et al.* 1995). The International Institute of Tropical Agriculture (IITA) and the National Agricultural Research Systems (NARS) have been investing important resources in

developing improved technologies for increasing the total cowpea production and the productivity per unit area and per unit time. Appreciable achievements have been realised in terms of agronomy, crop protection and in the development of varieties resistant to various diseases, insect pests, Striga and for earliness and high yield potential. A large number of improved cowpea varieties have been developed and released for cultivation in over 50 countries. The new varieties need 2-3 insecticide sprayings to protect them from insects like pod borers and pod sucking bugs for which no resistances are available. The small holder farmers, in Africa, where insecticides are not easily available are still practicing traditional intercropping. In this system, yields are very low, ranging from 0 to 150 kg/ha. Therefore, many scientists have diversified the objectives of their breeding programme to include breeding cowpea genotypes that suit the farmers' crop management systems.

Thus IITA has established a research station at Kano, Nigeria with the major focus on the development of improved cowpea varieties for intercropping (IITA, 1993). Farmers participation is an essential component of this cowpea breeding programme. From the available literature, it appears that many studies were carried out to estimate genetic variability of some cowpea characteristics, their heritability and genetic advances. However, it is necessary to study these estimates in the recent context of cowpea breeding. The economic parameters in which farmers are interested in, are grain yield and fodder for animal feed in the tropics and the semi arid tropics. This project aims at studying the genetic variability of some cowpea elite lines in respect to various crop management systems and test their acceptability by farmers as crop and food. Thus the objectives of this project are to:

(1) estimate the interaction between genotype and different crop management systems (pesticide spraying regime, cropping pattern, location and year in all possible combinations) ;

(2) estimate genetic variability under the above crop management systems ;

(3) assess the performance of the elite lines under farmers crop management systems and

(4) test the acceptability of these lines as a crop for food and fodder by farmers.

CHAPTER 2

LITERATURE REVIEW

2.1 GENETIC VARIABILITY IN COWPEA

Aglibut (1956) observed variations in pod length, maturity, anthocyanin concentration in petiole and stems, leaf colour and yield. Singh and Mehndiratta (1969) reported that the number of pods per plant had the highest genetic coefficient of variation among the traits studied. Trehan *et al.* (1970) reported a high genetic coefficient of variation for branches per plant, pods per plant, yield per plant and length of peduncle. Sohoo *et al.* (1971) observed a wide genetic variability under three environmental conditions for characters such as vine length, pods per plant and plant weight in 154 cowpea varieties.

Ramachandran *et al.* (1980) revealed that the major part of total variation in yield per plot, pods per plant, and internodal length was due to genetic causes. Dharmalingan and Kadambavanasudaram (1984) showed that there existed greater variability for traits such as harvest index, number of pods and seed yield and that the least contribution to genetic variability was number of seeds per pods. Atuahene-Amankwa and Hossain (1994) showed significant differences among varieties for haulm weight, days to maturity, pod yield, dry shoot weight at maturity except for dry shoot weight at flowering. De Mooy (1985) reported that production of pods per plant varied considerably but was generally low in Botswana. Ntare (1992) observed significant differences among cultivars for their ability to flower and set pods under high temperature conditions.

2.2 GENOTYPE X ENVIRONMENT (G x E) INTERACTION

Very few reports exist in literature on genotype by environment interaction in cowpea despite the fact that the performance of some cowpea genotypes vary across environments. Ntare (1986) observed significant differences among cultivars with respect to grain yield but cropping system x cultivar

interaction was not significant. Ntare and Williams (1992) reported that planting pattern had no siginificant effect on the yield of either cowpea or millet in intercrop. They observed that sowing date of cowpea relative to millet was a critical factor in the sahelian pearl millet-cowpea intercropping system. It was concluded that the primary causes of genotype x environment interactions were differential canopy development and insect damage effect.

2.3 HERITABILITY OF YIELD AND ITS COMPONENTS IN COWPEA

Singh and Mehndiratta (1969) reported high heritability values for 100-seed weight. Sreekumar *et al.* (1979) revealed high heritability for 100 -seed weight, grain yield and yield of haulms. Dharmalingan and Kadambavanasudaram (1984) recorded higher heritability estimates for pod length, 100 seed weight and harvest index. Ramachandran *et al.* (1980) found high heritability for days to flower (95.18%) and days to first harvest (95.74%).

Fery (1985), reported that pod length was moderately to highly heritable. Additive gene action was important and high heritability was often accompanied by high genetic advance (Veeraswany *et al.* 1973 and Tikka *et al.* 1977). However, non-additive gene action had been reported in some instances (Singh and Jain 1972). The number of seeds per pod was moderately heritable under most environmental conditions and heritability values averaged 52.8 percent. Non-additive gene action accounted for much of the variation (Fery 1985). Seed size was found to be moderately to highly heritable with estimates averaging 67.8%. A number of quantitative studies of the genetics of earliness parameters showed that broad sense heritability estimates averaged 48.3 percent for days to flowering and 47.8 percent for days to pod maturity. Several authors concluded that additive gene action is responsible for much of the genetic variation for earliness (Kheradnam and Niknejad, 1971; Lal *et al.* 1976; Tikka *et al.* 1976; Mak and Yap 1977 ; Zaveri *et al.* 1980). Other reports however, indicated that the action of non- additive genes and interactions between genotype and environment were important in some instances (Fery 1985).

He also reported that the yields of both the reproductive and the vegetative portions of the cowpea plant were moderately heritable under most environmental conditions. Heritability estimates for pods number, seed and fresh fodder yields were 53.1 percent, 45.0 percent and 54.7 percent, respectively. Zaria (1988) obtained very high estimates of broad sense heritability for pods per plant, seeds per plant and seed size.

2.4 GENETIC ADVANCE

Singh and Mehndiratta (1969) reported that expected genetic advance was appreciable for the number of bunches of pods per plant, 100-seed weight, pod number, pod length and yield. Sreekumar *et al.* (1979) indicated high genetic advance for 100-seed weight, yield of grain and yield of haulms. Ramachandran *et al.* (1980), showed that the genetic advance estimated as percent of means was maximum for seeds per pod followed by yield per plot and pods per plant. Trehan *et al.* (1970), obtained a high genetic advance for pod per plant.

Fery (1985) reported that the high heritability for the number of seeds per pod was accompanied by relatively low genetic advance. The high heritability estimates for earliness were associated with low estimates for genetic advance and that the negative association suggested that earliness was conditioned by effects other than additive gene action.

2.5 CORRELATIONS

Several authors have reported significant positive correlation between grain yield and pods number Imrie and Butler (1983) found that in each of the twenty cowpea accessions studied, seed yield correlated with total number of pods and forage yield. It was indicated that in all but two lines, yield per pod, harvest index, yield per geometric mean of total number of pods and forage yield were independent of plant size.

Trehan *et al.* (1970) showed that grain yield per plant was highly correlated with length of peduncle. Using multiple regression analysis and path coefficient analysis, Obisesan (1985) concluded

that the number of pods per plant, 100-seed weight and number of seeds per pod were the three primary components for predicting grain yield. The subtle indirect effects of vigour index, number of peduncles per plant on grain yield were more important than their direct effect. Both the direct and indirect effects of number of main branches per plant on grain yield appeared to be detrimental.

Singh and Dăbas (1985) reported significant positive correlation between plant height, pods per plant, pod length, grain per pod and grain yield under two environments. Correlations between pod length and grain per pod, pod length and 100-seed weight were positive and consistent in both the environments. They observed direct effects of high magnitude for pods per plant and 100-seed weight.

Atuahene-Amankwa and Hossain (1994) found that grain and haulm yields were not significantly correlated and that haulm yield was significantly and positively correlated with days to maturity and dry shoot weight at flowering. Kumar and Mishra (1981) revealed that dry matter yield had the highest positive direct effect on green-forage yield followed by plant height. According to them, indirect effect of plant height via dry matter yield and dry matter yield via plant height indicated that green-forage yield is mainly due to plant height and dry matter yield, or if an improvement in the plant is made there will be simultaneous improvement in green forage as well as dry matter yields. The high direct effect of terminal leaflet length, lateral leaflet width, leaf/stem ratio and dry matter yield showed the importance of these traits in influencing green-forage yield at the genotypic level. Ntare (1992) reported significant positive linear correlations between grain yield and other traits such as shoot weight, total flowers, total pods, mature pods, peduncles, branches, seeds per pod, harvest index, reproductive duration, crop growth and grain growth rate under sahelian environment. The consistently high correlation between shoot dry matter and pods per plant with grain yield indicated that seed yield resulted from high shoot dry matter and pods per plant. The correlation between seed yield and harvest index was generally low compared to similar studies in cereals. There was no direct association between reproductive growth duration and grain yield despite the considerable variation among genotypes for these traits. Pod number was the

single component most consistently associated with yield. The low correlation between harvest index and seed yield may be partly due to the difficulty of determining harvest index since in indeterminate grain legumes like the cowpea, considerable foliage is lost by the time the final seed is harvested.

Aggarwal (1986) reported that the dry plant weight was significantly correlated with yield at the late date of planting in two locations and that the harvest index was positively correlated with yield though not significantly.

2.6 COWPEA CROP MANAGEMENT

2.6.1 Cropping Pattern

Many studies have reported that most farmers have developed cropping systems that are based on intercropping or mixed cropping. Steiner (1985) reported that mixed cropping was the central component of traditional farming system in most of the tropical African regions. The most common cropping pattern in which cowpea is grown is intercropping with sorghum, millet, maize, cotton and groundnut (Malton, 1986; Raheja, 1986). Cowpea is grown for dry seeds as a monoculture and as mixed crop with cereals in many countries of Asia according to Mishra *et al.* (1985). Rivaldo and Milton (1988) revealed that in the semi-arid region, Northeast of Brazil, intercropping of various crop species is common in small production units whose primary objective is to obtain food for family consumption. Common components of these mixed cropping systems are cowpea, maize and cassava.

A good deal of work had been conducted on the agronomical aspects of the intercropped cowpea. Cunard (1981) observed that cowpea cultivars were shade intolerant when grown with millet but by growing millet in different row widths and by utilizing a mixture of cowpea cultivars, this problem was overcome. Olufajo (1986) found that the number of pods per cowpea plant was the component mainly affected by plant density. According to him, in both monocrop and mixtures with maize, pods per plant decreased as the cowpea population increased. In the intercrop combinations, pods per plant decreased

as the population of maize increased. Olafare and Ojomo (1986) observed that the yield of the cowpea entries when intercropped with any of the maize varieties evaluated was lower than when they were sole cropped. They obtained similar yield reductions in two years indicating no significant influence of the maize canopy types on the cowpea yields in intercrop. Muleba (1988) reported that despite the differences among cowpea cultivars in their ability to compete with millet, there were no advantages to intercropping at Poba, Djibo in Burkina Faso but there were some advantages to intercropping at Sadore, Niamey in Niger. Since the advantage was inconsistent across these Sahel locations, no reliable conclusion could be drawn.

2.6.2 Breeding Cowpea for Intercropping

Ntare (1988) after analysing the result of the study of intercropped cowpea lines with millet pointed out the need to identify genotypes specifically suited to intercropping. Hamblin and Zimmermann (1986) reviewed thoroughly the breeding of common bean, *Phaseolus vulgaris* for yield in mixture. They stated that the major differences between pure stand agriculture and mixed cropping were in the degree and type of competition that the different species were faced with. They concluded that genetic parameters, heritabilities and rates of advance in one set of conditions (pure stand) were likely to be a poor guide to these parameters in another set of conditions (mixtures) and vice versa. They emphasized the need for breeding for the cropping system (maize - bean) for instance rather than breed for individual components. They showed that this would require a radical change in thinking as well as in breeding methodology. Breeders of component crops of mixtures would either have to work closely together or work on two or more species at once. Thus, the potential for improvement was great and the development of adapted high-yielding cultivars would greatly improve the well being of substistence farmers.

In the study of the response of cowpea cultivars to planting pattern and date of sowing in

intercrops with pearl millet in Niger, Ntare (1992) found that planting pattern had no significant effect on the yield of either cowpea or millet. Cowpea yield was reduced by more than 50% by two weeks delay in sowing, confirming that the sowing date of cowpea relative to millet is a critical factor in the sahelian pearl millet-cowpea intercropping system. Marked differences in the effect of cowpea cultivars on millet yield were observed. These differences were consistent over sowing dates.

Singh (1989) reported that in sorghum-millet based systems, the planting pattern and plant densities varied a great deal among farmers and regions. In general, cowpea is intercropped at very low densities without any insecticide protection leading to a cowpea yield ranging from 100 to 200 kg/ha. This is the most widely practised cropping system by local farmers. Therefore, a breeding program, whose major objective was to develop cowpea varieties with greater productivity and yield stability under sorghum-millet-based systems was initiated by IITA in 1987 (IITA, 1989).

Significant differences in ranking between the two cropping systems have been reported in some experiments (IITA, 1989). These results suggested caution in using monocropping to evaluate materials for intercropping and a need for more information on the subject. IITA (1993) reported that results for the intercrop treatment indicated that if insects could be controlled, grain yield levels of 400 to 600 kg/ha were possible for cowpea with about 1500kg/ha of millet grain.

2.6.3 Cowpea Crop Protection

The major constraint to cowpea production is its susceptibility to various fungi, bacteria, viruses and insect pests, from germination to harvest and in storage. Sixteen major diseases attack cowpea crop in various agroecological zones of the Tropics. These diseases can be controlled by the adoption of appropriate cultural practices, the judicious use of pesticides, the use of resistant cowpea varieties and by Integrated Pest Management Strategy (IPMS) which implies the complementary use of all these control methods (Emechebe and Shoyinka, 1985).

The insect pest complex destroying cowpea crop includes: aphids, beanfly, leafhoppers, thrips, pod borers, pod sucking bugs, cowpea curculio and the storage weevil. Losses in grain or foliage attributable to cowpea field pests range from 20 to 100 percent. In most tropical countries cowpea cannot be grown successfully without at least one or two insecticide sprays. The associated crops with which cowpea is grown, perform various roles, some serve as hosts for the cowpea pests, others serve as barriers restricting movement of the pests in the field; others play roles yet undetermined (Jackai *et al.* 1985). A lot of effort has been made in developing low cost and efficient pest control technology by scientists at the International Institute of Tropical Agriculture (IITA) and National Agricultural Research Systems such as Institute for Agricultural Research (IAR), Samaru, Zaria but their impact is not much at farmers level. According to IITA (1993), most traditional farmers do not use chemical protection due to socio-economic and infrastructural constraints even though the new varieties when sprayed can yield between one and two metric tonnes per hectare and give high economic returns.

2.7 Achievements in the Improvement of Cowpea Production

Steiner (1985) showed that little amount of success has been recorded by extension services which try to introduce sole cropping in farmers crop management systems. Taking this fact into account, considerable efforts have been made to develop optimal intercropping patterns by many National Research Institutes and IITA. Malton (1986) reported that farmers, instead of adopting the recommended spacing for cowpea, applied varied plant densities, sticking to their traditional practices. The results of the study, by IITA, on the adoption of an improved cowpea package introduced to Nigerian farmers in 1982, strongly supported the current IITA emphasis on developing cowpea varieties that are suitable for intercropping and have high levels of insect resistance (IITA, 1992). Thus, the general strategies of IITA for cowpea breeding is to improve local varieties by incorporating disease, insect and Striga resistance as well as early maturity together with high yield potential adapted to various crop management systems.

2.8 Experiences in On-farm Varietal Trials

Maurya (1991) reported how farmers had been good partners in on-farm research for the selection of crop varieties. Ashby *et al.* (1991) showed how scientists can appreciate the farmers' reaction and opinions through the evaluation of a varietal trial with farmers' participation. Elemo (1993) evaluated the performance and acceptability of elite cowpea cultivars with or without insect pests control in the traditional cropping patterns at Bomo village located in the Northern Guinea Savanna agroecological zone in Nigeria. These studies pointed out that considerable knowledge and interesting result can be achieved with the farmer's participation in the evaluation of the improved varieties. Thus, at the last stage of variety development, when the breeding lines have been reduced to eight or ten on the basis of other agronomic characteristics, samples of these lines can be given to a group of farmers who will grow them in their own traditional way, ensuring representation of the most prevalent crop management system as IITA has been doing since 1992 (IITA, 1993).

CHAPTER 3

MATERIAL AND METHODS

This study consists of on-station experiments with two components and an on-farm experiment.

3.1 ON-STATION EXPERIMENTS

3.1.1 Location and Duration

Two experiments were conducted in Minjibir local government area in Kano State, and in Mallam Maduri Local Government Area in Jigawa State, Nigeria, both in Sudan savanna zone, during the rainy season in 1994. The third experiment was carried out in Samaru in Kaduna State, Nigeria in the Northern Guinea savanna zone during the 1994 and 1995 rainy seasons.

3.1.2 Planting material

(a) **Millet**: Only the variety ex-Borno was used as intercrop.

(b) **Cowpea**: The source and description of the twelve cowpea genotypes used are given in Table 1.

3.1.3 Experimental design

In all the three locations, the experiments were laid out in a split-split plot model in a randomized complete block design (RCBD) with the pesticide spraying regime as main treatment (with two components spray and no spray); the cropping pattern as sub-treatment (with two patterns: sole crop and intercrop) and the genotypes as sub-sub treatment. Each genotype was allocated randomly to a plot of four rows of 8m in 1994 and four rows of 7m in 1995 at Samaru due to land shortage. The cowpea genotypes were intercropped with millet at Minjibir and Mallam-Maduri while they were intercropped with sorghum at Samaru. The sorghum crop of the 1995 experiment failed at Samaru due to heavy rain which resulted in waterlogging at the sowing time. Therefore, only the data on the sole cowpea crop available was considered in a split plot design with the pesticide spraying regime as main treatment and the genotypes as sub-plot treatment.

3.1.4 Cropping Pattern

(a) **Sole Crop:** each genotype of cowpea was planted in four rows in each replication.

(b) **Intercrop:** each plot was made of two rows of millet alternated by two rows of the same genotype of cowpea. The distance between rows was 75 cm. Within row spacing was 20cm for all the cowpea genotypes except for 'kananado' which is a spreading type and was planted at 40cm apart. Four to six seeds were sown and later thinned to two plants per hill. Within row spacing was one meter for the millet intercrop.

3.1.5 Crop protection regime

The cowpea crop was subjected to the pesticide spraying regime mentioned above according to the design. The sprayed plots received at least two applications of Sherpa plus and one of Nuvacron on a weekly basis starting from the formation of flower buds to pods maturity. The crops at Samaru received a second application of Nuvacron in 1994 due to heavy infestation of pod sucking bugs during pod filling stage. The same crop was sprayed with Benlate at the rate of 300 g of Benomyl/ha in 1994 because of the prevalence of scab and Septoria diseases. In all the locations, Sherpa plus was sprayed at the rate of 15g of Cypermethrine and 125g of Dimethoate/ha as water emulsifiable concentrate. Nuvacron was sprayed at the rate of 200g Monocrotophos/ha.

