FLOWERING, POLLINATION AND POD FORMATION IN BAMBARRA GROUNDNUT (VOANDZEIA SUBTERRANEA THOUARS), IN GHANA

A thesis presented by Mr. S.K. Karikari B.Sc. (Agric.) Legon, in part fulfilment of the requirements for the M.Sc. degree of the University of Ghana.
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From: Department of Crop Science,
University of Ghana,
Legon.

DECLARATION

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

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S.K. KARIKARI

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E.V. DOKU
(SUPERVISOR)

Date ....

ABSTRACT

The probable centres of origin of bambarra groundnut (*Voandzeia subterranea*), have been mentioned as Northern Nigeria, Cameroons, and along the Nile from Khartoum to Gondokoro. It is grown throughout Africa, mainly in the savanna areas and has also spread to many other Tropical countries outside Africa.

It is one of the most important pulse crops in Africa, and in Ghana it ranks next to cowpea in production and consumption. In Africa where the diet of a majority of the people lack animal protein, bambarra groundnut is one of the legumes which supplies either in whole or in part, the protein part of the diet.

Varieties may be classified into three groups; those with long trailing stems, the open or spreading types, those with short trailing stems the compact or bunch and an intermediate or semi-bunch type which is between these two extremes. Visual assessment of habit agreed closely with petiole/internode ratio and as this ratio could be measured, it seems to be a more reliable criterion for grouping varieties. Varieties are becoming more compact under cultivation, and pod thickness is also being reduced, and it appears that the aerial parts i.e. stems, petioles and internodes, are evolving faster towards compactness than the rate at which pod thickness is being reduced.

In all varieties, flowering starts 28 days after germination and depending on variety, it may or may not cease before the end of the life

of the plant. More flowers and pods are produced during the dry season than the rainy season. Fertility coefficient is higher for the bunch than the open or semi-bunch varieties and although this does not differ much during the two seasons, the value is slightly higher during the dry season than the rainy season. Where water can be provided the dry season would be more favourable for the growth of bambarra groundnut.

The flowers appear to be obligatory self-pollinated although cross-pollination could take place with the aid of ants. The burial of pods inside the soil is also aided by ants and man. Varieties vary in their dependence on ants, the bunch varieties being less dependent than the open and semi-bunch varieties.

The ovary develops on the surface of or inside the soil, and fruit development occurs in two stages:

(a) definite development of pod followed by (b) development of seeds. Maturity is characterised by dryness and browning of the interior of the shell and appearance of brown patches on it. The lower seeds are heavier and produce more vigorous seedlings than the upper seeds.

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LIST OF ABBREVIATIONS AND SYMBOLS

°F	Degrees Fahrenheit
cms.	Centimetres
c.v.	Coefficient of variation
d.f.	Degrees of freedom
Fig.	Figure
L.S.D.	Least significant Difference
M.S.	Mean square
%	Percentage
r	Correlation coefficient
Reqd.	Required
*	Significant
**	Highly significant
s.d.	Standard deviation
s.s.	Sum of squares.
u.	mu.

CHAPTER I

INTRODUCTION

I. Origin and early history.

According to Hepper (1963), Voandzeia subterranea was described by Linnaeus in 1763 and given the name Glycine subterra and Du Petit Thouars in 1806 changed it to Voandzeia subterranea.

The origin of bambarra groundnut has interested many writers and although several of them have concluded that it is African in origin, it is still not clearly known which part of Africa it comes from. The plant goes under various names in different parts of Africa, (Dalziel 1937, Stanton 1966), and attempts have been made to trace the origin of the plant through vernacular names.

Bambarra is a district in Upper Niger, near Timbuktu, and Dalziel (1937), and Holm & Marloth (1940), are of the opinion that the crop originated from this place. According to Rassel (1960), however, the name Voandzeia doubtlessly comes from the deformation of a Malagasy term "Voanjo", ("Voa"= seed and "anjo"= that which satisfies well); Rassel therefore believes that the crop originated from Malagasy. This view is supported by De Candolle (1886) who in his book on "The Origin of Cultivated Plants", mentioned that the earliest travellers in Malagasy including Du Petit Thouars saw this leguminous annual. De Candolle said further that Schweinfurth and Ascherson found it wild on the banks of River Nile from Khartoum to Gondokoro. De Candolle concludes thus:

"...... in spite of the possibility of naturalisation from cultivation, it is extremely probable that the plant is wild in Tropical Africa".

Dalziel (1937) found the plant in a wild state in 1909 in North Yola province in Northern Nigeria and also mentioned that in the same year Lederman found it wild in Northern Cameroons.

According to Cobley (1956), the plant probably originated in Central Africa and plants in the semi-wild state have been found in parts of West Africa. One such findings was made by Hepper (1963) who in 1958 collected a wild strain from Northern Nigeria in an uncultivated savanna woodland about latitude 9°S and longitude 13°E near the village of Faran in Kilba country from the very place where Dalziel had collected some Voandzeia plant in 1909. Hepper also collected some wild strain at the village of Demassa near the border with French Cameroons.

According to Rassel (1960), the cultivation of bambarra groundnut seems to have preceded the introduction of the groundnut, (Arachis hypogea), of America origin. Rassel supports this with the evidence that Arab documents dating from 1380 cite several times a food plant with the name "gerti" which seems very likely to be Voandzeia and also that Flacourt and Cauche in 1651 saw the cultivation of Voandzeia by the Antankarantras in Malagasy before the discovery of groundnut.

From Africa, the plant has spread to other parts of the world. According to Cobley, it is known in parts of Tropical Central America where it must have been introduced by the slaves at the time of the great slave trade. This view of Cobley is shared by Bois (1927) who mentioned that roasted seeds of bambarra were sold to negroes in the streets of Rio de Jeneiro. It is further stated by Bois that the plant was grown in Mauritius Island. Rassel mentions Ceylon, India, Indonesia, Malaysia, New Calidonia, Northern Australia and Brazil among the other parts of the world where the plant is found.

As the plant has been cultivated in Africa from an early period (Bois 1927, Cobley 1956, Rassel 1960), and the manner of its introduction is not yet known, different means are necessary to ascertain its origin, and one of the most direct means, is to seek in what country it grows wild. Three such places have been mentioned; along the Nile from Khartoum to Gondokoro, in Northern Nigeria and Northern Cameroons. These places should therefore be regarded as probable places of origin of this plant while other places where the crop has been reported to be cultivated by ancient people should be regarded as probable secondary centres of origin or of diversity of the crop.

As a result of hybridisation followed by natural or artificial selection many ecotypes and cultivars occur at these secondary centres, and these differ in developmental pattern. For instance, Rassel observes that the Congo cultivars mature in five months whereas importations from Senegal and Malagasy mature in three to four months. Doku and Sinnadurai (1968) observed differences in habit and maturity period of three local high yielding varieties. Local cream (Legon No.3) matures in three months but local light reddish brown (Legon No.1) and local deep reddish brown (Legon No.67) mature in three and a half to four months. Local cream is bunch while local light reddish brown and local deep reddish brown are more open. There is a large variation in colour of the seeds from white, ivory and cream through light and dark browns to red or black. Mottled, mosaic, specked, variegated and patterned seeds are also found.

These wide variations are as expected since the plant is not confined to a single region of Africa. Turreson (1922) observed that species differentiation into ecotypes is much more likely to be found in common widespread species than local or endemic ones and also that pronounced earliness combines with moderate height while lateness combines with great height.

Turreson's observation bears out the variations in Voandzeia, indicating that the many ecotypes found in the species have arisen as a result of genotypical response to various habitats.

2. Economic importance.

Grain legumes in general have been recognised as an important contribution to both human and animal diet since the beginnings of agriculture. In the developing countries and particularly in Tropical Africa, the diets of a majority of the people lack animal proteins and in many areas pulse crops supply most, of the protein in the diet. Meat, fish and animal products such as eggs and milk are not only expensive but also scarce.

In many parts of Africa livestock owners regard their animals as a sort of investment and rarely are these animals eaten. Stanton (1966) observed that livestock in West Africa are numerous but are usually kept for purposes of accumulating capital and not as a source of milk of meat except on festive occasions. La-Anyane (1962) also reported that although the Northern Region of Ghana is generally associated with livestock farming, the people are mostly vegetarians and that only on special occasions such as weddings or religious observances would they slaughter cattle, sheep, goat or poultry for consumption. He further observed that the Frafras of this part of the country never eat their animals except when they die.

There are also cases when custom prevents certain classes of people especially women and children from eating meat. According to Stanton, in some cattle keeping areas in Africa milk is consumed by adults and old people but not by children and indeed nutritious foods are considered to be harmful to children. Stanton made reference to Morley (1958), who reported that Yoruba mothers believe that it spoils a child to feed it meat and that giving it eggs would turn it into a thief. La-Anyane mentioned that in parts of Manprusi women are not allowed to eat meat.

Many of these prohibitions which affect consumption of food of animal origin fortunately do not affect legumes so that generally speaking beans are the best alternative source of protein.

According to Sellschop (1962), the most important leguminous crops in terms of production and consumption in Africa are in the order, groundnut, cowpea and bambarra groundnut, (<u>Voandzeia subterranea</u>). The result of a survey in Ghana on leguminous food crops other than groundnuts indicated that the production and consumption of grain legumes in Ghana followed the same pattern as the entire African continent (Guerts 1959), except that the order of importance was cowpea, bambarra groundnut and lima bean. Thus, in Ghana the importance of bambarra groundnut is only next to cowpea in production and consumption.

Many territories in Africa tend to have zones of forest and savanna, the savanna occupying the larger portion. The vegetation zones of Ghana based on those of Taylor (1952) show that the country is divisible into three major regions, namely the forest zone and the coastal and the northern savanna zones. The areas outside the main forest zone where the rainfall is generally less than 50 inches per annum are characterised by savanna (Lane 1962). Over much of these areas the rainfall reaches its maximum during August - September, after which it falls off rapidly and is followed by a long dry season of four to five months when humidity is low.

Groundnut is not indiginous to Africa; bambarra groundnut on the other hand, is indiginous and was developed as a crop plant originally in the savanna zone where their wild ancestors are still to be found (De Candolle 1886, Dalziel 1937, Cobley 1958, Hepper 1963). The compact habit which is seen in many cultivars of bambarra groundnut have evolved as ecotypes under cultivation in the savanna areas (Hepper 1963, Doku 1968) to check the drying effect of the wind and so make the plant drought resistant and responsive to savanna conditions. Not only is it drought resistant but also it is one of the most pest and disease free legumes and its thick pods make it much less subject to damage in the field and in store than the groundnut. Bambarra groundnut therefore is one of the most popular legumes in Africa (Cobley 1956) or at least the crop best adapted to the savanna areas of Africa (Stanton 1966).

It features prominently in traditional farming systems as an inter-crop with cereals and root crops, sole cropping is also a traditional practice. Stanton (1966), recognises two contrasting systems of grain legume cultivation in Africa namely the bambarra groundnut type of culture and the cowpea type. The latter to which lima bean belongs is the commoner type and is traditionally an intercrop which is planted late in the season in comparison with the cereal or other main crops. In the bambarra groundnut type of culture which includes groundnut, pure crops are usually planted at a very close spacing to form a dense mat. (Fig.1)

According to Doku (1967), this division of grain legume culture may be true if the whole African continent is considered but practices differ with different countries and in Ghana this practice is on a very limited scale. Cereals and root crops always form the main crops which are inter-cropped with such grain legumes as cowpea, groundnut and bambarra groundnut. Discussing crop sequence in ecological zones in Ghana, Doku mentioned that bambarra groundnut or groundnut is interplanted with cereal crops during the second year of rotation in the drier Guinea Savanna areas of Brong-Ahafo (The Brong-Ahafo Yam Belt) and Northern Ghana, where the annual

Fig. 1. A pure stand of bambarra groundnuts

rainfall of about 30 inches falls in one season. In the drier areas of the south where the rainfall is also below 30 inches per annum, for example, the Accra plains, cassava is the first crop and is interplanted with vegetables and such grain legumes as groundnut and bambarra groundnut, which may be also seen occasionally as a first crop to be followed later by cassava.

In the F.A.O. Agricultural Studies No.55 (Agricultural and Horticultural Seeds), it is stated that bambarra groundnut is interplanted with sugar cane in Mauritius and in Kenya and South Africa it is grown with maize and sorghum.

Wills (1962) mentioned that bambarra groundnut is confined to the savanna zones and more frequently cultivated in the interior savanna and compound farming areas. According to Stanton (1966) bambarra groundnuts are still popular in the northern drier areas of West Africa where the soil is too poor for the cultivation of groundnuts, and Brammer (1962), mentioned bambarra groundnuts among the drought resistant crops that are suitable for the condition of the savanna ochrosols.

Boateng (1967) also reports that owing to the length and intensity of the dry season, agriculture in the northern savanna of Ghana is almost entirely confined to the rearing of livestock and the cultivation of cereals and such legume as bambarra beans which are unaffected by the dry season.

According to Rassel (1966), bambarra groundnut is the food legume best adapted to the poor soils of south Congo, where it out-yields groundnut in most cases. Pearl millet Pennisetum glaucum is the only cereal well adapted to this region and so Rassel concluded that if bambarra groundnut and Pearl millet could attract economic interest, thousands of individuals would enjoy revenues of which they are presently deprived and a large uncultivated acreage could be made valuable. Miracle (1967) also mentioned that small plots of pure stand of the crop yield cash revenues for people of this area.

The generic name Voandzeia is said to have been derived from a Malagasy term "Voanjo" meaning seed which satisfies well (Dalziel 1937, Rassel 1960). Its satisfying potentiality, however, is not only known in Malagasy but also among the Akans of Ghana, it is the food with which the delicacies of other foods are compared by the Akan simile, "it (the other food) is as delicious as bambarra groundnut". According to oral tradition in Ashanti a plate of bambarra groundnut was a complementary gift to distinguished persons. Its stew was among them item of foodstuffs that a young girl who had just married would on the first occasion prepare for the husband and members of his household. Stanton also mentions that bambarra beans are eaten at festivals in many places in Africa.

The seeds of bambarra groundnut contain 6.0% oil, 60% carbohydrates and 18% proteins, (those of groundnut are 45%, 27% and 17% respectively and cowpea 1.5%, 22% and 60% respectively), Stanton (1966). Although they contain a much lower percentage of oil, Miracle (1968), reports that the Azande of the Congo roast the nuts and pound them in mortar to extract oil. The high percentage of carbohydrate and proteins show that they none-the-less have a distinct food value. The following quotation from a report by A. Balland a pharmacist of the French colonial armies in 1903, quoted by Bois (1927) is of special interest:

"Admitting with physiologists that each day has to be employed in repairing the losses suffered by human organism, 120 - 130 grams of nitrogenous material, 50 grams of fat, 500 grams of carbohydrate or of amino acids even while realising the coefficient of digestibility, one can get exactly these elements in a kilogram of Voandzeia seeds. It is one of the rare examples which nature gives us of a complete food. Voandzeia therefore is a plant to be grown by reason of its exceptional food value." This proclamation, at a time when food science had hardly been developed as it is today, doubtlessly shows that the food value of Voandzeia was realised very early. Mullins (1962) also mentioned that although bambarra beans are not particularly rich in protein, yet its oil content gives it a caloric value equal to that of a good cereal and it is in itself a well balanced food which is often preferred to groundnut. According to Cobley (1956), the seeds have entered world trade but are little known outside Africa, where they provide one of the most nutricious of the pulses.

The beans are prepared in various ways by many tribes in Africa. According to Rassel (1960), Voandzeia seeds are consumed fresh or grilled before maturity by the people of the Congo. At maturity they are eaten after boiling. In the Ivory Coast it is utilised in the form of flour which makes it more digestible. In East Afrida they are roasted, then pulverised and eaten in the form of soup with or without oil and condiments. In Nigeria they are prepared in the form of a cake before they are eaten.

In Rhodesia, Johnson (1968), mentioned that it is boiled in the immature green state, shelled or unshelled, until quite soft and they are eaten either by themselves or mixed with green maize. The ripe shelled nuts which are hard and difficult to grind are pounded to flour and then boiled to a stiff porridge. The porridge remains good for a long time and is traditionally used as a travelling food. It was also preserved as a winter relish. An alternative method of preparation is to roast, break into small pieces, boil, crush and eat as a relish with "sedza", (maize meal porridge). The boiled and salted whole kernels are frequently offered as apetizers in restaurants in Angola and Mozambique. Johnson mentioned further that a well known Rusape cannery recently began to can bambarra nuts in gravy, the 8-oz cans retailing at 9 pence each and have proved to be quite popular.

Bambarra nuts are widely eaten in Ghana. According to La-Anyane (1962), the main meal of the rural people of Northern Ghana consists of cereals and vegetable protein foods like cowpeas and bambarra beans. There are various ways in which the beans are cooked and prepared. The fresh immature fruits are boiled with salt and these are sold by Hausa children in the streets of big towns and cities. The dry ones are boiled and crushed into cakes or balls which are fried in palm oil and then used as stew. The nuts are also boiled with pepper and salt in the preparation of "abeboi" which when served with "garri" (grated and heated cassava) or mashed fried ripe plantain popularly known as "tatare", makes a very delicious meal. The beans are being canned at the Nsawam Cannery and this has increased the availability of the product throughout the year, 44,000 cans of various sizes are turned out annually.

Its use as animal feed has long been realised. According to Rassel (1960) Amman has found out that the leaves are rich in nitrogen and phosphorous and so recommends it for grazing. Stanton also mentions that the haulm is palatable to stock.

Although no figures are available on acreage and yield of bambarra groundnut in Africa, its importance in Tropical agriculture especially those of the arid savannas cannot be over-emphasised. It is the most drought resistant pulse crop and produces a crop under conditions of high temperature and little rainfall where other pulses like groundnut and cowpea fail to thrive. It is therefore suited to the arid tropics where the soils are poor and where its short life cycle is completed within the short period that the scanty rains fall. It is gradually replacing groundnuts on most of the poor or exhausted soils (Stanton 1966). Rassel (1960) strongly recommends its cultivation on the soils of the arid tropics where population has still not left their economy of strict subsistence periodically threatened by famine.

Surprisingly enough, bambarra groundnut whose importance to Africa particularly Ghana is so remarkable has not received the attention it deserves. Information on the crop, concerning its botany especially as regards flowering and mode of pollination is not only limited but conflicting. This lack of reliable information has hindered progress in breeding and selecting improved varieties.

A study of the botany of the crop should therefore be a valuable contribution since knowledge to be gained from such a study would be required before embarking upon any breeding programme.

This work attempts a general classification of cultivated Ghanaian varieties. It also includes studies on flowering, pollination, and pod formation. Seasonal effects on flowering and yield were also touched upon.

Fig. 2 - Open or spreading variety of bambarra groundnut (semi-diagramatic).

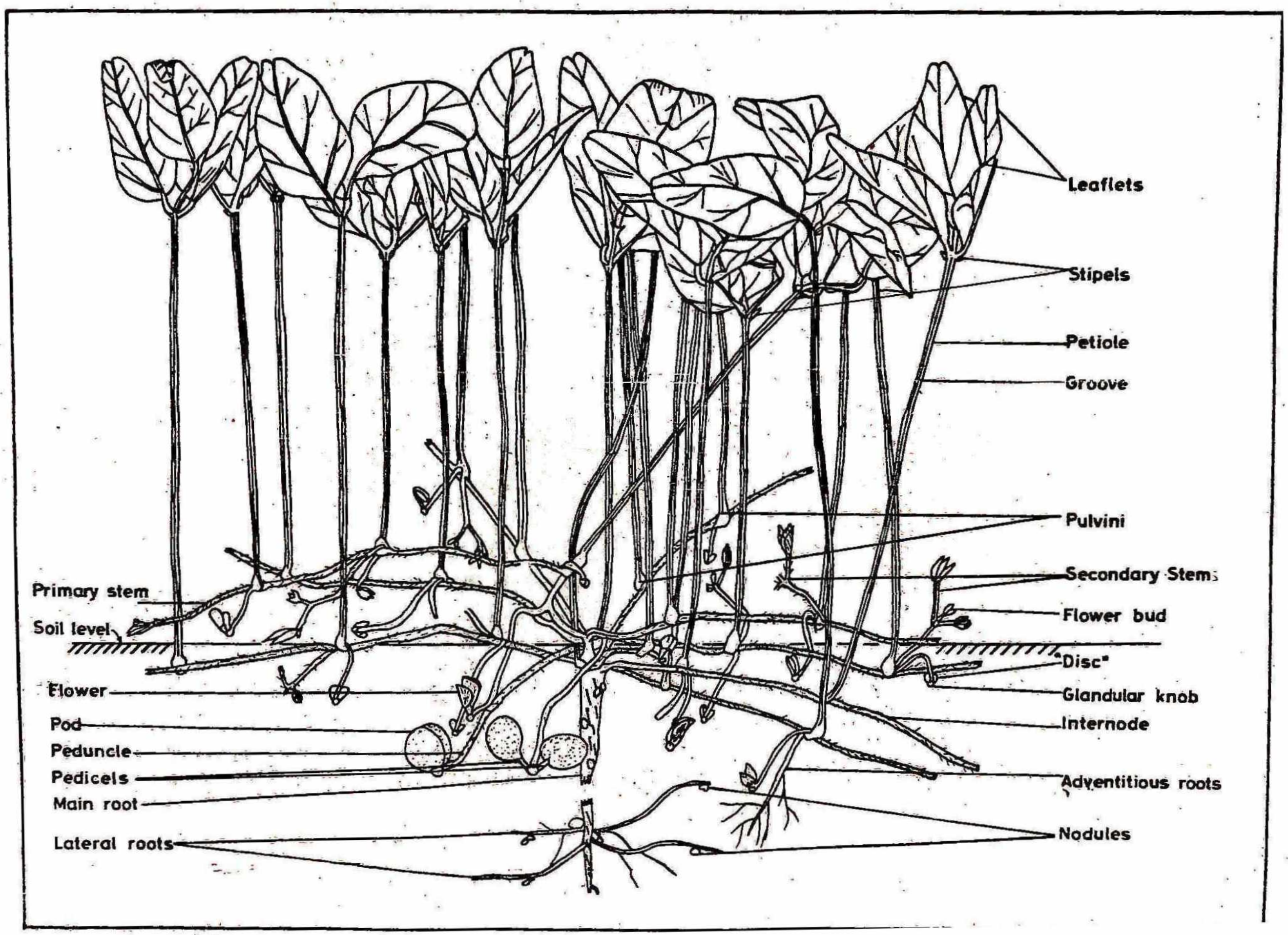
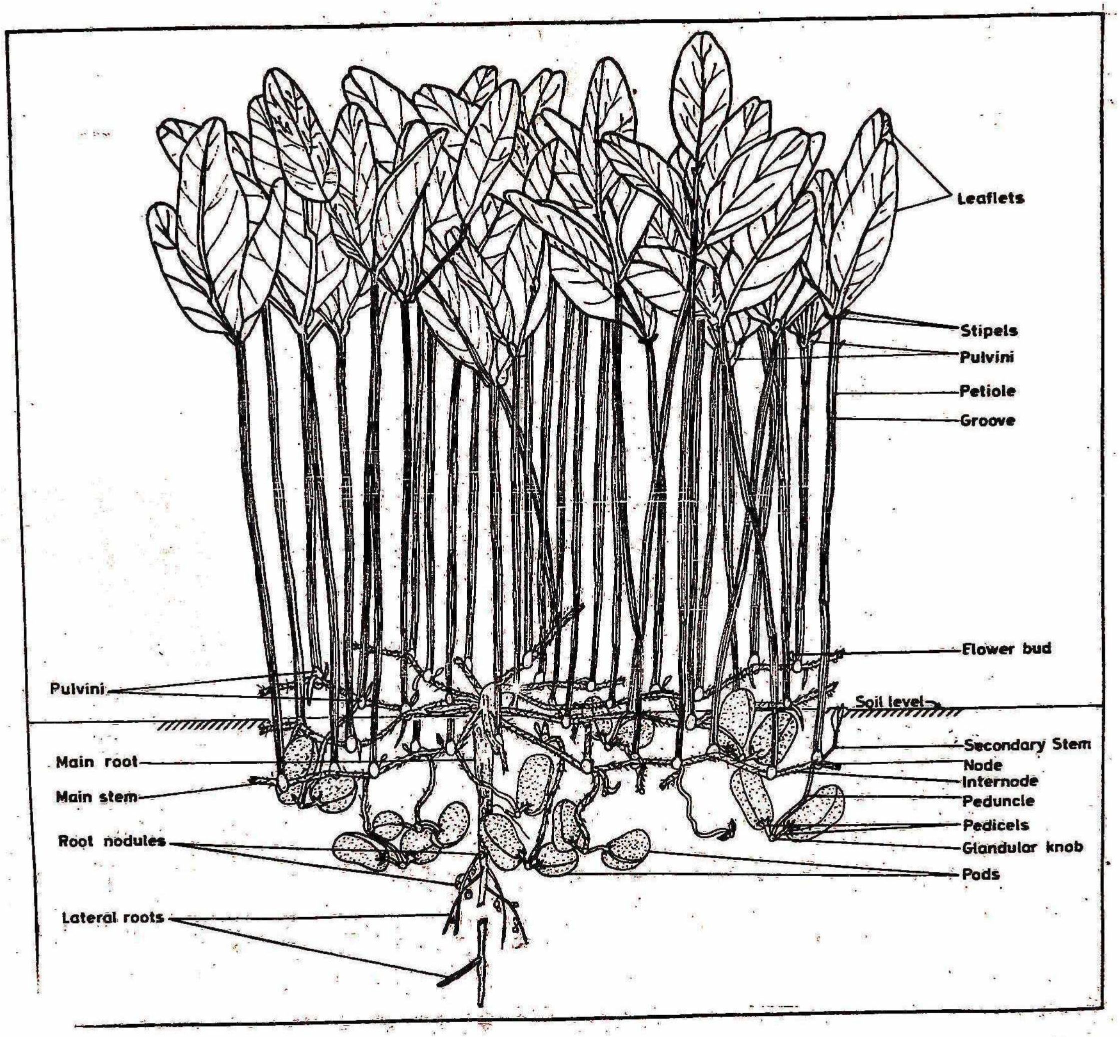


Fig.3 - Compact or bunch variety of bambarra groundnut (semi-diagramatic).



After this time new internodes are produced at about weekly intervals, and those near the base of the plant, which are usually buried under the surface of the soil, are shorter than those farther away. Leaf and a flower bud arise at each node in an alternate arrangement along the nodes.

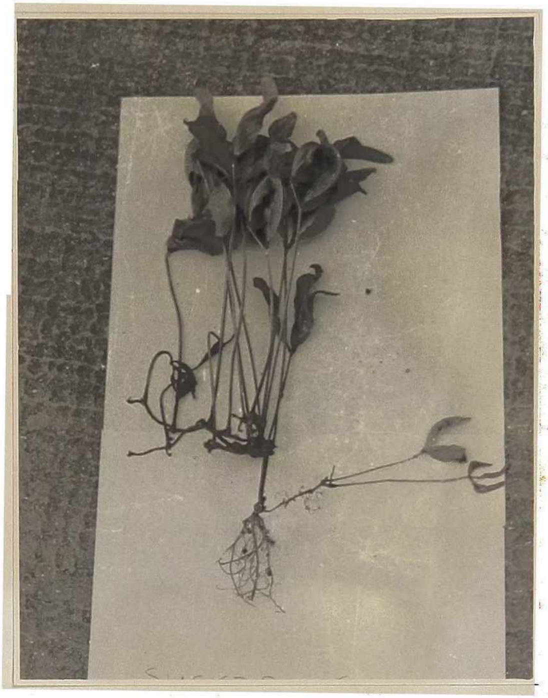
The leaves are trifoliate and are carried on long thin stiff errect and hairy petioles which have two narrow lateral flanges along the dorsal surface forming a wide groove along their length. The stems and petioles may be coloured pink, purple or bluish-green according to variety. The terminal leaflet is subtended by two stipels while the lateral ones have one stipel each. The lateral leaflets are borne directly by means of hairy pulvini on the petiole; the terminal leaflet is shortly stalked and again attached to the petiole by a marked and hairy pulvinus. The leaflets are ovate with sharp bases, weakly retuse tips, and entire margins. The lateral leaflets are less regular in shape and about five-sixth the length of the terminal ones.

