THE EFFECT OF PLANT POPULATION AND ARRANGEMENT ON THE YIELD AND AGRONOMIC CHARACTERS OF SOME CULTIVARS OF COWPEA *[*vigna unguiculata (L.) w**alp.)**

BY

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THESIS CERTIFICATION

This thesis entitled *THE EFFECT OF PLANT POPULATION AND ARRANGEMENT ON THE YIELD AND AGRONOMIC CHARACTERS OF SOME CULTIVARS OF COWPEA (Vigna unguiculata (L.) Walp.)* by RAYMOND YARIDA MASSAM meets the regulations governing the degree of Master of Science (Agronomy) of Ahmadu Bello University and is approved for its contribution to scientific knowledge and literary presentation.

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Date June, 1982

DEPARTMENT OF AGRONOMY
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(PG.8MS/176/80-82/6)

DEDICATION

THIS WORK IS DEDICATED

TO

MY LATE BROTHER

GEORGE ALLEN YARIDA

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INTRODUCTION

Legumes are a large group of plants second only to cereals as a source of food to man and his animals. They belong to the family leguminosae, one of the largest families of flowering plants. Cowpea is one of the important legumes grown in Nigeria which belongs to the sub-family paplionaceae. Three distirct groups of cowpea are in cultivation in Nigeria; the Catjang cowpea (*Vigna unguiculata* (L.) Walp.), the common cowpea (*Vigna sinensis* (L.) ex Hassak.) and the yardlong bean (*Vigna sesquipedalis* (L.) Fruw.) (Cobley and Steele, 1977; Purseglove, 1978).

In a country like Nigeria where cereals, root and tuber crops are the dominant staple food in the face of costly and short supplies of meat and fish, people are likely to suffer from deficiency of protein. Cowpea offers a great possibility for meeting this urgent need for food protein. However, because of low production and high demand, cowpea is sold at high prices and tended to limit the ability of a large proportion of Nigerians to ordinarily consume cowpea in their homes.

The annual production of cowpea in Nigeria is about 75,000 metric tonnes from 2.2 million hectares (Anon., 1973) with an average yield of 214 kg/ha. This production is very low

and so supply does not meet demand and thus the high cost. There is thus the need to increase the production of this crop in the country.

FACTORS AFFECTING YIELD

The low yield which characterise the production of cowpea in Nigeria are attributed to among other reasons, low plant density and poor crop management, particularly crop protection (Ojehomon, 1970; Steele, 1972). Striking yield increases have been obtained by controlling pests and it is now known that in order to obtain good yields from sole crops of cowpea the control of pests is imperative (Taylor, 1973; William, 1975; Raheja, 1976).

Three types of cowpea are generally grown in the country: spreading, semi-erect and erect types. Unimproved cultivars are generally prostrate or trailing,adapted to local conditions but invariably of low yield potential. In contrast, the primary characteristic of improved cowpea cultivars generated by the various breeding programmes is that their potential yield is significantly greater. Perhaps the most important attribute of improved cowpeas that makes them amenable for easy manipulation in the attempt to increase yield, apart from the exploitation of their genetic potential (for example by sound fertilization programmes)

is the erect or semi-erect habit of the plant. The spreading, semi-erect and erect cultivars respond differently to various agronomic practices, particularly spacing. Local cultivars which are mostly spreading types generally do not respond to high plant densities whereas, the improved erect and semi-erect cultivars do respond (Ojehomon and Bamiduro, 1971; Haizel, 1972; Steele, 1972).

It is not only high plant population which contributes to high yields, but also the way the plants are arranged. Ojehomon and Bamiduro (1971) have reported that erect cultivars respond best to rectangular arrangement, whilst semi-erect types respond best to square arrangements. Till now there is no specific recommendation for optimum plant population and inter- and intra-row spacings for the cowpea cultivars grown in the country.

OBJECTIVES OF THE PROJECT

Not much work has been done on cowpea plant arrangement in Nigeria, and particularly in northern Nigeria. There is, therefore, the need to conduct research on these aspects to make different spacing recommendations for the cowpea instead of recommending the same inter- and intra-row spacings for all types as seems the case at present.

This investigation was, therefore, conducted with the following objectives:

i) To determine the optimum plant population range for different types of cowpea which can give maximum grain yield per unit area.

ii) To find the best plant arrangement for the different types of cowpea.

iii) To observe how grain yield and various agronomic characters of cowpea are influenced by the varying plant population and different arrangements.

REVIEW OF LITERATURES

Agronomic studies on cowpea have been carried out in different parts of the world. The available literature on the effect of plant density and plant geometry on the yield and yield components of legumes in general and cowpea in particular is reviewed.

EFFECTS OF PLANT POPULATION ON PLANT GROWTH

Plant density plays an important role in increasing or decreasing the yield of a crop per unit area of land. For highest yield, optimum plant density is essential. An increase or decrease in plant population beyond the optimum does not help in getting higher yield from a unit area of land. Increasing yield of an individual plant by decreasing plant population below a certain specific density does not compensate for the loss due to diminished population, and increasing plant density above a certain limit makes individual plants too weak to produce normal yield.

In general, the yield of a crop plant increases with increase in plant population. When biological yield (total dry matter) is considered, it increases with an increase in density, reaches a maximum and remains constant even with further increase in density, following asymptotic curve (Willey and Heath, 1969).

However, when seed or reproductive yield is considered, a parabolic shape is obtained, i.e. yield increases with increase in density and reaches a maximum, beyond which further increase in density leads to a decline in seed yield (Holliday, 1960; Mitchell, 1976). The decrease in yield after reaching maximum density is attributed to the effect of competition between the plants at higher population.

Plant competition is a natural phenomenon in which plants growing in close proximity develop at the expense of others in the utilization of space, light, nutrients and moisture. Plants show extreme "plastic behaviour" particularly in size and form in response to environmental conditions. At lower than recommended density, mean plant height is reduced and branching is more profuse. At higher densities rather weed suppression occurs under more close canopy, but the risk of lodging is increased because high densities give rise to longer internodes and hence weaker stems. However, plants make wide adjustments to available space producing more or less similar yields over a considerable range of plants per unit area of land (Weber *et.al.*, 1966; Wilcox, 1974).

EFFECTS OF PLANT POPULATION ON SEED YIELD

All other conditions being equal, the optimum density for seed yield in a particular cultivar should be about the same irrespective of where it is grown. However, variations in the climatic and soil conditions of a place plus the degree of attack from insects, pests and diseases do cause differences from country to country or even in the same country as well as at the same locations.

COWPEA

Not much work has been done on the effect of population density on the yield of cowpea. The little work done seems to show a lot of variations between countries and even within a country at different locations.

Ezedinma (1965a) from southern Nigeria and Yayock and Asenime (1977) from northern Nigeria have reported that trailing cultivars fail to give yield increases at high plant population. According to Ezedinma (1965a), the lack of response was due to lack of their tertiary shoots to set pods and the indeterminate growth habit which results in a simultaneous vegetative and reproductive growth resulting in a constant exhaustion of the available photosynthate which in turn affected pod setting. Working with both erect

and spreading cultivars, also in Nigeria, Steele (1972) observed that the spreading types do not generally respond to population increases beyond 63,000 plants/ha. This he said was due to the ability of the spreading cultivars to compensate for the low population by spreading profusely.

Results in Uganda have shown that optimum plant density for high grain yield is between 26,000 - 50,000 plants/ha (Rubaihayo *et al.*, 1973), whereas in Tanzania, a population of 120,000 plants/ha has been reported as optimum (Enyi, 1973a). Erskine and Khan (1976) in Guinea reported no agronomic optimum for plant density but the increase from 100,000-250,000 plants/ha did not significantly increase grain yield. They concluded that it would be uneconomical to grow cowpea at above 100,000 plants/ha. Ojehomon (1970) working on the recommended 0.90 x 0.30m spacing in Nigeria found that yields were sub-optimal and suggested that higher densities may increase yields subsequently. Ojehomon and Bamiduro (1971) reported from southern Nigeria that higher yields resulted from increasing the plant density of both erect and semi-erect types up to 87,000 plants/ha. Remison and Okunariwo (1979) in the Southern Guinea savanna zone of Nigeria found the optimum population to be 83,000 plants/ha for Ife Brown and between 111,000-161,000 plants/ha for the variety New Era.

The result of the experiment carried out in Samaru by the Institute for Agricultural Research on plant density showed an increase in yield up to 80,000 plants/ha with erect cultivars (Anon., 1980).

Some workers have found yield reductions in grain legumes with increasing density (Erskine and Khan, 1976; Crothers and Westermann, 1976; Westermann and Crothers, 1977). Reduction of yield and its components at high densities may be due to density induced mortality as reported for *Vigna unguiculata* (Erskine and Khan, 1976).

A high plant population can be achieved by narrowing either the inter-row or the intra-row spacings. Since cowpea cultivars vary in their growth habit from erect bunch to the spreading types, the effect of mutual shading, carbon dioxide movement as well as incidence and spread of plant diseases may vary widely depending on the growth habit of the cultivar. Ezedinma (1965a) and Haizel (1972) have suggested that the erect bush habit is more efficient for grain production than the trailing indeterminate habit, because the former has a high pod-to-stem ratio, little tendency to perenniality and even pod ripening. The high production by erect cultivars may be due to better water and nutrient utilization as a result of less evapotranspiration or due to greater absorption of radiant energy.

EFFECTS OF PLANT POPULATION ON YIELD COMPONENTS

Grain yield in cowpea is a product of the number of flowering inflorescences initiated, the number of pods set per flowering inflorescence, and the number and weight of seeds per pod (Enyi, 1974). The highest seed yields are obtained when all these are maximised and density induced mortality allows the full expression of these characteristics (Westermann and Crothers, 1977). In dense stands autoregulation might operate to bring plant size and number into equilibrium.

In a study to compare the vegetative growth, development and seed yield of cowpea, Ojehomon (1970) found that the cultivars that had the highest flower buds (New Era) also had the highest flower bud and immature fruits abscission. He, therefore, concluded that it is highly unlikely that breeding for higher number of flower buds per plant would achieve higher yields.

In Ghana Haizel (1972) noted that at high plant densities cowpea produced fewer pods. The work of Remison and Okunariwo (1979) confirmed this as they reported that the number of pods per plant, seeds per pod and seed yield decreased at high densities in 1976 although there was stabilization of yield and components of yield over a wide range of density treatments in 1972.

However, Erskine and Khan (1976) reported that pods per plant and lateral branch development decreased, but seed number per pod increased with increasing plant population.

EFFECTS OF PLANT ARRANGEMENT ON SEED YIELD

Yield per unit land area is not dependent only on the number of plants per unit area, but also on the spatial a arrangement of the plants or in other words "plant rectangularity". Plant rectangularity can be better visualised in row crops and defined as the ratio of the distance between plants within the row to the distance between the rows. Studies have demonstrated that maximum yields result when plants approach equidistant spacings. Reynolds (1950) on peas, Donovan *et al* (1963); Weber *et al.* (1966) on soybean, Crothers and Westermann (1976) on snap bean observed that within a given population level, seed yield increased as the inter-row spacings approached a uniform distribution pattern.

Very little work has been done on planting configuration with cowpea. In most of the cases only rectangular arrangements were used. Square and rectangular arrangements have not been compared. Haizel (1972) working in Ghana with a spacing of 22.5 x 22.5 cm, 45 x 45 cm, 90 x 90 cm, 90 x 22.5 cm, 45 x 90 cm, and 45 x 22.5 cm found that square arrangements

MATERIALS AND METHODS

EXPERIMENTAL SITE

The experiments were carried out in 1980 and 1981 on fields Z5 and S4F of the Institute for Agricultural Research (I.A.R.) farm at Samaru (11^{o} 11'N, 7^{o} 40'E and 685 M above sea level) in the Northern Guinea Savanna zone. The climatic and soil conditions as well as the cropping history of the two plots used for the investigations are presented in Tables 1, 2 and 3.

PLANT POPULATION

Four plant populations (40,000, 65,000, 90,000 and 115,000 plants/ha) were tried. In the second year an additional population of 140,000 plants/ha was included as a side observation.

PLANT ARRANGEMENT

For each plant population, one square and three rectangular arrangements were tested. The square arrangements 50 x 50 cm, 39 x 39 cm, 33 x 33 cm and 30 x 30 cm corresponded to the plant populations of 40,000, 65,000, 90,000 and 115,000 plants/ha, respectively.

Three rectangular arrangements with fixed inter-row spacings of 90 cm, 60 cm, and 30 cm were used.

In case of 115,000 plants/ha, instead of 30 cm an inter-row spacing of 36 cm was used. The intra-row spacing to give the approximate required plant population/ha were computed in each case (Table 4).

Table 2. The Physical and Chemical Properties of the Soil from the Experimental Site.

Soil Properties	Characteristics	
	Field 75	Field S4B
Effective CEC	6.65	4.25
Textural Class	SL to Lms	SL to Lms
Total N %	0.056	0.045
Available N (ppm)	131.4	105.6
Total P (ppm)	4.2	2.45
pH in H_2O	5.4	5.2
Organic carbon %	0.245	0.098

SL = Sandy loam
LMS = Loamy sand.

Table 3. Cropping History of Fields 75 and S4B used for the investigation

Year	Crops grown in Plots	
	75	S4B
1974	Sorghum	Cotton/Sorghum
1975	Groundnut	Cotton
1976	Maize	Fallow
1977	Groundnut	Fallow
1978	Sorghum	Fallow
1979	Cowpea	Fallow
1980	Cowpea	Fallow

Table 4. Spacing Arrangements Used for the Various Plant Populations.