The two last sprays in Samaru in 1995 were made of a mixture of Sherpa plus and Nuvacron at the above rate because of the prevalence of Maruca and pod sucking bugs. The plots were kept weed free by regular hoe weeding.

3.1.6 Date of planting

The millet was first planted on June 15, 1994. Cowpea genotypes were planted about two weeks later. The cowpea was planted on July 2, 1994 at Minjibir, July 7, 1994 at Mallam Maduri and August 4, 1994 at Samaru in 1994. The second season experiment was planted at Samaru on August 14, 1995.

Table 1: Cowpea genotypes, Source and Characteristics

Genotypes	Source	Characteristics
IT86D-715	IITA	medium maturity, semi-determinate, white seeds
IT86D-719	IITA	early maturing, semi-determinate, white seeds
IT89KD-374-57	IITA	early maturing, spreading white seeds
IT89KD-391	IITA	medium maturing, tall erect, brown seeds
IT88DM-867-11	IITA	medium maturing, brown seeds
IT90K-59	IITA	early, spreading, brown seeds
IT89KD-319	IITA	medium, semi-spreading, white seeds
IT90K-277-2	IITA	medium, semi-determinate, white seeds
IT89KD-355	IITA	white seeds
IT89KD-261-3	IITA	white seeds
'Kanannado'	IITA	late, spreading, white seed
'Dan Ila'	IITA	medium, spreading, white seeds

3.1.7 Data collection

Cowpea: Observations were made on the two middle rows for sole crop plots and two cowpea rows in intercrop plots. The following characteristics were recorded.

(a) *Stand count*: The number of plants was counted in the observation plot after thinning and at harvest time.

(b) *Days to 50% flowering*: The number of days from sowing to the stage when 50% of the plants had flowered was recorded.

(c) *Days to maturity*: The number of days from sowing to the stage when 90% of the plants had mature pods.

(d) *Diseases and insects attack*: Diseases such as scab, Septoria, cowpea yellow mosaic virus and insect pests such as *Maruca testulalis*, pod sucking bugs were recorded and their incidence on the crop estimated.

(e) *Striga count*: The number of Striga plants infesting the cowpea plants in the observation plot was counted at harvest time.

(f) *Alectra count*: The number of Alectra plants infesting the cowpea plants in the observation plot was counted at harvest time.

(g) *Plant height at 50 days after planting*: The height of six plants chosen at random within observational plot was measured from ground level to the top of the canopy and the mean was recorded as plant height.

(h) *Number of pods*: The total number of pods harvested in the observational plot was counted and divided by the number of plants harvested to obtain the number of pods per plant.

(i) *Pod length*: The length of ten pods randomly selected was measured and the mean was taken as pod length for each genotype.

(j) *Number of seeds per pod*: Seeds from the ten pods, whose lengths were measured, were counted and the total number was divided by ten to obtain the number of seeds per pod.

(k) ***Hundred seed weight***: Hundred seeds were weighed using a sensitive balance.

(l) ***Grain yield***: The pods harvested for each genotype were threshed and weighed using a sensitive balance. The yield per plot was divided by the number of plants to get the yield per plant. The yield per hectare was calculated as follows:

$$\frac{\text{Yield per plot x } 10{,}000\text{m}^2}{\text{Plot area in m}^2}$$

(m) ***Fodder yield at harvest***: The haulms and fallen leaves of the observational plot were weighed at harvest for the plants that had reached maturity. The plants that did not produce mature pods were cut and their haulms weighed when their leaves senesced and started falling. The fodder yield at harvest per plant was calculated by dividing the plot yield by the number of plants at harvest. The fodder yield at harvest per hectare was calculated as follows:

$$\frac{\text{Fodder yield per plot x } 10{,}000\text{m}^2}{\text{Plot area in m}^2}$$

(n) ***Dry fodder yield***: The cut haulms were rolled and left on the field for sun drying for twelve to fifteen days after which the dry haulms were weighed. The fodder dry weight per plant was calculated by dividing the yield per plot by the number of plants cut. The yield per hectare was calculated by:

$$\frac{\text{Yield per plot x } 10{,}000\text{m}^2}{\text{Plot area in m}^2}$$

Millet: Data were collected on the millet row between the two rows of the same genotype of cow pea.

(a) ***Grain yield***: The mature millet heads were cut and treshed. Then grains were weighed using a sensitive balance.

(b) ***Stalk yield***: Millet stalks were cut at the ground level after harvesting the heads. They were sun-dried for fifteen days, then weighed.

3.1.8 Statistical analysis

Some of the data were analysed with GENSTAT V software package, following the analysis of variance procedure. In this analysis of variance (ANOVA), the pesticide control (sprayed and unsprayed) regime is named type, the cropping pattern (sole and mixed) is pattern and the genotypes, as genotypes. Location, years, pesticide spraying regime, cropping pattern and genotypes are random factors. The forms of the ANOVA for the combined analysis of the data over locations and over years are shown in Tables 2, 3 and 4.

They present the sources of variation, degrees of freedom (d.f), sums of squares (S.S.), mean squares (M.S.), expected mean squares (E.M.S.) and the F test of significance. The corresponding degrees of freedom are used for F ratio of single mean squares. For the composed ones they are calculated as follows:

For example for the interaction between genotypes and pattern we have:

$F_{pg} = (M_{pg} + M_{lpg})/(M_{tpg} + M_{lpg})$ by applying the method described by Obi (1986)

The degree of freedom of the numerator is:

$$n = (M_{pg} + M_{lpg})^2/[(M^2_{pg}/df_{pg}) + (M^2_{lpg}/df_{lpg})]$$

with M with subscript = mean square, df_{pg} = degree of freedom of cropping pattern x genotypes and df_{lpg} = degree of freedom of the interaction between location, pesticide spraying regime, cropping pattern and genotypes.

The degree of freedom of the denominator is:

$$d = (M_{tpg} + M_{lpg})^2/[(M^2_{tpg}/df_{tpg}) + (M^2_{lpg}/df_{lpg})]$$

with df_{tpg} = degree of freedom for the interaction between pesticide spraying regime, cropping pattern and genotypes and df_{lpg} = degree of freedom of the interaction between location, cropping pattern and genotypes.

The degrees of freedom of all the F ratios composed of a ratio of the sum of two means squares is calculated according to this pattern.

The F ratio composed of ratio of the sum of four mean squares as

$$F_g = (M_g + M_{lpg} + M_{lpg} + M_{lg})/(M_{lpg} + M_{lg} + M_{tg} + M_{pg}),$$

the numerator n' and the denominator d' are calculated as follows:

$$n' = (M_g + M_{lpg} + M_{lpg} + M_{lg})^2/[M^2{}_g/df_g) + (M^2{}_{lpg}/df_{lpg}) + (M^2{}_{lpg}/df_{lpg}) + (M^2{}_{lg}/df_{lg})],$$

where df_g = degree of freedom of the genotypes

df_{lpg} = degree of freedom of the interaction between pesticide spraying regime, cropping pattern and genotypes,

df_{lpg} is the same as defined above,

df_{lg} = degree of freedom of the interaction between location, pesticide spraying regime and genotypes. and

$$d' = (M_{lpg} + M_{lg} + M_{tg} + M_{pg})^2/[M^2{}_{lpg}/df_{lpg}) + (M^2{}_{lg}/df_{lg}) + (M^2{}_{tg}/df_{tg}) + (M^2{}_{pg}/df_{pg})],$$

where df_{lpg} and df_{pg} are as defined above

df_{lg} = degree of freedom of the interaction between location and genotypes,

df_{tg} = degree of freedom of the interaction between pesticide spraying regime and genotypes,

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Table 2: Form of the combined analysis of variance over locations showing sources of variation, degrees of freedom (d.f), sums of squares (S.S.), mean squares(M.S.), expected mean squares (E.M.S.) and the F-test for a split split plot model in a randomized complete block design, all the factors are random.

Sources of variation	Generalized d.f	Specific d.f	S.S.	M.S.	E.M.S.	F - Test
Locations (L)	l - 1	1	SS_l	M_l	$\sigma^2_e + g\sigma^2_{pr(lt)} + pg\sigma^2_{tr(l)} + pgt\sigma^2_{r(l)} + r\sigma^2_{ltpg} + rt\sigma^2_{lpg}$	$(M_l + M_{ltp} + M_{ltg} + M_{lpg})$
					$+ rp\sigma^2_{ltg} + rg\sigma^2_{ltp} + rtp\sigma^2_{lg} + rgt\sigma^2_{lp} + rpg\sigma^2_{lt} + rtpg\sigma^2_{l}$	$(M_{tp} + M_{lg} + M_{lt} + M_{ltpg})$
Reps in locations	l(r-1)	4	$SS_{r(l)}$	$M_{r(l)}$	$\sigma^2_e + g\sigma^2_{pr(lt)} + pg\sigma^2_{tr(l)} + pgt\sigma^2_{r(l)}$	$M_{r(l)} / M_{e(a)}$
Type (T)	t - 1	1	SS_t	M_t	$\sigma^2_e + g\sigma^2_{pr(lt)} + pg\sigma^2_{tr(l)} + r\sigma^2_{ltpg} + rp\sigma^2_{ltg} + rg\sigma^2_{ltp}$	$(M_t + M_{ltp} + M_{ltg} + M_{tpg})$
					$+ rl\sigma^2_{tpg} + rlp\sigma^2_{tg} + rlg\sigma^2_{tp} + rpg\sigma^2_{lt} + rlpg\sigma^2_{t}$	$(M_{tp} + M_{tg} + M_{et} + M_{ltpg})$
L x T	(l - 1)(t-1)	1	SS_{lt}	M_{lt}	$\sigma^2_e + g\sigma^2_{pr(lt)} + pg\sigma^2_{tr(l)} + r\sigma^2_{ltpg} + rp\sigma^2_{ltg} + rg\sigma^2_{ltp} + rpg\sigma^2_{lt}$	$(M_{lt} + M_{ltpg})/(M_{ltg} + M_{ltp})$
Error (a)	l(t-1)(r-1)	4	$SS_{e(a)}$	$M_{e(a)}$	$\sigma^2_e + g\sigma^2_{pr(lt)} + pg\sigma^2_{tr(l)}$	
Whole plot total	ltr - 1	11				
Pattern	p - 1	1	SS_p	M_p	$\sigma^2_e + g\sigma^2_{pr(lt)} + r\sigma^2_{ltpg} + rg\sigma^2_{ltp} + rt\sigma^2_{lpg} + rl\sigma^2_{tpg}$	$(M_p + M_{ltp} + M_{pgl} + M_{tgp}$
					$+ rtl\sigma^2_{pg} + rpg\sigma^2_{lt} + rgt\sigma^2_{lg} + rlgt\sigma^2_{p}$	$(M_{tp} + M_{lg} + M_{pp} + M_{ltpg})$
L x P	(l - 1)(p-1)	1	SS_{lp}	M_{lp}	$\sigma^2_e + g\sigma^2_{pr(lt)} + r\sigma^2_{ltpg} + rg\sigma^2_{ltp} + rt\sigma^2_{lpg} + rgt\sigma^2_{tp}$	$(M_{lp} + M_{ltpg})/(M_{lpg} + M_{lgp})$
T x P	(t - 1)(p-1)	1	SS_{tp}	M_{tp}	$\sigma^2_e + g\sigma^2_{pr(lt)} + r\sigma^2_{ltpg} + rg\sigma^2_{ltp} + rl\sigma^2_{pg} + rlg\sigma^2_{ltp}$	$(M_{tp} + M_{ltpg})/(M_{tpg} + M_{ltp})$
L x T x P	(l-1)(t-1)(p-1)	1	SS_{ltp}	M_{ltp}	$\sigma^2_e + g\sigma^2_{pr(lt)} + r\sigma^2_{ltpg} + rg\sigma^2_{ltp}$	M_{ltp} / M_{ltpg}
Error (b)	lt(p-1)(r-1)	8	$SS_{e(b)}$	$M_{e(b)}$	$\sigma^2_e + g\sigma^2_{pr(lt)}$	
Subplot total	ltr(p - 1)	12				

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Table 2 (Continued):

Sources of variation	Generalized d.f	Specific d.f	S.S.	M.S.	E.M.S.	F - Test
Genotypes (G)	g - 1	11	SS_g	M_g	$\sigma^2_e + r\sigma^2_{lpg} + rt\sigma^2_{lpg} + rlg\sigma^2_{tpg} + rp\sigma^2_{lg} + rtl\sigma^2_{pg}$ + $rlp\sigma^2_{tg} + rtp\sigma^2_{lg} + rltp\sigma^2_{g}$	$\frac{(M_g + M_{lg} + M_{tg} + M_{gp})}{(M_{lg} + M_{tg} + M_{pg} + M_{lpg})}$
L x G	(l - 1)(g-1)	11	SS_{lg}	M_{lg}	$\sigma^2_e + r\sigma^2_{lpg} + rt\sigma^2_{lpg} + rp\sigma^2_{lg} + rtp\sigma^2_{lg}$	$(M_{lg} + M_{lpg})/(M_{lg} + M_{lp})$
T x G	(t - 1)(g-1)	11	SS_{tg}	M_{tg}	$\sigma^2_e + r\sigma^2_{lpg} + rl\sigma^2_{tpg} + rp\sigma^2_{lg} + rlp\sigma^2_{tg}$	$(M_{tg} + M_{lpg})/(M_{lg} + M_{tpg})$
P x G	(p - 1)(g-1)	11	SS_{pg}	M_{pg}	$\sigma^2_e + r\sigma^2_{lpg} + rl\sigma^2_{tpg} + rt\sigma^2_{lg} + rtl\sigma^2_{pg}$	$(M_{gp} + M_{lpg})/(M_{lpg} + M_{tpg})$
L x T x G	(l-1)(t-1)(g-1)	11	SS_{lg}	M_{lg}	$\sigma^2_e + r\sigma^2_{lpg} + rp\sigma^2_{lg}$	M_{lg} / M_{lpg}
T x P x G	(t-1)(p-1)(g-1)	11	SS_{tpg}	M_{tpg}	$\sigma^2_e + r\sigma^2_{lpg} + rl\sigma^2_{tpg}$	M_{tpg} / M_{lpg}
L x T x P x G	(l-1)(t-1)(p-1)(g-1)	11	SS_{lpg}	M_{lpg}	$\sigma^2_e + r\sigma^2_{lpg}$	$M_{lpg} / M_{e(c)}$
Error (c)	ltp(g-1)(r-1)	176	$SS_{e(c)}$	$M_{e(c)}$	σ^2_e	
Sub-subplot total	ltpr(g - 1)	264				
Total	ltprg - 1	287				

Table 3 Form of the combined analysis of variance over years showing sources of variation, degrees of freedom (d.f), sums of squares (S.S.), mean squares(M.S.), expected mean squares (E.M.S.) and the F-test for a split plot model in a randomized complete block design, all the factors are random.

Sources of variation	Generalized d.f	Specific d.f	S.S.	M.S.	E.M.S.	F - Test
Years (Y)	y - 1	1	SS_y	M_y	$\sigma^2_e + g\sigma^2_{r(y)} + gt\sigma^2_{r(y)} + r\sigma^2_{ytg} + rt\sigma^2_{yg} + rg\sigma^2_{yt} + rtg\sigma^2_y$	$(M_y + M_{ytg}) / (M_{ty} + M_{yg})$
Reps in years	y(r-1)	4	$SS_{r(y)}$	$M_{r(y)}$	$\sigma^2_e + g\sigma^2_{r(y)} + gt\sigma^2_{r(y)}$	$M_{r(y)} / M_{e(a)}$
Type T	t - 1	1	SS_t	M_t	$\sigma^2_e + g\sigma^2_{r(y)} + r\sigma^2_{ytg} + rg\sigma^2_{yt} + rgy\sigma^2_t$	$(M_t + M_{ytg})/(M_{yt} + M_{tg})$
Y x T	(y - 1)(t-1)	1	SS_{yt}	M_{yt}	$\sigma^2_e + g\sigma^2_{r(y)} + r\sigma^2_{ytg} + rg\sigma^2_{yt}$	M_{yt} / M_{ytg}
Error (a)	y(t-1)(r-1)	4	$SS_{e(a)}$	$M_{e(a)}$	$\sigma^2_e + g\sigma^2_{r(y)}$	
Whole plot total	ytr - 1	11				
Genotypes (G)	g - 1	11	SS_g	M_g	$\sigma^2_e + r\sigma^2_{ytg} + rt\sigma^2_{yg} + ry\sigma^2_{tg} + ryt\sigma^2_g$	$(M_g + M_{ytg})/(M_{yg} + M_g)$
Y x G	(y - 1)(g-1)	11	SS_{yg}	M_{yg}	$\sigma^2_e + r\sigma^2_{ytg} + rt\sigma^2_{yg}$	M_{yg} / M_{ytg}
T x G	(t - 1)(g-1)	11	SS_{tg}	M_{tg}	$\sigma^2_e + r\sigma^2_{ytg} + ry\sigma^2_{tg}$	M_{tg} / M_{ytg}
Y x T x G	(y-1)(t-1)(g-1)	11	SS_{ytg}	M_{ytg}	$\sigma^2_e + r\sigma^2_{ytg}$	$M_{ytg} / M_{e(b)}$
Error (b)	yt(g-1)(r-1)	88	$SS_{e(b)}$	$M_{e(b)}$	σ^2_e	
Subplot total	ytr(g - 1)	132				
Total	ytgr - 1	143				

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Table 4. Form of the combined analysis of variance over locations showing sources of variation, degrees of freedom (d.f), sums of squares (S.S.), mean squares(M.S.), expected mean squares (E.M.S.) and the F-test for a split plot model in a randomized complete block design, all the factors are random.