The flowers spread out at ground level on hairy peduncles which arise from the nodes of the stem and to whose bulbous end one to three, but usually two, flowers may be attached by pedicels (Fig. 9). Flowers of most varieties have yellowish-white petals, some have deeper yellowish petals, sometimes with reddish-brown striations, and a few have light pinkish petals.

The fruits are bivalved pods, indehescent, white and smooth in the

Fig. 4

(a)



(b)

Bambarra groundnut plant showing (a) a sucker, and (b) two suckers arising from the collar below the hypocotyl.

Nigeria had longer trailing stems than most cultivated varieties which are more compact with shorter petioles. Hepper observed further that the pods of the compact Voandzeia had thicker shells while those of the open types had thinner shells. This observations of Hepper is shared by Rassel who also observed that the bunch varieties from Congo generally had thick-shelled pods (the percentage of seed to pod fluctuating between 55-70%) but varieties from North Africa and Malagasy as well as some of the Congo varieties are open types and these have thinner pods (the percentage of seed to pod varying between 70 and 80).

The three high yielding local types which have been recommended by Doku and Sinnadurai (1968), are distinguished by their seed colour, habit, and maturity period. Local cream (Legon No.3) which is bunch, has cream coloured seeds with a white hilum, and matures in three months whereas local light reddish brown (Legon No.1) and local deep reddish brown (Legon No.67) have a more open habit and mature between three and a half to four months.

Doku (1968), observed that the more compact a variety, the longer the petioles, an adaptation which ensured that the leaves received maximum light. The Legon collection of locally cultivated strains shows both extreme types of compactness and openness with gradations in between.

Seed colour and maturity period appear to have limited use as sole means of classification because varieties with different growth habits (an important character in bambarra groundnut) may have the same seed colour and mature at the same time. In any case, some of the varieties in the Legon collection are still seggregating for colour, (Doku 1968). Rassel (1960) also observed that seeds collected from fields cultivated by natives of the Congo showed different degrees of colour intensities and so concluded that natural heterogamy existed. Johnson (1968) also noted continuous variation between light and dark browns from planting of dark brown seeds.

Also in view of the suggestion that breeding system may depend on growth habit (Doku 1968), and that growth habit may change with soil type (Cobley 1956), it was desided to study the morphological variation (with emphasis on growth habit) in the collection at Legon with the hope of finding a more reliable criterion for grouping varieties and from each group select a representative type with which to carry on further research.

Materials methods and results

Seeds of 27 varieties were sown in rows, each variety being allotted two rows of twelve plants each. The spacing within the row was two feet apart, and that between rows, three feet apart. This wider spacing was adopted to give the plants maximum spread. Records taken included:

(i) Habit of growth.

(ii) Colour of flowers.

(iii) Number of stems per plant at maturity.

(iv) Internode lengths at maturity.

(v) Petiole lengths at maturity.

Relationship between fourth petiole and internode lengths.

(vii) Thickness of dry shell.

(viii) Length/breadth ratio of terminal leaflet.

(ix) Colour of dry seed and colouring around the hilum.

(i) Habit of growth.

At maturity, the varieties were visually assessed and grouped into three habit forms as shown in Table

Table 1. Visual assessment of habit.

	Habit		
	Bunch	Semi-bunch	Open
Variety	3	1	2
	15	4	38
	17	6	43
	18	12	47
	20	13	51
	21	14	52
	22	27	62
	28	35	64
	39	46	67

The 27 varieties observed seem to be equally distributed among the three habit groups. These visual groupings were then followed by other assessments and measurements and relationships between them (visual grouping and assessments and measurements) compared.

(ii) Colour of flowers.

The flowers of three varieties i.e. 18,20 and 51 have light pinkish petals, those of varieties 1,4,64 and 67 have yellowish petals with purplish striations on the standard petals. All the others have yellowish petals but the intensity of their yellowness varies with the time of the day and the age of the plant. When flowers open in the morning they are yellowish-white, but towards noon, they turn brown. Flowers of old plants are always brownish-yellow.

On the basis of flower colour, varieties may be grouped as follows:

(a) those with complete yellow flowers

(b) those whose yellow flowers have purplish striations at the lower end of the standard petal and

(c) complete purple flowers.

However, varieties in the same colour group do not always fall within the same habit group. Flower colour alone therefore does not appear to be a good criterion for grouping.

(iii) Number of stems per plant at maturity.

Five plants per variety were selected at random and the number of stems counted.

The number of stems per plant varied markedly between and within varieties (Table 2). For this character the coefficient of variation was very high probably because varieties were not pure with regard to this character. On the average the number of stems ranged between 6 and 14. Plants visually assessed as bunch had more stems than the open types, and the semi-bunch types, were intermediate. Assuming that the range was equally distributed, then plants with an average number of stems between 6 and 9. 9 and 12, and 12 and 14 should fall within open, semi-bunch and bunch groups, respectively. Varieties 43, 47,51,62,64 and 67 of the open group agree on visual assessment and measurement based on the number of stems, but varieties 2,38, and 52 did not fall within their expected group, i.e. the open group, but in the semi-bunch. group.

All the varieties visually assessed as semi-bunch fell into this group on the basis of the number of stems per plant, but two of the nine varieties i.e. varieties 20 and 39 visually assessed as bunch did not fall within this group on the basis of number of stems per plant, but in the semi-bunch group.

(iv) Internode lengths.

Four longest stems, (these being the earliest produced), which were also approximately at right angles to one another, were selected and the lengths of internodes from the base of each stem to the periphery were measured. Five plants each of varieties 1,3,4,18,64 and 67 were measured. Internode lengths increased from the base of the plant towards the periphery and varied within and between plants of the same variety but the fourth internode was among the least variable in the six varieties studied (Table 3).

(v) Petiole lengths.

The lengths of petioles corresponding to the internodes measured were taken on five plants from each of the six varieties.

Petioles also increased in length from the base towards the periphery of the stem but those at the distal ends of the fourth internodes were among the least variable (Table 4).

(vi) Relationship between fourth petiole and internode lengths.

Having found out that the fourth internodes and the petioles at their distal ends of six varieties were the least variable, the fourth internodes and petioles at their distal ends of five plants per variety, selected at random from each of the 27 varieties were measured on four longest branches. From these figures ratios of petiole lengths/ internode lengths (petiole length per unit of internode length) were calculated (Table 7 and Fig 6).

Internode and petiole lengths varied between and within varieties but the variation within varieties was quite small (Tables 3 and 4). Plants with longer internodes also had longer petioles (Fig.5 Table 7). The correlation coefficient r_{25} being + 0.5, and highly significant. This contradicts Doku's observation that the compact varieties had longer petioles, It is rather the ratio of petiole length/internode length (i.e. petiole length per unit of internode length) that is high for all varieties visually rated as bunch, low for the open, and intermediate for the semi-bunch. This ratio is between 9 and 11 for bunch varieties, between 7 and 9 for the semi-bunch and between 5 and 7 for the open types.

There was a close agreement between visual assessment of habit and petiole/internode ratio. All varieties visually assessed as open and semi-bunch fell into this group on measurements based on petiole/internode ratio. However, four out of the nine varieties, i.e. varieties 20, 21, 22 and 38 visually assessed as bunch fell into the semi-bunch group. Variations (measured by coefiicient of variation) in petiole internode ratio was comparatively high among varieties with the bunch habit i.e. 3.9% as compared to 1.8% and 1.6% of the open and semi-bunch varieties respectively (Fig.6). The close agreement between visual assessment of habit and measurements based on petiole/internode ratio, indicates that the latter can be used in grouping varieties. It places visual assessment on measurable basis.

(vii) Thickness of dry shell.

The thickness of the dry shells of twenty pods per plant taken at random were measured by means of a micrometer screw gauge. Thickness of dry shell varied between 0.30 mm. and 0.55 mm. (Table 8). All varieties visually assessed as open, had thicker shells with shell thickness ranging between 0.50 mm. and 0.55 mm; most of the semi-bunch varieties also had shells whose thickness fell between 0.50 and 0.55 mm. About half of the bunch varieties had thinner shells with shell thickness ranging between 0.30 mm. and 0.37 mm. and the other half had shells whose thickness was intermediate between the bunch and the open varieties.

Relationship between number of stems per plant, petiole/internode ratio, and shell thickness.

There was a significant positive correlation ($r_{25} = + 0.9$) between petiole/internode ratio and the number of stems per plant (Fig. 7 and Appendix 2), but there was no correlation between the former and shell thickness. The graph of petiole/internode ratio against shell thickness (Fig.8) showed three groupings as follows: nine varieties with low petiole/internode ratio between 5 and 7, whose shell thickness varied from 0.50 to 0.55 mm., and comprising entirely of all the varieties with open habit; five varieties with very high petiole/internode ratio between 9 and 11, whose shell thickness is between 0.30 mm. and 0.40 mm. and comprising some of the varieties with bunch habit; and 13 varieties with petiole/internode ratio between 7.4 and 8.2 whose shell thickness ranged between 0.41 and 0.51 mm. These comprised nine varieties of the semi-bunch group, and four of the bunch group. Two varieties of the semi-bunch group i.e. varieties 1 and 4 and one variety of the bunch group i.e. variety 20 had shells whose thickness fell in the range of those of open varieties, and three varieties of the bunch group i.e. varieties 17,21 and 28 had shells whose thickness fell in the range of the semi-bunch group.

Varieties of the open group whose petiole/internode ratio was low had fewer number of stems and thick-shelled pods. Varieties of the bunch group whose petiole/internode ratio was high had more stems but about half of them had pods whose shells were thin, the other half had thick-shelled pods.

Petiole/internode ratio, and number of stems per plant of varieties in the semi-bunch group were intermediate between those of the bunch and open groups, however, some of them had pods whose thickness fell within the range of the open group, but most of them had pods whose thickness was intermediate between the bunch and the open.

(viii) Length/breadth ratio of terminal leaflet.

The terminal leaflet is more regularly shaped than the two lateral ones and its size varies markedly between varieties. It was thought that this variation could be used to classify varieties. Twenty terminal leaflets, four from each of the five plants chosen, were measured. Leaflets varied in size between and within varieties but on the whole the length/breadth ratio for all the varieties was approximately 2:1 (Table 9). It therefore appears that this character cannot be a good criterion for grouping.

(ix) Colour of dry seed and colouring around the eye.

With the aid of the British Colour Council Horticultural Colour Chart, the colour of the dry seeds were described. Seeds with no colouring around the hilum distinctive from the general colour of the testa were described as "no eye", while those with distinctive eye colouring were described as "eye" (Table 10).

Where seed colour was not uniform the colour which predominated was used in describing the sample. Within some varieties, segregation for colour was still evident. Also there were occasions where varieties with different growth habits had the same seed colour. Seed colour therefore is not a good criterion for grouping.

3. Discussions and conclusions.

It appears that the most reliable criterion by which varieties may be grouped will be on the basis of growth habit namely compact or bunch,

Table 2 **Number of stems per plant at maturity**

	Variety	Plants 1	2	3	4	5	MEAN	s.d.±	C.V%
	15	14	4	14	16	10	13.6	2.20	16.2
	18	12	6	14	14	10	13.2	2.28	17.3
	13	8	6	10	16	16	13.2	1.82	15.7
	17	16	0	8	16	16	13.2	3.56	27.0
BUNCH	22	8	2	16	10	16	12.4	3.21	25.8
	28	10	6	12	12	12	12.4	2.20	18.3
	21	12	4	12	14	8	12.0	2.20	18.3
	20	12	4	14	10	9	11.8	2.28	19.3
	39	12	6	12	8	10	9.5	2.01	27.2
	27	11	9	12	14	12	11.6	1.82	15.7
	14	12	8	10	10	14	10.8	2.38	22.0
	13	8	9	10	10	6	10.6	2.61	24.6
	35	11	12	14	8	8	10.6	2.61	24.6
SEMI-BUNCH	46	14	14	10	10	5	10.6	3.71	35.0
	1	8	8	14	12	10	10.4	2.07	19.9
	6	10	6	12	8	16	10.4	3.31	31.8
	12	10	10	10	12	12	10.4	1.09	10.5
	4	10	8	12	12	6	9.6	2.01	27.2
	2	8	6	10	12	12	9.6	2.07	21.6
	38	6	8	8	12	12	9.2	2.68	29.1
	52	10	8	12	8	8	9.2	3.20	34.8
	47	7	10	8	8	12	9.0	2.00	22.0
OPEN	64	12	8	8	7	10	9.0	2.00	22.0
	43	5	7	9	10	12	8.6	2.70	31.3
	51	6	8	6	9	13	8.4	2.88	34.3
	67	13	6	8	9	6	8.4	2.88	34.3
	62	5	9	8	9	8	7.8	1.92	24.6

Table 3 - Variation within internodes (Variety 1)

		Internode (cms.)											
		1	2	3	4	5	6	7	8	9	10	11	12
Plant	Branch	1.0	1.3	1.6	1.7	1.7	1.8	2.0	2.2	1.9	1.8	-	-
	2	1.2	1.2	1.4	1.8	1.8	2.0	2.2	2.4	2.2	2.1	2.0	-
	3	0.9	1.0	1.3	1.9	2.0	2.2	2.3	2.4	2.4	2.3	2.1	-
1	4	1.3	1.6	1.7	1.7	1.7	1.7	1.8	1.8	2.0	1.9	1.9	-
	Mean	1.1	1.3	1.5	1.8	1.8	1.9	2.1	2.2	2.1	2.0	2.0	-
	s.d.±	0.55	0.25	0.10	0.10	0.14	0.22	0.14	0.28	0.22	0.22	0.10	-
	C.V.%	50.0	19.0	6.7	5.6	7.7	11.5	6.6	12.7	10.5	11.0	5.0	-
	1	1.0	1.3	1.5	1.7	1.7	1.8	2.0	2.1	2.1	2.0	1.1	1.7
	2	1.5	1.6	1.7	1.7	1.8	1.8	2.0	2.2	2.2	2.2	2.3	2.2
	3	1.2	1.4	1.5	1.9	2.1	2.1	2.3	2.3	2.5	2.5	2.4	2.2
2	4	1.3	1.3	1.6	1.7	1.7	1.8	1.9	2.0	2.1	2.1	2.0	2.0
	Mean	1.3	1.4	1.6	1.8	1.8	1.9	2.1	2.2	2.2	2.2	2.2	2.0
	s.d.±	0.20	0.14	0.10	0.10	0.20	0.14	0.17	0.14	0.20	0.22	0.25	0.25
	C.V.%	15.4	10.0	6.3	5.5	11.1	7.4	8.1	6.4	9.1	10.0	11.4	12.5
	1	1.2	1.4	1.6	1.6	1.7	1.7	2.0	2.1	2.3	2.3	2.0	2.0
	2	1.0	1.3	1.4	1.8	1.8	1.9	2.0	2.2	2.3	2.5	2.4	2.3
	3	1.2	1.6	1.6	1.7	1.9	2.1	2.3	2.5	2.5	2.5	2.4	2.3
3	4	1.0	1.1	1.2	1.9	1.9	2.1	2.1	2.1	2.2	2.3	2.3	2.2
	Mean	1.1	1.4	1.5	1.8	1.8	2.0	2.1	2.2	2.3	2.4	2.3	2.2
	s.d.±	0.10	0.20	0.20	0.10	0.20	0.14	0.20	0.41	0.10	0.20	0.10	0.14
	C.V.%	9.1	14.3	13.3	5.6	5.6	10.0	6.7	9.1	17.8	4.2	8.7	6.4
	1	0.9	1.0	1.4	1.7	1.7	1.8	2.0	2.0	2.2	2.0	1.9	1.9
	2	1.2	1.3	1.4	1.9	1.9	2.0	2.2	2.2	2.3	2.4	2.5	2.3
	3	1.3	1.4	1.7	1.8	1.8	2.1	2.1	2.3	2.4	2.6	2.6	2.4
4	4	1.0	1.2	1.6	1.7	2.0	2.2	2.3	2.4	2.4	2.5	2.4	2.4
	Mean	1.1	1.2	1.5	1.8	1.9	2.0	2.2	2.2	2.3	2.4	2.4	2.3
	s.d.±	0.17	0.17	0.14	0.03	0.14	0.17	0.14	0.17	0.10	0.26	0.30	0.24
	C.V.%	15.0	14.2	9.3	5.6	7.4	8.5	6.4	7.7	4.3	10.8	12.5	10.4
	1	1.0	1.4	1.6	1.6	1.9	2.0	2.1	2.3	2.3	2.4	2.2	2.0
	2	1.2	1.3	1.5	1.6	1.8	2.2	2.2	2.4	2.6	2.5	2.5	2.4
	3	1.1	1.6	1.7	1.7	2.1	2.1	2.4	2.4	2.5	2.6	2.4	2.4
5	4	1.3	1.3	1.4	1.6	2.0	2.2	2.2	2.2	2.3	2.4	2.5	2.5
	Mean	1.2	1.4	1.6	1.6	2.0	2.1	2.2	2.3	2.4	2.5	2.4	2.3
	s.d.±	0.14	0.14	0.14	0.05	0.14	0.10	0.10	0.10	0.14	0.10	0.14	0.22
	C.V.%	10.7	10.0	8.8	3.1	7.0	4.8	4.8	4.3	5.8	4.2	5.8	9.6

Table 3 continued - Variation within Internodes (Variety 3)

		Internode (cms.)											
Plant	Branch	1	2	3	4	5	6	7	8	9	10	11	12
	1	0.5	0.7	0.8	0.9	0.0	1.0	1.1	1.1	1.0	0.9	1.0	1.0
	2	1.0	1.0	1.1	1.2	1.3	1.4	1.5	1.4	1.4	1.3	1.3	1.0
	3	0.9	1.0	1.2	1.2	1.3	1.4	1.4	1.5	1.5	1.5	1.4	1.3
1	4	0.9	1.0	1.0	1.1	1.1	1.2	1.2	1.3	1.4	1.5	1.5	1.4
	Mean	0.8	0.9	1.0	1.1	1.2	1.3	1.3	1.3	1.3	1.3	1.3	1.2
	s.d.±	0.22	0.14	0.17	0.14	0.14	0.20	0.17	0.17	0.22	0.28	0.22	0.20
	C.V.%	27.5	15.6	17.0	12.7	11.6	15.4	13.1	13.1	16.9	21.0	16.9	16.7
	1	0.5	0.6	0.8	0.9	1.0	1.0	1.0	1.2	1.4	1.3	1.0	1.0
	2	0.5	0.6	0.6	0.9	1.0	1.2	1.2	1.3	1.4	1.4	1.4	1.2
	3	1.0	1.2	1.2	1.1	1.4	1.5	1.6	1.6	1.7	1.7	1.6	1.5
2	4	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.3	1.4	1.4	1.5	1.5
	Mean	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.5	1.4	1.3
	s.d.±	0.20	0.28	0.24	0.10	0.20	0.20	0.24	0.17	0.14	0.17	0.26	0.24
	C.V.%	28.5	35.0	26.7	10.0	18.2	16.7	18.5	12.2	9.3	11.3	18.6	18.5
	1	0.5	0.6	1.1	1.1	1.2	1.3	1.4	1.4	1.3	1.3	1.2	1.2
	2	1.0	0.7	0.7	0.9	1.0	1.1	1.2	1.2	1.2	1.4	1.4	1.5
	3	0.8	0.9	0.9	1.0	1.0	1.0	1.1	1.2	1.5	1.6	1.6	1.5
3	4	0.7	1.0	1.0	1.1	1.3	1.4	1.5	1.6	1.6	1.7	1.7	1.6
	Mean	0.8	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.4	1.5	1.5	1.5
	s.d.±	0.20	0.10	0.17	0.10	0.14	0.17	0.17	0.20	0.17	0.17	0.22	0.17
	C.V.%	25.0	12.5	18.9	10.0	12.7	14.2	13.1	14.3	12.1	11.3	14.7	11.3
	1	0.5	0.6	0.9	1.0	1.1	1.2	1.2	1.3	1.3	1.5	1.4	1.4
	2	0.5	0.7	0.8	1.0	1.0	1.2	1.2	1.3	1.4	1.5	1.3	1.3
	3	0.7	1.0	1.1	1.2	1.3	1.5	1.5	1.6	1.6	1.3	1.3	1.2
4	4	0.5	0.6	0.7	1.0	0.9	1.0	1.1	1.2	1.2	1.0	1.0	1.0
	Mean	0.6	0.7	0.9	1.1	1.1	1.2	1.3	1.4	1.6	1.4	1.3	1.2
	s.d.±	0.10	0.20	0.17	0.10	0.17	0.20	0.17	0.28	0.17	0.24	0.14	0.17
	C.V.%	16.7	28.5	19.9	9.10	15.5	16.7	13.1	20.0	10.6	17.1	10.8	14.2
	1	0.9	1.0	1.0	1.1	1.2	1.2	1.3	1.4	1.4	1.5	1.5	1.6
	2	0.6	0.6	0.7	0.9	1.0	1.1	1.2	1.3	1.3	1.4	1.4	1.4
	3	0.6	0.7	0.8	1.0	1.3	1.4	1.4	1.5	1.5	1.6	1.6	1.6
5	4	0.5	0.6	0.7	0.9	0.9	1.0	1.0	1.0	1.1	1.2	1.3	1.3
	Mean	0.7	0.7	0.8	1.0	1.1	1.2	1.2	1.3	1.4	1.4	1.5	1.5
	s.d.±	0.14	0.17	0.14	0.10	0.17	0.17	0.17	0.22	0.17	0.17	0.14	0.14
	C.V.%	20	24.3	17.5	10.0	15.5	14.2	14.2	16.9	12.1	12.1	9.3	9.3

Table 3 (continued) Variation within internodes (Variety 4).

Internodes (cms.)

Plant	Stem	1	2	3	4	5	6	7	8	9	10	11	12
	1	1.0	1.2	1.4	1.7	1.7	1.7	1.8	2.0	2.2	2.3	2.3	2.4
	2	1.2	1.4	1.5	1.8	1.8	1.8	1.9	2.1	2.3	2.4	2.6	2.6
	3	1.0	1.2	1.4	1.6	1.7	1.8	1.8	1.9	2.1	2.2	2.3	2.4
	4	1.4	1.6	1.7	1.7	1.9	2.0	2.0	2.1	2.1	2.1	2.2	2.2
1	Mean	1.2	1.4	1.5	1.7	1.8	1.8	1.9	2.0	2.2	2.3	2.4	2.4
	s.d.±	0.20	0.20	0.14	0.03	0.10	0.14	0.10	0.10	0.10	0.14	0.17	0.17
	c.v.%	16.7	14.3	8.2	1.8	5.6	7.7	5.3	5.0	4.5	6.1	7.1	7.1
	1	1.0	1.4	1.6	1.7	1.7	1.8	1.9	2.0	2.2	2.3	2.4	2.6
	2	1.0	1.3	1.4	1.7	1.8	1.8	1.9	2.1	2.1	2.2	2.2	2.3
	3	1.2	1.4	1.5	1.7	1.9	2.0	2.1	2.2	2.3	2.4	2.4	2.5
2	4	1.3	1.3	1.4	1.8	1.8	1.9	2.0	2.1	2.2	2.3	2.5	2.6
	Mean	1.1	1.4	1.5	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5
	s.d.±	0.14	0.05	0.10	0.02	0.03	0.10	0.10	0.03	0.03	0.03	0.14	0.14
	c.v.%	12.7	3.6	6.7	1.1	1.7	5.3	5.0	1.4	1.4	1.3	5.6	5.6
	1	1.2	1.4	1.5	1.7	1.7	1.8	1.9	2.0	2.0	2.1	2.2	2.3
	2	1.0	1.3	1.4	1.7	1.8	1.9	2.0	2.1	2.1	2.3	2.3	2.4
	3	1.1	1.3	1.5	1.7	1.7	1.8	1.9	1.9	2.2	2.3	2.4	2.4
3	4	1.4	1.5	1.6	1.7	1.8	1.9	2.1	2.1	2.2	2.2	2.4	2.5
	Mean	1.2	1.4	1.5	1.7	1.8	1.9	2.0	2.0	2.1	2.2	2.3	2.4
	s.d.±	0.17	0.10	0.03	0.00	0.05	0.05	0.10	0.10	0.05	0.10	0.10	0.03
	c.v.%	14.2	7.1	2.0	0.0	2.8	2.6	5.0	5.0	2.4	4.5	4.3	1.2
	1	1.0	1.3	1.5	1.6	1.8	1.8	1.9	2.0	2.1	2.2	2.3	2.4
	2	1.2	1.5	1.6	1.7	1.7	1.7	1.8	1.9	2.0	2.1	2.2	2.2
	3	1.1	1.4	1.5	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.4
4	4	1.1	1.2	1.4	1.7	1.8	1.9	2.1	2.2	2.3	2.4	2.5	2.5
	Mean	1.1	1.4	1.5	1.7	1.8	1.8	2.0	2.1	2.2	2.3	2.4	2.4
	s.d.±	0.03	0.14	0.03	0.05	0.14	0.10	0.14	0.14	0.14	0.14	0.14	0.14
	c.v.%	2.7	10.0	2.0	2.9	7.8	5.6	7.0	6.7	6.4	6.1	5.8	5.8
	1	1.3	1.5	1.6	1.7	1.7	1.8	1.9	1.9	2.0	2.1	2.2	2.3
	2	1.2	1.4	1.5	1.7	1.8	1.9	2.0	2.0	2.1	2.2	2.3	2.4
	3	1.4	1.4	1.4	1.7	1.7	1.8	2.0	2.1	2.2	2.3	2.4	2.5
5	4	1.3	1.6	1.4	1.7	1.8	1.9	2.1	2.1	2.2	2.3	2.4	2.5
	Mean	1.3	1.5	1.5	1.8	1.8	1.9	2.0	2.0	2.1	2.2	2.3	2.4
	s.d.±	0.03	0.10	0.10	0.02	0.05	0.05	0.05	0.10	0.10	0.10	0.10	0.10
	c.v.%	2.3	6.7	6.7	1.1	2.8	2.6	2.5	5.0	4.8	4.5	4.3	4.1

Table 3 (continued) <u>Variation within internodes (Variety 18).</u>

Internodes (cms.)