Spacings (cm)		Approximate number of plants/ha
Inter-row	Intra-row	
90	28	40,000
60	41	
30	83	
50	50	
90	17	65,000
60	25	
30	50	
39	39	
90	12	90,000
60	18	
30	36	
33	33	
90	10	115,000
60	15	
36	25	
30	30	

CULTIVARS

The three test cultivars were Ife Brown, Accession 355, and Accession 1696. Ife Brown (C_1) is a cultivar developed by the Institute for Agricultural Research, Samaru and the University of Ife. It is an erect cultivar with brown seed coat. It is day neutral and takes 3 - 3½ months to mature. Accession 355 (C_2) is derived from crosses between Ife Brown and New Era progenies. It is an erect cultivar with a brown seed coat. It is day-neutral and takes 3 - 3½ months to mature. Accession 1696 (C_3) is a local selection which spreads and is photoperiod-sensitive. It has a white seed coat. Its maturity time varies from 2-5 months depending on the time of the year it is planted.

EXPERIMENTAL LAYOUT

The investigations were carried out using a strip block design with 48 treatments (4 arrangements x 4 populations) x 3 cultivars. Treatments were replicated three times giving a total of 144 plots (Fig.1). The size of each gross plot was 5 x 3m. Yield data were collected from plots measuring 3 x 2m, while other observations were carried out on the remaining stands within each plot.

CULTURAL OPERATION

LAND PREPARATION:

The experimental area was ploughed and harrowed before laying out the experiment. Each of the plots was then hand-levelled to get a uniform surface for sowing on the flat.

FERTILIZER APPLICATION:

27 kg P_2O_5/ha (150 kg/ha single superphosphate) was uniformly spread and mixed into the soil just before sowing in all the plots.

SOWING:

Inter- and intra-row spacings were marked out according to the plan (Fig.1). Two seeds were sown per hole and seedlings thinned to one plant per stand at three weeks after germination. In 1980, seeds were sown on 8 July, while in 1981 sowing was done on 15 July. Five additional plantings (July 8, 15, 22, 29; August 5, 13) were done in 1981 trial but only in respect of Accession 1696. The purpose of planting this cultivar on several dates was to ensure that it fruited in view of its photoperiodic-sensitivity.

PLANT PROTECTION

The experimental plots were hand-weeded twice in 1980 and once in 1981 to reduce competition from weeds. From five weeks after germination the crop was regularly sprayed at fortnight intervals using mixture of Dithane M45 and Benlate at the

Table 1. Weather Records During the Experimental Periods and 10 Year Mean Weather Conditions at Samaru
Latitude 11° 11'N.

Month	Total rainfall (mm)		Ten Year mean Rainfall (mm)	Mean Max. temp. (air) °C		Mean Min. temp. (air) °C		Mean Temp. (ten years)	Sunshine hrs		R.H. % 8 a.m.		R.H. % 4 p.m.		Mean RH (ten years)	Mean wind speed km		Mean pan evap. (mm)	
	1980	1981		1980	1981	1980	1981	°C	1980	1981	1980	1981	1980	1981	R.H.	1980	1981	1980	1981
June	116.4	53.0	162.4	30.4	33.0	19.8	21.4	25.5	8.3	8.9	74.0	71.5	56.9	45.9	64.3	193.2	204.67	7.8	9.7
July	267.4	84.3	226.8	28.8	28.8	19.0	19.8	23.8	6.5	6.8	81.3	82.1	69.5	67.9	70.2	178.3	169.21	6.3	6.5
August	214.6	280.6	280.0	28.7	28.4	19.4	19.5	23.8	6.1	6.5	83.4	82.4	67.8	67.9	75.6	112.6	127.4	5.4	5.8
Sept.	79.9	133.3	226.4	30.7	30.1	19.5	19.4	24.2	7.6	7.7	75.5	76.4	62.6	65.2	69.2	91.57	113.8	5.9	5.4
Oct.	16.3	0.0	38.8	32.0	32.5	18.9	17.3	24.8	8.7	8.7	66.2	60.1	43.9	47.7	51.1	130.46	85.15	6.9	5.8
Nov.	0.0	-	1.1	28.5	29.1	19.7	14.2	23.6	9.3	7.1	21.3	23.6	17.5	21.7	25.5	141.67	142.0	8.7	9.4

rates of 2.5 kg and 0.6 kg/ha, respectively for the prevention and control of fungal diseases. They were also sprayed with cypermethrin (cymbush) at the rate of 2.5 litres/ha (ULV spray) to control insects, beginning immediately after flower initiation until the plants started drying.

HARVESTING

Four pickings were carried out in cv. Ife Brown and cv. 355 to avoid shattering. Cultivar 1696 failed to bear any seed in both years and hence there was no picking.

OBSERVATIONS

The following observations were recorded in all the cultivars in accordance with the procedures outlined. Unless it is specified to the contrary, all measurements were based on five randomly selected plants per plot. In 1981 measurements were restricted to only plant height and number of vegetative branches.

Plant height: Was measured from ground level to the tip of the longest branch.

Number of branches: Only those branches arising from the main stem were counted.

Leaf number: All open leaves on a plant were counted.

Leaf area: A comparison of the dry weight of the leaves on the plant to the weight of a known area of a sample of the leaves was used to compute the area of the leaves. This was done by using a round borer of a known diameter to bore a fixed number of randomly selected leaves from each sample. They were then oven-dried to a constant weight. Total leaf area was then calculated from the formula:-

$$L.A. - = \frac{W \times X}{w}$$

where L.A. = Total leaf area (cm^2)

W = Total leaf dry weight (g)

w = Dry weight of sample (g)

X = Leaf area of sample (cm^2)

Total dry matter: The oven dry-weight of the whole plants were recorded.

Number of peduncles per plant: This was counted at maturity, just before first picking of pods.

Number of pods per peduncle: This observation was made on 50 peduncles from 10 plants (5 from each plant) just before first picking.

Number of seeds per pod: The number of seeds from 50 randomly drawn pods from each plot was counted.

One Thousand(Test Weight): 1000 seeds were randomly drawn from each plot harvest and weighed.

Seed weight per unit area: From the yield obtained from the plots of a known net area (3 x 2m) the seed weight per hectare was determined after threshing and winnowing the produce from the entire net plot.

Statistical Analysis

The data collected were subjected to statistical analysis as described by Snedecor and Cochran (1967). The least significant difference was used for the comparison of treatment means. The Reciprocal Equation as described by Willey and Heath (1969) was used to estimate the optimum population density for each of the cultivars. The formula used was:

$$1/y = a + bp + cp^2$$

where y = yield/plant

a, b and c = Regression constant

p = population per unit area.

From this formula optimum population is calculated from the formula: $P = \sqrt{a/c}$

P = optimum population

a & c = Regression constants.

RESULTS

VEGETATIVE GROWTH AND DEVELOPMENT

PLANT HEIGHT:

Cultivar differences in plant height were significant in both years and the mean of the two years (Table 5 Figs.2 (a) and 3(a)). It is evident that 1606 was significantly much taller than the other two cultivars (Ife Brown and 355) which were similar in both years.

From Table 6 it is evident that plant population affected plant height significantly only in 1981. During that year the lowest population (40,000 plants/ha) which was similar to 65,000 plants/ha produced significantly taller plants than the two higher populations of 90,000 and 115,000 plants per hectare. Figs. 2(b) and 3(b) do not show any marked difference due to population density.

Different plant arrangements did not affect the plant height significantly in any of the two years. However, the tallest plants were produced in square arrangements during both years (Tables 7, Figs.2(c) and 3(c)). None of the treatment interactions exerted a significant influence on plant height.

Plant height was found to be positively but not significantly correlated to seed yield/ha in 1980 but positively and significantly correlated to seed yield/ha in 1981.

NUMBER OF BRANCHES PER PLANT:

Cultivar differences in the number of branches per plant were significant in 1980 and the mean of the two years, but not in 1981 (Table 5). In 1980, cv. 1696 being at par with cv. Ife Brown was significantly superior to cv. 355. In the mean of the two years cv. 1696 was significantly superior to the other two cultivars. Cv. Ife Brown was also superior to cv. 355. Fig.4 (a) shows that cv. Ife Brown and cv. 355 were slow in producing branches during early growth period (up to 66 days), but were faster in latter period (66-80 days). Performance of the three cultivars was almost the same in 1981 (Fig.5(a)).

Plant population affected the number of branches per plant significantly in 1981, but not in 1980 and the mean of the two years. In 1981, maximum and minimum number of branches were produced in 40,000 and 115,000 plants per hectare respectively. The effects of 65,000 and 90,000 plants/ha were similar to 40,000 and 115,000 plants/ha (Table 6). From Figs. 4(b) and 5(b) it can be seen that more branches were formed in shorter period in 1981 than in 1980.

The different spacing arrangements affected branching of the cultivars only in the mean of the two years (Table 7). Square arrangements produced higher numbers of branches than others though significantly superior only to 60 cm arrangement. Superiority of square arrangement can also be seen in Fig.4(c).

Plant population and spacing arrangement interaction were not significant for number of branches per plant.

The interaction between plant population and cultivar in respect of number of branches per plant was not significant in all cases. Number of branches per plant was significantly affected by spacing arrangement and cultivar in 1981, but not in 1980 nor the mean of the two years. In 1981, cv.1696 with square and 30cm arrangements produced significantly more branches than other combinations (Table 9).

The plant population, spacing arrangement and cultivar interactions were not significant in both years and the mean of two years.

Number of branches per plant was positively correlated with seed yield/ha in both years but significant only in 1981.

NUMBER OF LEAVES PER PLANT:

Number of leaves per plant were counted only in 1980. The different treatments and their interactions were not significantly effective in influencing the number of leaves per plant. However, cv. 1696 produced many more leaves per plant than the other two cultivars in the different treatment combinations.

The number of leaves per plant at 80 days after sowing was positively but not significantly correlated with seed yield/ha.

TOTAL LEAF AREA PER PLANT:

Cultivar differences in total leaf area per plant was significant (Table 5). The total leaf area for cultivar 1696 was significantly superior to the other two. Cultivars Ife Brown and 355 were similar in total leaf area.

Plant population affected total leaf area significantly. The lowest and highest plant population being at par, significantly produced more leaf area than the other two populations. However, 65,000 plants/ha was significantly better than 30,000 plants/ha (Table 6).

From Table 7, it is evident that spacing arrangement significantly affected total leaf area per plant. Square arrangement being at par with 60 cm were significantly better than 90 and 30 cm arrangements. The 90 cm was significantly superior to 30 cm arrangement.

Total leaf area per plant had been significantly affected by plant population and arrangement interactions (Table 8). The 60 x 15 cm arrangement with 115,000 plants/ha being at par with 50 x 50 cm with 40,000 plants/ha. produced significantly more leaf area per plant than all other arrangements.

Total leaf area per plant was not significantly affected by plant population and cultivar interactions.

Total leaf area per plant was not affected by spacing arrangement and cultivar interactions. However, cv.1696 had more leaf area followed by cv. Ife Brown in all arrangements except the square arrangement where cv.355 was next to cv.1696 (Table 9). The three factor interactions of plant population, spacing arrangement and cultivar was not significant.

WEIGHT OF LEAVES:

Cultivar differences in dry weight of leaves was significant. Cultivar 1696 produced more dry weight of leaves than cultivars Ife Brown and 355. Cultivar Ife Brown and cv.355 were at par (Table 5).

Plant population, spacing arrangement as well as all the treatment interactions did not affect dry weight of leaves significantly.

TOTAL DRY MATTER:

Except plant arrangement and cultivar interaction, all the treatments and their interactions did not affect total dry matter significantly.

Table 9 has clearly shown that the interaction between spacing arrangement and cultivar was significant. The interaction between the different plant populations and spacing arrangements produced the highest dry matter with 60 cm arrangement with cultivar 1696 though similar with 90 and square arrangements with cultivars 1696 and Ife Brown respectively. The lowest dry matter per plant was produced by 60 cm arrangement with cv.355.

YIELD COMPONENTS AND YIELD

Cultivar 1696 failed to produce pods in both years. Therefore, yield components and yield data were recorded only for Cv. Ife Brown and Cv.355.

NUMBER OF PEDUNCLES PER PLANT

Though cultivar Ife Brown produced more peduncles per plant than cv.355 in both years and their mean but the differences were not significant.