Sources of variation	Generalized d.f	Sepecific d.f	S.S.	M.S.	E.M.S.	F - Test
Locations (L)	l - 1	1	SS_l	M_l	$\sigma^2_e + g\sigma^2_{r(l)} + tg\sigma^2_{r(l)} + rg\sigma^2_{lt} + rt\sigma^2_{lg} + r\sigma^2_{ltg} + rtg\sigma^2_l$	$(M_l + M_{ltg}) / (M_{lt} + M_{lg})$
Reps in locations	l(r-1)	4	$SS_{r(l)}$	$M_{r(l)}$	$\sigma^2_e + g\sigma^2_{r(l)} + tg\sigma^2_{r(l)}$	$M_{r(l)} / M_{e(a)}$
Type (T)	t - 1	1	SS_t	M_t	$\sigma^2_e + g\sigma^2_{r(l)} + r\sigma^2_{ltg} + rg\sigma^2_{lt} + rl\sigma^2_{tg} + rgl\sigma^2_t$	$(M_t + M_{ltg}) / (M_{lt} + M_{tg})$
L x T	(l - 1)(t-1)	1	SS_{lt}	M_{lt}	$\sigma^2_e + g\sigma^2_{r(l)} + r\sigma^2_{ltg} + rg\sigma^2_{lt}$	M_{lt} / M_{ltg}
Error (a)	l(t-1)(r-1)	4	$SS_{e(a)}$	$M_{e(a)}$	$\sigma^2_e + g\sigma^2_{r(l)}$	
Whole plot total	ltr - 1	11				
Cowpea Genotypes(G)	g - 1	11	SS_g	M_g	$\sigma^2_e + r\sigma^2_{ltg} + rt\sigma^2_{lg} + rl\sigma^2_{tg} + rlt\sigma^2_g$	$(M_g + M_{ltg}) / (M_{lg} + M_{tg})$
L x G	(l - 1)(g-1)	11	SS_{lg}	M_{lg}	$\sigma^2_e + r\sigma^2_{ltg} + rt\sigma^2_{lg}$	M_{lg} / M_{ltg}
T x G	(t - 1)(g-1)	11	SS_{tg}	M_{tg}	$\sigma^2_e + r\sigma^2_{ltg} + rl\sigma^2_{tg}$	M_{tg} / M_{ltg}
L x T x G	(l-1)(t-1)(g-1)	11	SS_{ltg}	M_{ltg}	$\sigma^2_e + r\sigma^2_{ltg}$	$M_{ltg} / M_{e(b)}$
Error (b)	lt(g-1)(r-1)	88	$SS_{e(b)}$	$M_{e(b)}$	σ^2_e	
Subplot total	ltr(g - 1)	132				
Total	ltgr - 1	143				

3.1.3.1 **Determination of genetic variance and the interactions between locations, pesticide spraying regime, cropping pattern, years and genotypes components of variance**

a. From the cowpea data combined over locations

From table 2, we have component of variance of the interaction between location, pesticide spraying regime, cropping pattern and genotypes, σ^2_{ltpg}

$M_{ltpg} = \sigma^2_e + r\sigma^2_{ltpg}$ and $M_{e(c)} = \sigma^2_e$

so $M_{ltpg} = M_{e(c)} + r\sigma^2_{ltpg} ==> r\sigma^2_{ltpg} = M_{ltpg} - M_{e(c)}$

$==> \sigma^2_{ltpg} = (\mathbf{M_{ltpg} - M_{e(c)}})/\ \mathbf{r}$

Component of variance of the interaction between pesticide spraying regime, cropping pattern and genotypes, σ^2_{tpg}:

$M_{tpg} = \sigma^2_e + r\sigma^2_{ltpg} + rl\sigma^2_{tpg}$ and $M_{ltpg} = \sigma^2_e + r\sigma^2_{ltpg}$

therefore $M_{tpg} = M_{ltpg} + rl\sigma^2_{tpg}$ $==> rl\sigma^2_{tpg} = M_{tpg} - M_{ltpg}$

$==> \sigma^2_{tpg} = (\mathbf{M_{tpg} - M_{ltpg}})/\mathbf{rl}$

Component of variance of the interaction between location, cropping pattern and genotypes, σ^2_{lpg}:

$M_{lpg} = \sigma^2_e + r\sigma^2_{ltpg} + rt\sigma^2_{lpg}$, $M_{ltpg} = \sigma^2_e + r\sigma^2_{ltpg}$

therefore $M_{lpg} = M_{ltpg} + rt\sigma^2_{lg}$

$==> rt\sigma^2_{lpg} = M_{lpg} - M_{ltpg}$ $==> \sigma^2_{lpg} = (\mathbf{M_{lpg} - M_{ltpg}})/\mathbf{rt}$

Component of variance of the interaction between location, pesticide spraying regime, and genotypes, σ^2_{lg}:

$M_{lg} = \sigma^2_e + r\sigma^2_{ltpg} + rp\sigma^2_{lg}$, $M_{ltpg} = \sigma^2_e + r\sigma^2_{ltpg}$

therefore $M_{lg} = M_{ltpg} + rp\sigma^2_{lg}$ $==> rp\sigma^2_{lg} = M_{lg} - M_{ltpg}$

$==> \sigma^2_{lg} = (\mathbf{M_{lg} - M_{ltpg}})/\mathbf{rp}$

Component of variance of the interaction between cropping pattern and genotypes, σ^2_{pg}:

$$M_{pg} = \sigma^2_e + r\sigma^2_{ltpg} + rl\sigma^2_{tpg} + rt\sigma^2_{lpg} + rlt\sigma^2_{pg}$$

$$M_{pg} = (\sigma^2_e + r\sigma^2_{ltpg} + rl\sigma^2_{tpg}) + rt\sigma^2_{lpg} + rlt\sigma^2_{pg}$$

we have $M_{tpg} = \sigma^2_e + r\sigma^2_{ltpg} + rl\sigma^2_{tpg}$ and $rt\sigma^2_{lpg} = M_{lpg} - M_{ltpg}$

therefore $M_{pg} = M_{tpg} + M_{lpg} - M_{ltpg} + rlt\sigma^2_{pg}$

$$==> rlt\sigma^2_{pg} = M_{pg} + M_{ltpg} - M_{tpg} - M_{lpg}$$

$$\sigma^2_{pg} = \mathbf{[M_{pg} + M_{ltpg} - M_{tpg} - M_{lpg}]/rlt}$$

Component of variance of the interaction between pesticide spraying regime and genotypes, σ^2_{tg}:

$$M_{tg} = (\sigma^2_e + r\sigma^2_{ltpg} + rl\sigma^2_{tpg}) + rp\sigma^2_{ltg} + rlp\sigma^2_{tg}$$

$M_{tg} = M_{tpg} + rp\sigma^2_{ltg} + rpl\sigma^2_{tg}$ we have $rp\sigma^2_{ltg} = M_{ltg} - M_{ltpg}$

therefore $M_{tg} = M_{tpg} + M_{ltg} - M_{ltpg} + rpl\sigma^2_{tg}$

$==> rpl\sigma^2_{tg} = M_{tg} + M_{ltpg} - M_{tpg} - M_{ltg}$

$$==> \sigma^2_{tg} = \mathbf{[M_{tg} + M_{ltpg} - M_{tpg} - M_{ltg}]/rp}$$

Component of variance of the interaction between locations and genotypes, σ^2_{lg}:

$$M_{lg} = (\sigma^2_e + r\sigma^2_{ltpg} + rp\sigma^2_{ltg}) + rt\sigma^2_{lpg} + rtp\sigma^2_{lg}$$

$M_{ltg} = \sigma^2_e + r\sigma^2_{ltpg} + rp\sigma^2_{ltg}$ and $rt\sigma^2_{lpg} = M_{lpg} - M_{ltpg}$

therefore $M_{lg} = M_{ltg} + M_{lpg} - M_{ltpg} + rtp\sigma^2_{lg}$

$==> rtp\sigma^2_{lg} = M_{lg} + M_{ltpg} - M_{ltg} - M_{lpg}$

$$==> \sigma^2_{pg} = \mathbf{[M_{lg} + M_{ltpg} - M_{ltg} - M_{lpg}]/rtp}$$

Genetic variance, σ^2_g

$$M_g = (\sigma^2_e + r\sigma^2_{ltpg} + rp\sigma^2_{ltg}) + rt\sigma^2_{lpg} + rl\sigma^2_{tpg} + rtp\sigma^2_{lg} + rpl\sigma^2_{tg} + rlt\sigma^2_{pg} + rltp\sigma^2_g$$

$$M_g = M_{ltg} + M_{lpg} - M_{ltpg} + rl\sigma^2_{tpg} + M_{lg} + M_{ltpg} - M_{ltg} - M_{lpg} + rpl\sigma^2_{tg} + rlt\sigma^2_{pg} + rltp\sigma^2_g$$

from the above calculation we have:

$rl\sigma^2_{tpg} = M_{tpg} - M_{tplg}$, $rpl\sigma^2_{tg} = M_{tg} + M_{ltpg} - M_{tpg} - M_{ltg}$

and $rlt\sigma^2_{pg} = M_{pg} + M_{ltpg} - M_{tpg} - M_{lpg}$

therefore

$$M_g = M_{ltg} - M_{ltg} + M_{lpg} - M_{lpg} + M_{lg} + M_{ltpg} + M_{tpg} - M_{tplg} + M_{tg} + M_{ltpg} - M_{tpg} - M_{ltg}$$

$$+ M_{pg} + M_{ltpg} - M_{tpg} - M_{lpg} + rltp\sigma^2_g$$

$$= M_{lg} + M_{tpg} - M_{tpg} - M_{ltpg} + M_{ltpg} + M_{tg} - M_{ltg} + M_{pg} + M_{ltpg} - M_{tpg} - M_{lpg} + rltp\sigma^2_g$$

$$= M_{lg} + M_{tg} - M_{ltg} + M_{pg} - M_{tpg} - M_{lpg} + M_{ltpg} + rltp\sigma^2_g \; ==>$$

$$rltp\sigma^2_g = [M_g + M_{ltg} + M_{tpg} + M_{lpg} - M_{tg} - M_{lg} - M_{pg} - M_{ltpg}]$$

$$\sigma^2_g = \mathbf{[M_g + M_{ltg} + M_{tpg} + M_{lpg} - M_{tg} - M_{lg} - M_{pg} - M_{ltpg}]/rltp}$$

b. From the cowpea data combined over years

From table 3, we have

Component of variance of the interaction between year, pesticide spraying regime and genotypes, σ^2_{ytg}:

$M_{ytg} = \sigma^2_e + r\sigma^2_{ytg}$ and $MS_{e(b)} = \sigma_e^2$ therefore $M_{ytg} = M_{e(b)} + r\sigma^2_{ytg}$

$==> r\sigma^2_{ytg} = M_{ytg} - M_{e(b)}$ and $\sigma^2_{ytg} = \mathbf{[M_{ytg} - M_{e(b)}]/r}$

Component of variance of the interaction between pesticide spraying regime and genotypes, σ^2_{tg}:

$M_{tg} = \sigma^2_e + r\sigma^2_{ytg} + ry\sigma^2_{tg}$ therefore $M_{tg} = M_{ytg} + ry\sigma^2_{tg}$ and $ry\sigma^2_{tg} = M_{tg} - M_{ytg}$

$==> \sigma^2_{tg} = \mathbf{[M_{tg} - M_{ytg}]/ry}$

Component of variance of the interaction between year and genotypes, σ^2_{yg}:

$M_{yg} = \sigma^2_e + r\sigma^2_{ytg} + rt\sigma^2_{yg} = M_{ytg} + rt\sigma^2_{yg} ==> rt\sigma^2_{yg} = M_{yg} - M_{ytg}$

$==> \sigma^2_{yg} = \mathbf{[M_{yg} - M_{ytg}]/rt}$

Genetic variance, σ^2_g:

$M_g = (\sigma^2_e + r\sigma^2_{ytg} + rt\sigma^2_{yg}) + ry\sigma^2_{tg} + ryt\sigma^2_g$

$M_g = M_{yg} + M_{tg} - M_{ytg} + ryt\sigma^2_g ==> ryt\sigma^2_g = M_g + M_{ytg} - M_{yg} - M_{tg}$

$\sigma^2_g = \mathbf{(M_g + M_{ytg} - M_{yg} - M_{tg})/ryt}$

3.1.8.2. **Determination of the standard error of genetic variance and interaction between locations, pesticide spraying regime, cropping pattern, years and genotypes variances.**

Snedecor (1956) has shown that if the variance component σ_i^2 was computed from a linear function of independent mean squares, the approximate variance V of σ_i^2 is determined as:

$$V(\sigma_i^2) = (2/f^2)\Sigma\lambda_i^2 M_i^2/(df + 2)$$

where $\lambda_i = \pm 1$ and M_i are the mean squares used to determine the component of variance, df is the degrees of freedom of the respective mean squares, and f is the coefficient of the component of variance. Therefore the standard error is

$$SE(\sigma_i^2) = (V(\sigma_i^2))^{1/2} = [(2/f^2)\Sigma_i\lambda_i^2 M_i^2/(df + 2)]^{1/2}$$

Hallauer and Miranda (1986) used a satisfactory but conservative approximation of the standard error (SE) of heritability suggested by Dickerson (1969) where

$$SE(h^2) = SE(\sigma_i^2)/\sigma_{ph}^2 \quad \text{with } h^2 = \sigma_i^2/\sigma_{ph}^2$$

From the data combination over locations

Standard error of the component of variance of the interaction between genotypes, location, pesticide spraying regime and cropping pattern, $SE(\sigma^2_{ltpg})$

$$\sigma^2_{ltpg} = (M_{ltg} - M_{e(c)})/r$$

$$SE(\sigma^2_{ltpg}) = [(2(1/r)^2)((M^2_{ltpg}/df_{ltpg} + 2) + M^2_{e(c)}/df_e + 2)]^{1/2}$$

Standard error of the component of variance of the interaction between pesticide spraying regime, cropping pattern and genotypes, $SE(\sigma^2_{tpg})$

$$\sigma^2_{tpg} = (M_{tpg} - M_{ltpg})/rl$$

$$SE(\sigma^2_{tpg}) = [(2(1/rl)^2)((M^2_{tpg}/df_{tpg} + 2) + M^2_{ltpg}/df_{ltpg} + 2)]^{1/2}$$

Standard error of the component of variance of the interaction between location, cropping pattern and genotypes, $SE(\sigma^2_{lpg})$

$$\sigma^2_{lpg} = (M_{lpg} - M_{ltpg})/rt$$

$$SE(\sigma^2_{lpg}) = [(2(1/rt)^2)((M^2_{lpg}/df_{lpg} + 2) + (M^2_{ltpg}/df_{ltpg} + 2)]^{1/2}$$

Standard error of the component of variance of the interaction between location, pesticide spraying regime and genotypes, $SE(\sigma^2_{ltg})$

$$\sigma^2_{ltg} = (M_{ltg} - M_{ltpg})/rp$$

$$SE(\sigma^2_{ltg}) = [(2(1/rp)^2)((M^2_{ltg}/df_{ltg} + 2) + M^2_{ltpg}/df_{ltpg} + 2)]^{1/2}$$

Standard error of the component of variance of the interaction between cropping and pattern genotypes, $SE(\sigma^2_{pg})$

$$\sigma^2_{pg} = (M_{pg} + M_{ltpg} - M_{tpg} - M_{lpg})/rlt$$

$$SE(\sigma^2_{pg}) = [(2(1/rlt)^2)((M^2_{pg}/df_{pg} + 2) + (M^2_{ltpg}/df_{ltpg} + 2) + (M^2_{tpg}/df_{tpg} + 2)$$
$$+ (M^2_{lpg}/df_{lpg} + 2)]^{1/2}$$

Standard error of the component of variance of the interaction between pesticide spraying regime and genotypes, $SE(\sigma^2_{tg})$

$$\sigma^2_{tg} = (M_{tg} + M_{ltpg} - M_{tpg} - M_{ltg})/rpl$$

$$SE(\sigma^2_{tg}) = [(2(1/rpl)^2)((M^2_{tg}/df_{tg} + 2) + (M^2_{ltpg}/df_{ltpg} + 2) + (M^2_{tpg}/df_{tpg} + 2)$$
$$+ (M^2_{ltg}/df_{ltg} + 2)]^{1/2}$$

Standard error of the component of variance of the interaction between locations and genotypes, $SE(\sigma^2_{lg})$

$$\sigma^2_{lg} = (M_{lg} + M_{ltpg} - M_{ltg} - M_{lpg})/rtp$$

$$SE(\sigma^2_{lg}) = [(2(1/rpt)^2)((M^2_{lg}/df_{lg} + 2) + (M^2_{ltpg}/df_{ltpg} + 2) + (M^2_{dg}/df_{ltg} + 2)$$
$$+ (M^2_{lpg}/df_{lpg} + 2))]^{1/2}$$

Standard error of the component of the genetic variance $SE(\sigma^2_g)$

$$\sigma^2_g = [M_g + M_{ltg} + M_{tpg} + M_{lpg} - M_{tg} - M_{lg} - M_{pg} - M_{ltpg}]/rltp$$

$$SE(\sigma^2_g) = [(2(1/rltp)^2)((M^2_g/df_g + 2) + (M^2_{ltg}/df_{ltg} + 2) + (M^2_{tpg}/df_{tpg} + 2)$$
$$+ (M^2_{lpg}/df_{lpg} + 2) + (M^2_{tg}/df_{tg} + 2) + (M^2_{lg}/df_{lg} + 2) + (M^2_{pg}/df_{pg} + 2)$$

$+ (M^2_{lpg}/df_{lpg} + 2))]^{½}$

From the data combined over years

Standard error of the component of variance of the interaction between years, pesticide spraying regime and genotype, $SE(\sigma^2_{ytg})$

$$\sigma^2_{ytg} = (M_{ytg} - M_{e(b)}]/r$$

$$SE(\sigma^2_{ytg}) = [(2(1/r)^2)((M^2_{ytg}/df_{ytg} + 2) + (M^2_{e(b)}/df_{e(b)} + 2)]^{½}$$

Standard error of the component of variance of the interaction between pesticide spraying regime and genotype, $SE(\sigma^2_{tg})$

$$\sigma^2_{tg} = (M_{tg} - M_{ytg})/ry$$

$$SE(\sigma^2_{tg}) = [(2(1/ry)^2)((M^2_{tg}/df_{tg} + 2) + (M^2_{ytg}/df_{ytg} + 2)]^{½}$$

Standard error of the component of variance of the interaction between year and genotype, $SE(\sigma^2_{yg})$

$$\sigma^2_{yg} = (M_{yg} - M_{ytg}]/rt$$

$$SE(\sigma^2_{yg}) = [(2(1/rt)^2)[((M^2_{yg}/df_{yg} + 2) + (M^2_{ytg}/df_{ytg} + 2)]^{½}$$

Standard error of the genetic variance

$$\sigma^2_{g} = [M_g + M_{ytg} - M_{yg} - M_{tg}]/ryt$$

$$SE(\sigma^2_{g}) = [(2(1/ryt)^2)((M^2_{g}/df_{g} + 2) + (M^2_{ytg}/df_{ytg} + 2) + (M^2_{yg}/df_{yg} + 2)$$

$$+ (M^2_{tg}/df_{tg} + 2))]^{½}$$

3.1.8.3. **Determination of phenotypic variance, heritability and error variance and their standard errors**

From the data combined over locations

i. Phenotypic variance, σ^2_{ph}:

$$\sigma^2_{ph} = M_g/rptl = (\sigma^2_e + r\sigma^2_{lpgt} + rt\sigma^2_{lpg} + rp\sigma^2_{tg} + rl\sigma^2_{tpg} + rpt\sigma^2_{lg}$$

$$+ rlt\sigma^2_{pg} + rpl\sigma^2_{tg})/rptl$$

$$==> \sigma^2_{ph} = \sigma^2_g + (\sigma^2_{lptg}/ptl) + (\sigma^2_{lpg}/pl) + (\sigma^2_{tpg}/pt) + (\sigma^2_{lg}/l) + (\sigma^2_{pg}/p) + (\sigma^2_{tg}/t)$$

$$+ (\sigma^2_e/rplt$$

standard error of the phenotypic variance

$$SE(\sigma^2_{ph}) = [(2(1/rplt)^2)((M^2_g/df_g + 2))]^{1/2}$$

ii. Expression of heritability h^2B

$$h^2_B = \sigma^2_g/\sigma^2_{ph}$$

Standard error of heritability

$$SE(h^2_B) = SE(\sigma^2_g)/\sigma^2_{ph}$$

ii. Error Variance σ^2_e

$$\sigma^2_e = M_{e(c)}$$

Standard error of error variance, $SE(\sigma^2_e)$:

$$SE(\sigma^2_e) = [(2(1)^2)((M^2_{e(c)}/df_{e(c)} + 2))]^{1/2}$$

From the data combination over years

i. Phenotypic variance, σ^2_{ph}:

$$\sigma^2_{ph} = M_g/ytr = (\sigma^2_e + r\sigma^2_{ytg} + ry\sigma^2_{tg} + rt\sigma^2_{yg} + rty\sigma^2_g)/ytr$$

$$==> \sigma^2_{ph} = \sigma^2_g + (\sigma^2_{yg}/y) + (\sigma^2_{tg}/t) + (\sigma^2_{ytg}/yt) + (\sigma^2_e/ytr)$$

The heritability is calculated in the same way as defined above.