Plant	Stem	1	2	3	4	5	6	7	8	9	10	11	12
	1	0.6	0.7	0.9	1.0	1.2	1.2	1.3	1.3	1.4	1.5	1.6	1.6
	2	0.5	0.6	0.7	1.0	1.0	1.1	1.2	1.2	1.3	1.4	1.5	1.5
1	3	0.5	0.6	0.9	1.0	1.0	1.0	1.1	1.2	1.3	1.4	1.5	1.6
	4	0.6	0.7	0.8	0.9	0.9	1.0	1.1	1.1	1.2	1.3	1.4	1.4
	Mean	0.6	0.7	0.8	1.0	1.0	1.1	1.2	1.2	1.3	1.4	1.5	1.5
	s.d.±	0.05	0.05	0.10	0.05	0.14	0.10	0.10	0.26	0.26	0.26	0.26	0.10
	c.v.%	8.3	7.1	12.5	5.0	14.0	9.1	8.4	21.6	20.0	18.5	17.3	6.7
	1	0.7	0.7	0.9	1.0	1.1	1.2	1.2	1.3	1.5	1.5	1.6	1.6
	2	0.7	0.8	0.8	1.0	1.1	1.1	1.2	1.2	1.3	1.4	1.5	1.5
	3	0.6	0.8	0.9	0.9	1.0	1.1	1.2	1.3	1.4	1.4	1.5	1.6
2	4	0.5	0.6	0.7	1.0	1.0	1.3	1.4	1.4	1.4	1.3	1.4	1.4
	Mean	0.6	0.7	0.8	1.0	1.1	1.2	1.3	1.3	1.4	1.4	1.5	1.5
	s.d.±	0.10	0.10	0.10	0.05	0.05	0.10	0.10	0.26	0.05	0.26	0.26	0.10
	c.v.%	16.7	14.3	12.5	5.0	4.5	8.3	7.7	20.0	3.5	18.5	17.3	6.7
	1	0.5	0.7	0.8	1.0	1.1	1.1	1.2	1.3	1.4	1.5	1.5	1.6
	2	0.6	0.7	0.7	1.0	1.2	1.2	1.3	1.4	1.4	1.5	1.6	1.7
	3	0.5	0.6	0.6	1.0	1.2	1.3	1.4	1.4	1.5	1.6	1.6	1.7
3	4	0.5	0.6	0.7	1.0	1.2	1.2	1.3	1.4	1.5	1.6	1.6	1.7
	Mean	0.5	0.7	0.7	1.0	1.2	1.2	1.3	1.4	1.5	1.6	1.6	1.7
	s.d.±	0.05	0.05	0.03	0.00	0.05	0.03	0.03	0.05	0.05	0.05	0.05	0.05
	c.v.%	10.0	7.1	4.3	0.0	4.2	2.5	2.3	3.6	3.3	3.1	3.1	2.9
	1	0.6	0.8	0.9	1.0	1.1	1.1	1.2	1.3	1.3	1.3	1.5	1.5
	2	0.5	0.6	0.7	1.0	1.2	1.2	1.3	1.3	1.4	1.4	1.5	1.6
	3	0.7	0.8	1.0	1.0	1.1	1.2	1.3	1.4	1.4	1.5	1.6	1.7
4	4	0.8	0.9	0.9	1.0	1.0	1.1	1.2	1.3	1.3	1.5	1.7	1.7
	Mean	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.3	1.4	1.4	1.6	1.6
	s.d.±	0.14	0.14	0.14	0.00	0.03	0.05	0.05	0.05	0.05	0.10	0.10	0.10
	c.v.%	20.0	17.5	15.5	0.0	2.7	4.2	3.8	3.8	3.6	7.1	6.3	6.3
	1	0.8	0.7	0.9	1.0	1.1	1.1	1.2	1.3	1.4	1.5	1.5	1.6
	2	0.5	0.6	0.8	1.1	1.2	1.2	1.3	1.4	1.4	1.5	1.6	1.6
	3	0.6	0.7	0.8	1.0	1.0	1.2	1.2	1.3	1.3	1.4	1.5	1.5
5	4	0.7	0.8	0.9	1.0	1.0	1.0	1.1	1.1	1.1	1.2	1.3	1.4
	Mean	0.7	0.7	0.9	1.0	1.1	1.1	1.2	1.3	1.3	1.4	1.5	1.5
	s.d.±	0.14	0.03	0.05	0.05	0.10	0.10	0.03	0.14	0.14	0.14	0.14	0.10
	c.v.%	20.0	4.3	5.6	5.0	9.1	9.1	2.5	10.8	10.8	10.0	9.3	6.7

Table 3 (**continued**) <u>**Variation within internodes (variety 64)**</u>

Internodes (cms)

Plant	Stem	1	2	3	4	5	6	7	8	9	10	11	12
	1	2.7	2.9	3.1	3.3	3.3	3.4	3.6	3.7	3.7	3.8	3.9	4.0
	2	2.9	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4.0	4.1	4.2
	3	3.0	3.2	3.2	3.3	3.4	3.5	3.5	3.6	3.7	3.8	3.8	4.1
1	4	3.0	3.1	3.3	3.3	3.5	3.6	3.7	3.8	4.0	4.1	4.2	4.2
	Mean	2.9	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4.0	4.1
	s.d.$\pm$	0.14	0.14	0.10	0.05	0.10	0.10	0.10	0.10	0.14	0.14	0.17	0.14
	c.v.%	4.8	4.5	3.1	1.5	2.9	2.9	2.8	2.7	3.7	3.6	4.3	3.4
	1	2.9	3.0	3.2	3.4	3.6	3.7	3.8	3.9	3.9	4.0	4.1	4.1
	2	2.8	2.9	3.1	3.3	3.4	3.5	3.5	3.6	3.7	3.8	3.9	4.0
	3	3.0	3.1	3.2	3.3	3.3	3.4	3.5	3.6	3.6	3.7	3.8	3.9
2	4	2.8	2.8	3.0	3.2	3.2	3.3	3.4	3.5	3.6	3.6	3.7	3.8
	Mean	2.9	3.0	3.1	3.3	3.4	3.5	3.6	3.7	3.7	3.8	3.9	4.0
	s.d.$\pm$	0.10	0.14	0.10	0.05	0.17	0.17	0.17	0.17	0.14	0.17	0.17	0.14
	c.v.%	3.4	4.7	3.2	1.0	5.0	4.9	4.7	4.7	3.8	4.4	4.4	3.5
	1	2.9	3.0	3.1	3.2	3.3	3.3	3.4	3.5	3.5	3.6	3.7	3.8
	2	3.1	3.2	3.3	3.3	3.5	3.6	3.6	3.7	3.8	3.9	4.0	4.1
	3	3.0	3.1	3.2	3.3	3.4	3.5	3.8	3.6	3.6	3.7	3.8	3.9
3	4	2.8	2.9	3.1	3.3	3.5	3.5	3.5	3.6	3.7	3.8	3.9	4.0
	Mean	3.0	3.1	3.2	3.3	3.4	3.5	3.5	3.6	3.7	3.8	3.9	4.0
	s.d.$\pm$	0.14	0.14	0.10	0.05	0.10	0.14	0.05	0.10	0.14	0.14	0.14	0.14
	c.v.%	4.7	4.5	3.1	1.5	2.9	4.0	1.5	2.8	3.8	3.7	3.6	3.5
	1	2.8	2.9	3.1	3.3	3.3	3.4	3.5	3.5	3.6	3.7	3.8	4.0
	2	2.9	3.0	3.2	3.3	3.4	3.5	3.6	3.8	3.8	3.9	4.0	4.1
	3	3.0	3.2	3.3	3.3	3.5	3.6	3.7	3.7	3.8	4.0	4.1	4.2
4	4	3.1	3.2	3.3	3.3	3.4	3.4	3.5	3.6	3.6	3.7	3.8	3.9
	Mean	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.7	3.8	3.9	4.1
	s.d.$\pm$	0.14	0.14	0.10	0.00	0.05	0.10	0.10	0.14	0.10	0.14	0.14	0.14
	c.v.%	4.7	4.5	3.1	0.0	0.9	2.9	2.8	3.8	2.7	3.7	3.6	3.4
	1	3.0	3.2	3.3	3.4	3.5	3.6	3.6	3.7	3.8	3.8	3.9	4.0
	2	3.1	3.1	3.2	3.3	3.3	3.4	3.4	3.5	3.6	3.6	3.7	3.8
	3	2.9	3.0	3.1	3.4	3.5	3.5	3.6	3.7	3.8	3.9	4.0	4.1
5	4	2.9	2.9	3.0	3.3	3.4	3.6	3.7	3.8	4.0	4.1	4.2	4.3
	Mean	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4.0	4.1
	s.d.$\pm$	0.10	0.14	0.14	0.05	0.10	0.10	0.14	0.14	0.14	0.20	0.20	0.20
	c.v.%	3.3	4.5	4.3	1.5	2.9	2.9	3.9	3.8	3.7	5.1	5.0	4.9

Table 3 (continued) Variation within internodes (variety 67)

Internodes (cms)

Plant	Stem	1	2	3	4	5	6	7	8	9	10	11	12
	1	3.0	3.2	3.4	3.5	3.7	3.8	3.8	3.9	4.1	4.2	4.2	4.3
	2	3.1	3.2	3.3	3.4	3.4	3.5	3.5	3.6	3.7	3.8	3.9	4.0
	3	2.9	3.0	3.1	3.5	3.5	3.6	3.6	3.7	3.8	3.9	3.9	4.0
1	4	2.9	2.9	3.3	3.5	3.5	3.6	3.7	3.8	3.9	4.0	4.1	4.2
	Mean	3.0	3.1	3.3	3.5	3.5	3.6	3.7	3.8	3.9	4.0	4.0	4.1
	s.d.±	0.10	0.14	0.14	0.05	0.14	0.14	0.14	0.14	0.17	0.17	0.14	0.14
	c.v.%	3.3	4.5	4.2	1.4	4.0	3.9	3.8	3.7	4.4	4.3	3.5	3.4
	1	3.0	3.1	3.3	3.5	3.5	3.6	3.7	3.7	3.8	3.9	4.0	4.1
	2	2.7	2.9	3.0	3.6	3.6	3.7	3.8	3.8	3.9	4.0	4.2	4.3
	3	2.7	3.3	3.4	3.5	3.5	3.6	3.7	3.9	4.0	4.1	4.2	4.3
2	4	3.1	3.2	3.3	3.5	3.7	3.8	3.9	4.0	4.1	4.2	4.3	4.4
	Mean	2.8	3.1	3.3	3.5	3.6	3.7	3.8	3.9	4.0	4.1	4.2	4.3
	s.d.±	0.14	0.17	0.17	0.05	0.10	0.10	0.10	0.14	0.14	0.14	0.14	0.14
	c.v.%	5.0	5.5	5.2	1.4	2.8	2.7	2.6	3.6	3.5	3.4	3.3	3.3
	1	2.8	2.9	3.4	3.5	3.7	3.8	2.8	3.9	3.9	4.0	4.0	4.1
	2	2.9	3.1	3.0	3.5	3.6	3.6	3.7	3.5	3.9	4.0	4.1	4.2
	3	3.1	3.2	3.2	3.5	3.5	3.5	3.6	3.7	3.7	3.8	3.9	4.0
3	4	3.0	3.3	3.3	3.4	3.4	3.4	3.5	3.6	3.6	3.7	3.7	3.7
	Mean	3.0	3.1	3.2	3.5	3.6	3.6	3.7	3.8	3.8	3.9	3.9	4.0
	s.d.±	0.14	0.17	0.17	0.05	0.17	0.17	0.14	0.14	0.14	0.14	0.17	0.22
	c.v.%	4.7	5.5	5.3	1.4	4.7	4.7	3.8	3.7	0.37	3.6	4.4	5.5
	1	3.2	3.3	3.4	3.5	3.7	3.8	3.8	3.9	4.0	4.1	4.1	4.2
	2	3.0	3.1	3.3	3.5	3.8	4.0	4.0	4.1	4.2	4.2	4.3	4.4
	3	2.9	3.0	3.2	3.4	3.6	3.8	4.0	4.1	4.1	4.2	4.3	4.3
4	4	2.8	2.9	3.1	3.4	3.5	3.6	3.7	3.8	3.9	4.0	4.2	4.2
	Mean	3.0	3.1	3.3	3.5	3.7	3.8	3.9	4.0	4.1	4.1	4.2	4.3
	s.d.±	0.17	0.17	0.14	0.05	0.14	0.17	0.14	0.14	0.14	0.10	0.10	0.10
	c.v.%	5.7	5.5	4.2	1.4	3.8	4.5	3.6	3.5	3.4	2.4	2.4	2.3
	1	3.1	3.2	3.3	3.4	3.4	3.5	3.6	3.6	3.7	3.8	4.0	4.2
	2	2.9	2.9	3.0	3.5	3.6	3.7	3.7	3.8	3.9	4.0	4.1	4.1
	3	2.8	3.1	3.2	3.5	3.5	3.6	3.7	3.8	3.8	3.9	4.1	4.3
5	4	3.1	3.2	3.3	3.5	3.6	3.6	3.8	3.9	4.0	4.1	4.2	4.3
	Mean	3.0	3.1	3.2	3.5	3.5	3.6	3.7	3.8	3.9	4.0	4.1	4.2
	s.d.±	0.14	0.14	0.14	0.05	0.10	0.10	0.10	0.14	0.14	0.14	0.17	0.10
	c.v.%	4.7	4.5	4.4	1.4	2.9	2.8	2.7	3.7	3.6	3.5	4.1	2.4

Table 4 Variation within petioles (Variety 1)

P e t i o l e s (cms.)

lant	Stem	1	2	3	4	5	6	7	8	9	10	11	12
	1	12.0	12.5	13.0	13.7	13.5	13.7	14.0	14.1	14.2	14.6	13.7	13.4
	2	13.2	13.3	13.4	13.5	13.7	13.9	14.2	14.2	14.4	14.8	14.0	13.6
	3	12.6	12.6	12.9	13.0	13.1	13.2	13.3	13.4	13.6	13.7	14.1	13.0
1	4	12.4	12.8	12.8	13.3	13.4	13.5	13.6	13.7	13.8	13.8	14.0	13.1
	Mean	12.6	12.8	13.0	13.3	13.4	13.6	13.8	13.9	14.0	14.2	14.0	13.3
	s.d.±	0.50	0.36	0.26	0.22	0.17	0.30	0.40	0.36	0.36	0.47	0.17	0.28
	c.v.%	4.4	2.8	2.0	1.7	1.3	2.2	3.0	2.6	2.6	3.3	1.2	2.1
	1	12.5	12.6	12.8	13.2	13.5	13.6	13.8	13.9	14.1	14.2	13.5	13.0
	2	12.5	12.5	12.9	13.0	13.2	13.3	13.4	13.5	13.6	13.7	13.1	13.3
	3	12.7	12.8	13.0	13.2	13.3	13.4	13.5	13.6	13.7	13.8	13.2	12.9
2	4	12.4	12.7	13.1	13.2	13.4	13.5	13.7	13.8	13.9	14.0	13.0	11.0
	Mean	12.5	12.7	13.0	13.2	13.4	13.5	13.6	13.7	13.8	13.9	13.2	12.6
	s.d.±	0.14	0.14	0.14	0.10	0.14	0.14	0.17	0.17	0.22	0.20	0.10	1.00
	c.v.%	1.1	1.1	1.1	0.8	1.1	1.0	1.3	1.2	1.6	1.4	0.8	7.9
	1	12.0	12.2	12.7	13.3	13.3	13.4	13.6	13.7	13.8	13.9	13.5	13.3
	2	12.5	12.6	13.0	13.4	13.6	13.7	13.8	13.9	14.0	14.2	12.5	12.4
	3	12.5	12.7	12.8	13.3	13.2	13.3	13.4	13.5	13.6	13.7	13.0	12.9
3	4	13.0	13.4	13.5	13.5	13.7	13.8	13.9	14.0	14.1	14.2	14.0	13.5
	Mean	12.5	12.7	13.0	13.4	13.5	13.6	13.7	13.8	13.9	14.0	13.3	13.0
	s.d.±	0.41	0.50	0.36	0.10	0.77	0.77	0.22	0.22	0.22	0.24	0.63	0.49
	c.v.%	3.3	3.9	2.7	0.7	5.7	5.7	1.6	1.6	1.6	1.7	4.7	3.8
	1	12.0	12.2	12.5	13.3	13.3	13.4	13.5	13.6	13.7	13.8	13.6	13.0
	2	12.6	12.8	13.0	13.2	13.4	13.5	13.6	13.7	13.8	13.9	13.2	13.2
	3	12.8	12.9	13.0	13.3	13.4	13.7	13.8	13.9	14.0	14.1	13.8	13.1
4	4	13.0	13.2	13.4	13.4	13.6	13.6	13.7	13.9	14.1	14.2	13.2	13.2
	Mean	12.6	12.8	13.0	13.3	13.4	13.6	13.7	13.8	13.9	14.0	13.5	13.1
	s.d.±	0.42	0.42	0.37	0.05	0.14	0.14	0.14	0.14	0.17	0.17	0.30	0.10
	c.v.%	3.3	3.3	2.8	0.2	1.0	1.0	1.0	1.0	1.2	1.2	2.2	0.8
	1	12.5	13.0	13.0	13.3	13.4	13.5	13.6	13.6	13.7	13.8	13.4	13.2
	2	13.0	13.2	13.3	13.3	13.5	13.7	13.8	13.9	14.0	14.1	13.5	13.4
	3	12.6	12.7	12.8	13.2	13.3	13.4	13.5	13.6	13.6	13.7	13.8	13.9
5	4	12.3	12.6	12.7	13.4	13.2	13.3	13.4	13.5	13.6	13.6	13.4	13.0
	Mean	12.6	12.9	13.0	13.3	13.3	13.5	13.6	13.7	13.7	13.8	13.5	13.4
	s.d.±	0.30	0.28	0.26	0.03	0.14	0.17	0.17	0.17	0.20	0.22	0.20	0.39
	c.v.%	2.4	2.1	2.0	0.2	1.1	1.3	1.2	1.2	1.4	1.6	1.5	2.9

Table 4 (continued) Variation within petioles (Variety 3)

P e t i o l e s (cms.)

lant	Stem	1	2	3	4	5	6	7	8	9	10	11	12
	1	9.8	9.9	10.1	10.3	10.5	10.6	10.7	10.7	10.8	10.6	10.2	10.1
	2	9.0	9.5	10.0	10.4	10.4	10.5	10.6	10.7	10.8	10.4	10.1	9.9
	3	10.2	10.3	10.3	10.4	10.6	10.7	10.8	10.9	11.0	11.0	10.5	10.1
1	4	9.9	10.0	10.1	10.2	10.3	10.4	10.5	10.6	10.7	10.8	10.9	11.0
	Mean	9.7	9.9	10.1	10.3	10.5	10.6	10.7	10.7	10.8	10.7	10.4	10.3
	s.d.±	0.51	0.33	0.20	0.10	0.14	0.14	0.14	0.14	0.14	0.26	0.33	0.47
	c.v.%	5.2	3.3	3.0	0.9	1.3	1.3	1.3	1.3	1.2	2.4	3.1	4.5
	1	10.2	10.3	10.4	10.4	10.6	10.7	10.8	10.9	11.0	11.0	9.5	9.0
	2	9.6	9.8	10.0	10.3	10.4	10.4	10.5	10.6	10.7	10.8	9.9	9.4
	3	10.0	10.0	10.2	10.3	10.3	10.3	10.4	10.5	10.6	10.7	9.4	9.4
2	4	9.4	9.8	10.0	10.2	10.2	10.2	10.3	10.4	10.5	10.6	10.4	10.1
	Mean	9.8	10.0	10.2	10.3	10.4	10.4	10.5	10.6	10.7	10.8	9.8	9.5
	s.d.±	0.36	0.24	0.20	0.05	0.17	0.20	0.22	0.20	0.28	0.17	0.33	0.45
	c.v.%	3.7	2.4	2.0	0.3	1.6	1.9	2.1	1.9	2.6	1.6	3.4	4.7
	1	9.0	9.2	9.7	10.2	10.3	10.4	10.4	10.5	10.6	9.5	9.1	9.0
	2	9.5	10.0	10.1	10.2	10.2	10.3	10.4	10.4	10.5	10.0	9.5	9.2
	3	9.9	10.2	10.3	10.3	10.5	10.6	10.7	10.8	10.9	10.3	10.1	10.0
3	4	9.0	9.5	9.8	10.4	10.7	10.8	10.9	11.0	11.2	10.4	10.1	9.9
	Mean	9.4	9.7	10.0	10.3	10.4	10.5	10.6	10.7	10.8	10.1	9.7	9.5
	s.d.±	0.43	0.46	0.28	0.10	0.22	0.22	0.24	0.28	0.31	0.31	0.50	0.50
	c.v.%	4.6	4.7	2.8	0.9	2.1	2.1	2.3	2.6	2.9	3.1	5.1	5.3
	1	9.0	9.2	9.5	10.2	10.4	10.6	10.7	10.7	10.8	10.8	10.0	9.5
	2	9.7	9.9	9.8	10.3	10.6	10.7	10.8	10.9	11.0	11.2	10.5	10.1
	3	9.5	9.6	10.1	10.3	10.3	10.4	10.4	10.5	10.6	10.7	10.0	9.9
4	4	9.4	9.5	9.6	10.3	10.3	10.3	10.4	10.4	10.5	10.6	9.7	9.0
	Mean	9.4	9.6	9.8	10.3	10.4	10.5	10.6	10.6	10.7	10.7	10.1	9.6
	s.d.±	0.51	0.28	0.20	0.05	0.14	0.17	0.20	0.22	0.22	0.41	0.33	0.49
	c.v.%	5.4	2.9	2.0	0.5	1.3	1.6	1.9	2.0	2.1	3.8	3.3	5.1
	1	9.1	9.4	9.9	10.5	10.7	10.8	10.9	11.0	10.5	10.4	10.3	10.2
	2	10.1	10.2	10.3	10.4	10.5	10.6	10.7	10.8	10.9	10.5	10.4	10.0
	3	9.6	9.8	10.0	10.2	10.3	10.4	10.5	10.6	10.6	10.0	9.5	9.2
5	4	10.0	10.1	10.2	10.3	10.4	10.5	10.6	10.7	10.8	9.5	9.2	9.0
	Mean	9.7	9.9	10.1	10.4	10.5	10.6	10.7	10.8	10.7	10.1	9.9	9.6
	s.d.±	0.46	0.36	0.17	0.14	0.17	0.17	0.17	0.17	0.17	0.43	0.59	0.58
	c.v.%	4.7	3.6	1.7	1.3	1.6	1.6	1.6	1.6	1.6	4.3	6.0	6.0

Table 4 (continued) Variation within petioles (variety 4)

Petiole lengths (cms.)

Plant	Stem	1	2	3	4	5	6	7	8	9	10	11	12
	1	13.1	13.2	13.3	13.4	13.5	13.5	13.6	13.7	13.8	13.9	13.6	13.2
	2	13.2	13.3	13.4	13.5	13.7	13.8	13.9	14.0	14.1	13.5	13.4	13.1
	3	13.0	13.2	13.1	13.3	13.6	13.7	13.8	13.9	14.2	13.7	13.5	13.3
1	4	13.2	13.1	13.3	13.4	13.5	13.6	13.7	13.8	13.9	14.0	13.7	13.0
	Mean	13.1	13.2	13.3	13.4	13.6	13.7	13.8	13.9	14.0	13.8	13.6	13.2
	s.d.±	0.10	0.08	0.14	0.08	0.10	0.14	0.14	0.14	0.17	0.22	0.14	0.14
	c.v.%	0.7	0.6	1.0	0.6	0.7	1.0	1.0	1.0	1.2	1.6	1.0	1.1
	1	13.0	13.1	13.2	13.3	13.3	13.4	13.5	13.6	13.7	13.8	13.5	13.0
	2	12.8	13.0	13.3	13.4	13.5	13.6	13.7	13.8	13.9	14.0	13.9	13.2
	3	12.7	12.8	13.1	13.4	13.6	13.7	13.8	13.9	14.0	14.1	13.9	13.6
2	4	12.7	12.9	13.0	13.2	13.3	13.4	13.5	13.6	13.7	13.8	13.5	13.0
	Mean	12.8	13.0	13.1	13.3	13.4	13.5	13.6	13.7	13.8	13.9	13.7	13.2
	s.d.±	0.14	0.14	0.14	0.10	0.14	0.14	0.14	0.14	0.14	0.14	0.20	0.28
	c.v.%	1.1	1.1	1.1	0.8	1.0	1.0	1.0	1.0	1.0	1.0	1.5	2.1
	1	12.9	13.0	13.2	13.3	13.4	13.5	13.6	13.6	13.7	13.5	13.2	13.0
	2	12.8	13.1	13.3	13.4	13.6	13.7	13.8	13.9	14.0	13.8	13.6	13.2
	3	12.7	13.1	13.2	13.3	13.4	13.5	13.5	13.6	13.7	13.7	13.0	13.1
3	4	12.7	12.9	13.0	13.4	13.5	13.6	13.6	13.7	13.8	13.9	13.0	13.1
	Mean	12.8	13.0	13.2	13.4	13.5	13.6	13.6	13.7	13.8	13.7	13.2	13.1
	s.d.±	0.10	0.10	0.14	0.05	0.10	0.10	0.14	0.14	0.14	0.17	0.28	0.08
	c.v.%	0.8	0.8	1.1	0.3	0.7	0.7	0.10	1.0	1.0	1.2	2.1	0.6
	1	13.0	13.1	13.2	13.4	13.5	13.5	13.6	13.7	13.8	13.9	13.6	13.4
	2	12.7	12.8	13.1	13.4	13.6	13.7	13.8	13.9	14.0	13.5	13.4	13.2
	3	12.8	12.9	13.3	13.4	13.5	13.5	13.6	13.7	13.2	13.1	13.0	13.0
4	4	12.6	12.8	12.9	13.4	13.5	13.6	13.6	13.7	13.8	13.8	13.2	13.0
	Mean	12.8	12.9	13.1	13.4	13.5	13.6	13.6	13.7	13.8	13.6	13.3	13.2
	s.d.±	0.10	0.14	0.14	0.05	0.08	0.10	0.14	0.14	0.31	0.22	0.22	0.33
	c.v.%	0.8	1.1	1.1	0.3	0.6	0.7	1.0	1.0	1.0	2.3	1.6	2.5
	1	12.9	13.0	13.1	13.3	13.4	13.5	13.6	13.7	13.8	13.9	13.5	13.0
	2	13.0	13.2	13.5	13.5	13.6	13.7	13.8	13.9	14.0	13.5	13.2	13.1
	3	12.7	13.0	13.2	13.4	13.5	13.6	13.6	13.7	13.9	14.0	13.5	13.2
5	4	12.6	12.9	13.1	13.4	13.7	13.8	13.9	14.0	14.1	14.2	14.0	13.5
	Mean	12.8	13.0	13.2	13.4	13.6	13.7	13.7	13.8	14.0	13.9	13.6	13.2
	s.d.±	0.17	0.14	0.10	0.08	0.14	0.14	0.14	0.14	0.14	0.30	0.33	0.22
	c.v.%	1.3	1.1	0.8	0.6	1.0	1.0	1.0	1.0	1.0	2.2	2.4	1.7

Table 4 - (continued) Variation within petioles (variety 18)

Petioles lengths (cms)

Plant	Stem	1	2	3	4	5	6	7	8	9	10	11	12
	1	9.5	9.6	9.8	9.9	10.0	10.1	10.1	10.2	10.3	9.8	9.6	9.7
	2	9.6	9.7	9.9	10.0	10.1	10.2	10.3	10.4	10.5	10.0	9.9	9.6
	3	9.4	9.5	9.7	9.9	9.9	10.0	10.0	10.1	10.2	10.3	10.0	9.9
1	4	9.8	9.9	10.0	10.1	10.2	10.3	10.4	10.5	10.5	10.6	10.0	9.8
	Mean	9.6	9.7	9.9	10.0	10.0	10.2	10.2	10.3	10.4	10.2	9.9	9.8
	s.d.±	0.17	0.17	0.14	0.10	0.14	0.14	0.17	0.17	0.14	0.35	0.20	0.14
	c.v.%	1.8	1.8	1.4	1.0	1.4	1.4	1.7	1.7	1.3	3.4	2.0	1.4
	1	9.7	9.8	9.9	10.0	10.1	10.1	10.2	10.3	10.4	10.0	9.8	9.6
	2	9.5	9.6	9.7	9.9	10.0	10.0	10.1	10.1	10.2	10.3	9.9	9.8
	3	9.9	10.0	10.1	10.2	10.3	10.4	10.5	10.6	10.6	10.5	10.4	10.0
2	4	9.8	9.9	10.0	10.1	10.2	10.3	10.4	10.5	10.5	10.6	10.2	10.0
	Mean	9.7	9.8	9.9	10.0	10.2	10.2	10.3	10.4	10.4	10.4	10.1	9.9
	s.d.±	0.17	0.17	0.17	0.14	0.17	0.17	0.17	0.22	0.17	0.26	0.28	0.20
	c.v.%	1.8	1.8	1.7	1.4	1.7	1.7	1.7	2.1	1.6	2.5	2.8	2.0
	1	9.7	9.8	9.9	10.0	10.1	10.1	10.2	10.3	10.4	10.4	10.3	9.9
	2	9.9	10.0	10.1	10.1	10.2	10.3	10.4	10.5	10.5	10.6	10.2	10.0
	3	9.7	9.8	9.9	10.0	10.1	10.2	10.3	10.4	10.5	10.5	10.0	9.6
3	4	10.0	10.1	10.2	10.2	10.3	10.4	10.5	10.6	10.7	10.8	10.0	9.8
	Mean	9.8	9.9	10.0	10.1	10.2	10.2	10.4	10.5	10.5	10.6	10.1	10.1
	s.d.±	0.14	0.14	0.14	0.10	0.10	0.14	0.14	0.14	0.14	0.17	0.10	0.17
	c.v.%	1.4	1.4	1.4	1.0	1.0	1.4	1.3	1.3	1.3	1.6	1.0	1.7
	1	9.9	10.0	10.1	10.2	10.3	10.4	10.5	10.6	10.7	10.5	10.3	10.0
	2	9.8	9.9	10.0	10.1	10.1	10.2	10.3	10.4	10.5	10.3	10.0	9.8
	3	9.7	9.8	9.9	10.0	10.1	10.2	10.2	10.3	10.4	10.5	10.0	9.7
4	4	9.6	9.7	9.8	9.9	10.0	10.1	10.2	10.2	10.3	10.4	10.1	9.9
	Mean	9.8	9.9	10.0	10.1	10.1	10.2	10.3	10.4	10.5	10.4	10.1	9.9
	s.d.±	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.17	0.17	0.10	0.14	0.14
	c.v.%	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.6	1.6	1.0	1.4	1.4
	1	9.8	9.9	10.0	10.1	10.2	10.3	10.4	10.5	10.6	10.0	9.9	9.7
	2	9.6	9.7	9.8	9.9	10.0	10.0	10.1	10.2	10.3	9.9	9.8	9.6
	3	9.5	9.6	9.8	10.1	10.2	10.3	10.4	10.4	10.5	10.6	10.2	10.0
5	4	9.6	9.7	9.9	10.0	10.1	10.2	10.2	10.3	10.4	10.5	10.0	9.8
	Mean	9.6	9.7	9.9	10.0	10.1	10.2	10.3	10.4	10.5	10.3	10.0	9.8
	s.d.±	0.14	0.14	0.10	0.10	0.10	0.14	0.14	0.14	0.14	0.35	0.22	0.22
	c.v.%	1.4	1.4	1.0	1.0	1.0	1.4	1.4	1.3	1.3	3.4	2.2	2.2