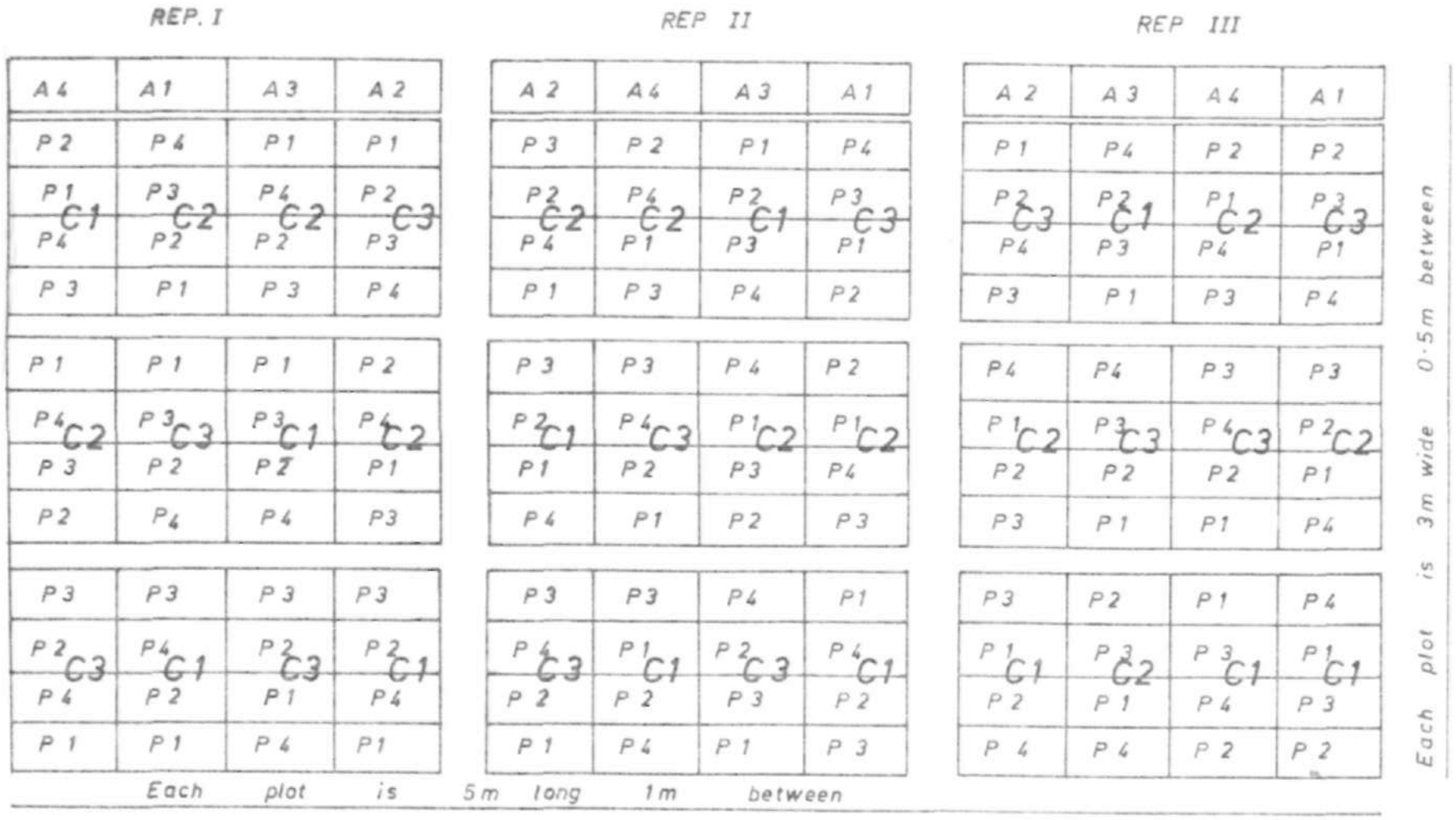


Fig:1: Field layout of the experimental plots.

KEY

C_1 = Ife Brown	A_1 = 90cm Inter-raw spacing	P_1 = 40,000 plants ha^{-1}
C_2 = 355	A_2 = 60cm " " "	P_2 = 65,000 " "
C_3 = 1696	A_3 = 30 cm " " "	P_3 = 90,000 " "
	A_4 = Square " " "	P_4 = 115,000 " "

Table 5. Mean Performance of Three Cowpea Cultivars as measured by various Vegetative Characters at Samaru, 1980 and 1980

Cultivar	Height of Plant (cm)			Number of Branches per plant			Number of Leaves per plant	Total Leaf area per plant(cm^2)	Dry weight of leaves (g)
	1980	1981	Mean	1980	1981	Mean	1980	1980	1980
Ife Brown	51.3	56.3	53.8	2.8	3.6	3.2	31.6	5766	387.9
355	38.9	40.6	39.8	2.4	3.1	2.7	25.9	4932	348.2
1696	96.4	143.9	120.2	3.4	4.6	3.9	67.5	8595	602.9
S.E.(+)	5.1	8.1	2.2	0.2	0.4	0.2	8.8	322.0	20.5
L.S.D.	19.8**	16.6**	10.29**	0.9	N.S.	0.4**	N.S.	1826.2*	116.7**

N.S. = Not significant.
S.E. = Standard Error
L.S.D. = Least significant difference
* = Significant (P = 0.05)
** = Highly significant (P = 0.01)

Table 6. Mean Effect of Plant Population as measured by various vegetative growth characters of three cowpea cultivars at Samaru; 1980 and 1981

Plant Population ('000/ha)	Height of Plant (cm)			Number of Branches per plant			Total Leaf area per plant (cm^2)
	1980	1981	Mean	1980	1981	Mean	1980
40	58.3	89.4	73.8	2.8	3.9	3.7	6945
65	68.7	82.9	75.5	2.7	3.8	3.3	6129
90	54.5	74.7	64.6	3.0	3.7	3.4	5497
115	67.4	74.7	71.1	2.9	3.4	3.1	7151
S.E.	4.2	4.5	4.9	0.2	0.2	0.2	135.3
L.S.D.	NS	9.6	NS	NS	0.47*	NS	390.6

NS = Not significant
S.E. = Standard Error
L.S.D. = Least significant difference
* = Significant (P = 0.05)
** = Highly significant (P = 0.01).

Table 7. Mean Effect of Plant Arrangement as measured by various vegetative growth characters of three cowpea cultivars at Samaru; 1980 and 1981.

Plant Arrangement	Number of Branches per plant			Number of leaves per plant	Total Leaf area per plant (cm^2)
	1980	1981	Mean	1980	1980
90	2.7	3.5	3.2	41.0	6278
60	2.5	3.5	3.0	41.1	6793
30	2.9	3.9	3.4	37.9	5617
Square	3.3	3.9	3.6	46.7	7032
S.E.(±)	0.2	0.2	0.2	4.7	135.3
L.S.D.	N.S.	N.S.	0.5**	N.S.	390.6**

N.S. = Not significant
S.E. = Standard Error
L.S.D. = Least significant difference
* = Significant (P = 0.05)
** = Highly significant (P = 0.01).

Table 8. Mean effect of Plant Population and arrangement as measured by Total Leaf area per plant, of the three cowpea cultivars at Samaru, 1980 and 1981

Plant Population ('000/ha)	Spacing Arrangement	Total Leaf area per plant (cm^2) 1980
40	90 x 28	6863
	60 x 41	7092
	30 x 83	5608
	50 x 50	8218
65	90 x 17	6088
	60 x 25	5676
	30 x 50	6412
	39 x 39	6339
90	90 x 12	5186
	60 x 18	5578
	30 x 36	5176
	33 x 33	6049
115	90 x 10	6974
	60 x 15	9825
	36 x 25	5272
	30 x 30	7533
	S.E. (±)	429.3
	L.S.D.	1239.7**

N.S. = Not significant
S.E. = Standard Error
L.S.D. = Least significant difference

* = Significant (P = 0.05)
** = Highly significant (P = 0.01)

Table 9. Mean Effect of Plant Arrangement and Cultivar as measured by various Vegetative Growth Characters of three Cowpea Cultivars at Samaru, 1980 and 1981.

Plant Arrangement	Cultivars	Number of Branches			Total dry matter (g) 1980
		1980	1981	Mean	
	Ife Brown	2.6	3.4	2.9	651
90	355	2.3	3.2	2.7	589
	1696	3.4	4.4	3.9	948
	Ife Brown	2.8	3.1	2.9	703
60	355	1.7	3.5	2.6	445
	1696	2.9	3.9	3.5	1166
	Ife Brown	2.8	4.1	3.6	626
30	355	2.8	2.9	2.8	676
	1696	3.3	4.9	4.1	807
	Ife Brown	3.1	3.9	3.5	941
Square	355	2.8	2.7	2.8	827
	1696	3.9	5.1	2.5	889
	S.E.(±)	0.4	0.5	0.35	92.4
	L.S.D.	NS	1.0*	NS	257.5*

NS = Not significant
S.E. = Standard Error
L.S.D. = Least significant difference
* = Significant (P = 0.05)
** = Highly significant (P = 0.01)

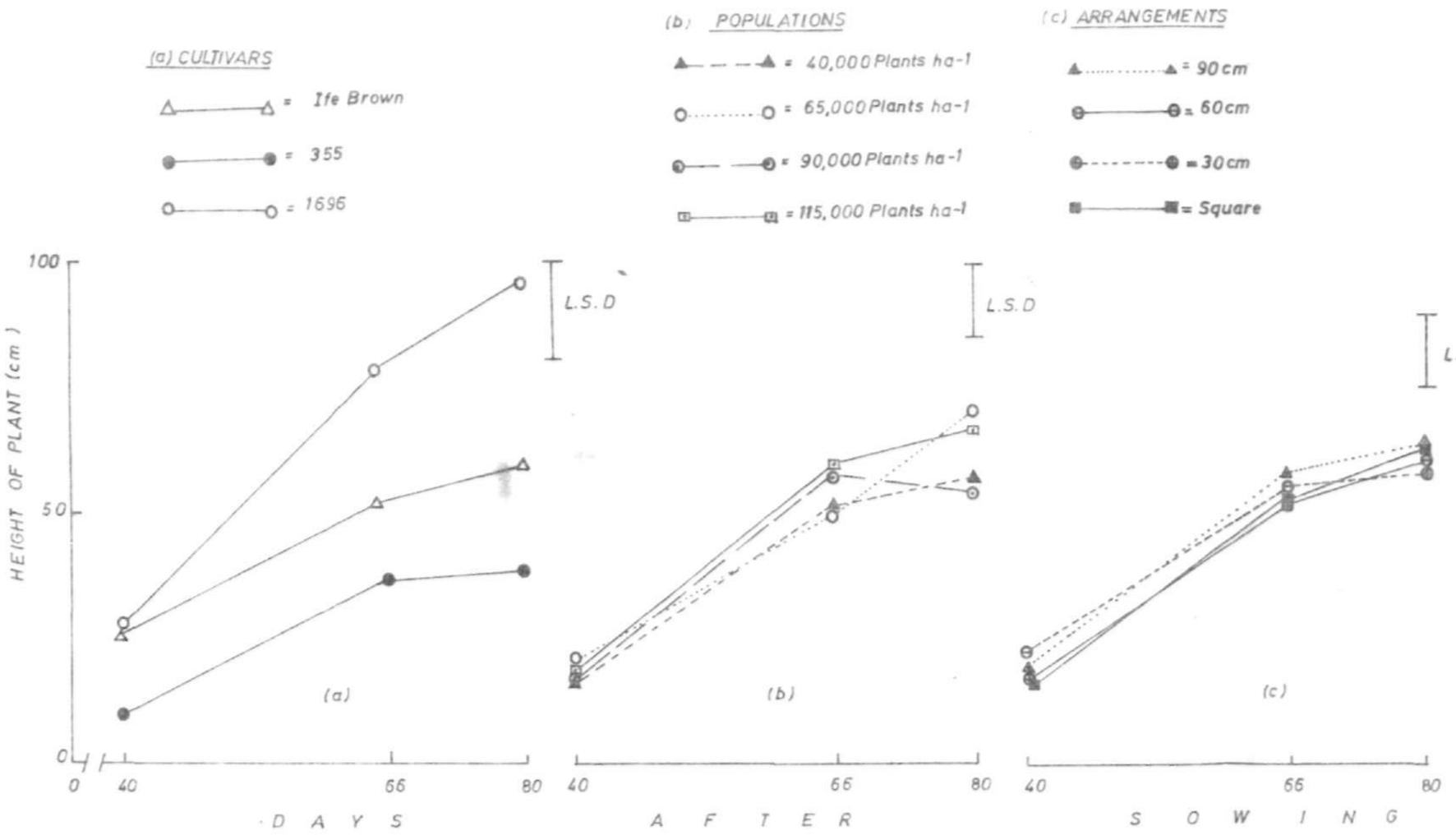


Fig. 2: Mean effects of plant population, plant arrangement and cultivar on the height of cowpea plants at Samaru, 1980.

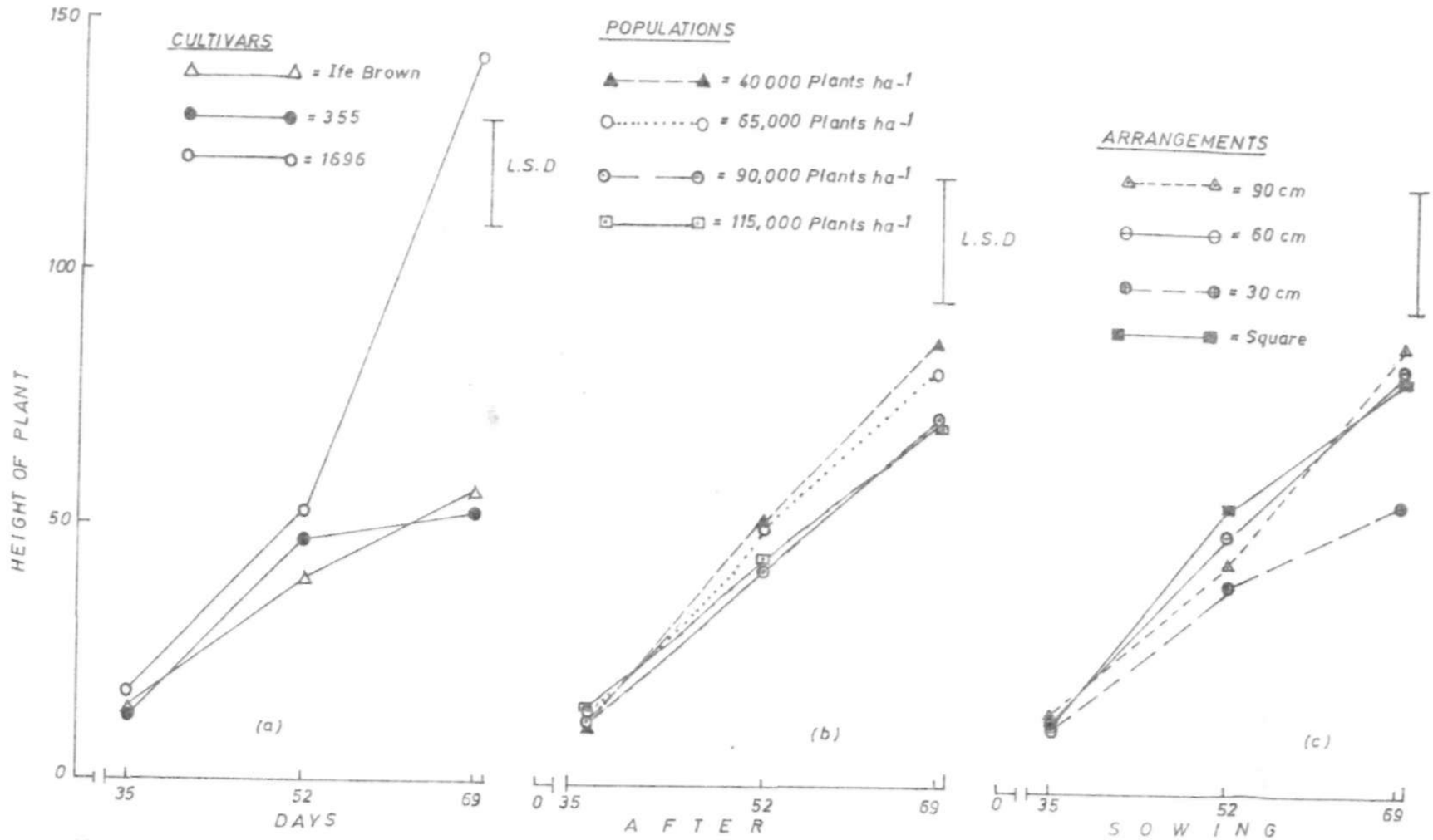


Fig. 3: Mean effects of plant arrangment, plant population and cultivar on the height of cowpea plants at Samaru, 1981.