Standard error of the phenotypic variance; $SE(\sigma^2_{ph})$

$$SE(\sigma^2_{ph}) = [(2(1/yrt)^2)[((M^2_g/df_g + 2))]^{1/2}$$

ii. Error variance, σ^2_e:

$$\sigma^2_e = M_{e(b)}$$

Standard error of the error variance, $SE(\sigma^2_e)$:

$$SE(\sigma^2_e) = [(2(1)^2)[((M^2_{e(b)}/df_{e(b)} + 2))]^{1/2}$$

3.2 ON-FARM EXPERIMENT

3.2.1 Farm site

Seeds of eight of the ten elite lines and the two local varieties were distributed to 70 farmers in Minjibir and Gezawa Local Government Areas in Kano State. Each genotype was given to seven farmers for planting in their own crop management system.

3.2.2 Genotypes used in the on-farm experiment

All the genotypes used in the on station experiments except IT 89 KD-355 and IT 89 KD-261-3 were distributed to farmers for the on-farm experiment.

3.2.3 Monitoring of the experiment

Each field was visited at least once in two weeks. Observations were taken on the way the crop was managed and discussions were held with the farmers to assess their appreciation of the performance of the genotypes. An observation plot of 10m x 5m consisting of test lines, was laid out in each field. A second observation plot of the same size, but consisting of local varieties, was laid out in the same field wherever planting of both local and test materials was done the same day.

3.2.4 DATA COLLECTED

In each observation plot, the stand count, disease and insect incidence, Striga incidence, number of pods, number of seeds per pod, pod length, grain yield and fodder yield were recorded. At the end of the season, the acceptability of the lines was assessed on the basis of a questionnaire.

3.2.5 Data analysis

The on-farm data were analysed using such descriptive statistics as means, range and percentage.

CHAPTER 4

RESULTS

The 1994 experiments were conducted in three different locations. Minjibir site received a rainfall of 631.9mm in 61 days. A rainfall of 783.02mm in 28 days was recorded in Mallam-Maduri. Samaru was more humid with 909.2mm rainfall in 79 days and 867.0mm in 74 days in 1994 and 1995, respectively. The cowpea crop was affected by insect pests and diseases, the severity of the attack varied from one location to another. The attack by Maruca testulalis and the complex of pod sucking bugs reduced drastically grain yield of the unsprayed plots at Mallam-Maduri and Samaru in 1994. Infestation of the crop by scab and Septoria was more severe in 1994 than in 1995 at Samaru. This resulted in the different trends observed in the following analysis.

4.1 On-Station

Data on pod length at harvest from Mallam-Maduri was not complete and Alectra infestation was observed on Samaru crop in 1994 only. These two characters were therefore not included in the analysis of the on-station data.

4.1.1 Data combined over locations

A - COWPEA

4.1.1.1 Mean values of the genotypes

A summary of the basic statistics obtained for 13 characters, including the grand means, standard errors of the means (S.E.), ranges and coefficients of variation (CV%) is shown in Table 5. Considerable variations among the genotypes were observed for all the characters.

The percent coefficients of variation ranged from 9.9% for plant height at 50 days after sowing to 77.4% for grain yield per plant. The range between the means was very wide for all the characters. The mean performance of each genotype for all characters under different crop management systems across locations is presented in Appendix I. All the genotypes had better performance in Minjibir than in Mallam Maduri except for plant height. The differences observed between the overall means for all the characters are not much under different cropping patterns except for grain yield per plant and grain yield per hectare, fodder yield at harvest

and dry fodder yield per ha. The overall mean performance of the genotypes for the 13 characters across locations is presented in Appendix II. The performance of the cowpea genotype under different crop management systems at Minjibir and Mallam Maduri are presented in Appendices III and IV respectively.

4.1.1.2 Variability observed among genotypes

The mean squares of the data combined over locations are presented in Table 6. Differences in locations were significant for days to 50% flowering, 100-seed weight, number of seeds per pod and fodder yield per plant at harvest and highly significant for plant height, days to maturity and number of Striga per plot. Differences in replications in locations and in pesticide spraying regime x location were significant for days to 50% flowering. The differences in cropping pattern were significant for fodder yield at harvest per plant and dry fodder yield per hectare. The difference in the interaction between cropping pattern and pesticide spraying regime was significant for the number of seeds per pod. The interactions between cropping pattern, locations and pesticide spraying regime were significant for days to maturity and highly significant for plant height, number of pods per plant, plant height, number of pods per plant, grain yield per plant and per hectare and number of Striga

Differences in genotypes were significant for plant height only. The interactions between genotypes and locations were significant for plant height, 100 - seed weight, number of seeds per pod, dry fodder yield per plant and per hectare and highly significant for days to 50% flowering, days to maturity and number of Striga, The interactions between genotypes, locations and pesticide spraying regime were significant for 100-seed weight, number of seeds per pod, number of pods per plant, grain yield per plant and per hectare. The interactions between genotypes, locations and cropping pattern were significant for number of pods per plant and highly significant for days to maturity and number of seeds per pod. The interactions between genotypes, locations, pesticide spraying regime and cropping pattern were significant for fodder yield at harvest per plant and dry fodder yield per plant and highly significant for dry fodder yield per hectare.

4.1.1.3 Estimates of variance components and heritability

(a) Genetic variance and genetic x environment components interaction variance estimates

Estimates of the genetic variance components and their standard errors obtained from the combined analysis of variance over locations are shown in Table 7. The magnitude of the genotype x location variance(σ^2_{gl})

estimates was higher than that of the genetic variance and all other interaction variances for most of the traits. Genetic variance estimate was higher than that of the interaction variances for plant height only.

The genetic variance and all the interaction variance estimates except σ^2_{gl} were negative for two or more traits as follows:

* genotype x cropping pattern, genotype x pesticide spraying regime and genotype x pesticide spraying regime x cropping pattern x location interactions variances for plant height, days to maturity, number of seeds per pod, number of pods per plant
* genotype x location x cropping pattern interaction variance for days to 50% flowering and dry fodder yield per plant;
* genetic variance, genotype x pesticide spraying regime, genotype x cropping pattern and genotype x cropping pattern x pesticide spraying regime interaction variance for 100-seed weight;
* genetic variance, genotype x cropping pattern and genotype x pesticide spraying regime interactions variances for days to maturity, fodder yield at harvest per ha and per plant;
* genetic variance, genotype x pesticide spraying regime x location and genotype x pesticide spraying regime x cropping pattern interactions variances for days to 50% flowering and dry fodder field per hectare
* genotype x cropping pattern and genotype x cropping pattern x pesticide spraying regime x location interactions variances for grain yield per plant and number of Striga plants at harvest;
* genetic variance, genotype x pesticide spraying regime and genotype x pesticide spraying regime x location interaction variances for dry fodder yield per plant
* and genotype x pesticide spraying regime x cropping pattern interaction variance for number of seeds per pod.

Most of the estimates were associated with large standard errors. All the negative variance estimates with larger standard errors indicated that either the estimates were not different from zero or they had very small values.

b) **Error variance, phenotypic variance and broad sense heritability estimates**

The phenotypic, error variance and broad sense heritability estimates are presented in Table 8. Phenotypic variance and error variance had low standard errors. These variance estimates were very large for fodder yield at harvest per plant and per hectare and dry fodder yield per hectare.

Heritability estimates recorded were relatively high for plant height (77.53%), moderate for number of pods per plant (39.56%). They were low for number of seeds per pods (19.22%), grain yield per plant (20.67%), grain yield per ha (27.67%), and number of striga per plot (15.11%). As a result of the negative estimates of o^2 obtained for some traits, heritability estimates for these traits were not computable. The standard errors of the heritability estimates were very large for many traits because of the same trend observed with the standard errors of the positive o^2

Table 5. Means, standard errors of a mean, ranges and coefficients of variation for 13 characters of cowpea at Minjibir and Mallam Maduri in 1994.

Character	Mean ± SE	Range	CV (%)
Plant height (cm)	55.1±5.5	47.6-62.6	9.9
Days to 50% flowering	39.3*±5.3	24.0*-45.2	13.5
Days to maturity	54.3*±13.2	31.8*-71.9	24.3
100 seed weight(g)	10.9±3.4	7.3-14.7	31.4
Number of seeds per pod	7.8±2.0	4.3-10.4	25.8
Number of pods per plant	8.3±5.7	4.1-12.0	68.8
Grain yield per plant (g)	7.9±6.2	4.1-11.5	77.4
Grain yield per ha (kg)	334±204.4	140.0-504.0	61.2
Fodder yield at harvest/plant (g)	111.4±57.5	72.2-162.8	51.7
Fodder yield at harvest/ha (kg)	5902.0±3020.2	3915.0-7936.0	51.2
Dry fodder yield per ha (kg)	2319.0±1052.7	1506.0-2880.0	45.4
Dry fodder yield per plant (g)	44.2±22.9	29.1-60.7	51.9
Number of Striga plants per plot at harvest	25.9±16.4	5.6-38.3	63.2

Where:

SE = Standard error of a mean
CV (%) = Coefficient of variation in (%)
* = all figures <40 for days to 50% flowering and <60 for days to maturity are not related to earliness but to the failure of some genotypes to flower and mature.

Table 6: Mean squares from the analysis of variance for 13 characters in cowpea at Minjibir and Mallam Maduri in 1994

Sources of variation	d.f	Plant height	Days to 50% flowering	Days to maturity	100-seed weight	Number of seeds per pod	Number of pods per plant	Grain yield per plant
Locations (L)	1	64305.95**	31270.84*	91770.4**	2811.25*	973.14*	8472.66	10351.42
Reps in locations	4	325.82	85.975*	250.25	3.875	5.56	24.46	18.95
Type (T)	1	10.47	26.28	2139.7	19.95	43.40	3484.11	4155.95
L x T	1	245.13	12.09*	1164.09	97.77	2.531	2292.15	3088.21
Error (a)	4	129.53	12.195	204.4	11.0	6.14	40.91	36.615
Whole plot total	11	6034.81	2881.99	8808.43	271.68	96.90	1319.127	1619.80
Pattern (P)	1	902.06	12.09	1124.2	80.43	59.22	427.1	326.96
P x L	1	213.04	5.28	366.8	40.95	15.77	454.99	470.68
P x T	1	13.22	15.59	7.7	4.65	5.61*	481.87	488.38
P x L x T	1	78.02**	4.25	198.3**	21.89	1.77	305.11**	349.45**
Error (b)	8	38.34	8.96	130.6	9.37	2.424	42.85	56.69
Subplot total	12	126.09	9.07	228.5	18.57	8.481	167.69	174.08

*, ** = significant at 5% and at 1% probability, respectively

Table 6 (continued)

Sources of variation	d.f	Plant height	Days to 50% flowering	Days to maturity	100-seed weight	Number of seeds per pod	Number of pods per plant	Grain yield per plant
Genotypes (G)	11	612.49*	1205.22	6243.6	154.90	109.047	163.61	169.41
G x L	11	167.58*	6212.64**	7638.6**	187.23*	94.981*	108.13	145.33
G x T	11	33.16	17.10	1249.6	33.35	6.437	61.61	79.89
G x P	11	13.97	8.92	442.2	27.55	14.023	41.87	33.09
G x L x T	11	35.71	10.68	1336.1**	47.44*	11.215*	62.07*	75.68*
G x L x P	11	27.71	5.10	514.3**	37.01	16.834**	49.60*	45.46
G x T x P	11	28.55	44.94	84.0	7.58	2.668	18.17	21.48
G x L x T x P	11	14.92	49.34	67.0	14.72	3.374	17.12	18.71
Error(c)	176	29.85	28.25	173.5	11.77	4.005	32.68	38.19
Sub-subplot total	264	58.82	333.58	848.0	29.09	13.444	43.54	50.01
Total	287							

*, ** = significant at 5% and at 1% probability, respectively

Table 6: (continued)

Sources of variation	d.f	Grain yield /ha ▲	Fodder yield at harvest/plant	Fodder yield at harvest/ha ▲	Number of Striga	Dry fodder yield/plant	Dry fodder yield/ha ▲
Locations (L)	1	11.42	207646*	56.81	134723.8*	30473.4	6.576
Reps in locations	4	0.189	7853.5	10.727	165.7	2483.05	1.187
Type (T)	1	4.968	1807	34.13	437.6	0.0	5.386
T x L	1	3.169	3932	17.14	1313.3	326.5	6.022
Error (a)	4	0.076	8052.5	26.133	327.23	1174.8	3.951
Whole plot total	11	1.874	25182.73	23.229	12586.04	4130.11	3.503
Pattern (P)	1	2.843	34812*	1275.0	1100.6	2356.8	162.329*
P x L	1	1.922	46	57.41	796.7	1137.2	0.264
P x T	1	1.409	254	0.0258	205.0	0.5	0.0648
P x L x T	1	0.787**	747	1.498	693.8**	113.1	0.5792
Error (b)	8	0.023	4977	14.42	602.1	529.0	2.0795
Subplot total	12	0.595	6306	120.7	634.4	653.3	14.989

▲ = all the figures under the marked characters are multiplied by 10^6
*, ** = significant at 5% and at 1% probability, respectively

Table 6: (continued)

Sources of variation	d.f	Grain yield /ha ▲	Fodder yield at harvest/plant	Fodder yield at harvest/ha ▲	Number of Striga	Dry fodder yield/plant	Dry fodder yield/ha ▲
Genotypes (G)	11	0.348	17395	38.53	1756.0	2102.0	5.647
G x L	11	0.242	19832	59.48	1475.2**	3002.2*	10.0746*
G x T	11	0.088	4847	9.299	194.5	459.6	1.902
G x P	11	0.061	7413	26.07	182.6	1029.8	3.398
G x L x T	11	0.096*	4657	8.214	105.6	537.8	1.231
G x L x P	11	0.035	6600	30.55	220.2	805.3	3.904
G x T x P	11	0.036	8682	19.38	135.6	1142.9	2.198
G x L x T x P	11	0.029	6473*	16.02	99.7	1001.6*	2.424**
Error(c)	176	0.042	3311	9.122	268.6	526.8	1.108
Sub-plot total	264	0.067	5370	14.73	352.8	771.2	2.021
Total	287						

▲ = all the figures under the marked characters are multiplied by 10^6
*, ** = significant at 5% and at 1% probability, respectively

Table 7. Variance components, first order interaction, genetic variance and their standard errors in cowpea at Minjibir and Mallam Maduri in 1994.

Character	$\sigma^2_{ig} \pm$ SE	$\sigma^2_{pg} \pm$ SE	$\sigma^2_{lg} \pm$ SE	$\sigma^2_{g} \pm$ SE
Plant height	-1.35±1.91	-2.28±1.46	9.92±5.69	19.79±10.43
Days to 50% flowering	0.90±2.28	0.69±2.21	520.52±203.07	-209.25±103.43
Days to maturity	-8.59±59.90	-7.39±22.45	487.97± +254.03	-50.83±164.37
100 seed-weight	-0.58±1.97	-0.19±1.60	9.79±6.45	-0.66±4.16
Number of seeds per pod	-0.34±0.45	-0.18±0.75	5.86±3.18	0.87±2.53
Number of pods per plant	-0.13±2.97	-0.73±2.27	1.13±4.42	2.70±3.69
Grain yield per plant	0.12±3.72	-1.26±2.06	3.58±5.59	1.46±4.01
Grain yield per ha	-1195.25±4515.02	1578.0±2761.46	11653.33±8631.65	3951.92±7373.06
Fodder yield per plant at harvest	-168.25±416.61	116.33±480.15	1254.0±731.22	-51.29±505.54
Fodder yield per ha at harvest▲	-0.19±0.916	-0.65±1.549	3061.0±2.263	-0.591±1.407
Dry fodder yield per plant	-18.29±54.79	6.93±65.52	221.73±108.18	-37.72±69.24
Dry fodder yield per ha▲	0.0747±0.13	-0.0234±0.20	0.614±0.364	-0.2007±0.217
Number of Striga per plot at harvest	4.42±9.09	-6.12±10.85	104.09±48.98	11.06±38.04

▲ = the figures of the marked characters are multipied by 10^6

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Table 7 (continued).

Character	σ^2_{qtg} ± SE	σ^2_{qtg} ± SE	σ^2_{0g} ± SE	σ^2_{ptg} ± SE
Plant height	-4.98±2.22	2.27±2.11	3.47±2.53	2.13±2.06
Days to 50% flowering	7.03±6.53	-0.73±4.36	-6.44±3.30	-7.37±3.24
Days to maturity	-35.37±10.74	2.77±7.04	211.45±87.46	74.48±33.91
100-seed weight	0.98±1.97	-1.19±1.08	5.45±3.25	3.72±2.60
Number of seeds per pod	-0.21±0.463	-0.12±0.28	1.31±0.77	2.24±1.12
Number of pods per plant	-5.19±2.52	0.18±1.63	7.49±4.21	5.41±3.43
Grain yield per plant	-6.49±2.81	0.46±1.86	9.50±5.10	4.46±3.21
Grain yield per ha	-4157.67±4104.903	1110.83±3032.29	11077.5±6546.57	1027.33±3006.97
Fodder yield/plant at harvest	1054.0±854.354	368.17±707.9	-302.67±521.29	21.17±604.33
Fodder yield per ha at harvest▲	2.30±2.119	0.56±1.644	-1.30±1.177	2.42±2.255
Dry fodder yield per plant	158.27±132.27	23.55±99.34	-77.30±74.32	-32.72±84.02
Dry fodder yield per ha▲	0.438±0.32	-0.038±0.214	-0.199±0.178	0.247.0±0.30
Number of Striga per plot at harvest	-56.3±16.12	5.98±11.00	0.98±9.49	20.08±15.80

▲ = the figures of the marked characters are multiplied by 10^6

Table 8. Error variance, phenotypic variance and heritability estimates and their associated standard errors in cowpea at Minjibir and Mallam Maduri in 1994.