Table 4 (continued). <u>Variation within petioles (Variety 64)</u>

Plant	Stem	1	2	3	4	5	6	7	8	9	10	11	12
	1	18.0	18.2	18.5	18.4	19.0	19.1	19.3	19.4	19.4	19.5	19.0	19.0
	2	18.6	18.7	18.9	19.2	19.4	19.5	19.6	19.7	19.7	19.8	19.0	18.9
	3	18.2	18.4	18.7	18.8	18.9	19.0	19.1	19.1	19.2	19.3	19.4	19.2
1	4	17.9	18.0	18.4	18.7	18.7	18.8	18.9	18.9	19.0	19.1	19.0	18.4
	Mean	18.2	18.3	18.6	18.9	19.0	19.1	19.2	19.3	19.3	19.4	19.1	18.9
	s.d.±	0.31	0.30	0.22	0.22	0.30	0.30	0.30	0.35	0.30	0.30	0.10	0.35
	c.v.%	1.7	1.6	1.2	1.2	1.6	1.6	1.6	1.8	1.6	1.5	0.5	1.9
	1	17.5	18.0	18.5	18.8	19.0	19.1	19.2	19.3	19.4	19.5	19.0	18.5
	2	18.5	18.6	18.7	18.8	19.0	19.3	19.4	19.5	19.6	19.7	19.5	19.0
	3	18.0	18.2	18.4	18.6	18.7	18.8	18.9	19.0	19.1	19.2	19.3	19.4
2	4	18.0	18.3	18.5	18.9	18.9	19.0	19.1	19.2	19.3	19.4	19.0	18.7
	Mean	18.0	18.3	18.5	18.8	18.9	19.1	19.2	19.2	19.4	19.5	19.2	18.9
	s.d.±	0.41	0.24	0.14	0.14	0.14	0.20	0.20	0.20	0.20	0.20	0.28	0.39
	c.v.%	2.3	1.3	0.8	0.7	0.7	1.0	1.0	1.0	1.0	1.0	1.5	2.1
	1	18.2	18.7	18.8	18.9	19.0	19.3	19.5	19.6	19.7	20.0	18.5	18.0
	2	17.0	18.0	18.5	18.8	19.1	19.4	19.6	19.8	19.9	19.5	19.5	19.0
	3	17.9	18.0	18.5	18.8	18.9	19.0	19.1	19.2	19.3	19.4	19.0	18.5
3	4	18.4	18.5	18.6	18.9	19.2	19.3	19.4	19.5	19.6	19.7	19.0	18.9
	Mean	17.9	18.3	18.6	18.9	19.1	19.3	19.4	19.5	19.6	19.2	19.0	18.6
	s.d.±	0.61	0.36	0.14	0.05	0.14	0.17	0.22	0.24	0.24	0.14	0.37	0.46
	c.v.%	3.4	2.0	0.8	0.3	0.7	0.9	1.1	1.2	1.2	0.7	1.9	1.1
	1	18.4	18.5	18.6	18.8	18.9	19.0	19.1	19.2	19.3	19.0	18.7	18.5
	2	18.1	18.2	18.4	18.7	18.8	18.9	18.9	19.0	19.0	18.7	18.6	18.6
	3	18.5	18.6	18.7	18.8	18.9	19.1	19.2	19.4	19.5	19.6	18.8	18.0
4	4	18.3	18.4	18.6	18.8	19.0	19.3	19.4	19.5	19.6	19.7	19.1	19.0
	Mean	18.3	18.4	19.6	18.8	18.9	19.0	19.2	19.3	19.4	19.3	18.8	18.5
	s.d.±	0.17	0.17	0.14	0.05	0.05	0.17	0.20	0.22	0.26	0.47	0.22	0.40
	c.v.%	0.9	0.9	0.8	0.3	0.3	0.9	1.0	1.1	1.3	2.4	1.2	2.2
	1	18.2	18.4	18.6	18.8	19.0	19.2	19.4	19.4	19.5	19.6	19.4	19.0
	2	18.1	18.5	18.7	18.9	19.1	19.1	19.2	19.2	19.3	19.4	19.1	19.8
	3	18.0	18.3	18.4	18.7	18.8	18.9	19.0	19.1	19.2	19.2	19.0	18.5
5	4	18.5	18.6	18.7	18.8	19.0	19.1	19.1	19.2	19.2	19.3	19.4	19.5
	Mean	18.2	18.5	18.6	18.8	19.0	19.1	19.2	19.2	19.3	19.4	19.2	19.0
	s.d.±	0.22	0.14	0.14	0.05	0.14	0.14	0.17	0.14	0.14	0.17	0.20	0.42
	c.v.%	1.2	0.8	0.8	0.3	0.7	0.7	0.9	0.7	0.7	0.9	1.0	2.2

Table 4 (continued) <u>Variation within petioles (variety 67)</u>

Plant	Stem	Petiole Lengths (cms) 1	2	3	4	5	6	7	8	9	10	11	12
	1	18.5	18.7	19.0	19.1	19.2	19.3	19.4	19.5	19.6	19.6	19.4	19.2
	2	18.4	18.5	18.8	19.0	19.0	19.0	19.1	19.2	19.3	19.3	19.0	19.1
	3	18.0	18.3	18.5	18.8	19.1	19.2	19.2	19.3	19.4	19.4	18.9	18.7
1	4	18.3	18.5	18.6	19.0	19.1	19.2	19.3	19.4	19.5	19.5	19.0	18.5
	Mean	18.3	18.5	18.7	19.0	19.1	19.2	19.2	19.4	19.5	19.5	19.1	18.9
	s.d.±	0.22	0.17	0.22	0.14	0.08	0.14	0.14	0.17	0.14	0.14	0.22	0.33
	c.v.%	1.2	0.9	1.2	0.7	0.4	0.7	0.7	0.9	0.7	0.7	1.2	1.7
	1	18.2	18.4	18.5	18.9	19.1	19.2	19.3	19.4	19.5	19.6	19.0	19.1
	2	18.9	19.0	19.1	19.2	19.4	19.5	19.6	19.7	19.7	19.8	19.2	18.9
	3	18.4	18.5	19.0	19.2	19.2	19.2	19.3	19.4	19.4	19.5	19.0	18.6
2	4	18.7	18.8	18.9	19.0	19.1	19.1	19.2	19.3	19.3	19.4	18.5	18.0
	Mean	18.6	18.6	18.9	19.1	19.2	19.3	19.4	19.5	19.5	19.6	18.9	18.7
	s.d.±	0.31	0.28	0.26	0.14	0.14	0.17	0.17	0.17	0.17	0.17	0.30	0.57
	c.v.%	1.6	1.5	1.4	0.7	0.7	0.9	0.9	0.9	0.9	0.9	1.6	3.0
	1	18.3	18.7	18.9	19.0	19.1	19.2	19.3	19.3	19.4	19.4	19.0	18.5
	2	18.4	18.5	18.8	19.1	19.4	19.5	19.5	19.6	19.7	19.0	19.0	18.5
	3	18.5	18.8	19.0	19.2	19.3	19.3	19.4	19.6	19.6	19.7	19.0	18.5
3	4	18.3	18.6	18.8	19.0	19.2	19.2	19.3	19.4	19.5	19.6	18.5	18.0
	Mean	18.3	18.7	18.9	19.1	19.2	19.3	19.4	19.4	19.5	19.6	18.9	18.3
	s.d.±	0.10	0.14	0.10	0.10	0.10	0.10	0.10	0.14	0.10	0.14	0.24	0.24
	c.v.%	0.5	0.7	0.5	0.5	0.5	0.5	0.5	0.7	0.5	0.7	1.3	1.3
	1	18.6	18.7	18.8	19.0	19.1	19.2	19.3	19.4	19.5	19.6	19.5	19.0
	2	18.4	18.8	18.9	19.0	19.2	19.3	19.4	19.6	19.7	19.8	19.4	19.2
	3	18.2	18.6	18.7	18.9	19.3	19.4	19.5	19.5	19.6	19.7	19.0	18.2
4	4	18.3	18.5	18.6	18.8	19.0	19.1	19.2	19.3	19.4	19.5	19.0	19.0
	Mean	18.4	18.7	18.8	18.9	19.2	19.2	19.4	19.5	19.6	19.7	19.2	18.9
	s.d.±	0.10	0.14	0.14	0.10	0.14	0.14	0.14	0.14	0.14	0.14	0.26	0.45
	c.v.%	0.5	0.7	0.7	0.5	0.7	0.7	0.7	0.7	0.7	0.7	1.4	2.4
	1	18.6	18.7	19.0	19.1	19.2	19.3	19.4	19.5	19.6	19.6	19.0	18.5
	2	18.8	18.9	19.2	19.2	19.4	19.5	19.6	19.7	19.8	19.9	19.1	19.0
	3	18.4	18.6	18.7	18.9	19.0	19.1	19.2	19.3	19.3	19.4	19.0	18.6
5	4	18.5	18.6	18.8	18.9	19.1	19.2	19.3	19.4	19.5	19.6	19.0	18.4
	Mean	18.8	18.9	18.9	19.0	19.2	19.3	19.4	19.5	19.5	19.6	19.0	18.6
	s.d.±	0.17	0.14	0.22	0.14	0.17	0.17	0.17	0.17	0.17	0.20	0.05	0.26
	c.v.%	0.9	0.7	1.2	0.7	0.9	0.9	0.9	0.9	0.9	1.0	0.2	1.3

	14	1.5	1.5	1.4	1.4	1.4	1.4	0.05	3.1
	27	1.4	1.2	1.2	1.3	1.2	1.4	0.07	5.1
	35	1.5	1.5	1.5	1.5	1.5	1.5	0.00	0.0
	46	1.4	1.5	1.5	1.5	1.6	1.5	0.11	7.3
SEMI-BUNCH	12	1.6	1.7	1.6	1.5	1.5	1.6	0.08	5.0
	13	1.6	1.6	1.6	1.5	1.6	1.6	0.05	3.1
	1	1.7	1.8	1.7	1.8	1.7	1.7	0.05	2.9
	6	1.7	1.7	1.7	1.7	1.7	1.7	0.00	0.0
	4	1.8	1.9	2.0	1.8	1.8	1.8	0.07	5.0
	2	2.2	2.2	2.2	2.2	2.2	2.2	0.00	0.0
	38	2.4	2.1	2.2	2.7	2.2	2.3	0.24	10.4
	47	2.5	2.6	2.6	2.5	2.6	2.6	0.07	3.7
	43	2.7	2.7	2.7	2.8	2.8	2.7	0.07	2.6
OPEN	51	2.9	2.9	2.8	2.7	2.7	2.8	0.10	3.5
	52	3.1	3.1	3.2	3.3	3.2	3.2	0.08	2.5
	62	3.3	3.3	3.3	3.0	3.0	3.2	0.08	2.5
	64	3.4	3.4	3.4	3.2	3.2	3.3	0.11	3.3
	67	3.5	3.6	3.6	3.4	3.3	3.5	0.13	3.7

Table 5 - Fourth internode length (cms) at maturity (Each reading is an average of 4 internodes per plant)

	Variety	Plants 1	2	3	4	5	MEAN	s.d.±	C.V.%
	3	0.9	1.2	1.1	1.1	0.9	1.0	0.14	14.0
	15	1.0	1.0	1.0	0.9	1.0	1.0	0.00	0.0
	17	1.1	1.0	1.1	1.0	1.0	1.0	0.05	5.0
	18	1.0	1.0	1.0	1.0	1.0	1.0	0.00	0.0
BUNCH	39	1.1	1.1	1.0	1.0	1.1	1.1	0.02	1.8
	28	1.2	1.2	1.2	1.4	1.3	1.3	0.08	6.2
	22	1.5	1.4	1.4	1.5	1.4	1.4	0.07	5.0
	20	1.5	1.5	1.3	1.3	1.3	1.4	0.10	7.1
	21	1.4	1.4	1.4	1.3	1.5	1.4	0.07	5.0

Table 6 - Fourth petiole length (cms) at maturity (Each reading is an average of 4 petioles per plant)

	Variety	Plants 1	2	3	4	5	MEAN	s.d.±	C.V.%
	17	10.2	8.6	10.5	9.3	9.4	9.6	0.75	7.8
	18	10.0	10.0	10.0	10.0	10.0	10.0	0.00	0.0
	3	10.5	10.2	9.0	11.7	10.0	10.3	0.96	9.3
	15	10.5	10.5	10.8	10.1	10.6	10.5	0.22	2.1
BUNCH	39	10.5	10.4	10.6	10.4	10.5	10.5	0.26	2.4
	28	9.0	10.6	11.4	11.1	10.8	10.6	0.93	8.7
	22	11.2	11.0	11.7	10.3	10.5	10.7	0.26	2.4
	21	10.7	10.7	11.0	11.3	11.3	11.0	0.30	2.7
	20	11.2	11.7	11.0	12.6	10.2	11.3	0.88	7.7
	27	10.2	12.6	11.2	11.7	11.0	11.3	0.88	7.7
	14	11.4	11.6	11.2	11.6	11.6	11.5	0.17	1.5
	35	12.6	12.7	11.6	12.4	12.1	12.3	0.45	7.7
	46	11.3	11.0	11.6	12.0	11.9	11.6	0.41	3.5
SEMI-BUNCH	13	12.9	12.6	12.6	12.9	12.8	12.8	0.13	1.0
	12	14.7	12.5	14.4	11.5	12.3	13.1	1.40	10.7
	6	14.0	14.4	12.9	11.7	13.2	13.2	1.01	7.6
	1	13.5	13.0	13.0	13.4	13.8	13.3	0.34	2.5
	4	13.0	13.7	13.6	13.8	13.1	13.4	0.38	2.8
	2	13.4	13.1	12.9	15.5	13.6	13.7	1.04	7.6
	38	14.9	15.0	16.2	13.5	12.8	14.5	1.34	9.2
	47	15.1	13.9	13.6	14.6	15.5	14.5	0.80	5.5
	43	14.2	14.6	15.0	15.1	14.9	14.8	0.36	2.4
OPEN	51	17.0	15.0	16.0	14.0	13.5	15.1	1.24	8.2
	62	15.4	16.5	17.4	17.1	15.8	16.4	0.84	5.1
	52	18.0	21.0	15.5	20.0	17.7	18.5	2.04	11.0
	64	18.5	18.7	18.7	19.0	19.0	18.8	0.21	1.1
	67	18.5	18.7	18.7	19.0	20.0	19.0	0.59	3.1

Table 7 - Fourth petiole length (cms)/Fourth internode length (cms)

	VARIETY	PETIOLE (P)	INTERNODE (I)	P/I
BUNCH	15	10.5	1.0	10.5
	3	10.3	1.0	10.3
	18	10.0	1.0	10.0
	17	9.6	1.0	9.6
	39	10.5	1.1	9.5
	28	10.6	1.3	8.2
	22	10.7	1.3	8.2
	21	11.0	1.4	8.1
	20	11.3	1.4	8.1
SEMI-BUNCH	35	12.3	1.5	8.2
	14	11.5	1.4	8.2
	12	13.1	1.6	8.2
	27	11.3	1.4	8.1
	13	12.8	1.6	8.0
	6	13.2	1.7	7.8
	1	13.3	1.7	7.8
	46	11.6	1.5	7.7
	4	13.4	1.8	7.4
OPEN	38	14.5	2.3	6.3
	2	13.7	2.2	6.2
	52	18.5	3.2	5.8
	64	18.8	3.3	5.7
	47	14.5	2.6	5.6
	43	14.8	2.7	5.5
	67	19.0	3.5	5.4
	51	15.1	2.8	5.4
	62	16.4	3.2	5.1

Table 8 - Thickness of dry shell (mm) (Each reading is an average of 20 shells

	VARIETY	SHELL THICKNESS
	15	0.34
	3	0.36
	18	0.37
	17	0.43
BUNCH	39	0.40
	21	0.42
	28	0.42
	20	0.50
	22	0.51
	14	0.43
	27	0.43
	46	0.43
	35	0.46
SEMI-BUNCH	13	0.47
	12	0.48
	6	0.50
	1	0.51
	4	0.51
	2	0.51
	38	0.51
	52	0.51
	47	0.52
OPEN	64	0.52
	43	0.53
	67	0.53
	51	0.54
	62	0.54

Table 9 - Length breadth ratio of terminal leaflet
(Each reading is an average of 20 leaflets)

	VARIETY	LENGTH (L)	BREADTH (B)	L/B
	3	6.7	3.3	2:1
	15	7.0	3.5	2:1
	39	7.0	3.9	2:1
	17	7.5	3.6	2:1
BUNCH	18	7.5	3.6	2:1
	22	7.6	3.6	2:1
	20	7.2	3.8	2:1
	28	7.4	3.7	2:1
	21	7.4	3.7	2:1
	14	8.4	4.2	2:1
	27	7.9	4.0	2:1
	46	7.5	3.9	2:1
	35	7.6	4.4	2:1
SEMI-BUNCH	13	7.5	4.1	2:1
	12	7.4	3.7	2:1
	4	8.0	3.7	2:1
	1	7.3	3.8	2:1
	6	7.6	4.0	2:1
	51	7.6	4.0	2:1
	67	8.0	4.6	2:1
	43	7.5	3.7	2:1
	64	7.6	3.6	2:1
OPEN	47	7.5	3.6	2:1
	52	7.7	4.1	2:1
	38	7.2	3.7	2:1
	2	7.1	3.6	2:1
	62	7.8	3.9	2:1

Table 10 - Colour of dry seed and colouring around the hilum.

	VARIETY	COLOUR
	15	Ivory - Dark brown eye.
	3	Cream - No eye.
	18	Brown with red patterned seed coat - No eye.
	17	Dawn pink - No eye.
BUNCH	39	Cream with brown specked seed coat - No eye.
	28	Dark brown mottled - No eye.
	22	Orange, with brown patterned seed coat - No eye.
	21	Ox-blood red - Cream eye.
	20	Brown mottled - No eye.
	35	Yellowish grey with brown mottled seed coat - No eye.
	14	Violet - Black eye.
	12	Cream with brown patterned seed coat - No eye.
	13	Lilac - Brown eye.
SEMI-BUNCH	6	Brown mottled - Violet eye.
	1	Light reddish brown - No eye.
	46	Peach, with brown patterned seed coat - Brown eye.
	4	Lilac purple - No eye.
	27	Cream with black patterned seed coat - No eye.
	38	Cream with cream patterned seed coat - Violet eye.
	2	Peach with brown patterned seed coat - Violet eye.
	52	Grey with black patterned seed coat - White eye.
	64	Reddish brown - No eye.
OPEN	47	Cream with black patterned seed coat - White eye.
	43	Light brown - Dark brown eye.
	67	Dark reddish brown (almost black) - No eye.
	51	Cream, - Halo black and white eye.
	62	Light brown - No eye.