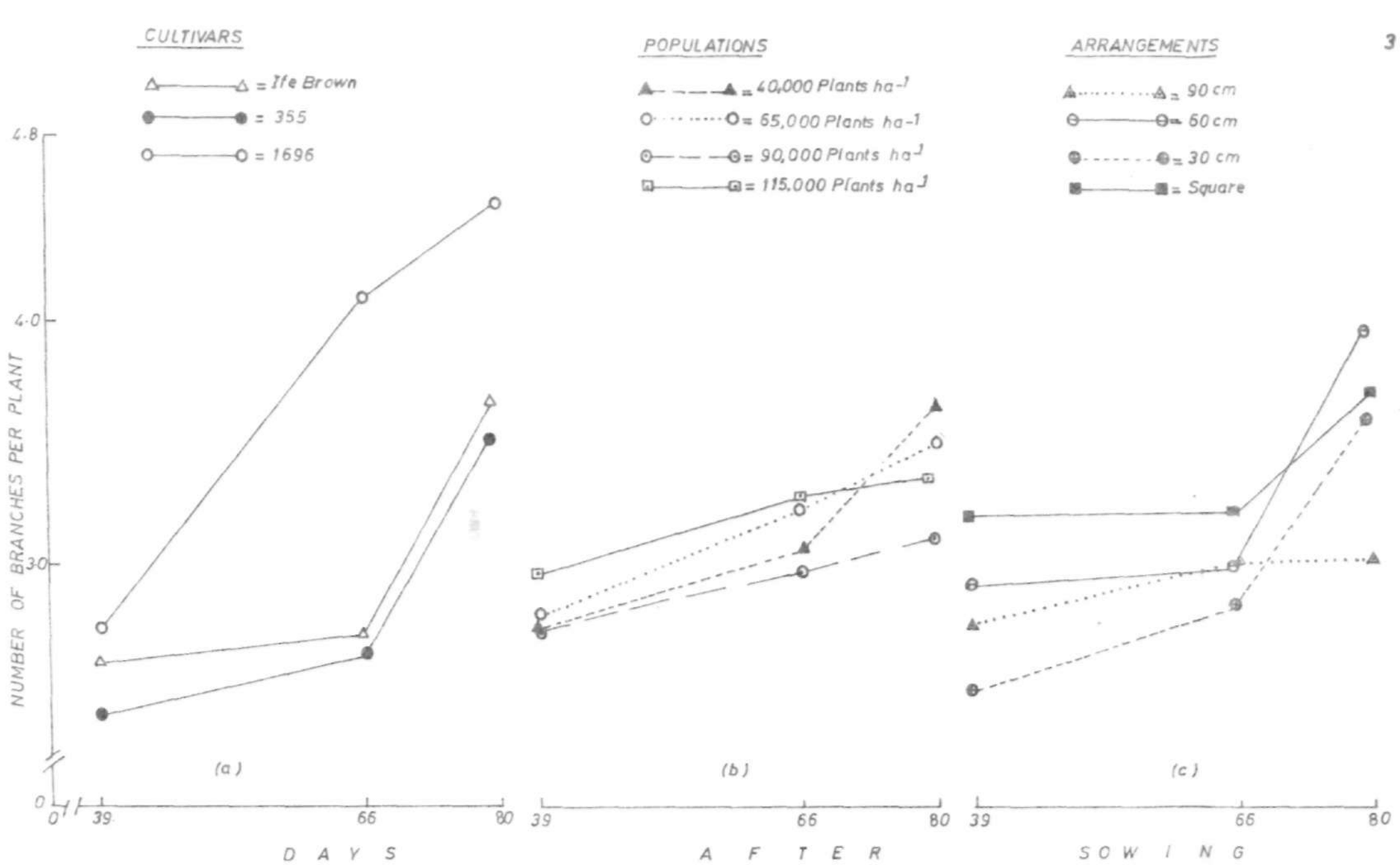


Fig. 4: Mean effects of plant population, plant arrangement and cultivar on the number of branches per plant of three cowpea cultivars at Samaru, 1980.

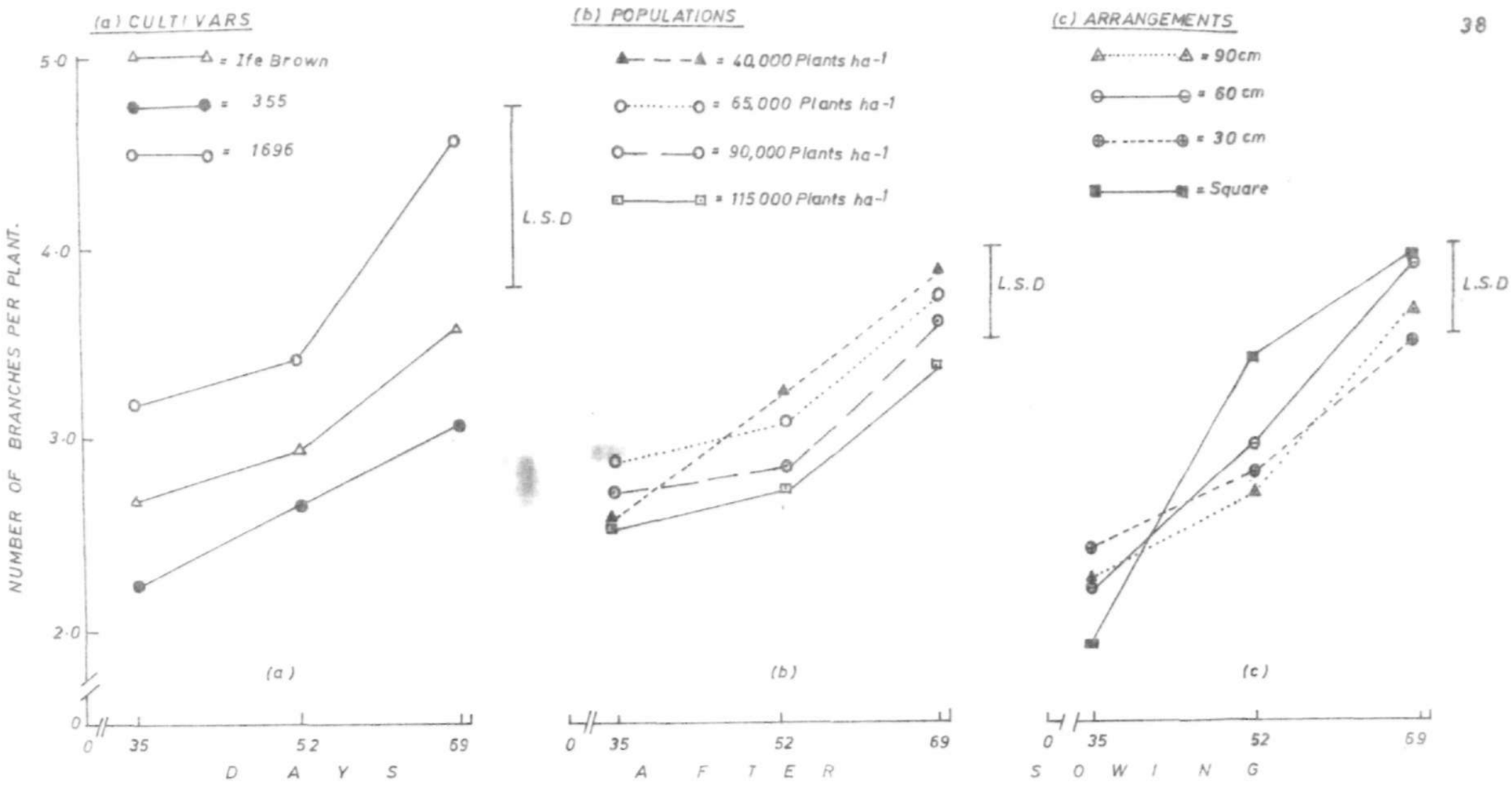


Fig. 5. Mean effects of plant population, plant arrangement and cultivar on the number of branches per plant, of three cowpea cultivars at Samaru, 1981

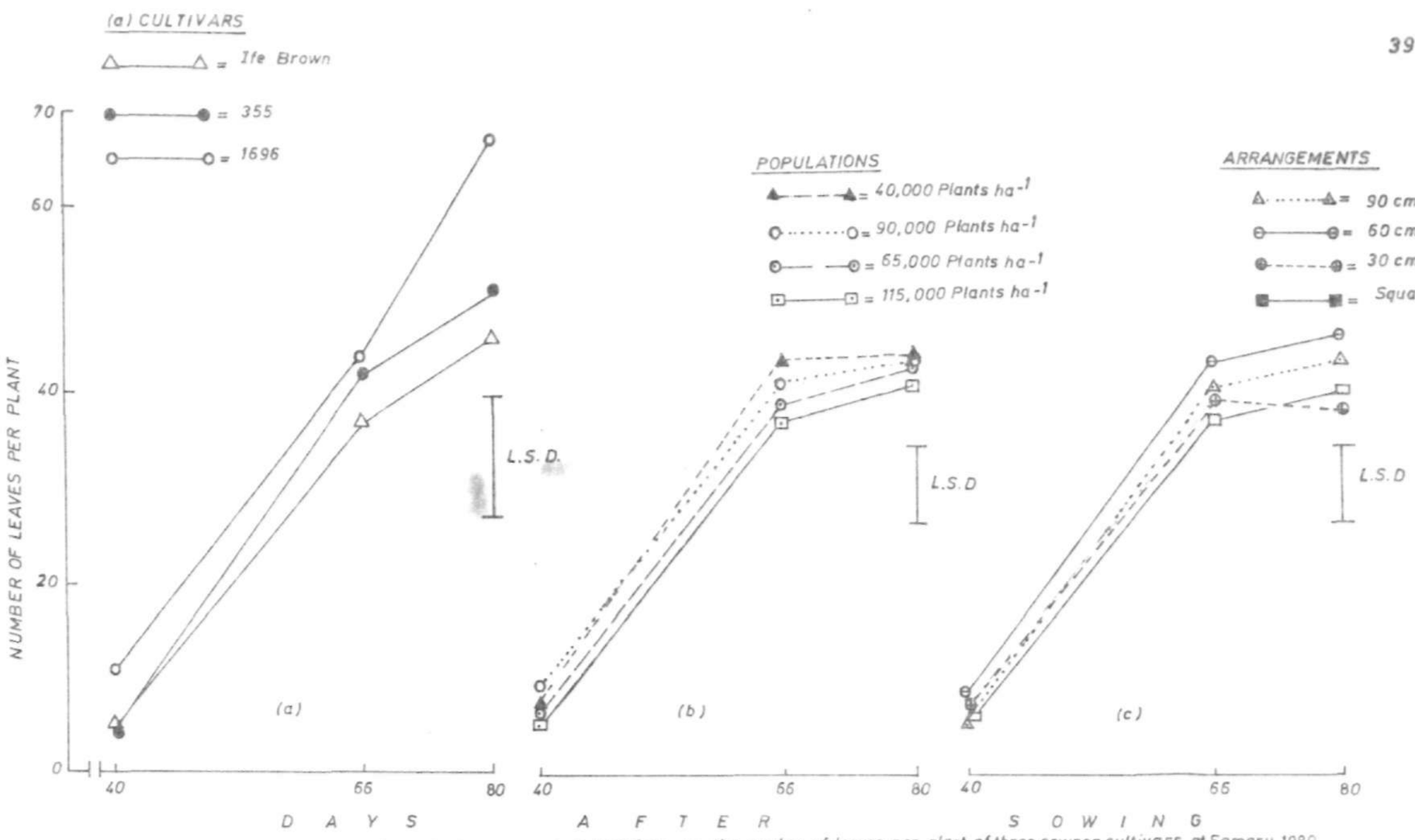


Fig. 6 :Mean effects of plant population, plant arrangment and cultivar on the number of leaves per plant of three cowpea cultivars at Samaru, 1980.