Character	Error variance $\sigma^2 \pm$ SE	Phenotypic variance $\sigma^2_{ph} \pm$ SE	Heritability $h^2_b \pm$ SE
Plant height	29.85±3.164	25.52±10.00	0.7753±0.409
Days to 50% flowering	28.25±2.99	50.22±19.70	-
Days to maturity	173.5±18.39	260.15±102.04	-
100-seed weight	11.77±1.25	6.45±2.53	-
Number of seeds per pod	4.005±0.43	4.54±1.78	0.1922±0.56
Number of pods per plant	32.68±3.46	6.82±2.67	0.3956±0.541
Grain yield per plant	38.19±4.048	7.06±2.77	0.2067±0.568
Grain yield per ha	41770.0±4427.61	14494.58±5685.24	0.2726±0.509
Fodder yield/plant at harvest	3311.0±350.97	724.79±284.29	-
Fodder yield/ha at harvest▲	9.122±0.97	1.61±0.63	-
Dry fodder yield per plant	526.8±55.84	87.58±34.35	-
Dry fodder yield/ha▲	1.108±0.12	0.24±0.09	-
Number of Striga per plot at harvest	268.6±28.47	73.17±28.70	0.1511±0.520

(-) = uncomputed because σ^2_g was negative.

▲ = the figures of the marked characters are multipled by 10^6

B Millet

Mean performance and variability

The mean weight of millet was 2.34 kg/plot for grain yield and 6.35 kg/plot for stalk yield (Table 9). The pesticide spraying regime on cowpea did not affect the millet yield. Considerable differences were observed across locations (Table 10 and Appendix V) and also there was no significant effect of the cowpea genotypes on millet since the mean squares due to genotype were not significant.

Table 9. Mean, standard errors of a mean, ranges and coefficients of variation for 2 characters of millet intercropped with cowpea genotypes

Character	Mean ± SE	Range	CV%
grain yield (kg)	2.34 ± 0.61	1.85 - 2.724	26.0
Stalk yield (kg)	6.35 ± 1.66	4.2 - 7.14	26.2

Table 10: Mean square in the analysis of variance for millet grain and stalk yield according to the genotype of the associated cowpea at Minjibir and Mallam Maduri in 1994

Source of variation	df	grain yield▲	Stalk yield
Locations (L)	1	112.786**	336.508
Reps in locations	4	3.388*	13.380
Type (T)	1	0.0313	0.649
T x L	1	0.224	16.721**
Error (a)	4	0.485	10.484
Whole plot total	11	11.685	40.848
Genotypes of Cowpea (G)	11	0.727	3.991
G x L	11	0.368	1.649
G x T	11	0.722	6.117
G x L x T	11	0.582	2.820
Error (b)	88	0.370	2.760
Subplot total	132	0.447	3.055
Total	143		

▲ = all the figures under the marked characters are multiplied by 10^6
*, ** = significant at 5% and at 1% probability, respectively

4.1.2 Data combined over years

4.1.2.1 Mean values of the cowpea genotypes

The means and their standard errors, ranges and percent coefficients of variation (CV,%) of the characters are shown in Table 11. Considerable variations among the genotypes were observed for all the characters. The coefficients of variation ranged from 11.5% for days to 50% flowering to 53.2% for fodder yield at harvest per plant. The range between the means was wide for all the characters except for number of seeds per pod and pod length. The mean performance of each genotype, the interactions between genotypes and year, pesticide spraying regime is presented in Appendices VI, VII and VIII. Differences existed between the mean performance of the genotypes in 1994 and 1995 for days to 50% flowering, days to maturity, 100-seed weight, number of seeds per pod and grain yield.

Appendix VIII shows that days to 50% flowering, days to maturity, grain yield and fodder yield were less affected by the pesticide spraying regime in 1995 than in 1994. This is due to the reduction in the insect pests and disease attack observed in 1995 compared to 1994. Plant height appeared insensitive to years and pesticide spraying regime(Appendix VI).

4.1.2.2 Variability displayed by the genotypes

The mean squares of the sources of variation obtained from the analysis of variance are shown in Table 12. Differences in years were signifcant for plant height and grain yield per hectare. Pesticide spraying regime x years was highly significant for days to 50% flowering, days to maturity, 100-seed weight, number of seeds per pod, pod lenght and dry fodder yield per plant and per hectare. Genotypes were significant for number of pods per plant, grain yield per plant and dry fodder yield per plant and highly significant for plant height. The interaction between genotypes and pesticide spraying regime was significant for fodder yield at harvest per plant. The interaction between genotypes, years and pesticide spraying regime was highly significant for days to 50%, flowering, days to maturity, 100-seed weight, number of seeds per pod, number of pods per plant, grain yield per hectare and pod length.

4.1.2.3 **Variance components**

(a) Genetic variance, σ^2_g and genetic x environment components interaction variance

The variance components are presented in Table 13. the magnitude of the genetic variance was higher than that of all the interaction variances for plant height, grain yield per plant, fodder yield at harvest per plant, dry fodder yield per plant and per hectare except the pesticide spraying regime x genotype interaction in fodder yield at harvest per plant. The magnitude of the genotype x pesticide spraying regime was higher than that of the genetic variance for days to 50% flowering, days to maturity, pod length and fodder yield at harvest per hectare too.

Years x pesticide spraying regime x genotype interaction variance estimates were postive for all the characters except plant height. Pesticide spraying regime x genotype interaction variance estimate were negative for 100-seed weight and number of pods per plant. Years x genotype interaction variance estimates were positive for plant height, fodder yield at harvest per plant and per hectare. Genetic variance estimates were negative for days to 50% flowering and pod length.

(b) error variance, phenotypic variance and broad sense heritability

The estimates of the error variance, phenotypic variance and broad sense heritability and the associated standard errors are also shown in Table 13. High heritability values were recorded for plant height, 83%; 100-seed weight, 72% and grain yield per ha, 77%. The heritability was medium for number of seeds per pod, 36%; fodder yield at harvest, 42 %; dry fodder yield,65 % and grain yield per plant, 67 %. It was very low for days to maturity; 2 %. Heritability estimates were not computed for characters with negative genetic variance (σ^2_g). Heritability estimate was higher than one for number of pods per plant. This is obviously an upward biased estimate because, theoretically, the maximum value for heritability, is one. The standard errors were large for the heritability estimates of all the characters for which it was calculated except plant height and number of pods per plant, following the trend observed with the corresponding genetic variance estimates.

Table 11. Means, standard errors of a mean, ranges and coefficients of variation for 13 characters of cowpea at Samaru, 1994 and 1995 combined.

Character	Mean ± SE	Range	CV(%)
Plant height (cm)	31.3±4.10	25.8-38.9	13.10
Days to 50% flowering	39.56±4.5	34.6-47.0	11.50
Days to maturity	57.5±18.0	42.2-72.3	31.3
100-seed weight (g)	11.5±3.8	6.9-16.4	32.9
Number of seeds per pod	6.5±1.6	5.3-8.2	25.0
Number of pods per plant	9.1±3.5	6.7-16.3	37.9
Grain yield per plant(g)	8.4±3.5	4.9-21.2	41.9
Grain yield per ha (kg)	613.0±185.1	431-885	30.2
Pod length (cm)	10.3±2.5	7.3-12.8	23.9
Fodder yield at harvest per plant (g)	45.4±24.2	26.1-77.6	53.2
Fodder yield at harvest per ha (kg)	3696±1778.4	2037-5910	48.1
Dry fodder yield per plant (g)	16.54±6.86	9.90-31.71	41.4
Dry fodder yield per ha (kg)	1322±467.7	809-2010	35.4

Where : SE = standard error of the means

CV (%) = coefficient of variation in %

Table 12: Mean squares from the combined analysis of variance for 13 characters in cowpea at Samaru in 1994 and 1995.

Sources of variation	d.f	Plant height	Days to 50% flowering	Days to maturity	100-seed weight	Number of seeds per pod	Number of pods per plant	Grain yield per plant
Years(Y)	1	150.60*	11556.25	29383.7	1557.62	629.17	276.2	742.61
Reps in year	4	136.135	18.81	179.9	13.575	1.743	67.015	36.785
Type (T)	1	29.61	18180.03	86387.0	2716.15	1831.84	7536.99**	6158.19**
T x Y	1	8.65	18496.00**	50737.6**	2185.56**	101.674**	28.60	31.41
Error (a)	4	31.09	19.1	214.75	20.835	3.64	33.075	15.38
Whole plot total	11	77.99	4398.54	15280.63	599.72	234.93	749.29	649.17
Genotypes (G)	11	126.20**	209.54	978.9	66.18	11.676	81.62*	229.63*
G x Y	11	16.14	287.89	878.9	31.39	7.223	10.80	17.68
G x T	11	19.99	384.63	1029.1	32.48	8.629	21.97	76.62
G x Y x T	11	15.06	381.39**	948.6**	45.51**	8.445**	36.48**	19.07
Error (b)	88	16.82	20.72	324.0	14.37	2.643	11.88	12.26
Subplot total	132	26.0	119.10	535.6	24.21	4.76	20.49	36.76
Total	143							

*, ** = significant at 5% and at 1% probability, respectively

Table 12: (Continued)

Sources of variation	d.f	Grain yield /ha ▲	Pod length	Fodder yield at harvest/plant	Fodder yield at harvest/ha▲	Dry fodder yield/plant	Dry fodder ▲ yield/ha
Years(Y)	1	3.425*	1075.621	527.4	0.313	495.51	2.144
Reps in years	4	0.113	14.748	2879.75	20.165	198.23	1.131
Type (T)	1	33.138**	3527.568	114031.7**	829.6**	6168.53	47.856
T x Y	1	0.067	971.465**	2160.5	5.952	927.71**	4.423**
Error (a)	4	0.050	14.20	2416.5	17.305	169.675	0.934
Whole plot total	11	3.389	517.31	12536.77	89.61	823.94	5.699
Genotypes (G)	11	0.289	22.453	4007.1	15.28	558.64*	1.7
G x Y	11	0.049	17.897	1040.2	6.855	139.44	0.649
G x T	11	0.147	25.612	1920.9*	9.907	120.46	0.679
G x Y x T	11	0.129**	18.825**	649.2	5.522	64.05	0.413
Error (b)	88	0.034	6.043	584.7	3.163	47.02	0.219
Subplot total	132	0.074	11.094	1024.6	5.239	104.90	0.438
Total	143						

▲ = all the figures under the marked characters are multiplied by 10^6
*,** significant at 5% and at 1% probability, respectively.

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Table 13. Variance components and their standard errors for cowpea from the data combined over years and estimates of broad sense heritability, Samaru, 1994 and 1995.

Characters	σ^2_{ge} ± SE	σ^2_{ig} ± SE	σ^2_{gy} ± SE	σ^2_g ± SE	σ^2_e ± SE	σ^2_{ph} ± SE	h^2_B ±SE
Plant height	-0.59±2.15	0.82±1.64	0.18±1.44	8.76±4.24	16.82±2.51	10.52±4.13	0.833±0.403
Days to 50% flowering	120.22±49.88	0.54±35.41	-15.58±31.24	-6.80±21.19	20.72±3.09	17.46±6.85	-
Days to maturity	208.2±125.06	13.42±91.50	-11.62±84.54	1.63±62.78	324.0±48.30	81.58±32.00	0.02±0.77
100-seed weight	10.38±5.99	-2.17±3.66	-2.35±3.61	3.99±3.01	14.37±2.14	5.52±2.1	0.72±0.55
Number of seeds/pod	1.93±1.11	0.03±0.79	-0.20±0.73	0.36±0.60	2.64±0.39	0.97±0.38	0.36±0.61
Number. of pods/plant	8.2±4.806	-2.42±2.78	-4.28±2.49	7.11±3.03	11.88±1.77	6.80±10.6	1.05±0.45
Grain yield/plant	2.27±2.57	9.59±5.16	-0.23±1.70	12.87±7.96	12.26±1.83	19.14±7.5	0.67±0.42
Grain yield/ha	31544.0±16940.204	3087±12802.67	-13247.33±9025.38	18460.67±11537.49	34279±5110.1	24123.08±9461.85	0.77±0.48
Pod length	4.26±2.48	1.13±2.08	-0.16±1.70	-0.19±1.40	6.43±0.9	1.87±0.73	-
Fodder yield at harvest/plant	21.5±89.71	211.95±132.55	65.17±80.16	141.27±150.68	584.7±87.16	333.93±130.98	0.42±0.45
Fodder yield at harvest/ha▲	786±740.0	731±741.45	222 ± 575	336.67±661.11	3163.0±471.5	1270±499	0.265±0.521
Dry fodder yield per plant	5.68±8.69	9.40±8.92	12.57±10.03	30.23±19.34	47.02±7.01	46.55±18.2	0.65±0.40
Dry fodder yield per ha	64617.33±55031.70	44354.67±51926.55	39409±50279.05	71250.67±66873.72	218766.0±32611.71	147517.33±57861.06	0.48±0.45

▲ = all the variance estimates and their standard errors are multiplied by 10^3 for this character
(-) = uncomputed because was σ^2_g negative

4.2 On-farm

4.2.1 Performance of the test lines

Data from fifty out of the seventy farmers to whom test lines were distributed were reliable. Three farmers planted early June and the crop failed due to lack of rain or they did not plant at all. Seventeen other farmers' harvested samples could not be used because they were a mixture of varieties. All the samples of 'Kananado' fell into this category. All the suspicious harvests were not taken into account in this analysis.

None of the farmers protected the cowpea crop against pests with pesticide. The cropping pattern adopted by them varied from cowpea intercrop with millet; sorghum; millet and sorghum; millet, sorghum and groundnut to a mixture of sorghum, groundnut and cowpea on the same row. This resulted in a mosaic of cropping pattern that added to the complexity of the on-farm data. Most of the farmers planted two different varieties of cowpea in alternate rows. All these facts limited the efficient use of the collected data for the evaluation of the mean performance of the lines on farmers' field.

The mean performance of the lines on farmers' fields is presented in Table 14 for number of pods per plant, number of seeds per pod, 100-seed weight, grain yield per plant, pod length and grain yield per hectare. The line 374-57 showed a good performance for all these traits except for number of seeds per pod. Some of these breeding lines performed better than the farmers' local variety and 'Danlla' as follows: IT89KD-374 for grain yield per ha, IT89KD-374-57 and IT88DM-867-11 for number of pods per plant, IT89KD-391 for 100-seed weight and IT89KD-374-57, IT89KD-867-11 and IT90K-277-2 for grain yield per plant. Others performed similar to the farmers' local varieties and better than 'Danlla' for pod length (IT89KD-391, IT86D-719 and IT89KD-374-57) and number of seeds per pod (IT86D-719, IT89KD-391 and IT89KD-319). In general, the ranges in the performance were very wide for all the traits except for 100-seed weight for IT86D-719, IT89KD-391 and farmers' local variety.

Only two farmers harvested fodder from 'Dan Ila' and IT88DM-867-11, all the remaining declared that the fodder disintegrated at maturity of the crop.

4.2.2 Assessment of the test lines by farmers

Sixty-three farmers out of the seventy were interviewed on their appreciation of the test lines performance as crop and food. The response of farmers is presented in Appendices IX and X. Eighty-eight per cent of the farmers who grew the breeding lines rated them better than their local varieties. Less than six per cent found these genotypes not different from or poorer than the local ones. For eighty-four per cent of these farmers, the maturity of the breeding lines was preferable to that of local varieties; two per cent rated them worse and about fourteen per cent of the famers found no difference between the maturity of these breeding lines and that of the local ones. Sixty-seven per cent found that the genotypes produced more grains than local varieties, twenty-five per cent reported that their grain production was less and six per cent found no difference between the breeding lines and the local ones. Thirty-seven per cent declared that breeding lines had more fodder, fifty per cent reported less fodder and ten per cent found no difference between these genotypes and the local varieties.

Farmers ratings for the other parameters such as susceptibility to pests and diseases, seed colour, spacing, influence on cereals and seeds preservation, are shown in Appendices IX and X. In general, the performance of the breeding lines were found to be better (based on the proportion of positive answers) than the local checks 'Danlla' and 'Kananado'. From the information presented in Appendix IX, local checks were superior to the breeding lines in fodder production. This was mainly due to the performance of 'Kananado'.

As food, all the test lines were found delicious, fast cooking by all the farmers who harvested some grains. Some of them found that the test lines were sweeter and softer than the local 'Danwiri'. They ate them as fresh pods, dry grain mixed with rice, in soup, or in specialities such as 'danwake', 'kosai' and 'yari-yau'. Many of these farmers suggested that the quantity of seeds of the test lines, the number of farmer participants and the number of lines to be tested by farmers should be increased in the future.