FIG. 5 RELATIONSHIP BETWEEN FOURTH PETIOLE LENGTH AND FOURTH INTERNODE LENGTH

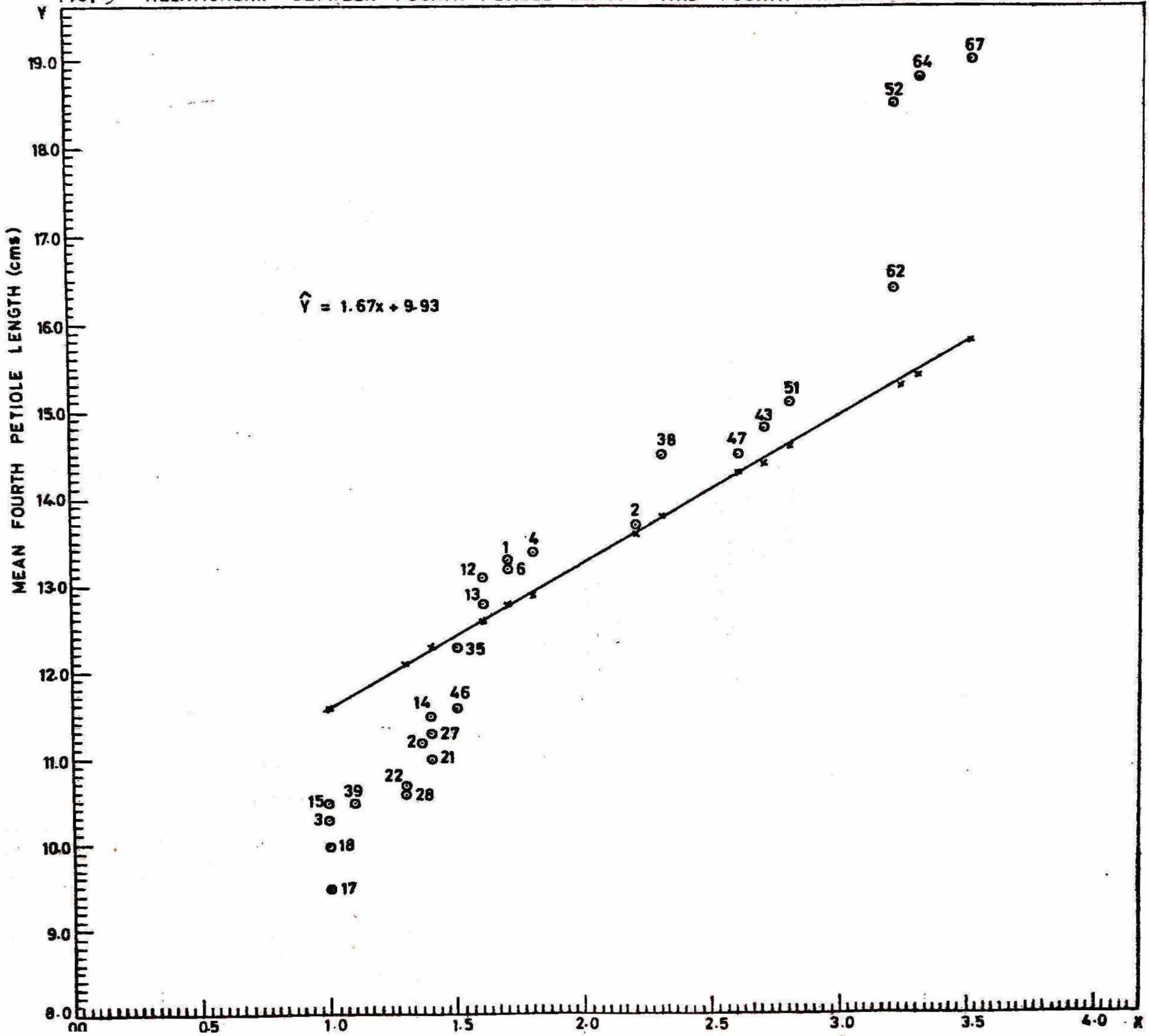


FIG. 6 PETIOLE LENGTH/INTERNODE LENGTH OF VARIETIES IN THE THREE HABIT GROUPS

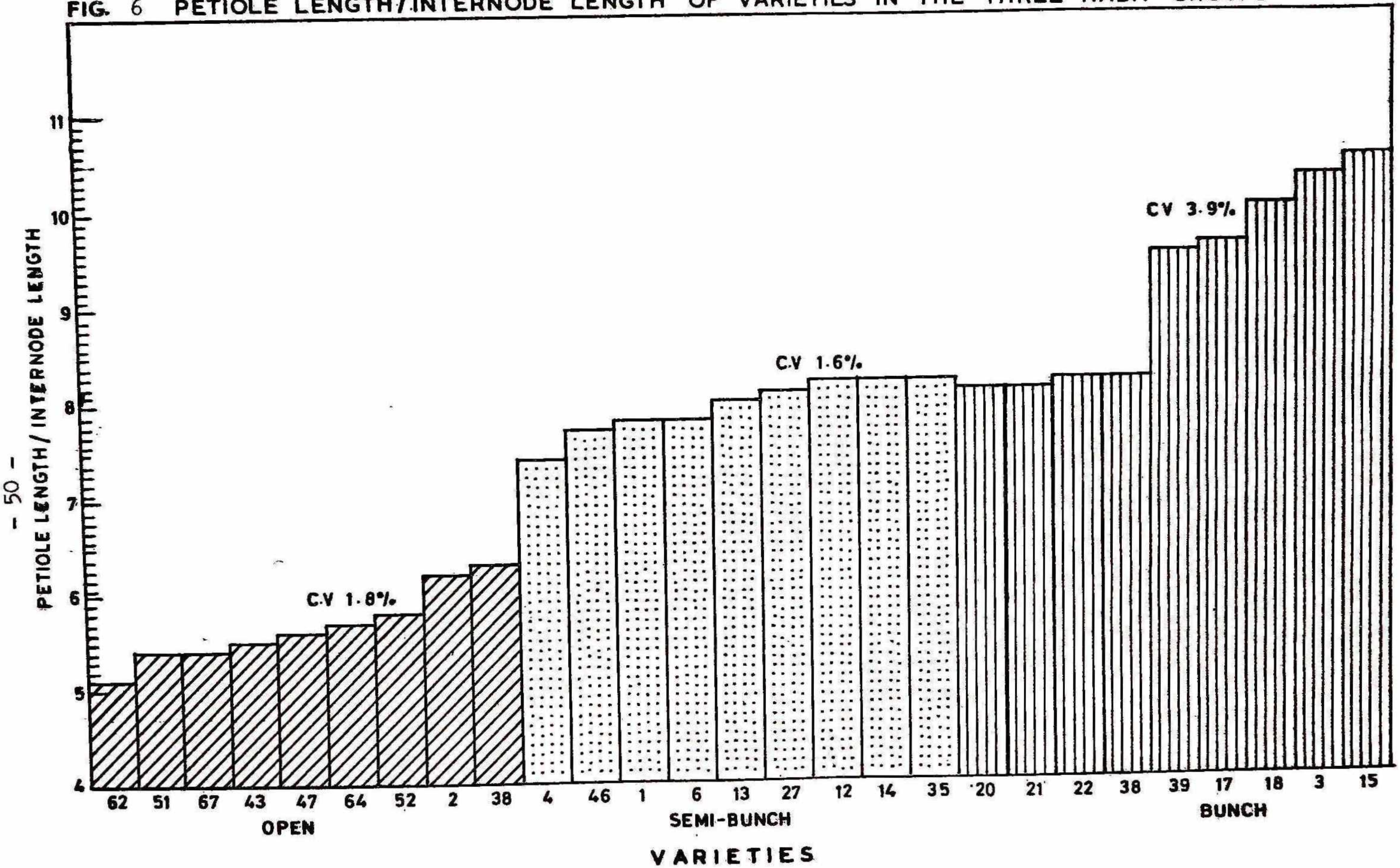


FIG. 7 HABIT AND NUMBER OF STEMS PER PLANT

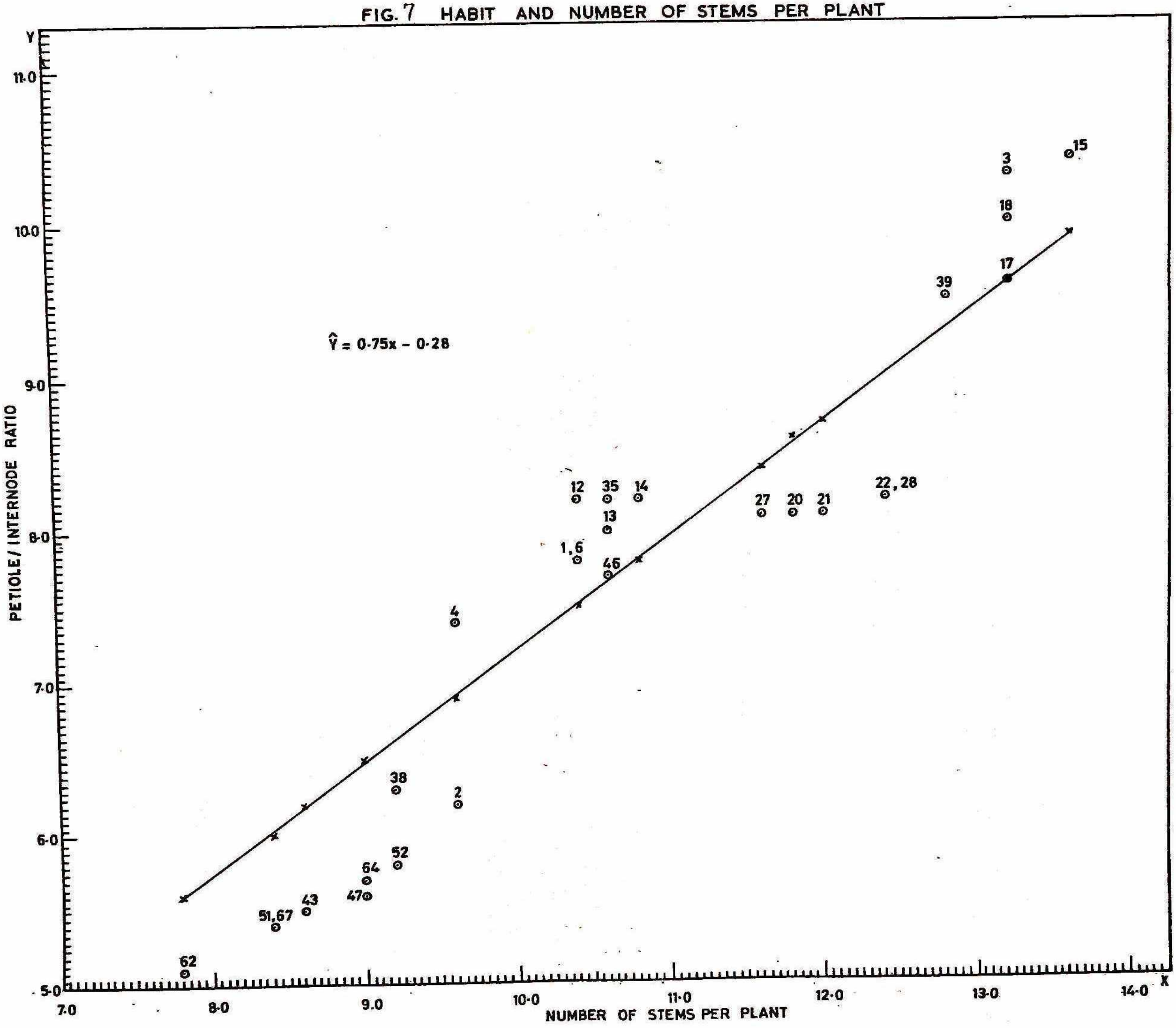
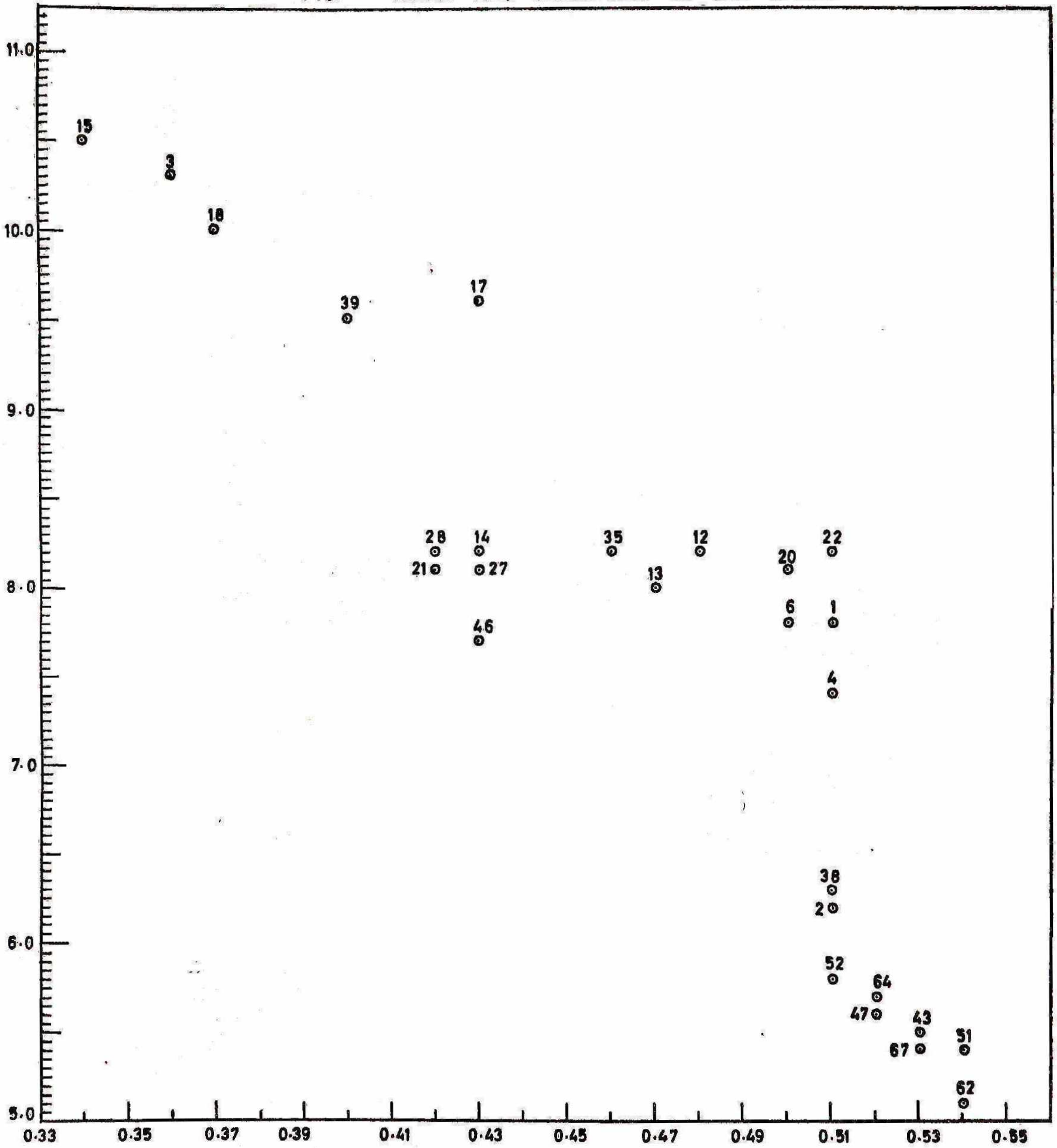


FIG. 8 HABIT AND THICKNESS OF DRY SHELL



THICKNESS OF DRY SHELL (mm)

open or spreading and intermediate or semi-bunch. However, other characters like flower and seed colours, duration of growth and shell thickness could be used to supplement and pin point groups more closely.

This classification is based on the gross external morphology of such characters as petiole and internode lengths and the number of stems per plant. Measurements of these characters and visual assessment of habit quite closely agree.

Bambarra groundnut was developed as a crop plant in the savanna zones where their wild ancestors are still to be found (Dalziel 1937, Cobley 1956, Hepper 1963 and Stanton 1966). It is obvious that the more successful plants are those that are better equipped to withstand the dry conditions of that area. In our collection, there are plants varying in habit from the very open e.g. variety 67, to the very compact e.g. variety 3 with gradations in between. According to Hepper the wild variety has long trailing stems while the cultivated one is more compact.

It has been observed that varieties with a compact habit which also have a high petiole internode ratio have more stems than those with open habit which have a low petiole internode ratio. In a cultivated farm in a savanna area where plants are not sheltered by vegetation and are therefore directly exposed, the bunch habit will afford protection from the drying winds which are common in the area. It is also easier to pull out compact varieties at harvest, because all the petioles are clustered together and can be held together by hand and pulled. Under cultivation in the savanna areas therefore, bunch types are more likely to be favoured and selected.

Open types with a running habit have persisted in the wild because this habit is needed to avoid complete shading by other plants. Since the bambarra plants will be growing together with other vegetation, they will not be directly exposed to the drying winds as in a cultivated field. There will therefore be no need to develop any compactness of habit. Indeed, it appears such a habit would be disadvantageous under wild conditions, for an entire compact plant will be within easy reach of predators, but only a portion of a spreading with traling stems, is likely to be damaged, the other trailing stems will therefore have a fair chance of surviving and continuing with the growth of the plant.

Observation on shell thickness contradicts Rassel and Hepper's findings that the pods of cultivated Voandzeia which have compact habit, had thicker shells and the wild ones which have open habit had thinner shells. The very opposite seems to have been found with the varieties used. The trailing varieties in the Legon collection which have thicker shells appear to be more closely related to the wild type of Hepper than the compact type, which have thinner shells.

This observation could be explained that seeds of wild types need a longer resting period under the long dry season of about six months in the savanna so that the seeds may germinate only when conditions become favourable for growth. Also seeds of wild varieties need to be protected from drying, and this protection is brought about by thick shells. Under cultivation however, selection will be in favour of pods with thin shells which could be shelled easily and this would explain why the bunch types i.e. those supposed to have been cultivatedlonger, have thinner shells than trailing ones, recently domesticated.

Most of the important cultivated varieties in Ghana are of the bunch type; also all varieties received from Rhodesia and Kenya, two places remote from the postulated centres of origin of the crop, are without exception of the bunch type. The presence of open types in West Africa may be due to its proximity to Northern Nigeria and Cameroons, two of the postulated centres of origin of the crop, where one is more likely to find varieties in their very early stages of domestication as well as much older domesticated varieties growing in farms in the same area. It therefore appears that under cultivation bambarra groundnut is gradually assuming a more compact growth habit and that this compact habit is accompanied by an increase in the number of stems probably brought about indirectly by selection for high yield since peduncles of flowers arise at nodes on the stems and so the more the stems the more the flowers and fruits.

It also appears that under cultivation, aerial parts i.e. stems, petioles and internodes have evolved faster towards compactness than the rate at which shell thickness is reduced.

Variety 3 (local cream), variety 1 (local light reddish brown), and variety 67 (local dark brown), were chosen as representatives of the three habit forms for this research. The latter variety has longer trailing stems and resemble the wild strain of Hepper, whereas the former is compact and bunch and may be taken as the most advanced type. Variety 1 is intermediate in bunchness between varieties 3 and 67. For all characters studied these varieties i.e. varieties 3,1, and 67 fell within the bunch, or compact, the semi-bunch or intermediate, and the open or spreading groups respectively.

4. Summary.

A general classification of varieties of *Voandzeia subterranea* has not been uundertaken, probably because of its relatively low economic value as compared to cowpea and groundnut. However, several authors have grouped varieties by the use of characters which they claim are less fluctuating. Internode and petiole lengths of varieties in the Legon collection have been found to be the least variable within varieties, and have been used in classifying them into three habit groups, namely compact or bunch, open or spreading, and intermediate or semi-bunch.

CHAPTER 3

FLOWERING

1. Introduction

According to Boateng (1967), Ghana lies so close to the equator that temperature varies little throughout the year. The only significant division of the year here is into rainy and dry seasons. At the coastal savanna on which the Accra plains lie, the rainfall reaches its maximum during two peak periods; the major rains come during the months of May, June and July, the minor rains occur in September and October followed by drought from December to February when little or no rain falls.

It is during the rainy season that most crops, especially vegetables, are grown because irrigation has not been developed to grow crops during the dry season. A few crops are however grown along streams and streets drains during the dry season when water from them is used.

There is very little literature on the flowering of bambarra groundnut especially as regards the botanical features of the flower itself. Perhaps Cobley (1956), is the only author who has described the botanical features of the flower but not in any detail. According to him the flowers are whitish-yellow in colour, the standard is broad and the keel is a straight structure enclosing the stamens of which nine are united by their filaments along most of their length and the tenth stamen is completely free. The ovary is surmounted by a short bent style which is covered with long hairs along the inner surface and tipped by a small stigma.

F.A.O. Agricultural Studies No.55 (Agricultural & Horticultural Seeds) gives periods within which the crop is grown in certain parts of Africa although the performance during these periods is not specified. It is also stated in this book that two crops are possible in the Tropics but the seasons involved are not mentioned.

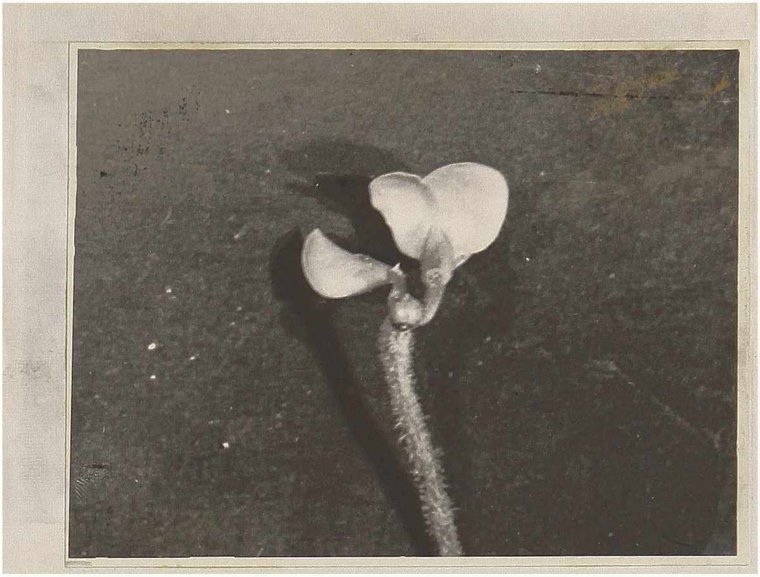
Cobley's botanical description is not detailed enough, and since F.A.O. Agricultural Studies No.55 (Agricultural and Horticultural Seeds) did not specify as to which seasons are better for growing the crop, it was thought necessary to study these aspects in greater detail because knowledge obtained in these studies will be useful for breeding and other agronomic work on the crop. The flower was therefore studied in a much greater detail. Observations were made on three selected varieties namely variety 3, (local cream), variety 1 (local light reddish brown), and variety 67 (local dark brown).

2. <u>Botanical description of the flower</u>

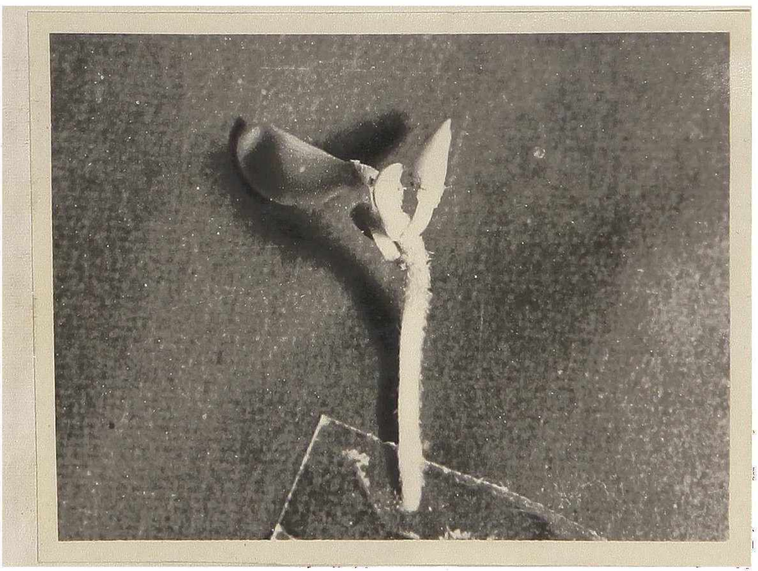
The flowers of *Voandzeia subterranea* are typically papilionaceous. They are borne in a racemose inflorescence on long peduncles with bulbous tips and behind each bulb two to three flowers, but usually two, are found (Fig. 9). The peduncles reach their maximum lengths at the initiation of pod formation but the pedicels reach theirs at the time of anthesis. The interval between opening of successive flowers in a raceme varies from 24 to 48 hours and that of flowers on the same peduncle does not exceed 24 hours, but rarely do they open at the same time (Fig. 10).

Fig. 9

(a)



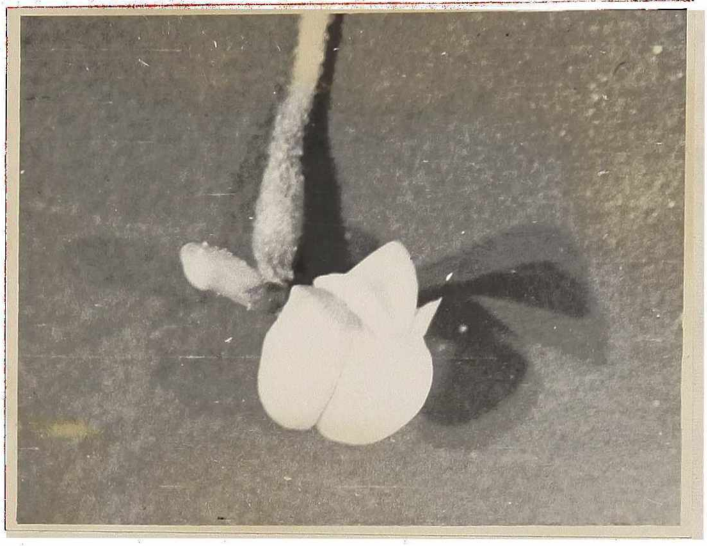
(b)



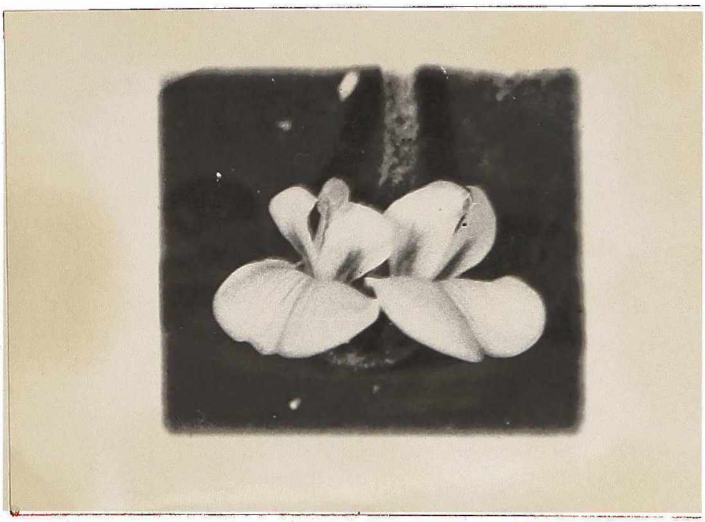
Inflorescence of bambarra groundnut showing
(a) 2 flowers on a peduncle. (b) 3 flowers on a peduncle.

Fig. 10

(a)



(b)



Flower opening in bambarra groundnut.
(a) One flower opening before the other and
(b) Two flowers opening simultaneously (Note the position of floral parts).

Flowers are generally yellowish-white in colour but the degree of yellowness varies with age and time of the day. When flowers open during the early hours of the morning, they are yellowish-white but towards the evening the colour changes through various shades of yellow to brown. Flowers that are produced towards the end of the life of the plant are usually light brown.

The flower (Figs 11 & 12) has a pair of hairy epicalyx, one being longer and thinner than the other. The calyx consist of five green hairy sepals, four being on the upper side (above the keel petal), and the remaining one on the lower side (below the standard). The four upper sepals are almost completely joined, being free only at the toothed edges, the lower sepal is free to a great extent and its lip is not as pointed as the others but is simple and accuminate. The epicalyx and calyx completely enclose the corolla in the early bud stage (Fig 11Aa), and as the bud develops into a flower, the corolla becomes more conspicuous, so that at the time of opening of the flower the calyx is seen as teeth of sepals encircling the base of the corolla (Fig 11Ab). The epicalyx drops off during the course of entry of the fertilised flower into the soil but the calyx persists on the pod and assumes a light brown appearance (Fig. 31).

The notched orbicular standard encloses the wing and Keel until the flower opens. The base of the standard is broadly inserted and fused firmly with the base of the staminal column. When the standard petal opens, it is bent over at about half its length so that the two wings stand perpendicular to it (Fig. 10). The wings remain in contact along their edges and the keel lies inside them. The keel is recurved and hooked and consists of two petals fused along their distal edges to the apex but open ventrally along the base. At its tip, a hollow is formed through which ants occasionally enter both unopened and opened flowers. The reproductive structures of the flower are completely enclosed inside the horn-like keel petals. The wings and keel are attached between the staminal column and the standard by pairs of claws.

In all flowers observed, the androecium consist of ten functional stamens, the monadelphous stamens form a fleshy tube leaving about the upper third to half of the filaments free. Up to the time of anthesis eight stamens including the free one are opposite the style and the other two are behind it but this arrangement is destroyed at anthesis (Fig. 13C). The filaments bear adnate, oblong, biloculate anthers. Within a particular variety, the anthers are uniform in size, but the size varies between varieties. Anthers of variety 3 for instance are smaller and its styles are also shorter than those of variety 1 and variety 67. The size of the pollen grain is thus related to the distance which the pollen tube must traverse from the stigma to the ovules. Since varieties with longer styles also have larger pollen grains, it appears this is an adaptation in providing the pollen tube with sufficient food to enable it to reach its destination. Although the ratio of size of pollen grain/length of style is constant for flowers of the same variety at anthesis, this ratio was high for the bunch varieties, low for the compact varieties and intermediate for the semi-bunch varieties. (Table 11).

Table 11 Size of anthers in relation to length of style and size of pollen. (Each reading is an average of 10 samples).

Variety	Size of anther	Length of style	Size of pollen grain	Size of pollen grain/length of style
3	21,320sq. u	4,640 u	104sq. u	0.022
1	24,250sq. u	5,100 u	136sq. u	0.027
67	29,680sq. u	5,320 u	160sq. u	0.030

In the bud stage, the gynoecium is longer than the androecium so that the stigma projects well above the anthers (Fig 13A) but the stamens keep elongating at a faster rate than the style so that at anthesis the stigma and the style are at the same height (Fig. 13B). This appears to be an adaptation to ensure self pollination.

The hypogynous ovary and particularly the style are somewhat laterally compressed. The stigma is club-shaped and laterally placed on the style leaving a projection of about a millimeter of the style above it. There is an invagination at the point where the ovary merges into the style and after this region and the style thickens considerably. At the end of the staminal column, the style is reflexed and becomes almost parallel with the anthers but extends beyond them into the hook of the keel. The style is bearded below the stigma, on the surface facing the standard, with a series of stiff downwardly-descending hairs. The ovary is monocarpellary and contain two ovules which develop along the ventral suture of the carpel. The lower ovule arises first.

Fig. 11 A Inflorescence showing axillary position of flowers of bambarra groundnut.
a = bud; b = expanded flower; c = withered flower.

Fig. 11 B Longitudinal optical section of flower.

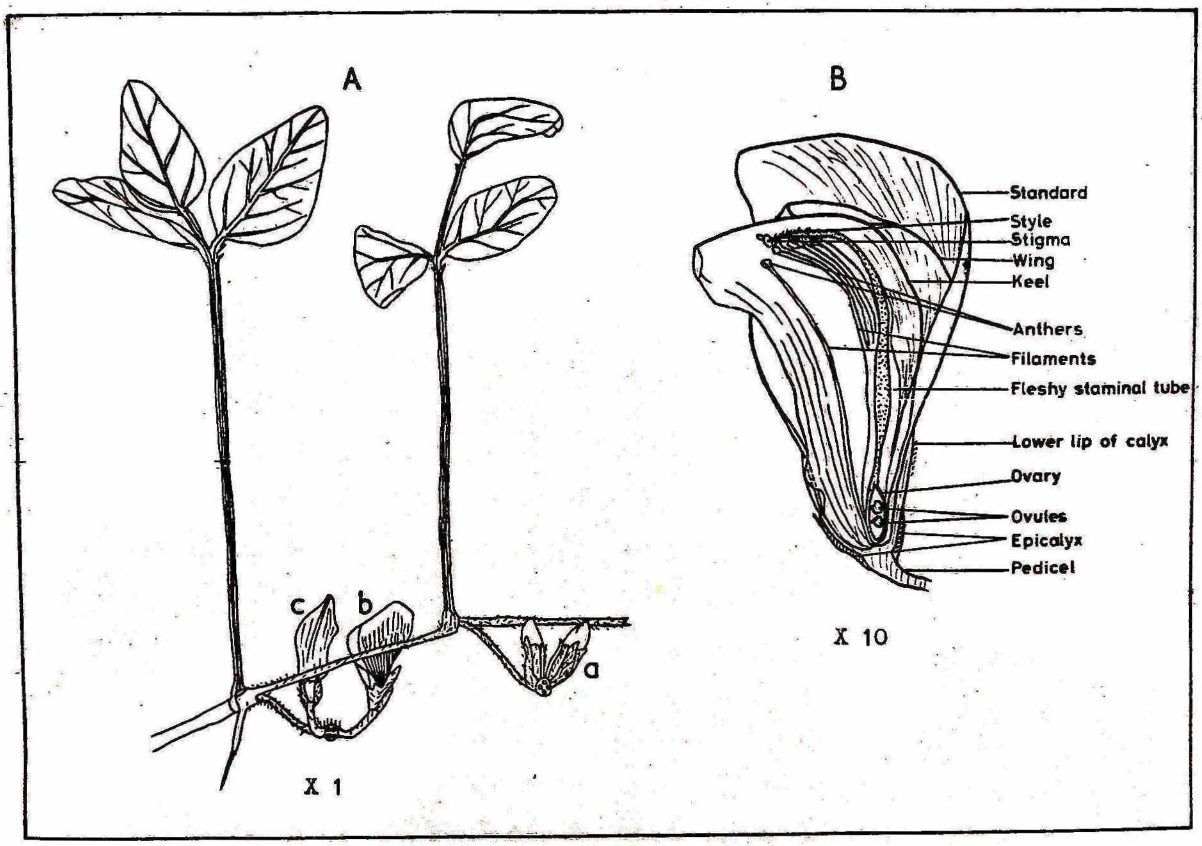
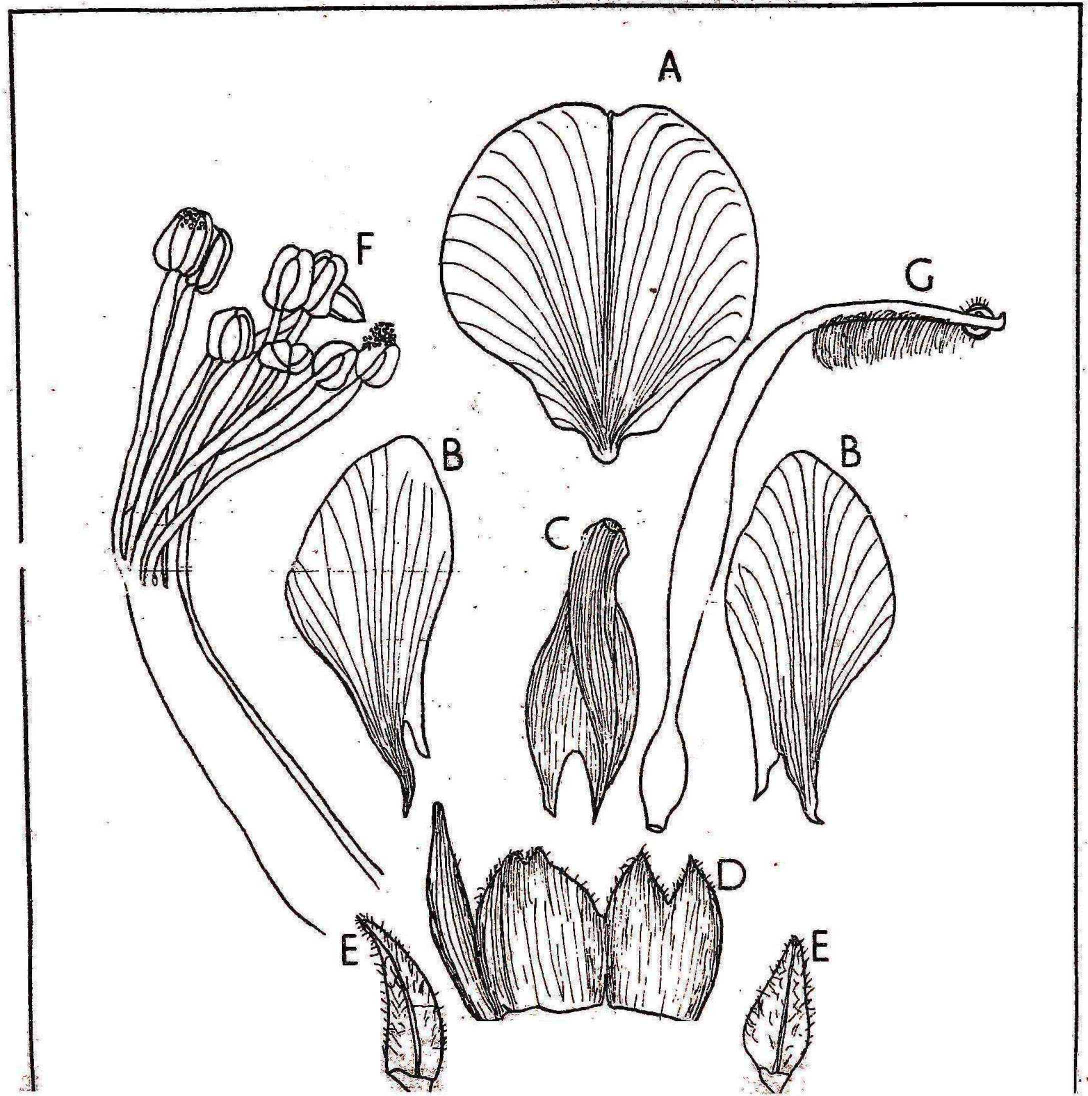


Fig. 12 - Dissected flower of Voandzeia subterranea



A = Standard.