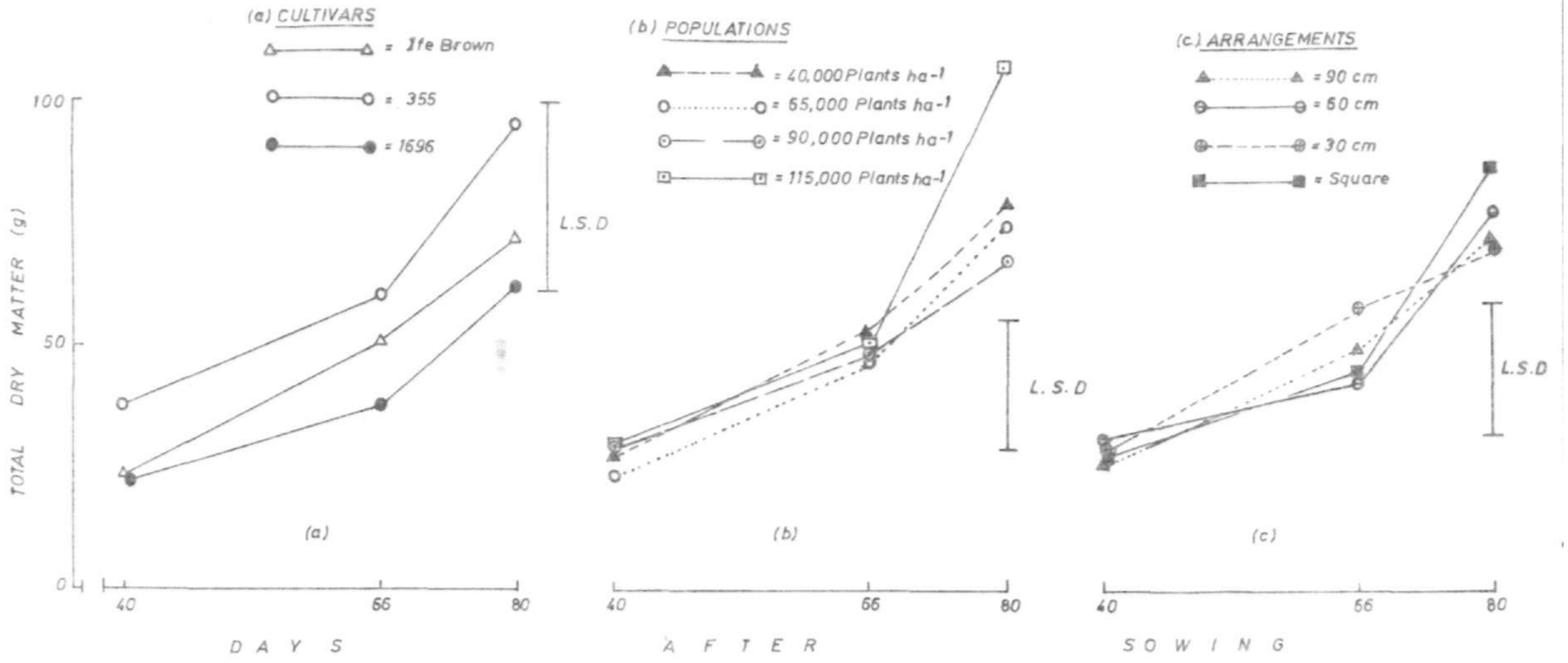


Fig. 7: Mean effect of plant population, plant arrangment and cultivar on the total dry matter yield of three cowpea cultivars at Samaru, 1980.

Number of peduncles per plant decreased with increase in plant population in both years and in the mean of the two years (Table 11). The differences were significant in 1981 and the mean of the two years but not in 1980. In 1981, the two lowest populations being at par produced significantly more peduncles per plant than the other two higher populations which were at par. For the mean of the two years, the effect of 40,000 plants/ha was significantly more pronounced over 90,000 and 115,000 plants/ha, but not over 65,000 plants/ha. Significantly, more peduncles were produced at 65,000 than at 115,000 plants per hectare but at par with 90,000 in influencing number of peduncles per plant. The two higher plant populations i.e. 90,000 and 115,000/ha were at par with each other.

The effects of plant arrangement on the number of peduncles per plant were not significant in both the years and their mean. However, the highest number of peduncles per plant is produced with 60 cm arrangements in 1980 and in the mean of the two years and in the 30 cm arrangement in 1981.

Interaction between plant population and spacing arrangement was not significant in both years and the mean of the two years.

From Table 13, it can be observed that there were significant differences in number of peduncles per plant in 1981, but not in 1980 and the mean for the two years. In 1981, cultivar Ife Brown produced significantly more peduncles than cv.355 in the lowest population but was at par in all the higher populations. Cv. Ife Brown produced significantly more peduncles per plant with decreasing plant population.

Interaction between spacing arrangement and cultivar was significant in both the years and their mean (Table 14). In 1980, 1981 and their mean, Cv. Ife Brown produced significantly more peduncles than Cv.355 only in 60 cm arrangement. In 1980, also with this arrangement cv. Ife Brown yielded significantly higher than the other arrangements. In 1981, 30 cm arrangement being at par with square arrangements produced more peduncles than 60 and 90 cm in both cultivars. For the mean of the two years, C.v. Ife Brown produced significantly more peduncles in 60 cm and 90 and 30 cm. 60 cm was at par with the square. The different arrangements did not affect Cv.355 significantly.

The three-factor interaction between plant population, plant arrangement and cultivar was not significant in both years and the means of the two years.

Combined analysis for the two years has shown that the number of peduncles per plant was significantly more in 1980 than in 1981 (Appendix 16).

The number of peduncles per plant was negatively correlated with seed yield/ha in 1981, but not in 1980.

NUMBER OF PODS PER PEDUNCLE

Number of pods per peduncle was not significantly influenced by the treatments and their interactions in any year.

There were significant differences in the number of pods per peduncle produced in the two years, the 1980 result being significantly higher than that of 1981 (Appendix 19).

There was no significant correlation between numbers of pods per peduncle and seed yields, though the correlation was positive in 1980 and negative in 1981.

NUMBER OF SEEDS PER POD

Cultivar effects were not significant in both the years and their mean. However, cultivar Ife Brown yielded more seeds per pod than cv. 355 in both the years and their mean.

It is evident from Table 15 that the higher the plant population the lower the number of seeds per pod. The only significant difference was observed in the mean for the two years, where the lowest population produced a higher number of seeds per pod than all the higher populations.

From Table 16 it can be observed that plant arrangement had affected the number of seeds per pod only in 1981 when square arrangement, being at par with 30 cm produced significantly more seeds per pod than the 90 and 60 cm inter-row arrangements which were at par with each other.

The interaction between plant population and spacing arrangement was not significant in both years and their mean. However, the highest number of seeds per pod was produced by the lowest population with rectangular (90 x 28 cm) arrangements in 1980 and square (50cm x 50cm) arrangements in 1981 and the mean of the two years.

The interaction between plant population and cultivar was not significant in both years and their mean. Cultivar Ife Brown however, produced more seeds per pod at all plant populations in both years and their mean. The number of seeds per pod for both cultivars decreased with increase in population in most of the combinations.

The interaction between spacing and cultivars were not significant in both years and their mean. Though the interaction effects are not significant it seems that different spacing arrangements had influenced Cv, Ife Brown but not Cv.355. Under square and 30 cm arrangements, cultivar Ife Brown bore more seeds per pod under 30 cm than under 90 and 60 cm arrangements.

The three-factor interaction between plant population, plant arrangement and cultivar were not significant in the two years and their mean. There were significantly more seeds per pod in 1981 than in 1980 (Appendix 22).

Number of seeds per pod was positively correlated with seed yield in 1980 and 1981, but it was significant only in 1981.

1000-SEED WEIGHT

Cultivar differences in 1000-seed weight was not significant in both years.

Table 15 revealed no significant differences in weight of 1000-seeds due to plant population. However, there was tendency of decline in test weight beyond 90 thousand plants/ha.

Spacing arrangement significantly affected 1000-seed weight only in 1981 and the mean of the two years (Table 16). In 1981 and for the mean of the two years, seeds were heavier in 30 cm, being at par with square arrangement in 1981 and with square and 60 cm in the mean for the two years. There were no significant differences between 90 and 60 cm arrangements. The data for 1980 revealed the same trend.

The interaction of different treatments were not significant.

The combined analysis has shown that 1000-seed weight was significantly heavier in 1980 than 1981 (Appendix 25).

One-thousand test weight was positively but not significantly correlated with seed yield/ha in both the years.

SEED YIELD PER PLANT

Due to some mistakes in data collection, the seed yield per plant for 1981 was discarded. Therefore only 1980 result has been reported. There was no significant cultivar differences in seed yield per plant.

Seed yield per plant was significantly decreased with increase inpplant population (Table 15). The lowest and highest plant population produced the highest and lowest seed yield per plant, respectively. However, 65,000 and 90,000 plants/ha being at par were significantly superior and inferior to the highest and lowest plant populations, respectively.

Spacing arrangements affected seed yield per plant significantly. The square and 90 cm arrangements being at par were significantly superior to the 60 and 30 cm arrangements which were at par with each other (Table 16).

The interaction between plant population and spacing arrangement was significant (Table 17). The different interactions had more seed yield per plant with low populations than with the high populations.

There were no significant differences in the plant population and cultivar interaction effects. Cultivar Ife Brown however, yielded higher than Cv.355 in all the plant populations. The yield of Cv.355 decreased with increase in plant population, but the result for Cv. Ife Brown was inconsistent.

No significant differences were observed for plant arrangement and cultivar interactions. However, Cv. Ife Brown yielded higher than Cv.355 in all the arrangements. The highest yield for the two cultivars were recorded in square spacing arrangements.

There were no significant differences in the interaction between plant population, spacing arrangement and cultivars.

SEED YIELD PER HECTARE

Cultivar Ife Brown yielded significantly higher than Cv.355 in 1980, but not in 1981. The mean yield of Cv. Ife Brown for the two years (1128 kg/ha) was significantly higher than that of Cv.355 (880 kg/ha) by about 27% (Table 10).

From Table 18 it is evident that different plant populations have affected seed yield. In both years and their mean, 90,000 plants/ha being at par with 115,000 plants/ha yielded significantly higher than the two lower populations. The same trend was found in the mean of the two years. In 1981, 90,000 and 115,000 plants/ha being at par with 65,000 plants/ha were

superior to the lower population of 40,000 plants/ha. There was no statistical difference between the two lower plant populations.

Spacing arrangement differed significantly in producing seed yields in 1981 and for the mean of the two years, but not in 1980 (Table 12). In 1981, 30 cm and square arrangements being at par yielded significantly higher than 60 and 90 cm which were also at par. The mean yield for the two years showed the same trend. In 1980, though the differences were not significant, 30 cm and square arrangements yielded higher than the other two arrangements.

The yield data presented in Table 20 show no significant differences due to plant population and spacing arrangement interaction. In 1980, however, highest yields were obtained in square arrangement in all the plant populations. Square arrangements of 30 x 30, 33 x 33, 39 x 39 and 50 x 50 cm yielded highest with 115,000; 90,000; 65,000; and 40,000 plants/ha, respectively. The yields of 1981 and of the two years revealed that square arrangements yielded higher than other arrangements in all the plant populations except for the 90,000 plants/ha.

Yield data presented in Table 13 differed significantly in cultivar and population interactions in 1980 and for the mean of the two years. The cultivar differences were found

only with the three higher plant populations. With all the plant populations except the highest one in 1981 Cultivar Ife Brown yielded higher than Cv.355.

Cultivar differences under different arrangements in both the years were not significant (Table 14). However, Cv. Ife Brown yielded higher in most cases. The mean value of the two years showed Cv. Ife Brown performed significantly better than Cv.355 with the two higher populations but was at par with Cv.355 with the lower populations.

The interaction effects of plant population, plant arrangement and cultivar were not significant in both the years and the mean of the two years. However, Cv. Ife Brown yielded the highest with 30 x 36 cm with 90,000 plants in both years and their mean. Cv. 355 also yielded highest with 30 x 36 cm in 1981 but with 60 x 18 cm and 36 x 25 cm in 1980 and the mean of the two years, respectively.

The combined analysis of the two years' result has shown that yields in 1980 were significantly higher than that of 1981 (Appendix 13).

Seed Yield from 140,000 plants/ha

Only seed yield was estimated from the look-side-trial. An average seed yield of 722 kg/ha was obtained. This yield although at par with 40,000 plants/ha was significantly lower than the yields from all the other plant populations.

In case of plant population and cultivar interactions the differences were not significant. Cultivar Ife Brown however, yielded (890 kg/ha) higher at this population than all the other populations except the 90,000 plants/ha and Cv.355 yielded (554 kg/ha) less than all the other populations except 40,000 plants/ha.

Table 10. Mean Performance of Two Cultivars of Cowpea for seed yield (kg/ha) at Samaru, 1980 and 1981.

Cultivar	Seed Yield (kg/ha)		
	1980	1981	Mean
Ife Brown	1339	916	1128
355	990	786	889
S.E. (±)	62.6	427	44.9
L.S.D.	269.4 **	N.S.	88.2**

N.S. = Not significant
S.E. = Standard Error
L.S.D. = Least significant
* = Significant (P = 0.05)
** = Highly significant (P = 0.01)

Table 11. Mean Fffect of Plant Population on the Seed Yield (kg/ha), and Number of Peduncles per plant at Samaru, 1980 and 1981

Plant Population ('000/ha)	Seed Yield (kg/ha)			Number of Peduncles per Plant		
	1980	1981	Mean	1980	1981	Mean
40	952	724	838	26.1	20.9	23.6
65	1143	844	994	25.1	19.9	22.5
90	1313	927	1220	24.1	14.7	19.4
115	1251	912	1082	23.3	13.4	18.3
S.E.	81.5	60.3	58.3	1.3	1.3	1.3
L.S.D.	166.4**	165.8*	150.3**	N.S.	2.72**	3.46**

N.S. = Not significant
S.E. = Standard Error
L.S.D. = Least Significant difference
* = Significant (P = 0.05)
** = Highly significant (P = 0.01)

Table 12. Mean Effect of plant arrangement on the seed yield (kg/ha) at Samaru, 1980 and 1981

Plant Arrangement (cm)	Seed Yield (kg/ha)		
	1980	1981	Mean
90	1166	694	930
60	1088	736	912
30	1445	997	1221
Square	1261	976	1118
S.E.	87.5	60.3	58.3
L.S.D.	N.S.	165.8**	150.3**

N.S. = Not significant
S.E. = Standard Error
L.S.D. = Least significant difference
* = Significant (P = 0.05)
** = Highly Significant (P = 0.01).