Table 14. Mean performance and range of cowpea genotypes in farmers' fields at Gezawa and Minjibir, 1994

Genotypes	Number of pods/plant		Number of seeds/pod		Grain yield/plant (g)	
	Mean	Range	Mean	Range	Mean	Range
'Danlla'	10.0	0-29.7	06.6	0-12.2	13.5	0-47.9
farmer's local	8.9	2.96-13.2	10.8	8.9-12.0	11.1	1.97-19.5
IT90K-59	6.5	0-19.5	08.8	0-11.8	6.9	0-17.6
IT89KD-374-57	25.7	6.89-80.9	09.3	6.7-10.7	23.6	4.96-70.1
IT88DM-867-11	21.7	0-85.3	06.5	0-11.5	23.3	0-87.9
IT86D-719	10.6	4.6-18.3	10.9	8.6-12.6	9.0	3.11-17.4
IT86D-715	8.8	0-16.83	08.0	0-11.0	7.8	0-15.5
IT89KD-391	7.4	3.97-16.1	10.7	9.3-12.0	9.8	5.9-17.3
IT90K-277-2	13.2	0-29.4	06.4	0-12.2	19.0	0-41.5
IT89KD-319	8.3	0-22.0	10.8	0-16.2	13.4	0-45.3

Table 14 (continued)

Genotypes	100-seed weight(g)		Grain yield (kg/ha)		Pod length (cm)	
	Mean	Range	Mean	Range	Mean	Range
'Danlla'	8.06	0-13.0	126.2	0-402.4	9.0	0-16.41
farmer's local	13.9	13.3-14.7	131.0	52.9-285.5	15.2	13.4-16.9
IT90K-59	10.9	0-15.3	80.8	0-144.6	11.7	0-15.4
IT89KD-374-57	12.5	9.5-14.5	214.5	62.4-476.6	14.3	12.6-16.2
IT88DM-867-11	9.3	0-14.7	108.4	0-334.1	8.9	0-15.3
IT86D-719	11.9	11.3-12.3	139.3	43.02-274.3	14.7	13.9-16.0
IT86D-715	9.3	0-13.5	127.0	0-235.4	10.9	0-14.0
IT89KD-391	16.3	15.3-17.1	116.2	95.5-143.3	16.3	14.6-17.4
IT90K-277-2	8.6	0-16.0	103.9	0-274.2	9.4	0-1.6
IT89KD-319	12.5	0-18.0	96.6	0-262.7	12.3	0-1.9

CHAPTER 5

DISCUSSION

The split-split plot model in a randomized complete block design used for the data analysis combined over locations and split plot design for the data combined over years for cowpea in Samaru and for the millet permitted the estimation of the potential performance of the genotypes studied under different crop management systems. The significant interaction between the genotypes and some environmental components such as location, year, pesticide spraying regime and cropping pattern was properly assessed. The ranges and means of traits (Tables 5 and 11) and significant difference in the interactions genotypes x locations; genotypes x locations x pesticide spraying regime; genotypes x location x pesticide spraying regime x cropping pattern; pesticide spraying regime x years and genotypes x pesticide spraying regime x years for many traits (Table 6 and 12) revealed the importance of the interactions effects on the performance of the cowpea genotypes. In the Sudan savanna zone, some of these breeding lines displayed better performance than the local varieties, 'Kananado' and 'Danlla' for all the characters (Appendix II). Other genotypes such as IT89KD-391, IT89KD-319 and IT89KD-867-11 failed to flower, mature and produce grains just like 'Kananado' and 'Danlla' under heavy infestation of Maruca testulalis and pod sucking bugs (Appendices III and IV).

Although 'Kananado' is considered traditionally as a fodder type variety in Sudan savanna zone, this study showed that its performance for fodder at harvest and dry fodder yield was less than that of some of these breeding lines (IT89KD-319, IT89KD-391, IT90K-277-2 and IT90K-59) for dry fodder yield per plant and IT89KD-319, IT89K-391 for fodder yield per plant at harvest. This was due to the fact that effectively sprayed cowpea crop would produce more grain and less fodder, then senesce, losing part of its leaves, faster than unsprayed crop. As such, when 'Kananado' is sprayed with pesticide, its fodder production is as low as that of some of the varieties that are considered as grain type (Appendices III and IV).

At Samaru in the Northern Guinea savanna, 'Kananado' was among the best performing

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genotypes for many characters. Its performance was as good as that of IT89KD-355, IT90K-59 for days to 50% flowering. 'Kananado' sprayed plot flowered and matured earlier in 1995 than in 1994 as a result of a delay of 10 days at the time of planting which made it closer to the appropriate photoperiod in 1995 (Appendix VIII). Some of the breeding lines were better or as good as 'Kananado' for many characters. The difference in the level of infestation of the crops by insect pests and diseases such as scab and Septoria appeared clearly in the significant difference observed for pesticide spraying regime x genotype x year interactions for most of the characters. Under very serious insect and disease attack, most of the genotypes failed to flower and mature as observed at Samaru in 1994.

Location variance and location x genotype variance were significantly different from zero (Table 5) at 1% due to higher infestation of the cowpea by Maruca testulalis, pod sucking bugs and Striga in Mallam Maduri than in Minjibir. This is in agreement with Ntare *et al.* (1993) who cited insect damage effect as one of the primary causes of GxE interaction in cowpea. As reported by Ntare and Williams (1992), planting pattern had no significant effect on the grain yield of cowpea. Blade *et al.* (1992) did not get the same conclusion in five out of thirteen experiments. However, this study revealed significant effect of cropping pattern on the fodder yield per plant at harvest and dry fodder yield per hectare. The delay in planting date affected positively by reducing the number of days to 50% flowering and days to maturity of the photosensitive genotypes such as 'Kananado'.

The analysis of variance allowed the computation of the variance components. Except σ^2_{gl}, σ^2_e and σ^2_{pl}, all other variance components showed negative values for one or more traits. Negative estimates of variance components have also been reported in self-fertilizing crops like cotton, soybeans, rice and barley by Matzinger (1963); in maize by Marquez-Sanchez and Hallauer (1970), Obilana (1977) and Campos (1977); in sorghum by Jan-Orn (1973), Mukuru (1973), Eckebil (1974), Lukhele (1981), Kimbeng (1990) and Showemimo (1991). Several negative estimates of variance components, mainly the interaction variance components were obtained in cowpea by Bliss *et al.* (1973).

Some of these authors attributed this to factors including sample size, assortative mating, deficiency in the statistical and genetic model, experimental layout, linkage and estimates of actual zero. In this study, sample size may be the cause of these negative values and the high standard error. The statistical model and the

layout were appropriate for bringing out the interactions with precision.

The resulting variance components were negative when the value to be substracted is larger than the other as observed in this study. This is not uncommon in quantitative genetic studies especially where only years and locations are considered for the genotype x environment interaction (Comstock and Moll, 1963; Cockerham, 1963).

The negative estimates of the variance components with large standard errors observed for some traits would mean that these variances had very small values rather than equal to zero. In the case of the interaction variance estimates that were very small, computing the genetic variance without taking them into account would not induce much bias in the estimates of genetic variance.

The importance of the magnitude of the interaction between genetic and environmental factors such as pesticide spraying regime, cropping pattern, locations and years for some traits confirmed the need for taking these factors into account in breeding program.

The observed heritability estimates for days to 50% flowering, days to maturity, 100-seed weight, and fodder yield would be very low under the assumption that the negative estimates of the genetic variance were very small. Heritability estimates for days to 50% flowering and days to maturity by the two approaches were low. This is in contradiction with the report that indicated high heritability estimates for days to 50% flowering and days to first harvest (Ramachandran *et al.*, 1980 and Roquib and Patnaik, 1990). The heritability estimates for 100-seed weight in the data combined over years were high as reported by Singh and Mehndiratta (1969), Araùjo and de Nunes (1983) and Dharmalingan and Kadambavamasudaram (1984). The high heritability revealed by the data combined over years for grain yield is in agreement with Sreekumar *et al.* (1979). This is however contrary to the estimates obtained in the data combined over locations under the assumption that negative variances had very low values. The results of Thiyagarajan *et al.* (1989) as related to plant height heritability estimates agree with the estimates obtained by the two approaches in the present study. The heritability estimates for number of pods per plant was 1.045. The upward bias observed here might be due to the fact that the difference between the positive components variance was not as much compared to other parameters' variance components and the weight of the negative estimates of σ^2_{tg} and σ^2_{gy} in the computation of σ^2_{ph}. If these interaction variances had very small

positive values, σ^2_{ph} would be higher than σ^2_g, although the heritability estimates would still be high. This high heritability value obtained at Samaru was not in accordance with the medium heritability observed with the same genotypes across locations. This might be due to higher level of heterogeinity in the environments such as higher infestation by pathogens, insects pests and Striga in one location or year than the other.

Such upward bias in heritability estimates were reported by Frey and Horner (1957), who used parent-offspring regression method to compute the heritability values. They suggested a correction of this bias by the use of standard unit method that fixed a ceiling of 100% to the heritability value. This correction cannot be adopted with the variance component method.

The difference in the heritability results may be due to the fact that their estimates were obtained from environments not as heterogenous as that of this study. Obilana and Fakorede (1978) stated that if a trait is strongly influenced by some environmental variations, its heritability would be low in a population in which those environments vary widely. On the other hand, in another population in which the environment is rigidly controlled so that these variations do not occur, the same traits would tend to have high heritability.

The large standard errors obtained for the positive variance components and the heritability might be due to the high heterogeneity in the environmental factors from location to location and year to year as shown by large coefficients of variation displayed by the combined analyses. Variance components estimated from data combined over years at the same locations might be more accurate since bias due to locations or year would be overcome.

Contrary to Ntare and Williams (1992) who concluded that cowpea cultivars had marked differences in their effects on millet yield, in the present study cowpea genotypes did not have any effect on millet.

Lines such as IT89KD-374-57, IT88DM-867-11 and IT90K-277-2 that were derived from crosses involving local varieties showed better performance than the farmers'local variety and the local check 'danlia' for traits like grain yield per plant. Their superiority over these local varieties would be enhanced by their resistance to bacterial blight, aphid and thrips (IITA 1993) under a heavy attack of cowpea crop by some of these pests. The yield performance of the associated crops could not be analysed because of the diversity of their number that reduced drastically the number of farmers with the same test lines and the same associated crops. It would be

more informative to work with farmers with the same associated crops.

Increasing the number of test lines per farmer and the number of the farmers evaluating the same set of lines, two to three lines (including farmer's local variety) per farmer and twenty farmers for the same set of lines for instance, might give more reliable results. Such design would allow thorough statistical analysis as reported by Versteeg and Huisjman (1991), Oyedokun and Oyeneye (1991), Shannon *et al.* (1991) and Elemo (1993). Opinions expressed by the farmers were reliable although those who did not get any harvested grain got confused on the matter of seed colour. The suggestions they made in relation to the increase of the number of participant farmers, the number of test lines per farmer and the quantity of seeds to be given to them for planting showed how much interest they had in this operation. This is the proof that the point made above in order to get more informative data could be achieved with these farmers. This set of breeding lines can be considered as acceptable by farmers of these local governments. More than fifty percent of the farmers found that the breeding lines increased the yield of the associated cereal even though this could not be statistically ascertained. The increase observed by farmers, could have been due to various factors such as the effect of farm yard manure and the associated legumes among which were the test lines.

CHAPTER 6

SUMMARY AND CONCLUSION

Ten breeding lines from the International Institute of Tropical Agriculture (IITA) and two local varieties, 'Kananado' and 'Danlla' were grown in 1994 at two locations (Mallam Maduri and Minjibir) in the Sudan savanna zone and at Samaru in Northern Guinea savanna zone in Nigeria. A second season crop was grown in 1995 at Samaru. Eight of these breeding lines and the two local varieties were tested under farmers' crop management systems at Gezawa and Minjibir local government areas in Kano State, Nigeria.

The on-station experiments were laid out in a split split plot design with pesticide spraying regime as main treatment (pesticide spray and no spray), cropping pattern as sub-treatment (sole crop and intercrop) and cowpea genotypes as sub-sub-treatment. Each sub-sub plot was made of four rows for sole cowpea. The intercrop sub-sub plot was composed of two rows of cowpea alternated by a row of millet. The rows were eight metres long and 75 cm apart. Hill to hill spacing was 1m for millet, 20cm for all the cowpea genotypes except 'Kananado' that was planted at 40cm apart. Observations were made on the inner four metres of the two middle rows of the sole crop of cowpea, on the similar portion of the two cowpea rows in the intercrop sub-sub plot and on the millet row between two rows of the same cowpea genotypes.

Seventy farmers participated in the evaluation of the genotypes under their traditional crop management system. The crop was monitored and observations were made on a plot of 10m x 5m on the test lines as well as farmers' local varieties planted at the same time and in the same pattern.

Data were collected on plant height, days to 50% flowering, days to maturity, number of pods per plant, 100-seed weight, pod length, number of seeds per pod, grain yield per plant and per hectare, fodder yield per plant and per hectare at harvest, dry fodder yield per plant and per hectare and number of Striga per observation plot at harvest. According to the availability of complete data, thirteen of these

traits from the on-station experiments and six from on-farm experiment were examined. Analysis of variance was carried out over locations from Minjibir and Mallam Maduri experiments and over years for Samaru experiments. The mean performance of the cowpea genotypes under farmers' condition was observed for 50 farmers out of seventy. The remaining samples were not reliable.

The cowpea genotypes displayed variation for each trait on-station as well as on-farm. Coefficients of variation ranged from 9.9 for plant height to 77.4% for grain yield per plant with the data combined over locations; from 11.5% for days to 50% flowering and to 53.2% for fodder yield at harvest with the data combined over years. This variability was confirmed by the significant difference observed among locations, the interactions like genotypes x locations; genotypes x locations x pesticide spraying regime; genotypes x locations x cropping pattern; genotypes x years x pesticide spraying regime and pesticide spraying regime x years for many traits. Plant height was stable under the two cropping patterns, pesticide spraying regime and years. Its variation across locations was significant. The wide range in performance displayed by the cowpea test lines in farmers' field further confirmed the genetic variability in the cowpea crop.

Genetic variance estimates had positive values for seven out of the thirteen traits from the data combined over locations and eleven out of thirteen from the data combined over years. Negative estimates of genetic variance were recorded for days to 50% flowering, days to maturity, 100-seed weight, fodder yield per plant and per hectare at harvest and dry fodder yield per plant and per hectare from the data combined over locations. With the combined analysis over years, only days to 50% flowering and pod length had negative genetic variance estimates. Most of the genetic variance estimates were associated with large standard errors.

With the data combined over locations, the magnitude of the genotype x location variance σ^2_{gl} estimates was higher than that of the genetic variance and all other interaction variances for most of the traits studied. Genetic variance estimate was higher than that of the interaction variance for plant height. With the data combined over years, the magnitude of the genetic variance was higher than that of all the

interaction variances for plant height. It was smaller than that of the pesticide spraying regime x year x genetic interaction variance and bigger than that of year x genetic interaction variance for many traits. The magnitude of the pesticide spraying regime x genotype interaction variance was higher than that of the genetic variance for days to 50% flowering and days to maturity only.

All the variance estimates obtained except that of the genotype x location interactions variance had negative values for one or more traits. The observed trends in the genetic variance, genotype x pesticide spraying regime, genotype x cropping pattern, genotype x cropping pattern x pesticide spraying regime, genotype x year and genotype x pesticide spraying regime x year interaction variance estimates varied from trait to trait. A study of the genetic variability in cowpea under various crop management systems (cropping patterns and pesticide spraying regime) for at least two years in the same locations would give more precision on the need for taking the genotype x environment components interactions into account in the estimation of the genetic variance by the breeder.

Heritability estimates computed by the two approaches were high for plant height, very low for days to 50% flowering and days to maturity under the assumptions that negative genetic variance estimates had very small values. Some contrast was observed in the heritability estimates for traits such as 100-seed weight, fodder yield at harvest and dry fodder yield computed by data combined over locations and data combined over years. This might be due to the differences which existed in the level of heterogeneity observed across locations and over years.

Only the location variance was highly significant for millet grain yield showing that the cowpea genotypes did not affect the millet performance that was better at Minjibir than at Mallam Maduri. Sorghum crop failed at Samaru during 1995 season due to heavy rain at the planting time which was late for sorghum crop. Some cowpea test lines such as IT89KD-374-57, IT88DM-867-11 and IT90K-277-2 performed better than the farmers' local varieties and the local check 'Danila' for some traits like grain yield per plant. Their superiority on the local varieties would be better expressed under heavy infestation of the cowpea crop by insect pests and disease to which they are more resistant than the local varieties

which are susceptible. The high proportion of farmers who gave a positive appreciation of the cowpea lines as crop and food suggested that they were acceptable in the areas of the study. Most of the farmers wished that their participation in varietal evaluation remains as a permanent feature of the development of improved varieties. These farmers' collaboration with breeders would increase the impact of the cowpea improvement programme at the producers' level.

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Appendix 1. Mean performance of cowpea genotypes by cropping pattern and pesticide spraying regime at Minjibir and Mallam Maduri in 1994.

Characters	Location		Pattern		Pesticide spraying regime	
	Minjibir	Mallam Maduri	Sole	Intercrop	Spray	no spray
Plant height	40.20	70.08	53.37	56.91	55.33	54.95
Days to 50% flowering	49.75	28.91	39.53	39.13	39.03	39.63
Days to maturity	72.11	36.41	56.24	52.26	56.99	51.53
Number of pods/plant	13.73	2.88	9.53	7.09	11.78	4.83
Number of seeds/pod	9.61	5.93	7.32	8.22	8.16	7.38
100-seed weight	14.04	7.79	10.38	11.44	11.18	10.85
Grain yield per plant	13.98	1.99	9.05	6.92	11.78	4.18
Grain yield/ha	533	135	433	235	465	203
Fodder yield at harvest per plant	138.3	84.5	122.4	100.4	108.9	113.9
Fodder yield at harvest per ha	5457	6346	8005	3798	5557	6246
Dry fodder yield per plant	54.5	33.9	47.1	41.4	44.2	44.2
Dry fodder yield/ha	2167	2470	3069	1568	2182	2455
Number of Striga	4.29	47.55	27.88	23.97	27.15	24.69

Appendix II. Mean performance of cowpea genotypes for 13 characters over locations (Minjibir and Mallam Maduri in 1994)

Genotypes	Plant height	Days to 50% flowering	Days to maturity	Number of pods per plant	Number of seed per pod	100-seed weight	Striga number at harvest
'Kananado'	55.56	42.08*	31.79*	4.13	4.34	8.43	31.75
'Dan Ila'	52.24	28.63*	40.42*	6.07	6.50	7.82	33.58
IT90K-59	57.12	43.13	69.75	10.02	10.22	12.70	5.63
IT89KD-374-57	48.75	43.38	71.42	12.03	9.47	12.98	24.08
IT88DM-867-11	47.57	43.79	36.71*	4.41	6.00	10.14	18.71
IT86D-719	60.85	42.38	69.83	8.73	10.35	12.88	21.46
IT86D-715	58.02	41.96	69.38	8.73	9.20	13.10	27.83
IT89KD-391	62.58	24.0*	38.75*	9.92	5.79	7.72	30.42
IT90K-277-2	57.80	43.88	71.92	11.09	8.95	14.65	38.33
IT89KD-319	49.07	31.29*	37.42*	5.82	4.95	7.26	31.96
IT89KD-355	59.81	45.21	57.92*	10.19	8.17	11.71	23.92
IT89KD-261-3	52.33	42.25	55.83*	8.54	9.32	11.58	23.38
SE	5.46	5.32	13.17	5.72	2.00	3.43	16.39

* = 50% of the plants of the genotypes with the marked figures did not flower, others did not mature
SE = Standard error

Appendix II (Continued).