B = Wing.

C = Keel.

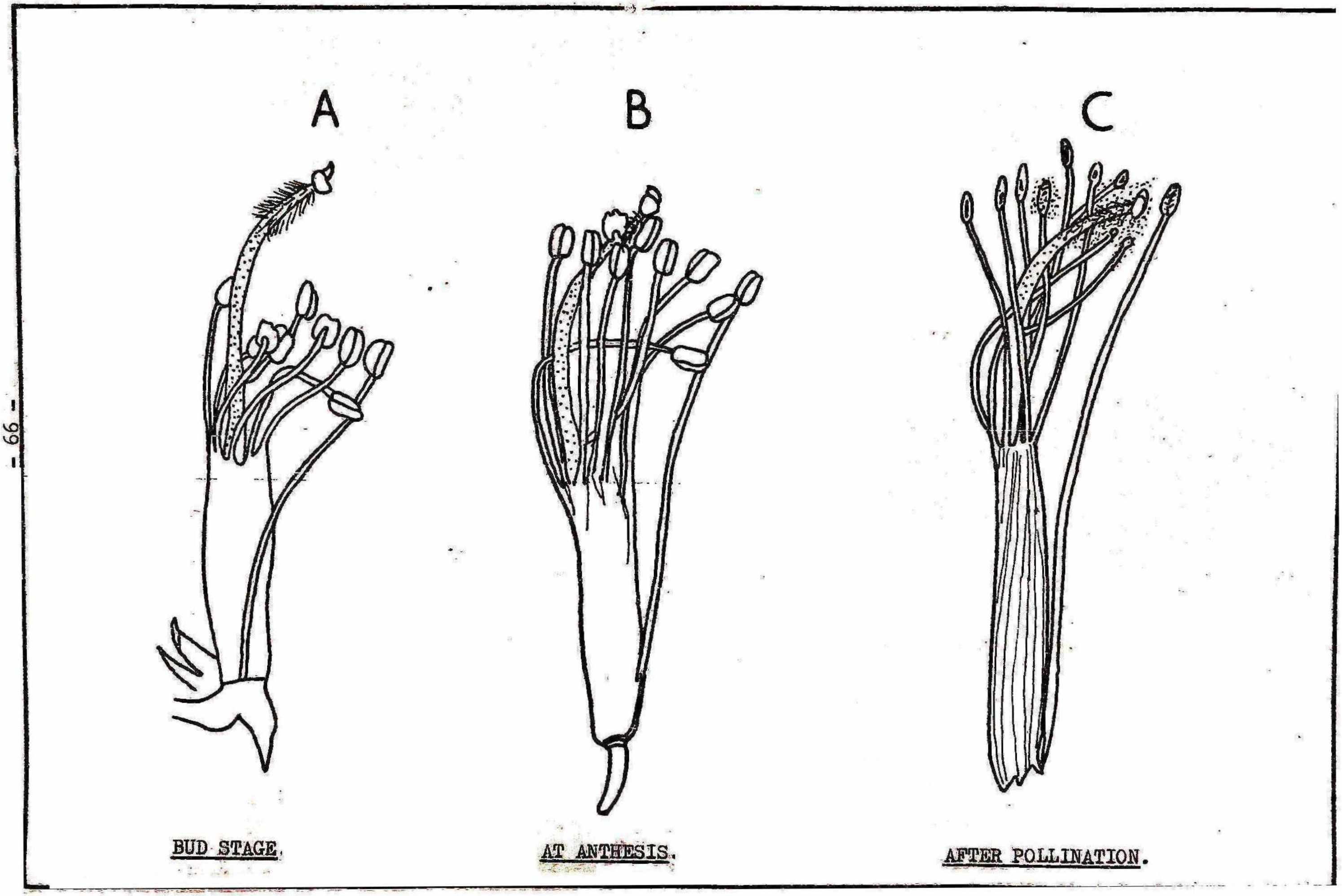
D = Calyx.

E = Epicalyx.

F = Androecium.

G = Gynoecium.

Fig.13 - Position of stamens in relation to style and stigma.



3. Flowering behaviour.

The first flowers open 28 and 31 days after germination during the dry and rainy seasons respectively. In varieties 1 and 67, flowering, once initiated, does not cease until the end of the life of the plant (Fig.15) but in variety 3 flowering stops about two weeks before the life of the plant comes to an end.

Since the flowers of bambarra groundnut are ephemeral, it was possible to study the daily production of flowers: Flowers which are destined to open the following day reach their maximum size at about 6 p.m. the previous day, when they are observed to be much swollen. Such flowers open at sunrise with maximum opening occuring between 8.30 and 10 a.m., except during cool weather when the opening time is delayed. Flowers which open before noon start to close around 3.30 p.m., the period between opening and closing of flowers being roughly constant. Between 18 and 24 hours after opening, the petals, the androecium and the upper portion of the style drop off

4. Effect of season on flowering.

Experiments were performed to find out which of the two seasons was more favourable for flowering

Materials and Methods

During each season, seeds of the three varieties were sown in the field in a randomised block design with six replicates. Two such experiments were set out, each replicate consisted of single rows of twelve plants of each variety spaced at two feet apart. Three seeds were sown

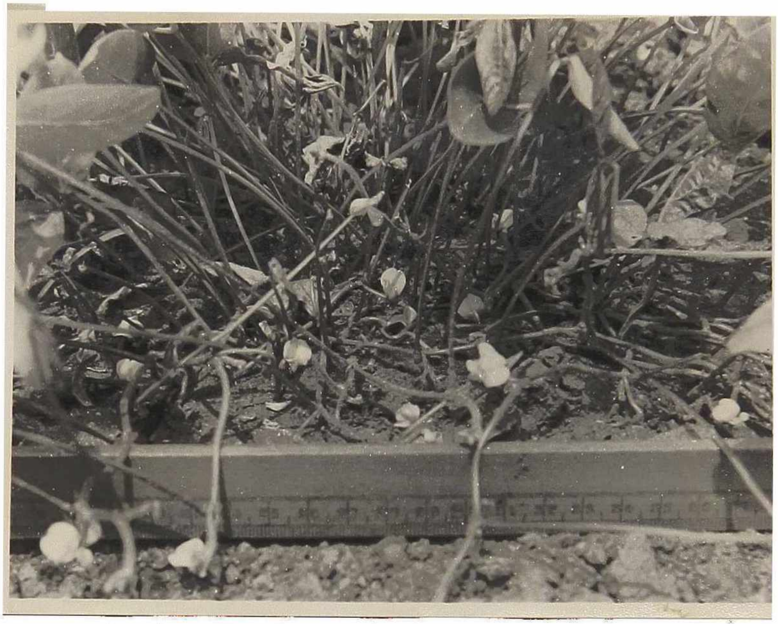


Fig. 14 - Peak stage of flowering in variety 67. (Note the ant holes and casts beneath the flowers).

Fig. 15 - Flowering at the end of the life cycle of variety 67.

in a hole and at two leaf stage the seedlings were thinned to one so that uniformity could be obtained. The plants were watered regularly when the soil was dry. Meteorological records during the months of growth were taken. (Appendices 3 to 10).

From one of the experiments, records were taken of the total number of flowers that opened during the day. As some of the flowers were partially buried, plants had to be raised before such flowers could be counted and occasionally some flowers dropped off accidentally. The other set was not disturbed and plants from it were harvested at maturity and records taken on pod production. The total number of flowers as well as the total number of pods per plant during the two seasons were then determined. Fertility coefficients (i.e. the percentage of the number of flowers/number of pods), and the flower/pod ratio during the two seasons were also calculated.

Results and observations

For all varieties, the number of days between date of germination and commencement of flowering was not influenced by season (Table 12).

Table 12 Effect of season on time of flowering.

Season	Months	Variety 3	Variety 1	Variety 67
Rainy	June-August	31	31	31
Dry	Dec.-February	28	28	28

The total number of flowers and pods produced, fertility coefficients, and the flower/pod ratio for the three varieties during the rainy and dry seasons are also shown in Tables 13, 14, 15 and 16.

Table 13 - Mean number of flowers per plant

Variety	Rainy season	Dry season	Mean
3	607.5	668.6	638.0
1	488.2	732.8	610.5
67	468.0	639.6	553.8
Mean	521.2	680.3	

Rainy season vs. dry season, significant at p = 0.01

L.S.D.	p = 0.05	Variety	=15.3
	p = 0.01	"	=20.7
L.S.D.	p = 0.05	Variety x rainy season vs. dry season	=10.8
	p = 0.01	" " " " " " "	=14.7

Table 14 - Mean number of pods per plant

Variety	Rainy season	Dry season	Mean
3	140.4	154.4	147.4
1	48.8	76.9	62.9
67	41.5	61.4	51.4
Mean	76.9	91.8	

Rainy season vs. dry season, significant at p = 0.01

L.S.D.	p = 0.05	Variety	= 5.3
	p = 0.01	"	= 7.2
L.S.D.	p = 0.05	Variety x rainy season vs. dry season	= 7.5
	p = 0.01	" " " " " " "	=10.1

Table 15 Fertility coefficients

Variety	Rainy season	Dry season	Mean
3	23.0	23.1	23.05
1	10.0	10.5	10.3
67	9.0	9.6	9.3
Mean	14.0	14.4	

Table 16 Flower/pod ratio

Variety	Rainy season	Dry season	Mean
3	4.3 : 1	4.3 : 1	4.3 : 1
1	10.0 : 1	9.5 : 1	9.8 : 1
67	11.1 : 1	10.4 : 1	10.8 : 1
Mean	8.5 : 1	8.1 : 1	

Barlett's method was used to test homogeneity of experimental error variances and it was found that the error terms of the two experiments of yield data were sufficiently homogeneous to permit the combined analysis of variance, with the calulation of one generalised error for comparison of both experiments (Appendices 11 and 12).

A significantly higher number of flowers and pods were produced during the dry season than during the rainy season. In variety 3, about 10%, and in varieties 1 and 67 about 50% more flowers were produced during the dry season.

A curve of the number of flowers per plant against days (Figs.16 to 20) shows four stages in the progression of flowering and these can be distinguished as follows:-

(a) Stage of slow progression.

(b) Stage of rapid progression.

(c) Peak stage.

(d) Stage of decline.

On examination of the curves it is found that, period of slow progression of flowering lasted for 6 days for all the three varieties during the dry season but during the rainy season, this period lasted for 12,15 and 14 days for varieties 3,1, and 67 respectively. More flowers were produced at this stage during the rainy season than the dry season, but flower production per day was higher during the dry season than the rainy season.

Stage of rapid progression lasted for 8,9, and 8 days for varieties 3,1, and 67 respectively during the dry season; during the rainy season, however, this stage lasted for 7, 10, and 11 days for varieties 3, 1, and 67 respectively. Although this stage was shorter during the dry season than the rainy season, more flowers were produced during the dry than the rainy season.

The peak stage during the dry season was for 16, 11, and 12 days for varieties 3, 1, and 67 respectively but during the rainy season this period lasted for 17 days for all varieties. At this stage production was higher during the dry season than the rainy season for varieties 3 and 67. In variety 1 however, slightly more flowers were produced at the peak stage during the rainy season than the dry season.