Table 13. Mean Effect of plant population and cultivar as measured by seed yield (kg/ha) and number of peduncles per plant at Samaru, 1980 and 1981

Plant Population ('000/ha)	Cultivar	Seed Yield (kg/ha) 1980	1981	Mean	Number of peduncles per plant 1980	1981	Mean
40	Ife Brown	977	851	914	25.1	23.3	24.2
	355	927	589	759	26.9	18.5	
65	Ife Brown	1359	884	1122	26.3	19.7	23.1
	355	928	805	867	23.8	20.0	21.9
90	Ife Brown	1536	1028	1282	25.6	14.2	19.9
	355	1090	826	958	22.6	15.1	18.8
115	Ife Brown	1486	899	1193	22.6	12.9	17.8
	355	1017	923	970	23.9	13.8	18.8
	S.E.	76.5	118.8	77.2	1.6	0.5	1.1
	L.S.D.	156.2**	N.S.	198.9**	NS	1.0**	N.S.

N.S. = Not significant
S.E. = Standard Error
L.S.D. = Least significant difference
* = Significant (P = 0.05)
** = Highly significant (P = 0.01)

Table 14. Mean effect of plant arrangement and cultivar as measured by seed yield (kg/ha) and number of peduncles per plant at Samaru, 1980 and 1981

Spacing Arrangement (cm)	Cultivar	Seed Yield (kg/ha)			Number of Peduncles per plant		
		1980	1981	Mean	1980	1981	Mean
90	Ife Brown	1348	627	987	22.7	15.2	20.2
	355	984	762	873	23.4	16.8	20.2
60	Ife Brown	1137	805	971	29.4	17.6	23.8
	355	1038	668	853	24.4	14.8	19.6
30	Ife Brown	1414	1098	1256	22.7	18.8	20.8
	355	876	896	856	23.7	18.4	21.2
Square	Ife Brown	1459	1133	1295	24.3	18.4	21.5
	355	1064	819	941	25.7	17.3	21.5
	S.E.	76.5	111.7	77.0	1.6	0.5	1.41
	L.S.D.	N.S.	N.S.	151.3*	4.7*	1.1*	2.70*

N.S. = Not significant
S.E. = Standard Error
L.S.D. = Least significant difference
* = Significant (P = 0.05)
** = Highly significant (P = 0.01)

Table 15. Mean effect of plant population as measured by number of seeds per pod and seed weight per plant at Samaru, 1980 and 1981

Plant Population ('000/ha)	Number of Seeds per pod			Seed weight per plant (g)
	1980	1981	Mean	1980
40	7.5	9.3	8.4	38.4
65	6.9	8.6	7.7	35.8
90	6.9	8.3	7.6	35.7
115	6.6	8.6	7.6	30.9
S.E.(±)	0.2	0.4	0.2	0.8
L.S.D.	N.S.	NS	0.5**	2.3**

N.S. = Not significant
S.E. = Standard Error
L.S.D.= Least significant difference
* = Significant (P = 0.05)
** = Highly significant (P = 0.01)

Table 16. Mean effect of plant arrangement as measured by number of seeds per pod 1000-seed weight and seed weight per plant at Samaru, 1980 and 1981

Spacing Arrangement (cm)	Number of Seeds per Pod			1000-Seed Weight			Seed Weight per plant (g)
	1980	1981	Mean	1980	1981	Mean	1980
90	7.1	8.1	7.6	135.5	124.5	130.0	24.7
60	7.2	8.2	7.6	137.8	126.5	132.1	22.2
30	6.8	9.0	7.9	140.1	132.4	136.2	21.9
Square	6.9	9.3	8.1	138.9	129.7	134.3	24.9
S.E. (±)	0.25	0.4	0.2	2.5	2.6	2.3	0.8
LSD.	N.S.	0.8*	N.S.	N.S.	5.4*	4.5*	2.3*

N.S. = Not significant
S.E. = Standard Error
L.S.D. = Least significant difference
* = Significant (P = 0.05)
** = Highly significant (P = 0.01).

Table 17. Mean effect of plant population and arrangement as measured by seed yield per plant at Samaru, 1980 and 1981.

Plant Population ('000/ha)	Plant Arrangement (cm)	Seed Weight per plant (g) 1980
40	90 x 28	28.3
	60 x 41	24.2
	30 x 83	22.9
	50 x 50	26.9
65	90 x 17	23.7
	60 x 25	25.0
	30 x 50	29.6
	39 x 39	23.0
90	90 x 12	24.3
	60 x 18	21.3
	30 x 36	22.5
	33 x 33	27.2
115	90 x 10	22.7
	60 x 15	18.3
	36 x 25	18.7
	30 x 30	22.9
	S.E.	1.5
	L.S.D.	4.6**

N.S. = Not significant
S.E. = Standard Error
L.S.D. = Least significant difference
* = Significant (P = 0.05)
** = Highly significant (P = 0.01).

DISCUSSION

VEGETATIVE GROWTH AND DEVELOPMENT

At the time of last sampling, cultivar Ife Brown and cv.355 were in reproductive stage whereas c.v. 1696 was still in full vegetative growth stage. At the time of final harvesting of cv. Ife Brown and cv. 355, flowering had just started in cv. 1696 which produced a negligible number of pods even at one and a half months after the final picking of the other two cultivars.

In cultivar 1696 vegetative growth was much more vigorous than reproductive stage till the end. This could be the reason for its failure to produce pods as most of the photosynthate manufactured could be diverted to vegetative parts. The limited supply of photosynthate to the reproductive parts might have caused flower abscission and/or seed abortion as reported by Fzedinma (1965a) and Steele (1972).

Cultivar differences

Cultivars differed significantly as reported in previous chapter in the vegetative characters. In all these characters, cultivar 1696 proved to be more vigorous than Ife Brown and 355. There were no significant differences in the number of leaves per plant and total dry matter and also

for number of branches per plant in 1981, though the performance of the three cultivars were in the same order, cultivar 1696, > cv. Ife Brown > cv. 355.

These differences seem to be genetic. Cv. 1696 being a trailing and long duration cultivar performed better in vegetative characters than Ife Brown and 355 which are semi-erect and of short to medium duration.

Effects of Plant Population

All the growth parameters except total leaf area were not significantly affected by different plant populations in 1980.

The total leaf area was significantly higher at the highest and lowest than the two medium populations. The differences in leaf area might be due to more leaves per plant (though not significant) at the highest plant population and larger leaves at the lowest population respectively, though the differences were not significant.

Height of plant and the number of branches per plant were significantly affected by varying plant populations only in 1981. The difference between the two years was probably due to differences in the fertility status of the soil in the two experimental sites and the weather conditions during the two years.

The soil fertility and the weather conditions were better in 1980 so that the plants might not have suffered for want of nutrients or moisture as might have been the case in 1981.

In 1981, both the height of the plants and the number of branches per plant were similar in the three higher populations and significantly less than in the lowest population. The general trend was a reduction with an increase in population. Ojehomon and Bamiduro (1971) had reported reduced growth at high plant populations.

Effects of Spacing Arrangement

Spacing arrangement affected the mean number of branches and total leaf area significantly, being higher in the square than the other spacing arrangements. However, square arrangement was found to be at par with medium spacing arrangement for total leaf area with narrow and wide spacing arrangement for the number of branches per plant. Even where the differences were not significant square arrangements were found to be superior to the other spacing arrangements. This finding is in conformity with the findings of Ojehomon and Bamiduro (1971) who reported that square arrangement was best for semi-erect cultivars. The reason for the superiority of square arrangements could be due to the uniform spatial distribution to all the plants which prevented the plants from competing with each other for essential growth requirements.

Treatments Interactions

The interaction between population and spatial arrangement significantly affected total leaf area only. The total leaf area was generally more in square arrangements at all plant populations. With all the populations, square arrangement was either superior to all or at par with one or two rectangular arrangements. Population and cultivar interactions did not affect plant growth significantly. Spacing arrangement and cultivar interactions had significant effect on the total dry matter and in 1981 on the number of branches per plant. In cv. Ife Brown, more branches were formed in 30 cm arrangement which was at par with the square and 90 cm arrangements. Cultivar 355 was unaffected by the different spacing arrangements. Cultivar 1696 had maximum number of branches in square arrangement though there were no significant difference between square, 30 and 90 cm arrangements. Cultivar Ife Brown and cv. 355 produced maximum dry matter in the square arrangements while cv. 1696 did so at 60 cm. Statistically, square and 60 cm were the same for cv. Ife Brown; square, 30 and 90 cm for cv. 355 and 60 and 90 cm for cv. 1696. In all rectangular arrangements, cv.1696 produced more dry matter than the other two cultivars. From this finding it seems that for erect cultivars square arrangements or medium inter-row

spacing and for trailing cultivars rectangular arrangements with wide inter-row spacings are more suitable.

YIELD COMPONENTS

Yield components including number of peduncles per plant, number of pods per peduncle, number of seeds per pod, 1000-seed weight and seed yield per plant were measured only in two cultivars (Ife Brown and 355) and not in cv.1696 which failed to produce seeds.

Cultivar differences

There were no significant differences between cultivarss in all the above yield components parameters. However, in all the yield components, cv. Ife Brown produced more than cv. 355.

Effects of Plant Population

Various plant populations significantly affected the number of peduncles per plant in 1981 and for the means, number of seeds per pod (mean) and seed yield per plant in 1980 but did not affect number of pods per peduncle and 1000-seed weight in any year. Except seed test weight which was not sensitive to populations, all the other yield components tended to decline with increasing plant population.

Similar findings have been reported by others. Erskine and Khan (1976), Remison and Okunariwo (1979) have reported that number of pods per plant decreased at very high plant populations.

Whereas Enyi (1974), Crothers and Westermann (1976) and Remison and Okunariwo (1979) reported decrease in number of seeds per pod with an increase in plant population Erskine and Khan (1976) found an increase with increase in plant density. Aguilar et al., (1977) observed that 1000-seed-weight was less sensitive to plant density in snap bean.

Effects of Spacing Arrangements

Among the yield components only seed yield per plant, 1000-seed weight in 1981 and its mean for two years as well as the number of seeds per pod in 1981 were significantly affected by different spacing arrangements. Clear cut differences were observed in seed yield per plant which was higher at square and 90 cm row width arrangements. Number of seeds per pod in 1981 was higher in square and 30 cm row width arrangements.

Treatments Interactions

Interactions between population and spacing arrangement was significantly affected only in seed yield per plant. The highest seed yields per plant were obtained with square arrangement for high plant populations of 115,000 and 90,000 plants/ha and with rectangular arrangements of lower populations of 65,000 and 40,000 plants/ha, although the differences were not statistically significant. Population and cultivar interactions significantly reduced the number of peduncles per plant with increasing plant population only in 1981. Spacing arrangement and cultivar interactions affected only the number of peduncles per plant in both years and the mean for the two years. Unlike cv.355, cv. Ife Brown produced significantly more peduncles per plant at 60 cm row width and square arrangements. None of the yield components was affected by population, arrangement and cultivar interactions.

SEED YIELD PER HECTARE

Cultivar Differences

There were significant cultivar differences in seed yield/ha. Cv. Ife Brown yielded significantly more than cv. 355 in 1980 and the mean of the two years. Lack of significant differences in 1981 was probably because none of the yield

components as well as the vegetative characters were significantly different in 1981. Total yield was higher in 1980 than in 1981. This was attributed to more favourable weather conditions in 1980 than 1981, and because of the higher fertility of the soil in plot 75 used in 1980.

Effects of Plant Population

Plant population significantly affected seed yield/ha in both years and their mean. In both years and their mean yields from 90,000 plants/ha were the highest though at par with 115,000 plants/ha in all cases. In 1981 there were no significant difference between the yields obtained with 65,000, 90,000 and 115,000 plants/ha. The optimum plant population per hectare appeared to be 90,000 for Ife Brown and 96,000 for cv.355.

Even with the adverse effects of higher plant population on leaf area, number of peduncles per plant and number of seeds per pod, there was an increase in seed yield at higher population. This could be due to greater number of plants per hectare which compensated for the reduction in the other yield components.

Many researchers have reported similar results. In erect and semi-erect cultivars seed yield increased with increase in population up to 120,000 (Enyi, 1973a); 87,000 (Ojehomon and Bamiduro, 1971); 104,000 (Nangju, 1979); 83,000 (Remison and Okunariwo, 1979); 100,000 (Mohdnoor, 1980) and 80,000 (Anon., 1980).

Some workers have reported reductions in grain yield at very high populations (Crothers and Westermann, 1976; Erskine and Khan, 1976, and Westermann and Crothers, 1977).

Erskine and Khan (1976) found no agronomic optimum for plant density but that increases from 100,000 - 250,000 plants/ha did not significantly increase grain yield/ha though it required two and half times the sowing rate. They therefore concluded that it would be uneconomical to go above 100,000 plants/ha since the seeds are expensive. Leakey (1972) also reported that highest yields obtained with high density in snap bean was wasteful of seeds because the percentage of plants surviving at harvest was much reduced.

According to Enyi (1974) seed yield in cowpea is a product of number of flowering inflorescences initiated, the number of pods set per flowering inflorescence, the number of seeds and weight of their pods. Reduction of yields at very

high densities therefore may be due to density induced mortality which do not allow these characteristics to be maximized as reported in cowpea by Erskine and Khan, (1976). In soybean, Probst (1945) also reported increased lodging at high density. According to Ojehomon (1970) there may have been more flower production at higher densities but increased number of flower production does not necessarily increase production of mature seeds; probably because of higher rates of flower abortion at high densities.

The efficiency of conversion of biomass (total dry matter) into seed yield may be less at high densities as reported by Ishag (1973a) in field beans.