Genotypes	Grain yield/plant (g)	Grain yield/ha (kg)	Fodder per plant at harvest (g)	Fodder yield/ha at harvest (kg)	Dry fodder yield/ plant(g)	Dry fodder yield per ha (kg)
'Kananado'	4.10	140.0	125.6	4886.0	46.1	1756
'Dan Ila'	6.01	273.0	111.4	6150.0	44.6	2444
IT90K-59	9.83	465.0	114.5	6758.0	48.7	2814
IT89KD-374-57	10.17	443.0	88.8	5083.0	42.0	2236
IT88DM-867-11	4.17	168.0	116.8	6397.0	47.0	2390
IT86D-719	7.84	403.0	72.2	4859.0	29.1	1974
IT86D-715	7.60	355.0	82.2	4237.0	31.6	1684
IT89KD-391	10.88	372.0	145.8	7936.0	53.5	2830
IT90K-277-2	11.49	504.0	124.2	6520.0	48.8	2567
IT89KD-319	6.06	189.0	162.8	7080.0	60.7	2880
IT89KD-355	11.05	394.0	110.1	6997.0	46.8	2742
IT89KD-261-3	6.58	299.0	82.3	3915.0	31.8	1506
SE	6.18	204.4	57.54	3020.2	22.95	1052.7

SE = Standard error.

Appendix III Mean performance of cowpea genotypes under different crop management systems at Minjibir in 1994

Genotypes	Plant height				Days to 50% flowering				Number of Striga/plot at harvest			
	Spray		No spray		Spray		No spray		Spray		No spray	
	Sole	Intercrop	Sole	Intercrop	Sole	Intercrop	Sole	Intercrop	Sole	Intercrop	Sole	Intercrop
'Kananado'	42.60	46.27	38.27	41.50	84.00	84.00	84.33	84.33	0.67	1.00	0.67	3.67
'Dan Ila'	37.27	40.50	39.63	44.83	57.00	58.00	57.00	57.00	6.33	2.00	3.00	3.00
IT90K-59	35.93	45.67	37.07	41.20	41.33	41.33	41.33	41.00	0.00	1.00	2.67	0.00
IT89KD-374-57	33.47	35.47	29.80	37.97	43.67	42.67	44.00	43.00	2.33	2.00	3.33	1.33
IT88DM-867-11	32.40	35.90	31.33	36.73	44.00	44.00	44.67	44.00	0.67	2.33	2.00	0.00
IT86D-719	39.87	45.70	37.40	45.53	42.67	42.00	42.33	42.00	1.33	0.33	1.00	6.67
IT86D-715	40.10	46.40	36.30	42.43	41.33	42.00	41.33	42.00	12.33	3.00	13.33	10.00
IT89KD-391	45.77	49.00	36.77	42.67	48.00	48.00	48.00	48.00	2.00	4.67	1.67	6.00
IT90K-277-2	41.87	45.83	35.17	40.60	44.67	44.33	45.00	45.00	3.67	1.67	9.00	15.00
IT89KD-319	37.63	41.10	33.07	37.10	62.33	62.33	63.00	62.67	16.67	1.00	1.33	3.67
IT89KD-355	44.17	50.10	44.07	51.13	44.67	45.33	47.67	45.00	1.33	4.00	1.67	5.67
IT89KD-261-3	36.80	41.70	34.93	42.57	41.67	42.33	41.67	42.00	5.33	5.67	17.67	12.33

Appendix III (Continued)

Genotypes	Days to maturity				100-seed weight (g)				Number of seeds per pod			
	Spray		No spray		Spray		No spray		Spray		No spray	
	Sole	Intercrop	Sole	Intercrop	Sole	Intercrop	Sole	Intercrop	Sole	Intercrop	Sole	Intercrop
'Kananado'	109.33	108.33	36.67*	0.00*	19.27	22.67	7.60	0.00	8.30	9.23	2.77	0.00
'Dan Ila'	81.33	80.67	80.67	80.67	13.23	14.17	14.20	14.07	10.87	10.80	9.47	10.63
IT90K-59	69.00	69.33	68.67	69.00	13.27	12.77	13.27	13.20	10.57	10.07	10.30	10.30
IT89KD-374-57	72.67	69.00	73.00	73.00	13.60	13.93	12.87	13.57	9.57	9.23	7.97	9.23
IT88DM-867-11	73 33	73.67	73.33	73.33	15.07	15.27	14.70	15.53	9.00	8.70	7.77	9.90
IT86D-719	68.67	68.67	71.00	71.00	12.93	13.03	13.03	14.77	9.83	10.97	9.73	9.93
IT86D-715	69.67	69.67	68.67	68.67	13.27	13.50	13.43	13.43	10.13	8.63	9.87	9.17
IT89KD-391	77.33	78.00	77.33	77.33	15.67	15.93	14.80	15.37	10.50	11.13	10.17	12.13
IT90K-277-2	71.67	71.00	73.00	73.00	16.70	16.20	16.60	16.10	10.53	10.63	9.80	9.90
IT89KD-319	89.67	89.67	60.00*	60.00*	15.87	16.90	9.60	15.70	11.27	11.00	5.83	11.47
IT89KD-355	72.67	72.67	73.33	73.33	13.87	14.40	15.33	14.30	9.20	10.87	11.20	10.17
IT89KD-261-3	69.00	69.33	71.00	71.00	12.30	13.43	12.83	12.33	11.30	9.83	9.40	11.93

* = All the days to maturity values less than 65 mean that the genotypes concerned did not mature in some or all the replications.

Genotypes	Number of pods/plant												
	Spray		No spray		Spray		No spray		Spray				
	Sole	Inter-crop	Sole	Inter-crop	Sole	Inter-crop	Sole	Inter-crop	Sole	Inter-crop	Sole	Inter-crop	Sole
'Kananado'	14.29	13.67	3.21	0.00	12.61	15.30	3.87	0.00	56.40	86.6	124.8	266.0	22.9
'Dan Ila'	22.62	12.53	4.62	7.89	23.26	13.36	4.10	6.87	235.3	73.7	159.3	149.8	101.8
IT90K-59	23.63	10.06	11.80	9.87	29.03	12.29	10.31	10.41	66.4	157.4	148.0	77.6	28.7
IT89KD-374-57	40.94	10.43	11.13	4.93	35.27	9.56	9.30	4.88	92.5	143.7	120.7	86.5	30.1
IT88DM-867-11	15.63	6.13	4.78	5.00	16.45	5.58	4.40	4.84	57.7	181.8	200.0	67.5	48.2
IT86D-719	16.04	15.01	7.53	5.97	17.03	13.95	6.66	5.76	129.4	57.4	74.4	51.8	41.7
IT86D-715	23.34	12.27	10.25	8.54	24.00	11.01	9.15	7.13	144.6	68.8	124.7	168.7	52.7
IT89KD-391	39.57	28.15	6.51	5.03	42.96	32.98	6.05	5.01	257.0	103.7	245.8	112.1	90.1
IT90K-277-2	30.73	23.95	9.26	11.01	38.19	24.61	7.91	9.99	160.4	233.6	138.1	75.3	65.5
IT89KD-319	18.26	17.57	0.62	10.12	17.48	19.81	0.57	10.60	298.2	217.9	294.0	251.5	129.0
IT89KD-355	31.15	19.25	10.66	10.35	31.74	25.50	13.09	12.08	109.8	73.6	105.8	147.0	43.0
IT89KD-261-3	21.74	13.76	10.64	8.65	21.58	11.69	6.73	6.00	105.60	57.9	142.4	134.7	39.3

Appendix III (Continued).

Genotypes	Grain yield (kg/ha)				Fodder yield at harvest (kg/ ha)				Dry fodder yield (kg/ ha)			
	Spray		No spray		Spray		No spray		Spray		No spray	
	Sole	Intercrop	Sole	Intercrop	Sole	Intercrop	Sole	Intercrop	Sole	Intercrop	Sole	Intercrop
'Kananado'	521	379	166	0	2278	1719	4056	6481	856	917	1556	2148
'Dan Ila'	1359	423	160	219	13778	2422	8744	4907	5889	815	4167	1667
IT90K-59	1266	466	466	300	2806	5074	6639	2389	1206	2407	2878	874
IT89KD-374-57	960	329	530	234	2472	4722	7144	4611.0	889	741	3961	2219
IT88DM-867-11	687	189	200	166	2417	4963	8472	1833	1333	2000	3894	667
IT86D-719	841	409	358	282	7428	1893	3944	2074	2222	711	1667	844
IT86D-715	1049	334	498	239	7361	2000	7111	5222	2667	915	2750	1593
IT89KD-391	1483	963	303	223	8833	3093	13256	4907	3000	1485	4444	2111
IT90K-277-2	1796	710	539	332	7639	5444	8333	2796	3111	1889	3533	1111
IT89KD-319	769	452	26	267	12528	4719	13894	7044	5500	1556	6556	2878
IT89KD-355	1138	551	733	384	4722	1537	6444	4859	2111	707	2889	1778
IT89KD-261-3	1003	386	282	210	5083	1852	5367	4563	1778	563	1456	2133

Appendix IV. Mean performance of cowpea genotypes under different crop management systems at Mallam Maduri in 1994

Genotypes	Plant height				Days to 50% flowering				Number of Striga/plot at harvest			
	Spray		No spray		Spray		No spray		Spray		No spray	
	Sole	Intercrop	Sole	Intercrop	Sole	Intercrop	Sole	Intercrop	Sole	Intercrop	Sole	Intercrop
'Kananado'	60.07	76.17	68.60	71.00	0.00▲	0.00▲	0.00▲	0.00▲	75.00	47.00	68.33	57.67
'Dan Ila'	60.30	66.17	66.67	62.53	0.00▲	0.00▲	0.00▲	0.00▲	71.67	84.00	56.33	42.33
IT90K-59	73.27	78.23	76.73	68.87	44.67	44.33	44.33	46.67	8.67	10.33	19.33	3.00
IT89KD-374-57	60.93	60.67	67.33	64.33	44.00	43.00	43.33	43.33	47.33	48.67	54.67	33.00
IT88DM-867-11	62.90	65.13	55.37	60.80	35.00▲	51.33	52.67	34.67▲	39.00	40.33	39.33	26.00
IT86D-719	78.77	80.33	80.30	78.93	43.00	42.00	42.67	42.33	55.00	40.33	41.33	25.67
IT86D-715	70.27	75.03	77.27	76.33	42.00	42.33	42.33	42.33	53.67	41.67	54.00	34.67
IT89KD-391	83.60	80.50	82.27	80.10	0.00▲	0.00▲	0.00▲	0.00▲	57.00	62.67	51.67	57.67
IT90K-277-2	74.13	70.13	74.50	80.20	43.00	42.67	43.00	43.33	77.00	68.67	90.67	41.00
IT89KD-319	57.80	62.80	57.17	65.87	0.00▲	0.00▲	0.00▲	0.00▲	68.00	64.67	45.67	54.67
IT89KD-355	65.57	71.90	75.67	75.90	46.67	32.33▲	50.00	50.00	41.00	47.00	47.33	43.33
IT89KD-261-3	64.90	64.90	65.83	67.03	42.33	43.00	43.00	42.00	32.33	41.00	33.67	39.00

▲ = days to 50% flowering <40 do not mean that the concerned genotypes flowered earlier but that 50% of the plants did not flower in some or all replications.

Appendix IV (Continued)

Genotypes	Days to maturity				100-seed weight				Number of seeds per pod			
	Spray		No spray		Spray		No spray		Spray		No spray	
	Sole	Intercrop	Sole	Intercrop	Sole	Intercrop	Sole	Intercrop	Sole	Intercrop	Sole	Intercrop
'Kananado'	0.00*	0.00*	0.00*	0.00*	0.00	6.53	0.00	11.40	0.00	6.90	0.00	7.50
'Dan Ila'	0.00*	0.00*	0.00*	0.00*	0.00	0.00	0.00	6.87	0.00	4.30	0.00	5.90
IT90K-59	69.00	70.00	71.00	72.00	11.03	12.47	12.10	13.70	10.50	10.07	9.83	10.10
IT89KD-374-57	71.00	68.67	72.67	71.33	13.00	12.83	12.27	11.83	10.27	10.50	9.60	9.40
IT88DM-867-11	0.00*	0.00*	0.00*	0.00*	0.00	8.90	0.00	11.67	0.00	5.73	0.00	6.90
IT86D-719	71.00	69.67	70.00	68.67	11.77	12.40	11.97	13.10	10.70	10.50	10.37	10.77
IT86D-715	69.00	69.33	70.00	70.00	12.03	13.07	13.43	12.63	8.97	9.47	8.77	8.60
IT89KD-391	0.00*	0.00*	0.00*	0.00*	0.00	0.00	0.00	0.00	0.00	2.37	0.00	0.00
IT90K-277-2	70.00	70.67	73.67	72.33	15.97	9.13	15.37	11.10	9.20	8.23	7.17	6.13
IT89KD-319	0.00*	0.00*	0.00*	0.00*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IT89KD-355	74.00	48.00*	25.00*	24.33*	8.93	8.90	4.30	13.63	6.90	5.97	5.40	5.63
IT89KD-261-3	70.67	0.00*	71.33	24.33*	10.87	11.43	12.17	7.30	10.67	8.20	7.53	5.70

* = All the values less than 65 mean that the concerned genotypes did not mature in some or all the replications.

Appendix IV (Continued).

Genotypes	Number of pods/plant				Grain yield/plant (g)				Fodder yield at harvest/plant (g)				Dry fodder yield/ plant (g)			
	Spray		No spray		Spray		No spray		Spray		No spray		Spray		No spray	
	Sole	Inter-crop	Sole	Inter-crop	Sole	Inter-crop	Sole	Inter-crop	Sole	Inter-crop	Sole	Inter-crop	Sole	Inter-crop	Sole	Inter-crop
'Kananado'	0.00	0.67	0.02	1.15	0.00	0.29	0.01	0.75	104.5	135.3	71.6	159.5	40.6	52.6	25.8	47.4
'Dan Ila'	0.05	0.24	0.09	0.53	0.01	0.18	0.03	0.27	41.4	91.8	83.1	56.8	18.2	31.9	30.0	18.1
IT90K-59	6.69	8.28	4.17	5.66	4.97	5.69	1.72	4.22	154.2	131.4	102.4	78.3	60.6	51.1	28.6	45.8
IT89KD-374-57	9.13	9.07	4.36	6.24	6.17	8.55	2.61	5.05	73.2	49.3	96.3	48.3	29.7	36.7	38.6	28.4
IT88DM-867-11	0.03	1.77	0.00	1.93	0.04	0.78	0.00	1.31	77.1	120.1	140.7	89.5	26.3	59.7	41.5	44.2
IT86D-719	7.66	6.97	5.06	5.63	5.03	6.06	3.59	4.67	93.3	42.6	88.9	40.1	39.0	22.8	34.5	23.5
IT86D-715	5.74	3.95	3.26	2.48	3.67	2.38	1.76	1.71	44.9	19.0	52.1	34.7	21.0	13.2	20.8	17.2
IT89KD-391	0.00	0.13	0.00	0.00	0.00	0.07	0.00	0.00	117.3	83.4	102.2	145.1	38.9	28.6	37.0	51.2
IT90K-277-2	6.09	3.72	1.57	2.41	4.96	3.40	0.68	2.21	150.2	60.1	96.9	79.2	53.4	29.8	34.2	36.1
IT89KD-319	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	82.1	29.6	45.2	83.6	29.2	10.6	15.7	29.3
IT89KD-355	3.41	3.28	0.57	2.83	2.15	1.99	0.23	1.59	129.2	82.5	164.9	68.3	39.8	46.3	59.8	39.8
IT89KD-261-3	6.40	1.69	3.96	1.48	3.00	0.91	1.97	0.73	119.2	26.2	52.4	20.3	42.1	18.5	23.7	10.9

Appendix IV (Continued).

Genotypes	Grain yield (kg/ha)				Fodder yield at harvest (kg/ha)				Dry fodder yield (kg/ha)			
	Spray		No spray		Spray		No spray		Spray		No spray	
	Sole	Intercrop	Sole	Intercrop	Sole	Intercrop	Sole	Intercrop	Sole	Intercrop	Sole	Intercrop
'Kananado'	0.00	13.0	01.0	36.0	5764	5787	5194	7806	2250	2241	1917	2167
'Dan Ila'	01.00	10.0	02.0	14.0	3681	5130	7486	3056	1600	1778	2667	972
IT90K-59	477.0	331.0	188.0	223.0	14806	7500	10736	4111	6153	2972	3597	2426
IT89KD-374-57	567.0	377.0	266.0	283.0	7028	2278	9667	2741	2889	1704	3875	1611.0
IT88DM-867-11	02.00	43.0	0.00	61.0	8944	6648	13639	4259	2806	3306	4014	2102
IT86D-719	305.0	341.0	420.0	270.0	8611	2426	10167	2333	3653	1315	4056	1324
IT86D-715	344.0	100.0	178.0	95.0	4167	796	5278	1963	1972	556	2056	963
IT89KD-391	0.00	05.0	0.00	0.00	12264	4241	9889	7009	4069	1500	3556	2472
IT90K-277-2	291.0	167.0	71.0	129.0	10000	3037	10167	4741	3667	1509	3583	2130
IT89KD-319	0.00	0.00	0.00	0.00	8792	1204	3500	4880	3097	426	1223	1806
IT89KD-355	158	88.0	19.0	79.0	13528	3463	17889	3537	4139	1935	6319	2056
IT89KD-261-3	214.0	36.0	154.0	109.0	8722	1074	3583	1074	3167	759	1694	500

Appendix V Mean performance of millet intercropped with cowpea genotypes at Minjibir and Mallam-Maduri (1994)

Genotypes	Grain yield (kg/18m²)			Stalk yield (kg/18m²)		
	Minjibir	Mallam-Maduri	Over Locations	Minjibir	Mallam-Maduri	Over locations
'Kananado'	3.12	1.43	2.31	7.40	5.00	6.20
'Dan Ila'	2.92	1.31	2.12	7.53	4.93	6.23
IT86D-715	3.59	1.40	2.49	8.67	4.93	6.80
IT90K-277-2	3.43	1.42	2.43	7.90	4.33	6.12
IT89KD-374-57	3.01	1.24	2.13	7.35	4.88	6.12
IT89KD-391	3.09	1.46	2.27	7.93	4.73	6.33
IT88DM-867-11	3.25	1.48	2.37	7.73	4.27	6.00
IT86D-719	2.30	1.40	1.85	5.60	4.27	4.93
IT89KD-319	3.70	1.72	2.71	8.80	5.48	7.14
IT89KD-261-3	3.04	1.48	2.26	8.57	5.10	6.83
IT89KD-355	3.53	1.29	2.41	8.78	4.75	6.77
IT90K-59	3.64	1.81	2.72	8.29	5.17	6.73

Appendix VI Mean performance of cowpea genotypes by year and by pesticide spraying regime at Samaru

Characters	1994	1995	Spray	No spray
Plant height(cm)	32.35	30.31	31.78	30.88
Days to 50% flowering	30.6*	48.5	50.8	28.3*
Days to maturity	43.3*	71.8	82.0	33.1*
100-seed weight(g)	8.24	14.82	15.87	7.18
Number of seeds/pod	4.4	8.6	10.1	2.9
Number of pods/plant	7.7	10.5	16.3	1.8
Grain yield per plant (g)	6.08	10.62	14.89	1.81
Grain yield/ha(kg)	459	767	1093	133
Pod length (cm)	7.55	13.01	15.23	5.33
Fodder yield at harvest/plant (g)	47.3	43.5	17.3	73.6
Fodder yield at harvest/ha (kg)	3743	3649	1296	6096
Dry fodder yield per plant (g)	18.40	14.69	10.0	23.09
Dry fodder yield per ha (kg)	1444	1200	745	1898

* = Figures < 40 for days to 50% flowering and 70 for days to maturity are not due to earliness but to the fact that some genotypes did not flower or mature in some or all replications.