FIG. 16 DAILY PRODUCTION OF FLOWERS IN VOANDZEIA SUBTERRANEA DURING THE DRY SEASON

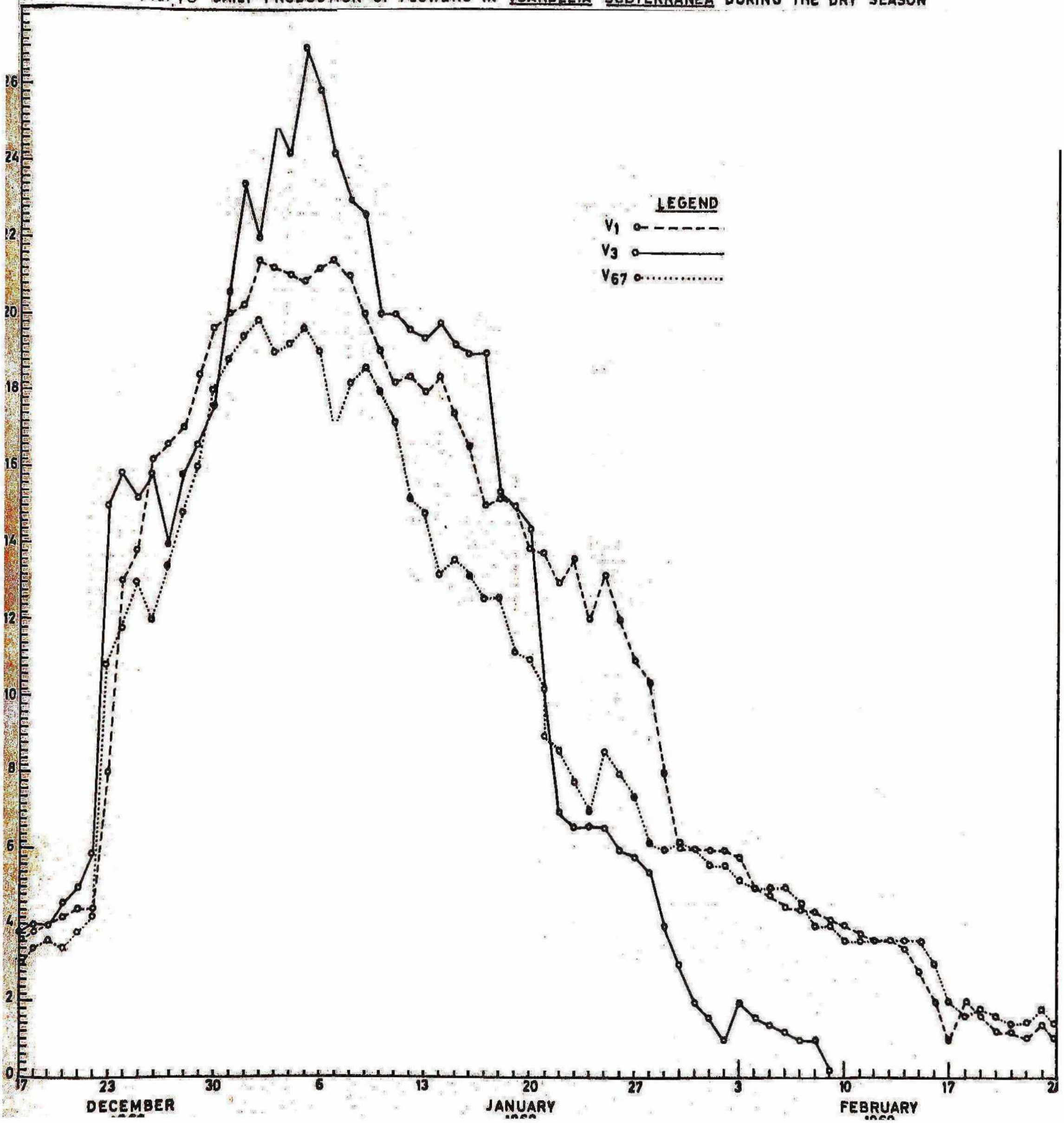


FIG 17 DAILY PRODUCTION OF FLOWERS IN *VOANDZEIA SUBTERRANEA* DURING THE RAINY SEASON

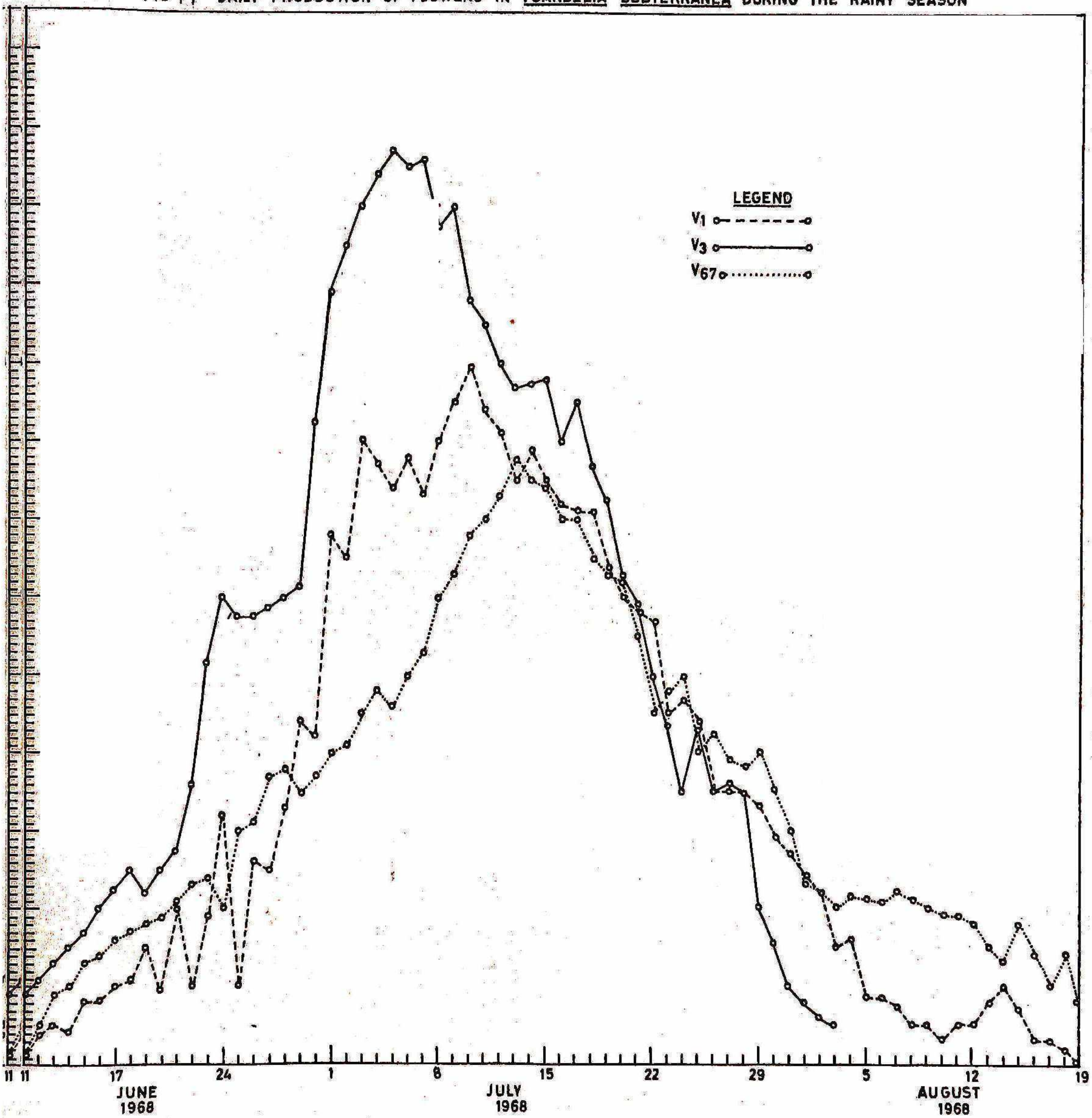


FIG. 18 DAILY PRODUCTION OF FLOWERS IN VOANDZEIA SUBTERRANEA (VARIETY 3) DURING THE RAINY AND DRY SEASONS

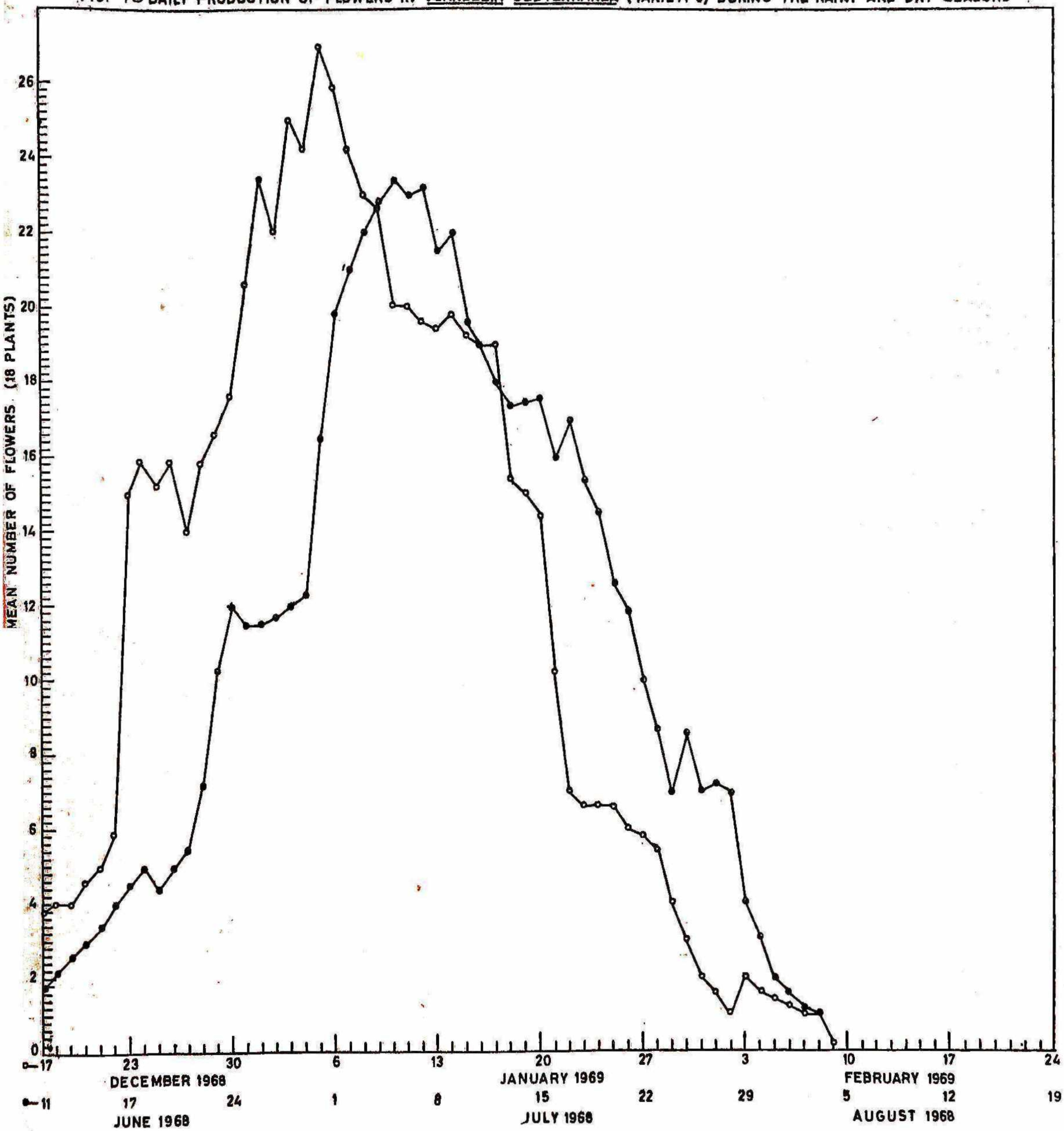


FIG. 19 DAILY PRODUCTION OF FLOWERS IN *VOANDZEIA SUBTERRANEA* (VARIETY 1) DURING THE RAINY AND DRY SEASONS

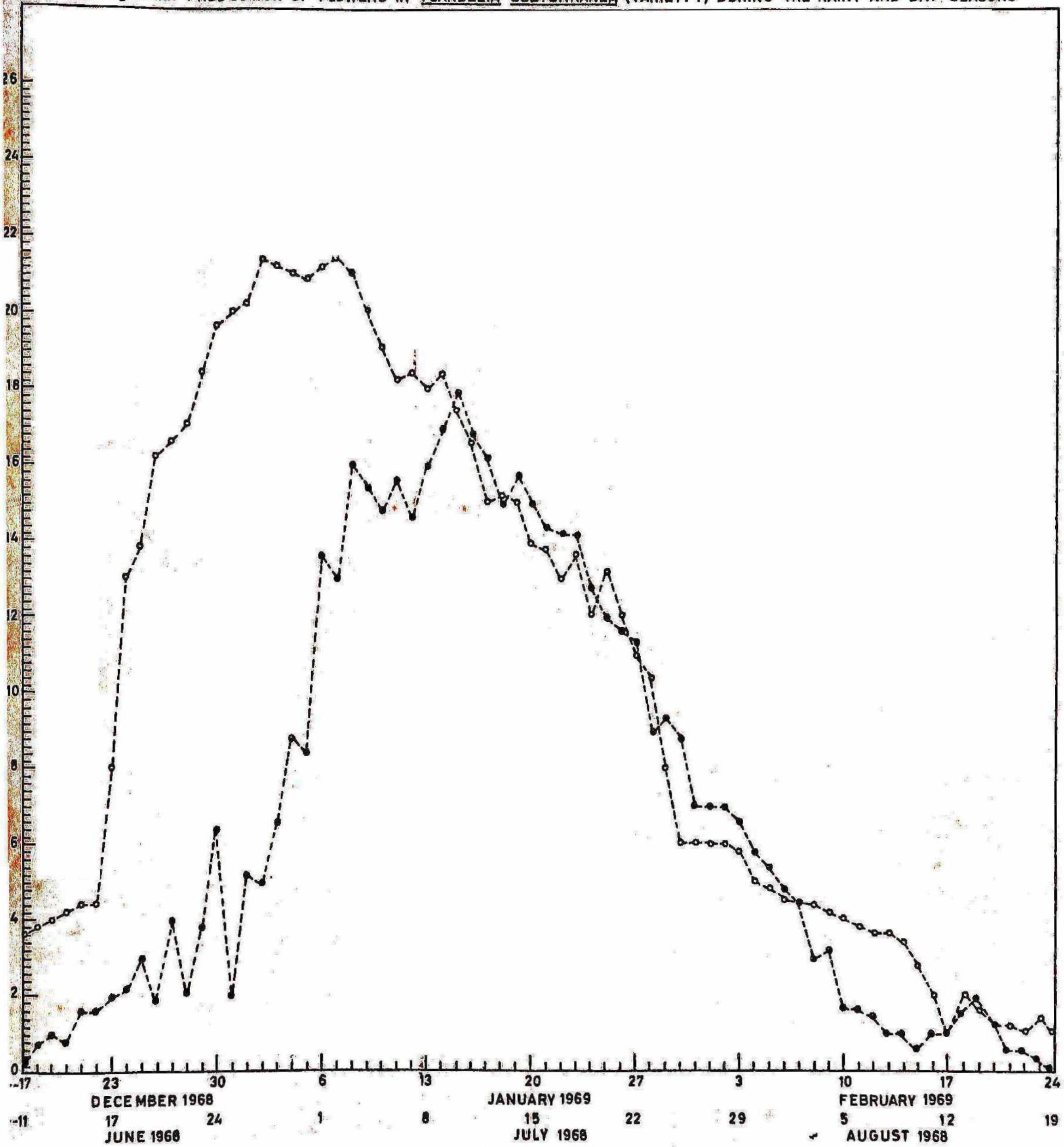
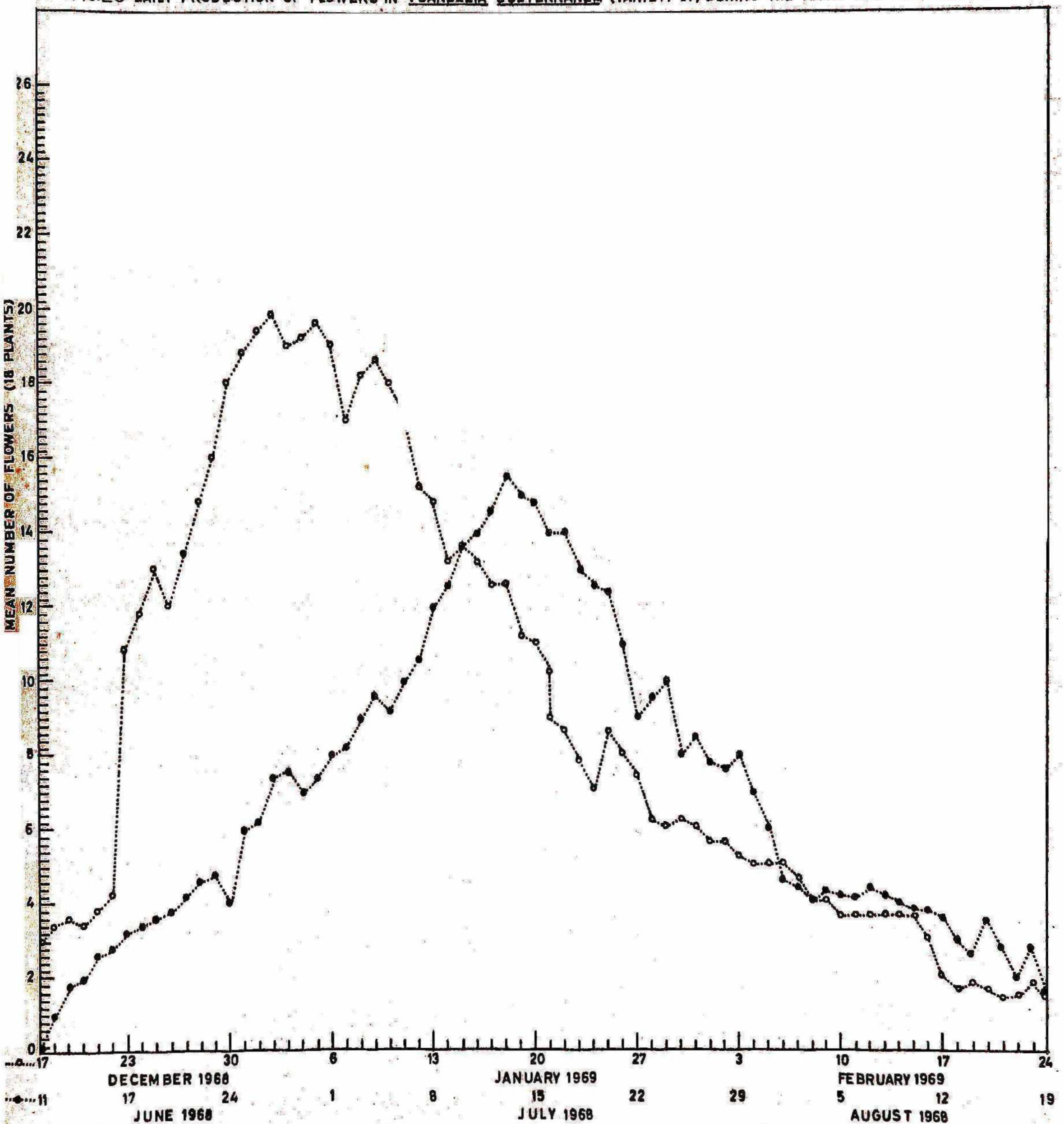


FIG. 20 DAILY PRODUCTION OF FLOWERS IN VOANDZEIA SUBTERRANEA (VARIETY 67) DURING THE RAINY AND DRY SEASONS



The stage of decline of flowering lasted for 40 days for variety 3, and 44 days each for varieties 1 and 67 during the dry season. In the rainy season, this stage lasted for 34 days in variety 3 and 28 days each in varieties 1 and 67. The total flower production at this stage was more during the dry season than the rainy season.

5. Time required for fruit maturity.

Introduction

It appears that not all flowers have enough time to develop into mature fruits because during harvest fruits at various stages of development are observed. One finds on the same plant,

(a) occasionally, fruits whose seeds have either rotten or germinated.

(b) fruits which are in the stage of pod and seed maturity.

(c) fruits whose pods have developed but whose seeds are not mature.

(d) fruits whose pods are in the process of development but which are empty of seeds,

and

(e) fertilised flowers just before they develop into pods (discs).

Knowledge of the time required from flowering to pod maturity will be useful in deciding when harvesting should commence. It was therefore decided to investigate this and a study was made on flowers of plants growing adjacent to the experimental plots.

<u>Materials and methods</u>

Flowers of each variety on selected plants were marked be means of metal tags. Tags were fixed on flowers whose peduncles were sufficiently long but placed near those whose peduncles were short.

Fruits in the course of formation were followed up to complete maturity by cutting sections through them (Fig.30) and examining the nature of the pods and seeds contained therein. This was done on ten plants each of the three varieties.

Observations

Thirty days after flowering the seeds were not quite ripe but were still soft and the inner parenchyma of the shell was thick, white, and watery. But at 40 days, the pods became ripe, the seeds were mature, and the shells no longer had the thick, white and watery parenchyma. This minimum time is required by the three varieties for pod maturation.

Discussions and conclusions

It therefore follows from this observation that useful flowering i.e. flowering which leads to the production of mature fruits should end about 40 days before the end of the life of the plant and therefore as much as possible, the majority of flowers produced during the life of the plant should come before the last forty days of the life of the plant, for good harvest to be obtained.

Flower production lasts for 70 days in varieties 1 and 67 during the rainy and dry seasons (Figs. 19 &20). In variety 3 however, flower production lasts for 55 days during both seasons (Fig. 18).

Since fertilised flowers need about 40 days to develop into mature pods, it indicates that only flowers which are produced during the first thirty days of flowering get enough time to develop into pods.

During the dry season, the last day of the peak of flowering in variety 3 occurred at the thirtieth day, while that of varieties 1 and 67 occurred at the twenty-sixth day. Thus, the periods of slow, rapid and peak of flowering came before the last 40 days during which flowers produced are not able to develop into mature pods. In variety 3, 153.3 out of 668.6, i.e. 22.9%, of total flowers are produced during the last 40 days and so do not form mature pods. In varieties 1, and 67, the proportion is 37.2% and 35.6% respectively.

During the rainy season, the last day of the peak of flowering in variety 3 occurred at the thirty-sixth day thus, six days of the peak stage did not fall within the period of useful flowering. In varieties 1 and 67 the last days of the peak of flowering occurred after the forty-second day. Thus 12 days of the peak of flowering occurred outside the period of useful flowering. In variety 3, 245.3 out of 610.5, i.e. 40.1%, of the flowers did not fall within the period of useful flowering. In varieties 1 and 67 this proportion was 259.2 out of 488.2, i.e. 53.1%, and 282.3 out of 468.1, i.e. 60.3%, respectively.

Thus, when the crop is sown during the rainy season a larger proportion of the period of peak of flowering fall outside the period of useful flowering and this very much lessens the chance of a good harvest.

6. <u>Concluding remarks on flowering and pod production.</u>

Growth and fruit production of crops is strongly influenced not only by genetical factors but also by environmental factors. Of the environmental factors rainfall is very important especially in this part of the world where farmers depend mostly on rainfall for growing their crops. However, with irrigation, the farmer is enabled to grow crops throughout the dry season and also can control the amout of water supplied to the plant.

It has been observed that bambarra groundnut was developed as a crop plant in the savanna and that the bunch habit which is seen in many cultivars and ecotypes, have evolved in response to cultivation under savanna conditions. The crop has thus become adapted to the long dry season (4-6 months) of this area and varieties with the more open habit resembling the wild strain would appear to be more drought tolerant than the cultivated bunch varieties.

Most crops require a dry sunny period for flowering and pollination and these plants are not successfully pollinated when wet with dew or rain. Bambarra groundnut produces its pods in the soil and so a lot of rain may cause some of the pods to germinate or rot prematurely if these are not harvested soon after maturity. Pods need a dry period towards the end of its life so that the moisture content will be reduced before they are harvested. The common practice of harvesting after the plant has dried often results in much loss of seed through rotting and premature germination of seeds and pods which had matured earlier. In local practice it is quite frequent for selected matured nuts to be removed from the plant before the rest are fully mature and before the whole plant is lifted. This practice of harvesting individual pods as they ripe have been shown to minimise the losses due to rotting and premature germination of seeds. If, however, large acreages are planted this practice cannot be conveniently applied and so the crop has to be harvested at a stage when a high percentage of the pods are mature.

Although a significantly higher number of flowers and pods are produced during dry season than the rainy season, the increase was greater, in varieties 1 and 67 than in variety 3. Fertility coefficients also increased during the dry season, but this increase was again greater in varieties 1 and 67 than in variety 3. Also flower/pod ratio decreased in varieties 1 and 67 during the dry season without a corresponding decrease in variety 3.

These obserfations of the seasonal variations are due to the plants adaptability to drought and climatic conditions prevailing during the dry season. Heavy rainfall seems to have an adverse effect on the performance of the crop.

The significant difference in variety x season interation, indicate that the varieties do not behave alike during the seasons. It has been suggested that varieties with the more open habit resemble the wild strain and that cultivated varieties are more compact. Since the compact variety has been in cultivation longer than the open varieties, it is likely that it has become more used to water and therefore the rainy season does not have so much adverse effect on it as it would have on the wild types which are more adapted to the long dry season of 4 - 6 months of the savanna. Thus when the varieties are grown under rain fed conditions the open ones which resemble the wild strain, behave as if they were outside their usual zones of cultivation and this leads to poor yields.

The dry season from many points of view is a better period in which to grow crops than the rainy season, because during the rainy season humidity is high, temperatures are low, the sky may be overcast and sunshine reduced. Factors which increase plant diseases and pest outbreaks, are also more favoured during the rainy season than the dry.

Crop ecology becomes related to insect ecology when one considers insects and the effects of climate on their distribution and activity. It has been observed that ants soften the soil and so make it easier for the fertilised flowers to penetrate it. Therefore during the rainy season when the soil may become water-logged, the ants cannot function properly. In fact, continuous rainfall may make the soil difficult to work when harvesting a crop which bears geocarphic pods. Sometimes continuous rain may prevent harvesting altogether. It is recommended that where water can be provided, during the dry season, this season is better for the growth of bambarra groundnut.

Summary

The flower of Voandzeia subterranea is typical of the papilionaceae. Flowering starts 28 days after germination and depending on variety, may or may not cease before the end of the life of the plant. More flowers and pods are produced during the dry than the rainy season. Fertility coefficient which is higher for the bunch than the open varieties does not differ much during the two seasons although coefficients are slightly higher during the dry season. It is suggested that if water can be provided, the dry season would be more favourable for the growth of bambarra groundnut.

CHAPTER 4

POLLINATION

1. Introduction

There is no precise knowledge on the flowering and pollination mechanisms of bambarra groundnut even though a number of workers have attempted to find these out. The findings of these authors may be put into two broad groups (i) those who think that the flowers are self-pollinated, and (ii) those whose views are in favour of cross-pollination by the aid of insects.

According to Cobley (1956) for example, the petals are often undeveloped or fail to open and self-pollination is the rule, the flowers being cleistogamous. The broad standard petal closely enfolds the two wings and keel. Cobley's view is shared by Johnson (1968) who observed that the flowers were normally self-pollinated and that they were fertilised before opening.

Doku (1968), however, observed that the standard petals of bambarra flowers opened fully in nature flowers during the early hours in the morning from 6 a.m. onwards. The flowers were always near or at ground level and in some cases might be partially buried. The pollen matured and the stigma became receptive before the flower was fully opened but it was not known whether the flower was protandrous or protogynous.

On the other hand F.A.O. Agricultural Studies No.55 (Agricultural and Horticultural Seeds), states that the flowers of bambarra groundnut are partially self- and partially cross-pollinated, the extent of cross-pollination depending on insect activity although the insects involved are not mentioned. It is further stated in this book that 60 - 80% of natural crossing has been reported in Tunisia.

Doku (1968), observed that both self- and cross-pollination could take place in varying degrees depending on variety or strain and that this was brought about by two species of ants Pheidole megacephala and Monomorium pharaonis without which pollination might be severely limited or prevented altogether. The ants moved freely through the hole at the tip of the horn-like keel petal thereby effecting pollination. Doku further observed that varieties with more open habit of growth depended more on ants for their pollination than the compact or bunch types.

In a later paper, Doku (unpublished), observed that the movement of ants was most likely to bring about pollination between different flowers of the same plant (geitonogamy) which provided the stimulus for pod development and that when autogamy occurred in absence of ants this stimulus was completely lost in the case of the semi-bunch and open varieties, but was reduced in the case of the bunch varieties. Autogamous pollination could therefore take place without ants but further development of the fertilised flower was severely restricted in the semi-bunch and open varieties.

According to Rassel (1960), who observed monoecy in bambarra in the Congo, there are (i) small female flowers with well developed, normally functional pistils and small stamens without pollen and (ii) bigger male flowers with yellowish papilionaceous petals. These flowers have abortive filiform pistils and elongated stamens provided with pollen. He also observed thrips and other insects in great numbers inside the corollas of the male flowers and therefore concluded there was a possibility of entomorphilous pollination.

To clear up these findings which appear contradictory and inconsistent, preliminary observations were made on floral opening, pollination and fertilization and an experiment also carried out to investigate the role of ants in pollination and pod formation.

2. Preliminary observations

Preliminary observations on six varieties revealed that although the standard and wing petals do fully open in mature flowers with sunrise, the keel never opens and always encloses the reproductive parts of the flower (i.e. the pistil and stamens). The flowers which are at ground level do not normally cluster together but are spread out on peduncles. Each peduncle ends in a bulb on which can be found pedicels of one to three, but usually two flowers

Pollen maturity and stigma receptivity occurred just before or soon after the opening of the standard and wing petals. The stigma and stamens are almost of the same length at this time (Fig13B) and pollen tubes have been found growing on the stigmatic surface and in some cases piercing the stylar tissues to fertilise the ovary of flowers of plants growing in the presence of ants as well as those growing without them (Fig.21).

Three species of ants, two of them the same species mentioned by

Doku (1968), and the third unidentified (Fig.22), but similar to the common brown ant which is commonly found on sugar, were observed on plants throughout the flowering period. No other species of insects were observed on bambarra groundnut but the three species were also seen on cowpea (Vigna unguiculata)(Fig.24), groundnut (Arachis hypogea), lima bean (phaseolus lunatus), and soya bean (Glycine soja). These ants live separately in casts which are built under the canopy of the bambarra plants soon after the initiation of floral buds and once established rarely move from plant to plant. They make holes just beneath the bulb which terminate the floral peduncle. This bulb is glandular and secrets a sugar identified as glucose (Fig.25) through two pairs of openings which appear as brown dots on the surface of the bulb (Fig.28).

This secretion may be seen coming out through the openings as small droplets especially during the early hours of the morning. The ants are usually found hiding in their holes from where they shoot out their antennae on to the surface of the bulb to suck the sugar. Occasionally the ants may become gregarious and eat up some of the flowers. Some of the flowers may also fall off accidentally but the ants usually remain in their holes below the bulb even when there are no flowers. This suggests that it is the sugar and not any other part of the flower (e.g. pollen) which attracts them. Caterpillars are also fond of eating this glandular part of the peduncle.

As floral development progresses, the peduncle also elongates and depending on its distance from the soil, a flower may or may not be fertilised before it enters the ground. Flowers near the base of the plant where the stems are buried, enter the ground before they are fertilised but as one moves away, from the central part of the cluster, the distance between flowers and soil surface increases, flowers may therefore not be in touch with the soil before being fertilised. It is through the holes and casts made by the ants (Fig. 23 & 27) that flowers are pushed into the soil by the elongation of the peduncle to develop into pods. After pod formation is initiated, the peduncle ceases to elongate (Fig 30).

3. The role of ants in pollination and pod formation

The experiment was conducted in the field in the dry season so that watering could be controlled. Eight adjacent plots were randomised for treatment with D.D.T (controlled) and without D.D.T (uncontrolled).

Five percent D.D.T powder was spread uniformly on the four plots allocated for the controlled treatments. Six varieties representing the three habit groups (varieties 3 and 18, bunch, varieties 1 and 4, semi-bunch, and varieties 64 and 67, open), were planted at a spacing of 2 ft. by 2 ft., one week after the application of the D.D.T powder. The varieties were randomised within each of the controlled and uncontrolled plots. Wide spacing was adopted to enable individual plants and plots for controlled treatment to be encricled with D.D.T powder. Each plot consisted of single rows of twelve plants per variety with a border row which helped to prevent drifting of D.DT powder on to adjacent uncontrolled plot.

Three weeks after germination, each plant was encircled with 5%

D.D.T powder at about six inches away from the base of the plant and also at the borders of the controlled plots. The powder was watered down to prevent it from being blown on to adjacent uncontrolled plots. The application of D.D.T powder was repeated at frequent intervals.

During the period of growth, the soil was not disturbed in any way except for daily watering and occasional removal of weeds. The plants were harvested 100 days after germination, and records taken of pods, and discs.

Observations

No ants were seen in the controlled plots during the entire period of the experiment but the three species of ants mentioned were present in their numbers in the uncontrolled plots and carried on with their usual activities.

Plants in the controlled and uncontrolled plots flowered and were normally fertilised but in the controlled plots many of such flowers failed to enter the ground and either remained in that state as discs (i.e. the young fruit which intervenes between fertilization and fruit enlargement) or formed pods on the surface of the soil. (Fig.26). Pods formed on the surface of the soil were green instead of brown, had thick watery shells and poorly developed seeds. Most of the pods formed on the surface were single seeded.

A few pods in the controlled plots were formed underneath the soil though the majority of these could not go deeper than a few centimeters. Such pods were, however, normal and most of them were two seeded. Plants

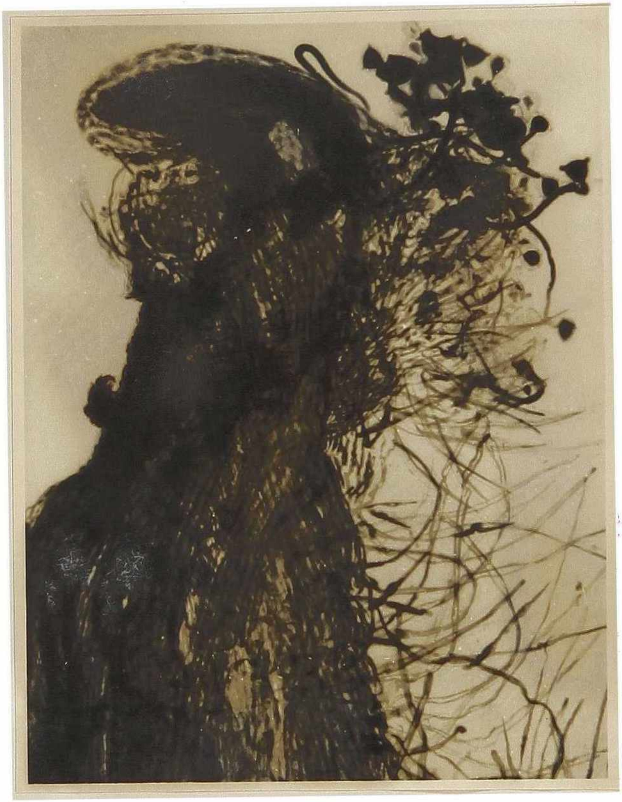


Fig. 21 - Pollen tubes germinating on the stigmatic surface of a flower of bambarra groundnut growing in absence of ants.

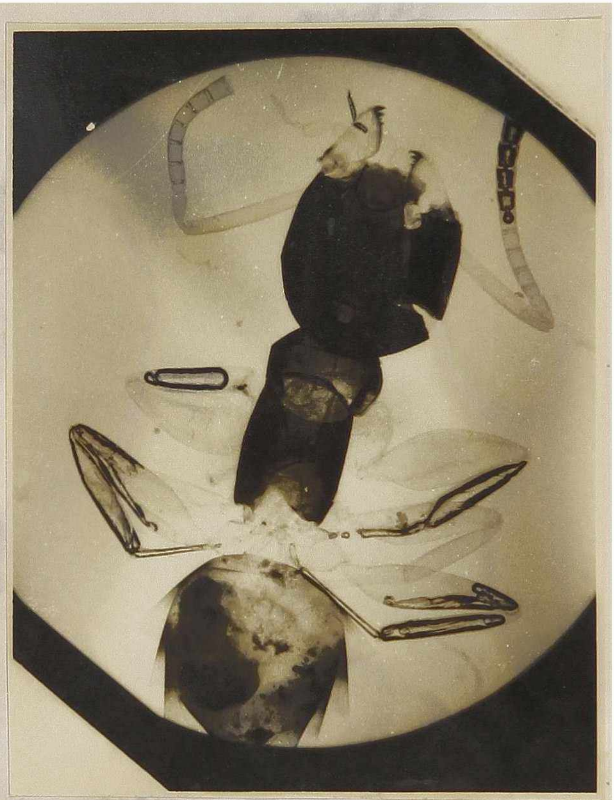


Fig.22 - A species of ant (unidentified), found on flowers of bambarra groundnut.

Fig. 23 - Ant holes and casts formed below fertilised flowers of variety 67.

Fig. 24 - Similar cast made by the ants at the nectary of cowpea flower.

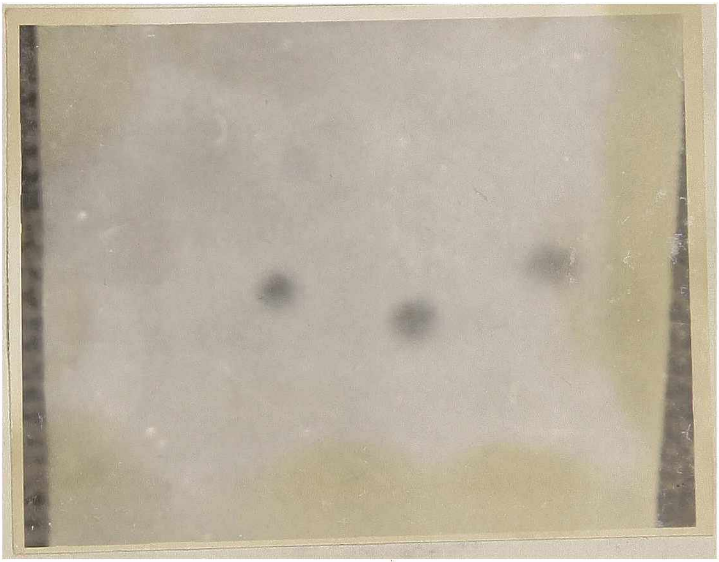


Fig. 25 - One way descending chromatogram for identification of the sugar secreted by flowers of bambarra groundnut. The bottom spot has an R_f value of 0.18 in butanol-acetic acid-water solvent which is equivalent to glucose.

Fig.26 - Pods formed on the surface of the soil in plants growing without ants. Note the ring of DDT powder around the plant.

Fig.27 - Pods formed in the soil in plants growing in presence of ants. Note the ant holes and casts underneath the peduncle.

Fig. 28 - Bulbous glandular tip of floral peduncle of bambarra groundnut showing the openings through which a glucose sugar is secreted.

in the controlled plots were not as vigorous as those to the uncontrolled plots especially during the last few weeks of the life of the plant.

Results

Number of pods per plant (Table 17)

(a) Varietal differences: Pods produced by the bunch varieties were significantly higher than those of the semi-bunch and open varieties, although differences in the latter varieties were not significant, more pods were produced in the semi-bunch varieties than the open ones.

(b) Effects of treatments: Pod production the presence of ants was significantly higher than without ants. However, the increase in the number of pods due to the activities of ants was only significant in the semi-bunch and open varieties but not in the bunch varieties.

Number of unburied discs per plant (Table 18)

(a) Varietal differences: A significantly higher number of unburied discs were produced in the semi-bunch and open varieties than in the bunch varieties.

(b) Effect of treatment: A significantly higher number of unburied discs were produced in absence of ants than in their presence. However, the increase in the number of discs due to the absence of ants was only significant for the semi-bunch and open varieties but not for the bunch.

Number of pods and discs together (Table 19).

(a) **Varietal differences:** The difference in the number of pods and discs taken together between the bunch, semi-bunch and open varieties was significant.

(b) **Effect of treatment:** There was no significant difference between treatments when pods and discs were taken together, the mean being almost equal under the two treatments.

Table 17 Number of pods per plant

Variety	Habit	Ants	No Ants	Mean
3	Bunch	140.4	134.7	137.4
18	"	144.8	144.4	144.6
1	semi-bunch	61.7	32.6	47.2
4	"	56.2	35.9	46.1
64	Open	60.6	25.9	43.3
67	"	50.0	37.7	43.9
Mean		85.6	68.5	

Ants vs. No Ants, significant at $p = 0.01$

L.S.D.	$p = 0.05$	Variety	= 5.4
	$p = 0.01$	"	= 7.2
L.S.D.	$p = 0.05$	Variety x Ants Vs. No Ants	= 7.6
	$p = 0.01$	" " " " " "	=10.2

Table 18 Number of unburied discs per plant

Variety	Habit	Ants	No Ants	Mean
3	Bunch	2.9	6.2	4.6
18	"	3.7	5.4	4.6
1	semi-bunch	4.2	31.3	17.8
4	"	9.0	29.7	19.4
64	Open	9.1	43.3	26.2
67	"	3.1	15.4	9.3
Mean		5.3	21.9	

Ants vs. No Ants, significant at p = 0.01

L.S.D.	p = 0.05	Variety	= 4.2
	p = 0.01	"	= 5.6
L.S.D.	p = 0.05	Variety x Ants Vs. No Ants	= 5.9
	p = 0.01	" " " " " "	= 7.9

Table 19 Number of pods and unburied discs per plant

Variety	Habit	Ants	No Ants	Mean
3	Bunch	143.3	140.8	142.1
18	"	148.5	149.8	149.1
1	semi-bunch	64.9	63.9	64.4
4	"	62.5	65.6	65.4
64	Open	67.9	71.2	70.5
67	"	53.1	53.1	53.1
Mean		90.8	90.7	

Ants vs. No Ants, not significant.