The inhibition of nodulation might be another reason for decreased yield at high densities as reported by Sprent et al. (1977) in field beans. If high densities can cause reduction in nodulation in cowpea then yields will be affected as cowpea is reported to produce optimum seed yields when effectively nodulated (Summerfield et al., 1976; Summerfield et al., 1978; Minchin and Summerfield, 1978).

High plant density may also reduce root volume and so affect nodulation. This could again affect seed yield at high densities.

In 1981, yields from higher plant populations 65,000, 90,000 and 115,000 plants/ha were statistically similar. Similar results have been reported by Remison and Okunariwo (1979) in cowpea, Atkins (1961) and Lucas and Milbourn (1976) in snap bean. They noted that the non variation of results at higher populations was possibly because of less pod retention at high densities whereas widely spaced plants (low density) had the ability to produce pods over a longer period.

Effects of Spacing Arrangement

Spacing arrangements significantly affected seed yield/ha in 1981 and the mean of the two years but not in 1980. As discussed earlier, soil fertility and weather conditions might have led to the response observed in 1980.

In 1981 and the mean of the two years, square and 30 cm row-width arrangements yielded significantly more than 90 and 60 cm row-width arrangements.

Haizel (1972) found that square arrangements produce higher rate of seed increase and so higher grain yields. Panwar and Singh (1979) however, found no significant differences in square and rectangular arrangements under late sowing conditions in India.

Treatment Interactions

Only population and cultivar and arrangement and cultivar interactions influenced the seed yields/ha significantly.

Population and cultivar interactions significantly affected seed yield in 1980 and the mean of the two years but not in 1981. Cultivar Ife Brown yielded significantly more than cv. 355 at all the plant populations both in the mean of the two years and at the three higher populations in 1980.

Spacing arrangement and cultivar interactions significantly affected the mean yield of the two years. Yield of Ife Brown in square arrangements was similar to 30 cm row-width arrangement and significantly better than 90 and 60 cm row-width arrangements. Cultivar 355 yielded almost the same at all the different spacing arrangements. Both cultivars, however, yielded more under square arrangements but the differences were not significant.

Many workers have reported that within a given population level, yield increased as the inter-row spacing approached a uniform distribution pattern (Reynolds, 1950; Donavan et al., 1963; Crothers and Westermann, 1976). Ojehomon and Bamiduro (1971) also found the square arrangements to be the best for semi-erect cultivars.

SUMMARY AND CONCLUSIONS

Field trials were conducted at the research farm of the Institute for Agricultural Research (I.A.R.)., Samaru, during 1980 and 1981 wet seasons to determine the effects of plant populations and spacing arrangement on the yield and various agronomic characters of different types of cowpea.

The treatments consisted of three cultivars of cowpea, viz., Ife Brown, 355 and 1696; four plant populations-- 40,000, 65,000, 90,000 and 115,000 plants/ha; and for each population four spacing arrangements including one square and three rectangular arrangements.

In most of the growth parameters, cv. 1696 was found to be superior to the other two cultivars. The different plant populations and spacing arrangements significantly affected only the total leaf area per plant. Lowest and highest plant population and square or medium inter-row spacings for erect cultivars and rectangular arrangement with wide inter-row spacings for trailing cultivars were found to be more suitable.

Cultivar 1696 failed to produce any appreciable seed yield in both years. Hence, yield and yield components were studied only in the other two cultivars, both of which did not differ

significantly in all the yield components. However, in all the yield components, cultivar Ife Brown yielded more than cv. 355. Generally, there was reduction in all the yield components with increase in plant population, except 1000-seed weight which was not sensitive to population changes. Spacing arrangements statistically influenced the seed yield per plant which was higher at square and 90 cm rectangular arrangements. Though not statistically, highest seed yields per plant were obtained at square arrangement of high plant populations (115,000 and 90,000 plants/ha) and at rectangular arrangements of lower plant populations (65,000 and 40,000 plants/ha).

In both years, Ife Brown yielded more than cv.355. In 1980, both cultivars yielded more with 90,000 and 115,000 plants/ha, whereas in 1981 their yields at these populations were at par with the yield obtained at 65,000 plants/ha. Different spacing arrangements did affect seed yields in 1981 and the mean of the two years. Square and 30 cm row-width arrangements yielded significantly more than 90 and 60 cm row width arrangements.

Based on the findings, it may be concluded that cv. Ife Brown is a more promising cultivar than cv. 355 for the northern Guinea Savanna zone. For high grain yield, cultivation of Ife Brown at 90,000 plants/ha and cv. 355 at 96,000 plants/ha with square or narrow inter-row spacings of 30 cm row width may be recommended.

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APPENDICES

APPENDIX 1. Analysis of variance table for Cowpea height (cm) at Samaru, 1980

Source	D.F.	SS	MS	F
Replication	2	4551.58	2275.94	-
Arrangement	3	395.57	131.86	0.20
Population	3	5198.49	1732.83	2.78^{ns}
Arrang. Pop.	9	11591.36	1287.89	2.06^{ns}
Error (a)	30	18759.75	625.33	-
Cultivar	2	87851.99	43925.99	36.07**
Error (b)	4	4871.99	1217.99	-
Arrang. C.v.	6	8966.92	1494.49	1.36^{ns}
Pop. C.v.	6	5406.10	901.02	0.82^{ns}
Arrang. Pop. C.v.	18	12680.11	204.45	0.19^{ns}
Error (c)	60	6571.14	1095.27	-
Total	143	-	-	-

ns = Not significant
* = Significant (P = 0.05)
** = Highly significant (P = 0.01)
DF = Degrees of Freedom
SS = Sum of Squares
MS = Mean Squares
F = F-values
Design = Strip block design

APPENDIX 2. Analysis of variance table for cowpea height (cm) at Samaru, 1981

Source	D.F.	SS	MS	F
Replication	2	2238.18	1119.09	-
Arrangement	3	3035.75	1011.92	1.32^{ns}
Population	3	6718.19	2239.39	2.93*
Arrang. Pop.	9	2294.24	254.92	0.33^{ns}
Error (a)	30	22930.34	764.30	-
Cultivar	2	297740.70	297740.70	187.99**
Error (b)	4	3167.52	1583.76	-
Arrang. Cv.	6	6978.25	2326.08	1.80 ^{ns}
Pop. Vs.	6	483.05	161.02	0.12 ^{ns}
Arrang. Pop. Cv.	18	4040.36	448.92	0.35 ^{ns}
Error (c)	60	38748.86	1291.63	-
Total	143	-	-	-

APPENDIX 3. Combined analysis of variance table for cowpea height (cm) at Samaru, 1980 and 1981

Source	D.F.	SS	MS	F
Replication	2	6431.10	3215.55	-
Year	1	23482.20	23482.20	27.96**
Arrangement	3	1656.80	552.27	0.65ns
Population	3	5006.80	1668.93	1.98ns
Arrangement Pop.	9	3013.80	334.87	0.4 ns
Arrangement Year	3	1774.40	591.47	0.70ns
Population Year	3	5571.30	1857.10	2.20ns
Arrangement Pop. Yr.	9	5277.80	586.42	0.70ns
Error (a)	62	52242.40	842.60	-
Cultivar	2	354198.20	177099.10	738.22**
Error (b)	4	957.70	239.93	-
Arrangement Cv.	6	4314.30	719.05	0.73ns
Population Cv.	6	3388.80	564.80	0.57ns
Year Cv.	2	30816.00	15408.00	15.67**
Arrangement Pop. Cv.	18	5215.30	289.74	0.29ns
Arrangement Cv. Yr	6	12411.90	2068.65	2.10ns
Population Cv. Yr.	6	11647.30	647.07	0.66ns
Arrang. Pop. Cv. Yr.	18	3070.00	511.67	0.52ns
Error (c)	128	121942.70	983.41	
Total	287	-	-	-

APPENDIX 4. Analysis of variance table for cowpea number of branches per plant at Samaru, 1980

Source	D.F.	SS	MS	F
Replication	2	14.71	7.36	-
Arrangement	3	11.04	3.68	2.81 ns
Population	3	1.81	0.60	0.46 ns
Arrangment Pop.	9	11.21	1.24	0.95 ns
Error (a)	30	39.24	1.31	-
Cultivar	2	22.66	11.33	24.11**
Error (b)	4	1.89	0.47	-
Arrangement Cv.	6	5.27	0.88	0.42ns
Population Cv.	6	6.38	1.06	0.50ns
Arrangement Pop. Cv.	18	5.21	0.29	0.14ns
Error (c)	60	-	-	-
Total	143	-	-	-

APPENDIX 5. Analysis of variance table for cowpea number of branches per plant at Samaru, 1981

Source	D.F.	SS	MS	F
Replication	2	3.48	1.74	-
Arrangement	3	5.25	1.75	1.82ns
Population	3	9.34	3.11	3.23*
Arrangement Pop.	9	1.84	0.20	0.21ns
Error (a)	30	28.89	0.96	-
Cultivar	1	56.46	56.46	12.77ns
Error (b)	2	8.82	4.42	-
Arrangement Cv.	3	16.46	5.48	3.51*
Population Cv.	3	9.31	3.10	1.98ns
Arrang. Pop. Cv.	9	13.34	1.48	0.94ns
Error (c)	30	46.86	1.56	-
Total	95	-	-	-

APPENDIX 6. Combined Analysis of variance table for cowpea number of branches per plant at Samaru, 1980 and 1981

Source	D.F.	SS	MS	F
Replication	2	16.17	8.08	6.79**
Year	1	60.22	60.22	50.60**
Arrangement	3	14.89	4.96	4.16**
Population	3	3.80	1.27	1.06 ns
Arrangement Pop.	9	4.83	0.54	0.45 ns
Arrangement Year	3	1.40	0.37	0.31 ns
Population Year	3	7.36	2.45	2.06 ns
Arrangement Pop.	9	8.21	0.91	0.76 ns
Error (a)	62	74.16	1.19	-
Cultivar	2	75.29	37.65	38.42**
Error (b)	4	3.93	0.98	-
Arrangement Cv.	6	4.73	0.79	0.55 ns
Population Cv.	6	10.57	1.76	1.22 ns
Year C.v.	4	3.83	0.96	0.66 ns
Arrangement Pop. Cv.	18	16.06	0.89	0.62 ns
Arrange,ent Cv. Yr.	6	17.00	2.83	1.97 ns
Population Cv. Yr	6	5.11	0.85	0.59 ns
Arrang. Pop. Cv. Yr.	18	20.84	1.16	0.81 ns
Error (c)	124	179.07	1.44	-
Total	287	-	-	-

APPENDIX 7. Analysis of variance table for cowpea number of leaves per plant at Samaru, 1980

Source	D.F.	SS	MS	F
Replication	2	17412.41	8706.21	-
Arrangement	3	1435.19	478.39	0.61 ns
Population	3	404.38	134.79	0.17 ns
Arrangement Pop.	9	3529.69	392.19	0.50 ns
Frror (a)	30	23349.03	778.30	-
Cultivar	2	48835.50	24417.75	6.49 ns
Error (b)	4	15034.10	3758.33	-
Arrangement Cv.	6	3938.10	656.35	0.78 ns
Pop. Cv.	6	1688.59	281.43	0.34 ns
Arrangement Pop. Cv.	18	5919.66	328.87	0.39 ns
Error (c)	60	50381.48	839.69	-
Total	143	-	-	-

APPENDIX 8. Analysis of variance table for cowpea total leaf area (cm^2) at Samaru, 1980

Source	D.F.	S	MS	F
Replication	2	74900000	37450000	-
Arrangement	3	41100000	13700000	8.26**
Population	3	62800000	20933333	12.62**
Arrangement Pop.	9	5600000	6222222	3.75**
Error (a)	30	497600000	1658666	-
Cultivar	2	353990000	176990000	35.56*
Error (b)	4	19910000	4977500	-
Arrangement Cv.	6	84597700	14096167	1.47 ns
Population Cv.	6	91743300	15290550	1.59 na
Arrangement Pop. Cv.	18	167360000	9297777	0.97 ns
Error (c)	60	576374000	9606233	-
Total	143	-	-	-

APPENDIX 9. Analysis of variance table for cowpea dry weight of leaves at Samaru, 1980

Source	D.F.	SS	MS	F
Replication	2	6462.48	3231.34	-
Arrangement	3	2193.41	731.14	0.07 ns
Population	3	2078.32	692.76	0.72 ns
Arrangement Pop.	9	4427.29	491.92	0.51 ns
Error (a)	30	28877.91	962.57	-
Cultivar	2	18026.55	9013.28	44.33**
Error (b)	4	813.23	203.31	-
Arrangement Cv.	6	4391.68	731.94	1.54 ns
Population Cv.	6	1097.61	182.94	0.38 ns
Arrangement Pop. Cv.	18	10447.59	580.42	1.22 ns
Error (c)	60	28569.75	476.16	-
Total	143	-	-	-

APPENDIX 10. Analysis of variance table for cowpea total dry matter (g) at Samaru, 1980

Source	D.F.	SS	MS	F
Replication	2	18013.01	906.51	-
Arrangement	3	7075.23	2358.41	0.69 ns
Population	3	10079.12	3359.71	0.99 ns
Arrangement Pop.	9	3175.26	3528.14	1.04 ns
Error (a)	30	101348.43	3378.27	-
Cultivar	2	25270.87	12635.44	1.12 ns
Error (b)	4	45085.24	11271.25	-
Arrangement Cv.	6	18302.35	3050.39	2.94*
Population Cv.	6	6214.04	1035.67	0.99 ns
Arrangement Pop.Cv.	18	13717.88	762.10	0.73
Error (c)	60	62183.69	1036.38	
Total	143	-	-	-

APPENDIX 11. Analysis of variance table for cowpea seed yield (kg/ha) at Samaru, 1980