Appendix VII Mean performance of cowpea genotypes for 13 characters (combined over years at Samaru 1994 and 1995)

Genotypes	Plant height	Days to 50% flowering	Days to maturity	Number of pods/plant	Number of seeds/pod	100-seed weight (g)	Pod length (cm)	Grain yield /plant (g)
'Kananado'	32.9	44.6	72.3	16.3	7.5	16.4	12.8	21.2
'Dan Ila'	30.4	38.8	58.2	6.7	6.8	11.0	9.8	5.8
IT90K-59	29.4	46.6	60.8	8.3	7.0	11.7	10.7	6.7
IT89KD-374-57	25.8	37.6	55.9	7.8	5.3	11.2	8.9	5.3
IT88DM-867-11	28.9	40.2	51.3	8.3	5.4	11.5	10.8	6.3
IT86D-719	33.9	34.6	42.2	7.4	5.4	7.0	7.3	6.5
IT86D-715	31.0	36.5	66.3	8.6	7.5	11.9	10.0	8.0
IT89KD-391	38.9	36.3	47.6	9.7	5.3	10.7	9.9	7.6
IT90K-277-2	29.9	37.8	65.7	10.7	6.7	13.9	11.3	10.5
IT89KD-319	30.1	37.8	62.2	10.4	8.2	12.6	11.3	10.2
IT89KD-355	31.5	47.0	61.5	8.6	6.7	11.9	11.0	6.9
IT89KD-261-3	33.5	37.1	46.8	7.3	6.3	8.7	9.9	4.9
SE	4.1	4.6	18.00	3.45	1.6	3.8	2.5	3.5

SE = Standard error

Appendix VII (continued).

Genotypes	Grain yield per ha (kg)	Fodder yield at harvest/plant (g)	Fodder yield at harvest/ha(kg)	Dry fodder yield per plant (g)	Dry fodder per ha (kg)
'Kananado'	885.0	77.6	3763	31.7	1531
'Dan Ila'	528.0	35.1	3106	11.7	1021
IT90K-59	478.0	30.3	2496	12.5	990
IT89KD-374-57	521.0	33.7	3329	11.0	1076
IT88DM-867-11	566.0	37.5	3363	13.5	1212
IT86D-719	521.0	40.1	3820	14.9	1399
IT86D-715	702.0	47.2	4183	16.5	1490
IT89KD-391	682.0	68.5	5910	23.7	2010
IT90K-277-2	746.0	76.0	5482	24.8	1802
IT89KD-319	848.0	42.2	4039	17.8	1646
IT89KD-355	431.0	26.1	2037	10.6	809
IT89KD-261-3	445.0	30.8	2824	9.9	876
SE	185.1	24.2	1778.4	6.9	467.7

SE = Standard error

Appendix VIII Mean performance of cowpea genotypes by pesticide spray regime at Samaru in 1994 and 1995

Genotypes	Plant height				Days to 50% flowering				Days to maturity			
	1994		1995		1994		1995		1994		1995	
	spray	no spray	spray	no spray	spray	no spray	spray	no spray	spray	no spray	spray	no spray
'Kananado'	34.00	39.00	28.33	30.17	70.67	0.00	53.00	54.67	106.3	0.00	86.7	96.0
'Dan Ila'	30.67	30.83	29.00	31.00	53.67	0.00	49.33	52.00	92.0	0.00	78.7	62.0
IT90K-59	30.00	30.00	30.33	27.17	47.00	48.67	45.00	45.67	77.0	0.00	73.3	92.7
IT89KD-374-57	27.33	26.00	23.00	26.67	51.33	0.00	47.00	52.00	83.7	0.00	76.0	64.0
IT88DM-867-11	31.67	28.00	28.00	28.00	55.33	0.00	52.00	53.33	90.0	0.00	82.7	32.7
IT86D-719	35.50	33.00	32.83	34.33	52.33	0.00	51.33	34.67	90.3	0.00	78.3	0.00
IT86D-715	34.00	31.00	32.83	26.00	51.33	0.00	46.67	48.00	90.3	0.00	78.7	96.0
IT89KD-391	39.10	40.00	38.67	37.67	51.33	0.00	46.67	47.33	80.7	0.00	78.3	31.3
IT90K-277-2	29.67	31.67	29.00	29.33	50.67	0.00	48.33	52.00	85.0	0.00	0.00	79.0
IT89KD-319	32.33	30.33	31.67	26.00	53.67	0.00	48.67	48.67	81.7	0.00	73.	93.3
IT89KD-355	38.67	29.00	29.00	29.17	48.67	47.60	45.67	46.00	79.3	0.00	70.7	96.0
IT89KD-261-3	33.67	31.00	33.50	35.67	52.00	0.00	47.33	49.00	82.0	0.00	74.6	30.7

figures < 40 for days to flowering and < 70 for days to maturity are not due to earliness of the lines but to the fact that they did not flower or mature in some or all the plots.

Appendix VIII (continued).

Genotypes	100-seed weight (g)				Number of seeds per pod				Pod length (cm)			
	1994		1995		1994		1995		1994		1995	
	spray	no spray	spray	no spray	spray	no spray	spray	no spray	spray	no spray	spray	no spray
'Kananado'	21.83	0.00	20.23	23.40	10.43	0.00	11.23	8.37	18.05	0.00	17.96	15.02
'Dan Ila'	16.53	0.00	14.83	12.67	9.63	0.00	11.93	5.63	15.06	0.00	14.74	9.39
IT90K-59	14.67	0.00	12.40	19.63	8.13	0.00	11.80	8.13	14.08	0.00	14.51	14.08
IT89KD-374-57	16.93	0.00	13.60	14.07	7.37	0.00	9.13	4.57	13.44	0.00	13.60	8.35
IT88DM-867-11	15.90	0.00	16.10	13.83	6.40	0.00	10.20	5.03	13.86	0.00	14.60	14.89
IT86D-719	13.90	0.00	14.03	0.00	9.67	0.00	11.87	0.00	14.29	0.00	14.91	0.00
IT86D-715	14.80	0.00	15.90	17.03	10.50	0.00	11.67	7.83	13.86	0.00	13.66	12.37
IT89KD-391	17.87	0.00	17.67	7.13	7.91	0.00	11.13	2.27	16.88	0.00	17.32	5.22
IT90K-277-2	18.23	0.00	15.90	21.57	8.60	0.00	10.40	7.77	15.49	0.00	15.32	14.20
IT89KD-319	16.53	0.00	14.70	19.10	10.10	0.00	12.20	10.33	14.83	0.00	14.89	15.32
IT89KD-355	15.87	0.00	13.50	18.33	7.20	0.00	12.00	7.43	14.60	0.00	15.89	13.30
IT89KD-261-3	14.67	0.00	14.30	5.67	10.07	0.00	12.20	2.97	16.68	0.00	16.97	5.78

Appendix VIII (continued).

Genotypes	Number of pods /plant				Grain yield/ plant (g)				Fodder yield at harvest /plant (g)				Dry fodder yield/ plant (g)			
	1994		1995		1994		1995		1994		1995		1994		1995	
	spray	no spray	spray	no spray	spray	no spray	spray	no spray	spray	no spray	spray	no spray	spray	no spray	spray	no spray
'Kananado'	30.03	0.00	22.87	12.45	31.48	0.00	37.57	15.53	43.8	162.8	34.6	69.4	25.64	60.00	18.57	22.62
'Daa Ila'	12.38	0.00	11.99	2.59	7.92	0.00	12.53	2.69	11.0	51.0	11.9	66.4	6.67	18.19	4.23	17.69
IT90K-59	14.15	0.00	15.97	3.00	9.49	0.01	14.01	3.16	8.1	56.3	12.1	44.7	5.67	19.33	11.24	13.93
IT89KD-374-57	13.18	0.00	15.78	2.24	8.11	0.00	13.41	1.36	7.8	64.6	6.6	55.6	4.58	21.82	3.32	14.48
IT88DM-867-11	11.78	0.00	16.45	0.81	8.65	0.00	15.54	0.88	15.5	60.8	18.5	55.1	8.64	20.77	8.20	16.29
IT86D-719	10.25	0.00	19.33	0.00	8.88	0.00	17.29	0.00	8.0	55.0	25.2	72.3	5.61	20.80	12.51	20.67
IT86D-715	14.75	0.00	16.97	2.39	11.53	0.04	18.46	1.96	20.6	66.7	34.6	67.0	11.30	21.77	14.13	18.64
IT89KD-391	20.81	0.00	16.90	0.91	14.14	0.00	15.19	1.00	15.1	122.1	17.2	119.0	10.85	42.53	12.04	29.43
IT90K-277-2	17.63	0.02	20.09	4.89	16.11	0.01	22.40	3.62	23.0	127.1	23.3	130.6	14.97	39.60	10.59	33.90
IT89KD-319	15.83	0.00	17.79	7.96	14.67	0.00	17.90	8.05	17.3	94.6	20.9	35.9	10.15	34.28	13.23	13.34
IT89KD-355	11.50	0.00	19.16	3.90	7.37	0.00	17.29	2.93	5.3	48.8	13.3	36.9	3.49	15.92	11.67	11.23
IT89KD-261-3	12.25	0.00	13.80	3.01	7.46	0.00	9.92	2.16	8.3	41.7	12.7	60.1	4.22	14.78	8.46	12.13

Appendix VIII (continued).

Genotypes	Grain yield (kg/ ha)				Fodder yield at harvest (kg/ha)				Dry fodder yield (kg/ha)			
	1994		1995		1994		1995		1994		1995	
	spray	no spray	spray	no spray	spray	no spray	spray	no spray	spray	no spray	spray	no spray
'Kananado'	1452	0.00	1331	757.0	2161	8528	1250	3111	1250	3139	681	1056
'Dan Ila'	687	0.00	1212	215.0	967	4028	1111	6319	583	1431	403	1667
IT90K-59	719	1.00	931.0	262	622	5056	778	3528	431	1722	708	1097
IT89KD-374-57	772	0.00	1178	136	733	6000	583	600	431	2028	292	1556
IT88DM-867-11	706	0.00	1472	88	1267	5125	1764	5294	722	1750	764	1611
IT86D-719	862	0.00	1221	0.00	794	5653	1736	7097	556	2139	875	2028
IT86D-715	982	4.00	1663	160.0	1731	6322	3153	5528	917	2069	1444	1528
IT89KD-391	1277	0.00	1359	92	1375	9472	1528	11264	958	3278	1028	2778
IT90K-277-2	1244	1.00	1470	270	1692	9722	1556	8958	1111	3028	722	2347
IT89KD-319	1117	0.00	1508	766	1225	9500	1903	3528	722	3444	1083	1333
IT89KD-355	558	0.00	927	241	403	3664	889	3194	264	1208	792	972
IT89KD-261-3	628	0.00	946	205	700	3083	1181	6333	361	1111	792	1241

Appendix IX. Farmers' opinion on the performance of cowpea genotypes performance in comparison to farmers' local varieties (answer

Cowpea genotypes	Number of farmers inter-viewed	Rating of the genotype for general performance according to the farmers				Opinion about maturity			
		better	No diff-erence	poorer	No ans-wer	Prefe-rable	worse	No diff-erence	No ans-wer
IT86D-719	7	100	0	0	0	100	0	0	0
IT90K-59	7	100	0	0	0	71.43	0	28.57	0
IT89KD-374-57	7	85.71	14.29	0	0	85.71	0	14.29	0
IT90-277-2	7	100	0	0	0	85.71	0	14.29	0
IT89KD-391	5	80	20	0	0	80.0	0	20.0	0
IT88DM-867-11	5	80	20	0	0	80.0	20.0	0	0
IT86D-715	7	85.71	14.29	0	0	71.43	0	0	0
IT89KD-319	6	66.67	16.67	16.66	0	100	0	0	0
Dan Ila	6	50.0	0	33.33	16.67	50.0	0	0	50.0
Kananado	6	66.67	0	16.67	16.66	66.67	0	0	33.33
Breeding lines	51	88.24	5.88	5.88	0	84.31	1.96	13.73	0
Local checks (Dan Ila + Kananado)	12	58.33	0	25.00	16.67	58.33	0	0	41.67

Appendix IX. (continued).

Cowpea genotypes	Acceptability of the seed colour				Plant spacing option for planting these genotypes in next season			Effect of the genotypes on the associated cereal				
	positive	negative	no answer	confusion	more closely	same spacing	wider spacing	no answer	increase	decrease	no effect	no anwer
IT86D-719	85.71	0	14.29	0	28.57	57.14	14.29	0	71.43	0	14.29	14.28
IT90K-59	28.57	14.29	14.29	42.86	42.86	14.29	42.86	0	42.86	0	57.14	0
IT89KD-374-57	85.71	0	0	14.29	57.14	14.29	28.57	0	28.57	14.29	42.86	14.28
IT90-277-2	100	0	0	0	28.57	57.14	14.29	0	57.14	14.29	28.57	0
IT89KD-391	60	0	40	0	0	60	40	0	80	0	20	0
IT88DM-867-11	20	40	0	40	40	60	0	0	60	0	40	0
IT86D-715	57.14	0	28.57	14.29	57.14	42.86	0	0	85.71	14.29	0	0
IT89KD-319	100	0	0	0	0	50	50	0	33.33	0	66.67	0
'Dan Ila'	66.67	0	33.33	0	16.67	50	16.67	16.67	66.67	0	0	33.33
'Kananado'	83.33	16.67	0	0	16.67	0	83.33	0	50	0	50	0
Breeding lines	68.63	5.88	11.76	13.73	33.33	43.13	23.54	0	56.86	5.88	33.33	3.93
Local checks (Dan Ila + Kananado)	75.00	8.33	16.67	0	16.67	25.00	50.00	8.33	58.33	0	25.00	16.67

Appendix IX. (continued).

Cowpea genotypes	Grain production				Fodder production			Susceptibility to pest and disease		
	more	less	no diference	No answer	more	less	no difference	more	less	no difference
IT86D-719	85.71	14.29	0	0	28.57	71.43	0	28.57	57.14	14.29
IT90K-59	57.14	42.86	0	0	28.57	71.43	0	28.57	71.43	0
IT89KD-374-57	57.14	28.57	14.29	0	14.29	71.43	14.29	28.57	42.86	28.57
IT90-277-2	57.14	14.29	14.29	14.29	14.29	42.86	42.85	14.29	42.86	42.85
IT89KD-391	100	0	0	0	40	60	0	40	60	0
IT88DM-867-11	80	20	0	0	80	20	0	60	40	0
IT86D-715	57.14	28.57	14.29	0	42.86	42.86	14.29	28.57	42.86	28.57
IT89KD-319	50	50	0	0	66.67	33.33	0	66.67	33.33	0
'Dan Ila'	33.33	33.33	0	33.33	33.33	66.67	0	66.67	16.67	16.67
'Kananado'	33.33	16.67	0	50	100	0	0	50	33.33	16.67
Breeding lines	66.67	25.49	5.88	1.96	37.25	52.94	9.8	35.29	49.02	15.69
Local checks (Dan Ila + Kananado)	33.33	25.0	41.67	0	66.67	33.33	0	58.33	25.00	16.67

Appendix X. Farmers' opinions on saving cowpea seeds for planting during next season (answer in %)

Cowpea genotypes	Saving seeds for the cowpea test lines for planting next season			Saving farmers' cowpea local variety for planting next season, according to test line grown by the farmers		
	Yes	No	No answer	Yes	No	No answer
IT86D-719	28.57	71.43	0	42.86	57.14	0
IT90K-59	85.57	14.29	0	100	0	0
IT89KD-374-57	57.14	42.86	0	71.43	28.57	0
IT90-277-2	28.57	42.86	28.57	42.86	57.14	0
IT89KD-391	60	40	0	40	40	20
IT88DM-867-11	40	40	20	60	40	0
IT86D-715	14.29	42.86	42.86	28.57	57.14	14.29
IT89KD-319	100	0	0	83.33	16.67	0
'Danlia'	16.67	33.33	50	33.33	16.67	50
'Kananado'	16.67	33.33	50	50	50	0
Breeding lines	52.94	35.29	11.76	58.82	37.25	3.92
Local checks (Dan Ila + Kananado)	16.67	33.33	50.00	41.67	33.33	25.00

Appendix XI Questionnaire:

Farmer participatory evaluation of cowpea genotypes

1. Name of farmer
2. Address/village
3. Improved cowpea genotypes
4. How did you rate the improved I.I.T.A cowpea in comparison to your local 'Danwiri'
   a. Better
   b. Not different
   c. Poorer
5. If better, for which reason?
   a. Good germination
   b. Vigorous growth/good fodder production
   c. Early maturity
   c. Good grain production
6. Is the maturity of the I.I.T.A cowpea
   a. Preferable to the local?
   b. Worse than the local?
   c. Maturity makes no difference to the farmer
7. Does the improved I.I.T.A cowpea produce
   a. More grain than the local type?
   b. Less grain than the local type?
   c. About the same amount of the grain as the local?
8. Does the improved I.I.T.A cowpea produce
   a. More fodder?
   b. Less fodder?
   c. About the same amount of fodder?
9. In comparison to the local cowpea, the improved I.I.T.A cowpea
   a. Showed more pest and disease attack
   b. Showed less pest and disease attack

c. Had about the same amount of damage

10. The colour of the I.I.T.A improved cowpea seed was .....

Is this color acceptable ? (a) Yes (b) No

11. Will you save some of the seed of this year to plant in your farm next year ? (a) Yes (b) No

12. Now that you know how it grows, how would you plant it?

a. More closely

b. At the same spacing

c. At wider spacing

13. Did the I.I.T.A improved cowpea influence the yield of the associated cereal crops ? (a) Yes (b) No

If yes, did the cereal yield

a. Increase?

b. Decrease?

14. Will you keep your own seed to plant next year?

a. Yes

b. No

15. How did you find the taste of the cowpea?

16. In what form did you eat it?

17. What do you suggest for the improvement of this programme ?