Source	D.F.	SS	MS	F
Replication	2	851000	425500	-
Arrangement	3	958520	319506.7	1.39 ns
Population	3	34983860	11661286.0	50.8**
Arrangement Pop.	9	1716370	190707.8	0.83 ns
Error (a)	30	6882310	229410.3	-
Cultivar	1	11007420	11007420.0	25.12*
Error (b)	2	876310	438155.0	-
Arrangement Cv.	3	386730	128919.0	0.72 ns
Population Cv.	3	3037480	1012498.3	5.7**
Arrangement Pop. Cv.	9	690490	76721.1	0.43 ns
Error (c)	30	5361010	178700.3	-
Total	95	-	-	-

APPENDIX 12. Analysis of variance table for cowpea seed yield (kg/ha) at Samaru, 1981

Source	D.F.	SS	MS	F
Replication	2	227960	113980.0	-
Arrangement	3	1791377	197125.7	7.8**
Population	3	634436	211478.6	3.12*
Arrangement Pop.	9	674844	74982.6	0.89 ns
Error (a)	30	2527250	84241.6	-
Cultivar	1	403202	403202.0	9.2 ns
Error (b)	2	87426	43713.0	-
Arrangement Cv.	3	656036	218678.6	2.92 ns
Population Cv.	3	2951490	98383.0	1.88 ns
Arrangement Pop. Cv.	9	405061	45006.7	0.6 ns
Error (c)	30	2245623	74854.1	-
Total	95	-	-	-

APPENDIX 13. Combined analysis of variance table for cowpea seed yield (kg/ha) at Samaru, 1980 and 1981

Source	D.F.	SS	MS	F
Replication	2	103850	51925.0	-
Year	1	4739640	4739640.0	58.04**
Arrangement	3	1507300	502433.3	6.15**
Population	3	2283620	761206.7	9.32**
Arrangement Pop.	9	560480	62275.6	0.76 ns
Arrangement Year	3	152990	50996.7	0.62 ns
Population Year	3	658480	219493.3	2.69*
Arrangement Pop. Cv.	9	538130	59992.2	0.73 ns
Error (a)	62	5062500	81653.2	-
Cultivar	1	2752390	2752390	28.33*
Error (b)	2	194270	97135.0	-
Arrangement Cv.	3	731370	243776.7	3.41*
Population Cv.	3	1747990	582663.3	8.15**
Year Cv.	1	576480	526480	8.06**
Arrangement Pop. Cv.	9	339420	37713.3	0.03 ns
Arrangement Cv. Yr.	3	526600	175533.3	2.45 ns
Population Cv.	3	842660	280886.7	3.99**
Arrangement Pop.Cv.Yr	9	810610	90067.8	1.25 ns
Error (c)	62	4434520	71524.5	-
Total	101	-	-	-

APPENDIX 14. Analysis of variance table for cowpea number of peduncles per plant at Samaru, 1980

Source	D.F.	SS	MS	F
Replication	2	162.16	81.08	1.97 ns
Arrangement	3	261.08	87.03	2.18 ns
Population	3	104.21	34.74	0.85 ns
Arrang. Pop.	9	263.74	29.30	0.71 ns
Error (a)	30	1233.26	41.10	-
Cultivar	1	9.08	9.08	0.25 ns
Error (b)	2	72.25	36.13	-
Arrangement Cv.	3	294.48	98.16	3.08*
Population Cv.	3	111.05	37.02	1.16 ns
Arrangement Pop. Cv.	9	407.67	45.29	1.42 ns
Error (c)	30	956.61	31.88	-
Total	95	-	-	-

APPENDIX 15. Analysis of variance table for cowpea number of peduncles per plant at Samaru, 1981

Source	D.F.	SS	MS	F
Replication	2	182.13	91.06	-
Arrangement	3	114.08	38.03	0.89 ns
Population	3	1022.26	340.80	7.9**
Arrangement Pop.	9	56.71	6.30	0.15 ns
Error (a)	30	1286.04	42.87	-
Cultivar	1	12.55	12.55	0.28 ns
Error (b)	2	91.09	45.56	0.28 ns
Arrangement Cv.	3	61.60	20.50	3.15*
Population Cv.	3	137.36	45.75	7.04**
Arrangement Pop. Cv.	9	93.08	10.34	1.72 ns
Error (c)	30	196.33	6.50	-
Total	95	-	-	-

APPENDIX 16. Combined analysis of variance table for cowpea number of peduncles per plant at Samaru, 1981 and 1981

Source	D.F.	SS	MS	F
Replication	2	2.49	1.2	-
Year	1	2653.69	2653.67	61.35**
Arrangement	3	131.21	43.75	1.01 ns
Population	3	878.80	292.90	43.25**
Arrangement Pop.	9	154.91	17.20	0.39 ns
Arrangement Year	3	243.94	81.30	1.88 ns
Population Year	3	247.66	82.55	1.91 ns
Arrangement Pop. Year	9	162.55	18.06	0.42 ns
Error (a)	62	2681.96	43.25	-
Cultivar	1	21.46	21.46	3.36 ns
Error (b)	2	12.73	6.37	-
Arrangement Cv.	3	209.58	69.86	2.95*
Population Cv.	3	46.44	15.48	0.65 ns
Year Cv.	1	0.15	0.15	0.006 ns
Arrangement Pop. Cv.	9	285.52	31.72	1.34 ns
Arrangement Cv. Yr.	3	47.60	15.87	0.67 ns
Population Cv. Yr	3	202.33	67.44	2.84*
Arrangement Pop. Cv. Yr.	9	314.05	35.23	1.48 ns
Error (c)	62	1470.16	23.71	-
Total	191	-	-	-

APPENDIX 17. Analysis of variance table for cowpea number of pods per peduncle at Samaru, 1980

Source	D.F.	SS	MS	F
Replication	2	0.32	0.160	-
Arrangement	3	0.480	0.160	1.39 ns
Population	3	0.320	0.106	0.92 ns
Arrangement Pop.	9	0.590	0.065	0.57 ns
Error (a)	30	3.460	0.115	-
Cultivar	1	0.0021	0.0021	0.018 ns
Error (b)	2	0.230	0.115	-
Arrangement Cv.	3	0.140	0.046	0.45 ns
Population Cv.	3	0.510	0.170	1.65 ns
Arrangement Pop. Cv.	9	0.880	0.098	0.95 ns
Error (c)	30	3.098	0.103	-
Total	95	-	-	-

APPENDIX 18. Analysis of variance table for cowpea number of pods per peduncle at Samaru, 1981

Source	D.F.	SS	MS	F
Replication	2	1.49	0.75	-
Arrangement	3	0.46	0.15	1.15 ns
Population	3	0.88	0.29	2.23 ns
Arrangement Pop.	9	2.28	0.25	2.00 ns
Error (a)	30	3.87	0.13	-
Cultivar	1	0.92	0.92	15.30 ns
Error (b)	2	0.11	0.06	-
Arrangement Cv.	3	0.89	0.31	1.34 ns
Population Cv.	3	0.99	0.33	1.43 ns
Arrangement Pop. Cv.	9	0.37	0.04	0.17 ns
Error (c)	30	7.01	0.23	-
Total	95	1	-	-

APPENDIX 19. Combined Analysis of variance table for cowpea number of pods per peduncle at Samaru, 1980 and 1981

Source	D.F.	SS	MS	F
Replication	2	0.60	0.30	1.76
Year	1	1.08	1.08	6.35*
Arrangement	3	0.21	0.07	0.41 ns
Population	3	1.07	0.36	2.12 ns
Arrangement Pop.	9	0.56	0.63	3.71**
Arrangement Year	3	0.73	0.24	1.41 ns
Population Year	3	0.12	0.03	0.18 ns
Arrangement Pop. Year	9	0.98	0.33	1.94 ns
Error (a)	62	10.45	0.17	
Cultivar	1	0.50	0.50	71.40*
Error (b)	2	0.01	0.0	-
Arrangement Cv.	3	0.31	0.16	0.86 ns
Population Cv.	3	0.30	0.10	0.83 ns
Year Cv.	1	0.42	0.42	3.50 ns
Arrangement Pop. Cv.	9	1.38	0.15	1.25 ns
Arrangement Cv. Yr.	3	1.10	0.37	3.08*
Population Cv. Yr.	3	1.69	0.56	4.67**
Arrangement Pop. Cv. Yr.	9	1.08	0.12	1.00 ns
Error (c)	62	7.70	0.12	-
Total	191	-	-	-

APPENDIX 21. Analysis of variance table for cowpea number of seeds per pod at Samaru, 1981

Source	D.F.	SS	MS	F
Replication	2	5.70	2.85	-
Arrangement	3	21.01	7.00	4.02*
Population	3	14.85	4.92	2.83 ns
Arrangement Pop.	9	7.46	0.82	0.47 ns
Error (a)	30	52.32	1.74	-
Cultivar	1	3.80	3.80	0.89 ns
Error (b)	2	8.54	4.27	-
Arrangement Cv.	3	1.72	0.57	0.44 ns
Pop. Cv.	3	0.33	0.11	0.08 ns
Arrangement Pop. Cv.	9	11.06	1.23	0.95 ns
Error (c)	30	39.25	1.30	
Total	95			

APPENDIX 22. Combined analysis of variance table for cowpea number of seeds per pod at Samaru, 1980 and 1981

Source	D.F.	SS	MS	F
Replication	2	9.11	4.56	-
Year	1	138.73	138.73	81.6**
Arrangement	3	6.72	2.24	1.31 ns
Population	3	19.80	6.60	3.88**
Arrangement Pop.	9	7.98	0.88	0.52 ns
Arrangement Year	3	16.06	5.35	3.14*
Population Year	3	2.66	0.89	0.52 ns
Arrangement Pop. Year	9	9.74	1.08	0.63 ns
Error (a)	62	105.61	1.70	-
Cultivar	1	16.46	16.46	8.12 ns
Error (b)	2	4.06	2.03	-
Arrangement Cv.	3	1.43	0.48	0.46 ns
Population Cv.	3	0.71	0.24	0.23 ns
Year Cv.	1	1.64	1.64	1.58 ns
Arrangement Pop. Cv.	9	9.83	1.09	1.05 ns
Arrangement Cv. Yr.	3	2.51	0.84	0.81 ns
Population Cv. Yr.	3	1.58	0.53	0.51 ns
Arrangement Pop. Yr.	9	16.37	1.82	1.75 ns
Error (c)	62	64.25	1.04	-
Total	191	-	-	-

APPENDIX 23. Analysis of variance table for cowpea 100-seed weight (g) at Samaru, 1980

Source	D.F.	SS	MS	F
Replication	2	604.6	302.30	-
Arrangement	3	272.7	90.90	0.61 ns
Population	3	196.9	65.63	0.44 ns
Arrangement Population	9	1075.4	119.49	0.80 ns
Error (a)	30	4468.8	148.96	-
Cultivar	1	77.1	77.10	0.84 ns
Error (b)	2	184.2	92.10	-
Arrangement Cv.	3	138.3	46.07	0.20 ns
Population Cv.	3	1363.9	454.63	1.97 ns
Arrangement Pop. Cv.	9	1203.8	133.76	0.58 ns
Error (c)	30	6904.4	230.15	-
Total	95	-	-	-

APPENDIX 24. Analysis of variance table for cowpea 1000-seed weight (g) at Samaru, 1981

Source	D.F.	SS	MS	F
Replication	2	586.5	293.2	-
Arrangement	3	844.3	291.1	3.42*
Population	3	224.9	74.9	0.88 ns
Arrangement Pop.	9	238.6	26.5	0.30 ns
Error (a)	30	2559.0	85.3	-
Cultivar	1	25.0	25.0	0.05 ns
Error (b)	2	995.5	497.5	-
Arrangement Cv.	3	84.9	28.3	0.51 ns
Population Var.	3	46.2	15.4	0.28 ns
Arrangement Pop. Cv.	9	295.2	32.8	0.59 ns
Error (c)	30	1660.6	55.4	
Total	95			

APPENDIX 25. Analysis of variance table for cowpea 1000-seed weight (g) at Samaru, 1981

Source	D.F.	SS	MS	F
Replication	2	428.3	214.10	-
Year	1	4588.5	4588.50	36.39**
Arrangement	3	1044.7	348.23	2.76*
Population	3	316.4	105.47	0.84 ns
Arrangement Pop.	9	916.0	101.78	0.81 ns
Arrangement Year	3	102.2	34.07	0.27 ns
Population Year	3	104.9	34.97	0.28 ns
Arrangement Pop. Yr.	9	371.5	41.28	0.33 ns
Error (a)	62	7818.1	126.09	
Cultivar	1	94.7	94.70	0.61 ns
Error (b)	2	308.6	154.30	-
Arrangement Cv.	3	43.3	14.43	0.09 ns
Pop. Cv.	3	711.9	237.30	1.57 ns
Year Cultivar	1	6.7	6.70	0.04 ns
Arrangement Cv.	9	298.7	33.19	0.22 ns
Arrangement Cv. Year	3	180.3	60.10	0.39 ns
Population Cv. Yr.	3	699.0	233.00	1.54 ns
Arrangement Pop. Cv. Yr.	9	1226.7	136.30	0.90 ns
Error (c)	62	9355.2	150.89	-
Total	191	-	-	-

APPENDIX 26. Analysis of variance table for cowpea seed weight per plant at Samaru, 1980

Source	D.F.	SS	MS	F
Replication	2	1597.60	798.80	52.6
Arrangement	3	190.37	63.46	4.18*
Population	3	305.93	101.98	6.52**
Arrangement Pop.	9	653.65	72.63	4.78**
Error (a)	30	455.52	15.18	
Cultivar (b)	1	1403.05	1403.05	9.34 ns
Error (b)	2	300.27	150.16	
Arrangement Cv.	3	7.96	2.65	0.078 ns
Population Cv.	3	163.30	54.43	1.61 ns
Arrangement Pop. Cv.	9	148.74	16.53	0.49 ns
Error (c)	30	1012.26	33.74	
Total	95			