Variety x Ants vs. No Ants, not significant.

L.S.D.	p = 0.05	Variety	= 4.3
	p = 0.01	"	= 5.8

4. Discussions and conclusions

Many legumes, especially forage ones, depend on insects such as bees, flies, ants, etc., to pollinate their flowers and where such pollinators are limited or absent, whole fields may fail to produce a commercial crop or even fail altogether.

In bambarra groundnut, however, the three species of ants mentioned are the only insects which have so far been found on the plant and these can enter and get out freely through the hole at the tip of the horn-like keel petal. Although pollination can be effected by this means, it is doubtful if this is the only means of doing so.

The extent to which legume flowers depend on insects for pollination is determined by their floral characteristics e.g. monoecy, dichogamy, etc. Monoecy of bambarra flowers which Hassel has observed in the Congo has not been found among any of our varieties. The flowers are complete and the stamens and pistil remain enclosed in the horn-like keel petals which never completely opens. Dichogamy has not been observed and pollen maturity and stigma receptivity occur at about the same time (i.e. at opening of the standard and wing petals) meaning that the flower is neither protandrous nor protogynous. At this stage the anthers and stigma are at the same height (Fig 13B) and self pollination can therefore be effected except perhaps for the existence of self-incompatibility which is not likely to be widespread since single plants grown in isolation produced pods.

Pollen germination on the stigmatic surface and its penetration of the stylar tissue have been observed from flowers in both the controlled and uncontrolled plots (Fig.21). Therefore even though bambarra groundnut still retains some characters of entomorphilous pollination such as brightly coloured petals and brush arrangement of hairs on the style which is supposed to sweep the pollen out of the body of the insect, it appears from this experiment that self pollination can take place without ants, and this ultimately results in pod formation. It seems what the ants do is to soften the soil and so make it easier for the fertilised flowers to penetrate, and since the total number of pods and unburied discs taken together did not differ significantly in the presence and absence of ants, it would appear that the lower number of pods produced by the semi-bunch and open varieties in the absence of ants might be entirely due to the inability of their fertilised flowers to penetrate the soil.

In traditional practice, farmers earth up the plants at flowering time to help bury the fertilised flowers and thus encourage pod development. This is exactly what the ants do.

Probably, in the wild state ants and other agents helped in the burial of fertilised flowers and in the early stages of domestication farmers found it necessary to earth up plants in order to increase pod yields and this practice has persisted to this day. Under continuous cultivation however, varieties are being evolved whose dependence on agents for pod burial is gradually being lost and the bunch varieties which have been in cultivation longer has become less dependent on agents than the open types which appear to be in their early stages of domestication. That was why the bunch varieties produced practically tha same number of pods whether or not ants were present.

Self-fertilisation is a recent innovation in the process of domestication (Stebbins 1957, Elliott 1958), and many legumes under cultivation have been subjected to intense selection under which a genetic system tolerant to inbreeding has become established. The bunch varieties which have been under cultivation for a longer time have therefore become more adapted to inbreeding and are able to bury their fertilised flowers and develop pods without the aid of agents (insects or man).

The open types which resemble the wild varieties are only now becoming adapted to inbreeding and have not yet reached a stage of perfection as the bunch types and therefore still depend on insects and man to bury their pods.

A picture that emerges at present is that bambarra groundnut is not only assuming a more compact growth habit under cultivation, but is becoming less dependent on agents (ants and man) for effective burial of its pods.

5. Summary

Six cultivars of bambarra groundnut, representing the range of the three habit forms in the collection at Legon were grown in the field in the presence and absence of ants. The number of pods and fertilised flowers taken together did not differ significantly under the two treatments but a significantly greater number of pods were produced when ants were present, indicating that without ants a large number of fertilised flowers failed to develop into pods.

Of the pods that developed without ants a large number remained on the surface of the soil, where conditions for pod formation and development are not so favourable and therefore many fetilised flowers in that situation could have perished. Plants grown without ants were also less vigorous and wilted earlier than those with ants.

It is suggested that ants aided the burial of pods which in turn helped in the absorption of water and minerals from the soil. Varieties may show differences in their dependence on agents for pod burial.

CHAPTER 5

FRUIT DEVELOPMENT

1. Introduction

Knowledge on fruitification of bambarra groundnut is sparse. According to Dalziel (1937), and Hutchinson and Dalziel (1958), the peduncle bends down into the earth after fertilisation of the flower. The flower has a smooth bulbous tip and bottle brush arrangement of hairs which help to excavate a sort of tunnel into which the young pod on its pedicel is drawn rather than pushed. It is further stated that in East Africa, the base of the plant is lightly covered with soil after flowering to promote fruit development.

Cobley (1956), on the other hand, observed that the tip of the flowering peduncle is modified into a smooth glandular swelling and after fertilisation the peduncle bends downwards towards the soil its glandular apex forcing a tunnel into which the fertilised flowers are dragged.

According to Rassel (1960), the penetration of the ovaries into the soil is assured by the elongation of the floral peduncle, the bulb only leads and protects the ovaries in the course of the journey. This view of Rassel is shared by Johnson (1968), who observed that it is the elongation of the peduncle which pushes the ovary into the soil to develop into a pod.

The present knowledge indicates that three differing views are shared on the mechanism by which the flower enters into the soil. Further development of the fertilised flower inside the soil has also not been make their holes and casts just beneath the bulb which terminates the floral peduncle and it is through these holes and casts that fertilised flowers are pushed into the soil to develop their pods. The ovary does not develop above ground but ageocarpic pods may be formed when fertilised flowers are obstructed from entering the soil (Fig.29).

3. <u>Stages in fruit development</u>

The colour of the fertilised ovules changes from light green to white as they enter the soil and passes through two stages to maturity. They are:-

(a) Development of pod before it has assumed its definite shape and reached its ultimate size and

(b) Development of seeds inside the pod

studied. It was therefore thought necessary to find out the mechanism by which the fertilised flower enters the soil and also the successive stages in the development of pod and seed.

2. Preliminary observations

The flower is borne on a short pedicel which is also attached by means of a long peduncle to the node of the stem. The flower's positive geotropism enables it to point towards the soil. As floral development progresses the peduncle elongates and depending on its distance from the soil, a flower may or may not be fertilised before it enters the ground. Flowers near the base of the plant where the stems are buried enter the soil before they are fertilised, but flowers farther away from the base of the plant are fertilised before they enter the ground. Ants

(a) Stages of pod development

The period of pod development lasts 30 days from the day of fertilisation (Fig. 30). During this period, the pod grows continuously in length and thickness until it has reached its ultimate size after which further growth ceases. During its period of development, the pod is made up internally of very watery parenchymatous cells in which the fertilised ovules are embedded, and these ovules develop very little during this stage. Although the different stages in fruit development are not clear cut and one stage merges into the other, five stages may be distinguished.

(i) Aerial disc stage

This stage is indicated by the entry of the disc into the soil (Fig.30a). The disc as used in this context is defined as the young fruit during the phase of development which intervenes between fertilisation and pod enlargement. This stage lasts between one to two days during which the discs increse slightly in size but are still enclosed within the epicalyx.

(ii) Soil penetration stage

The second phase (Fig.30b) starts with a rapid elongation of the peduncle which pushed the disc into the soil and continues until soil penetration is complete or some obstruction is encountered. If there is no obstruction pods are formed when the peduncle has penetrated up to a depth of 4 to 5 cms. The upper portion of the peduncle is green. After soil penetration the subterranean portion becomes white. Both portions are hairy, but the function of these hairs is not known; it is likely they serve in absorption. The ovules at this stage are deep green in colour and this colour persists even on ovules that have been underground for several days. The epicalyx is lost during the penetration of the disc into the soil. After the disc has been in the soil for five to seven days, pod enlargement begins and peduncle elongation ends.

(iii) Disc inside the soil stage

There is not much difference between this stage and the preceding one. The disc remains inside the soil for a week more (Fig.30c).

(iv) Early stage in pod enlargement

The beginning of this stage is characterised by the swelling of the apical region simultaneously with the bending of the pedicel and the young fruit through 45°. This stage occurs at about two weeks after fertilisation. (Fig.30d)

(v) Immature pod stage

As growth progresses the pod assumes a horizontal position with its ventral suture uppermost. Pod enlargement proceeds from the apex to the base and is associated with faster development of the lower ovule. Maximum size is reached 30 days after fertilisation (Fig.30e).

Pod maturity

Although the pod reaches its maximum size 30 days after fertilisation, further development in the soil enables it to become drier and harder. During the course of growth, the remains of the style continues to diminish so that at maturity little or no trace of it is found on the pod. (Fig.31A). Instead a scar appears in its place. This scar is often surmounted by a light projection of the shell giving it a beak appearance. In some pods however, no beaks are formed, instead there is a light depression in whose centre the scar of the style is situated. The part of the fruit to which the scar of the pedicel subsist is the upper part, and the lower part is where the style is attached. The pod also has a dorsal and ventral side. Very often the ventral part is more or less flattened while an accentuated groove persists on the dorsal side. At maturity the shell is usually reticulate. (Fig.31B).

(b) Development of seeds

The development of seeds inside the pod starts as soon as the pod has reached its maximum size and lasts for about ten days. A section through the pod (Fig.32) shows that it sonsist of two embryos whose two cotyledons are embedded in a thick albuminous layer to which the integuments strongly adhere. The layer of albumen is surrounded by a layer of thick watery parenchymatous cells. As the cotyledons grow in size (Fig.32), the proportion of albuminous layer decreases until it completely disappears. The parenchymatous lining of the interior of the shell equally disappears with seed development. Seed maturity is not complete until the parenchyma has completely disappeared and this is indicated by the browning of the inner part, and formation of brown patches on the sides of the shell (Fig.32).

In all varieties examined, two ovules are found in the pod. Both ovules may develop into seed but in many cases one ovule fails to develop, and the pod then assumes a bell-shaped appearance (Fig.31A), and the ovules which fail to develop remain inside the pod without any appreciable change in size. Its colour however, changes from green to brownish. In two-seeded pods the seeds are partially separated by a thin papery partition or parenchymatous cell, the surface of contact of the two seeds is flat, and not perpendicular but inclined to the longitudinal axis of the pod. The distal ends of the seeds are rounded and smooth taking the form which the shell gives them. The seeds differ in form, the upper seed is smaller and slightly elongated and its hilum is near the middle, while the lower seed is more rounded and the hilum is found at the upper extremity (Fig.34). The hilum is always on the ventral part.

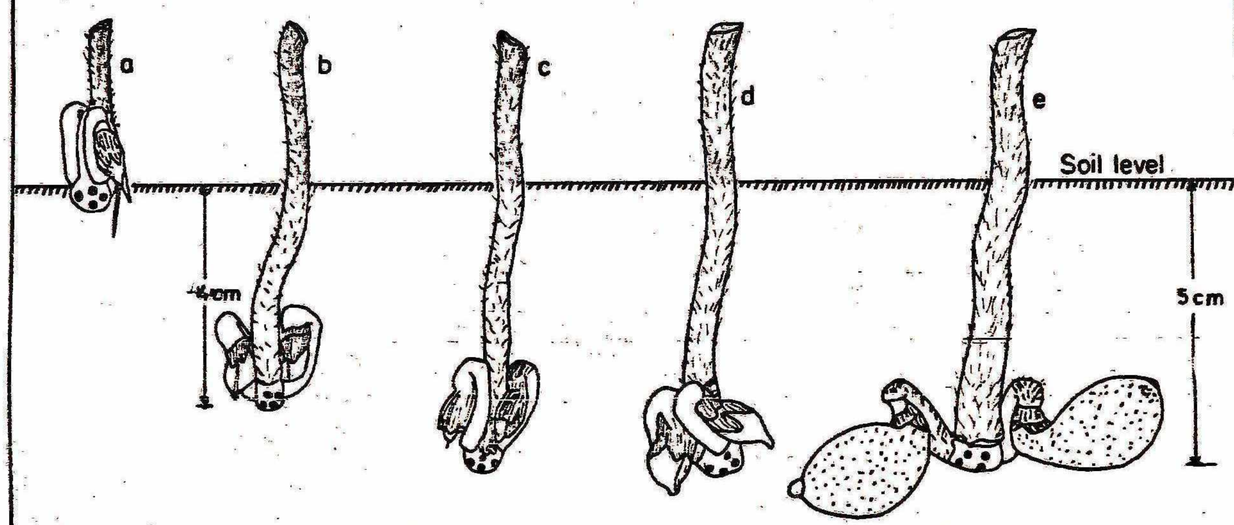
The difference in the form of the two seeds leads to difference in weight which appears to be to the advantage of the lower seed (Figs.31 & 34). An experiment was therefore conducted to find out which of the two seeds was heavier.

<u>Materials and methods</u>

Seeds of six varieties representing the range of the three habit forms in the collection at Legon (varieties 3 and 18, bunch: varieties 1 and 4 semi-bunch, and varieties 64 and 67 open) were sown in the

Fig.29 - Ageocarpic pods formed by obstructing fertilised flowers from entering the soil.

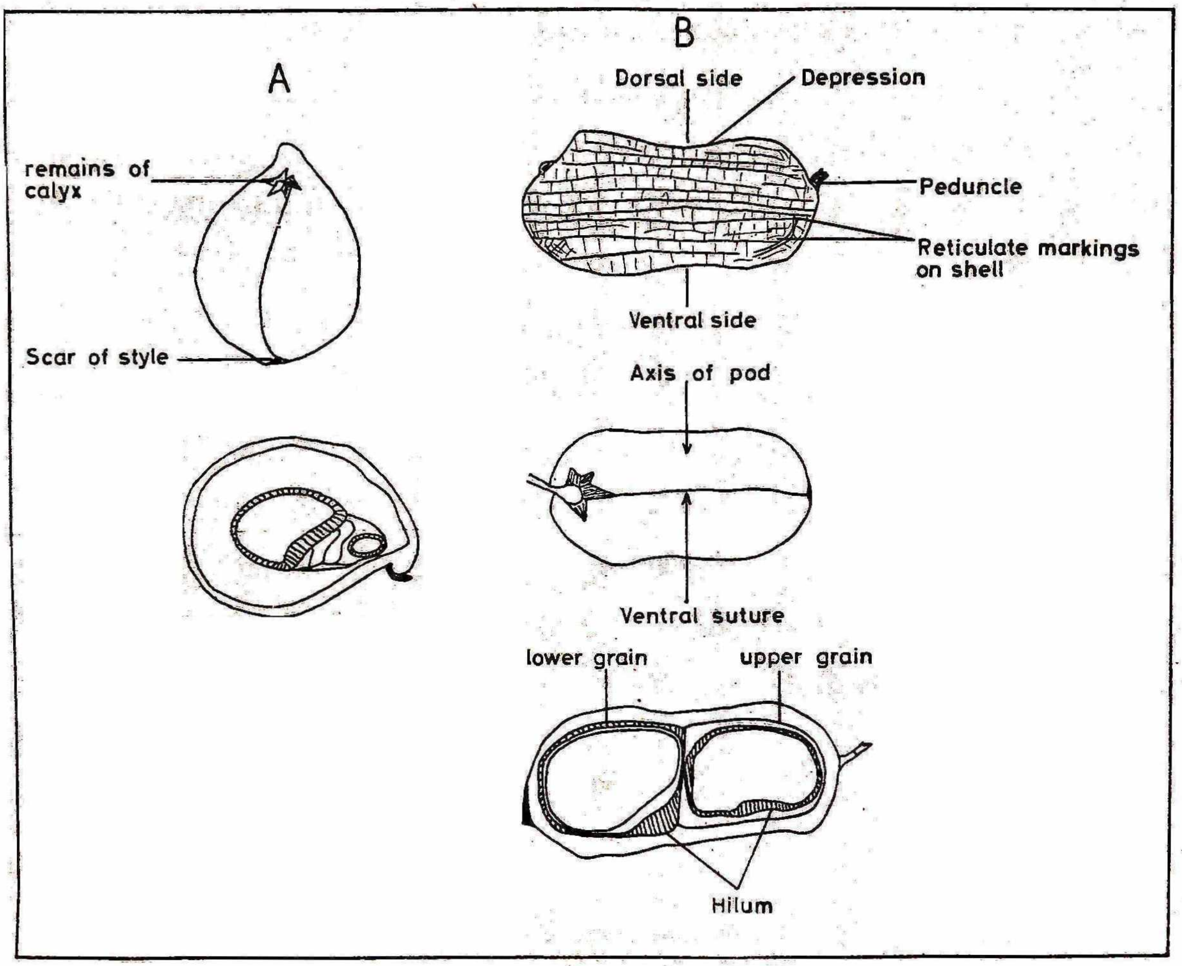
Fig. 30



SUCCESSIVE STAGES OF FRUIT DEVELOPMENT

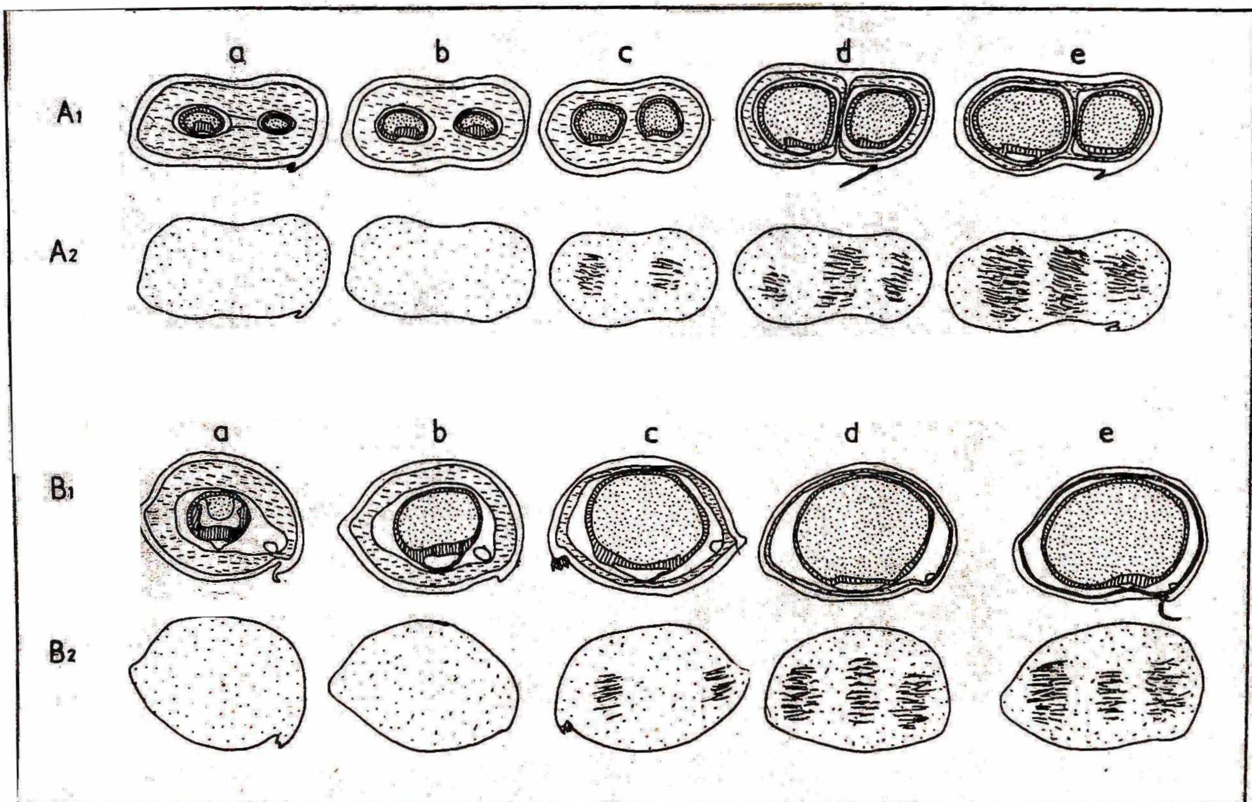
a. – Aerial "disc" 1–2 days after syngamy
b. Soil penetration 5–7 days
c. "Disc" inside the soil 10–12 days
d. Early stage in pod enlargement 15 days
e. Immature pod 20–30 days

Fig. 31 – Shape of pods and seeds.



A = One-seeded pod. B = Two-seeded pod.

Fig.32 The pod at various stages of seed development.



A = Two-seeded pod. B = One-seeded pod.

1 = Longitudinal section through the pod. 2 = Outside appearance of the pod.

a-e Stages in seed development.

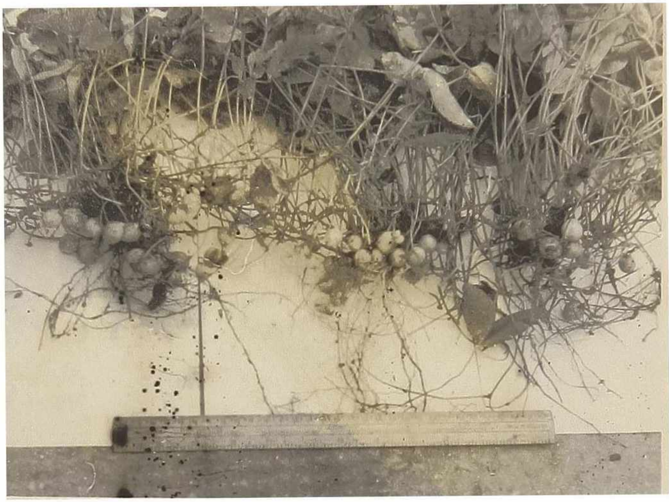


Fig.33 - Fruits of bambarra groundnut at maturity.

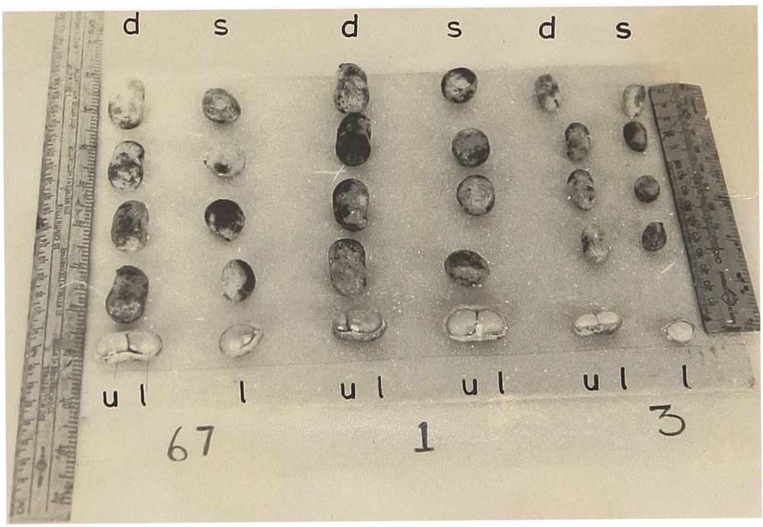


Fig.34 - Seeds of 3 varieties of bambarra groundnut in double-seeded (d) and single-seeded (s) pods. (Note the size of the lower (l) and upper (u) seeds and the position of their hilums).

field in a randomised block design with four replicates. Each plot consisted of a single rows of twelve plants spaced at 2 ft. apart in the row and 3 ft. apart between rows apart. Plants were harvested at maturity and 100 double-seeded pods were selected at random. After drying the pods were shelled and 100 seeds of each category of the six varieties weighed. Samples of each category were sown and their performance observed.

Results

Table 20 Mean weight (gms) of 100 seeds

Variety	Habit	Lower seed	Upper seed	Mean
3	Bunch	45.2	40.7	43.0
18	"	37.5	33.0	35.3
1	semi-bunch	60.3	58.4	59.4
4	"	56.5	50.1	53.3
64	Open	67.5	64.1	65.8
67	"	78.1	70.2	74.2
Mean		57.5	52.8	

		Lower seed vs. upper seed	= ~~Not~~ significant
L.S.D.	p = 0.05	Varieties	= 8.4
	p = 0.01	"	=11.3

Varieties x Lower seed vs. upper seed = Not significant

Lower seeds of all varieties were significantly heavier than upper seeds. Varieties also differed significantly in the weight of their seeds: the open varieties bore the heaviest seeds the compact varieties the lightest seeds and the weight of the seeds of the semi-bunch varieties was intermediate between the two. The difference between seeds of varieties within the same habit group was not significant. Variety X lower seed vs. upper seed interaction was also not significant indicating that differences between lower and upper seed weight were about the same for all the varieties. Seeds of the lower category were more vigorous in growth.

4. Discussions and conclusions

The observation that the peduncle bends downwards towards the soil after fertilisation is erroneous. The flower is positively geotropic and the bud points towards the ground the moment it is just visible. The hairs on the peduncle do not help to excavate a tunnel into which the pod is drawn because they are very soft and brittle. The fertilised flowers are rather pushed by the elongation of the peduncle into the holes and casts made by the ants below the peduncle, and this is the view of Rassel and Johnson although these authors did not make any reference to ants.

The observation that the lower larger seeds also give rise to more vigorous seedlings indicate that it might be more advantageous to select such seeds for planting.

5. Summary

Flowers of *Voandzeia subterranea* are positively geotropic and this helps their entry into the ground. The ovary does not develop in the air but only when it is on or inside the soil. The transformation into fruit occurs in two stages:-

(a) definite development of pod, followed by

(b) development of seed.

The first stage occurs during the first 30 days after fertilisation and the second stage lasts for about 10 days. Maturity is characterised by dryness and browning of the interior of the shell and appearance of brown patches on it. The part of the pod on which the pedicel subsist is the upper part and the lower part is the portion where the style is attached.

Seeds for sowing should be selected from the lower part of the pod, since these are larger and heavier and also give rise to more vigorous seedlings than those at the upper end.

CHAPTER 6

CONCLUDING REMARKS

In order to understand the crop more fully, further research is needed into many aspects, some of which have been brought to light by these investigations.

There is no doubt that the crop originated in Africa, and three places where wild relatives of the crop have been found, have been suggested as the probable centres of origin of the crop. It is likely that the crop may have originated from only one of these places and the other places are probably secondary centres of origin or of diversity where the crop was first domesticated. Further evidence for the establishment of the actual centre of origin of the crop is therefore required.

A market survey carried out in Ghana revealed that the light coloured varieties, especially local cream, are more popular on the markets than the dark coloured ones. A palatability test caried out by the staff of the Department of Crop Science revealed that the dark coloured varieties are more palatable. Work should therefore be done in conjunction with the Department of Biochemistry on nutritive values of all varieties so far collected and this data correlated with varietal differences in palatability. Such data will be useful especially for organisations interested in canning the beans.

The classification of varieties into habit groups was based on external morphological characters of the plant. Such characters are to some extent influenced by the environment. It is likely that the spreading varieties which also produce large vegetative parts and big sized fruits may be polyploids. Cytogenetical studies should therefore be undertaken to verify this, and also to find out how a grouping based on chromosome behaviour will compare with the grouping based on morphological characters.

In the absence of ants, autogamy occurs which leads to a reduction in pod production in most varieties, especially those in the open and semi-bunch groups. In the bunch varieties e.g. varieties 3 and 18, which have been observed to be true breeding and 100% self-fertilised, although there was no reduction in the number of fruits produced in the absence of ants, reduction in fruit size was observed during subsiquent generations. Close inbreeding therefore may reduce yield or fruit size and this should further be investigated.

The author shares Doku's (1968) observation that not all varieties in the Legon collection are able to inter-cross freely. This suggests the existence of some incompatibility mechanisms among varieties, and this needs further study. Varieties should be crossed in pairs and the F_2 examined to find out varieties which had crossed with each other. The open varieties have big pods but the bunch varieties which have small pods produce more pods than the open varieties. A successful cross between plants of the two groups may produce a hybrid variety in which big pod size and large pod number are combined.

In the three varieties studied, pollen maturity and stigma receptivity occurred at about the same time. This study should be extended to all the other varieties.

Flowers that are produced during the last 40 days of the life of the plant do not get enough time to develop into pods. If such flowers are removed as they are formed pods already formed may grow bigger. Removing all these flowers will not be an easy job. A search should therefore be made for varieties which produces most, if not all of its flowers before the last 40 days since this will be a useful character to use for breeding.

No serious pest has so far been seen on bambarra groundnut, but may be in the near future a pest may attack the crop. The useful role which ants play in pollination and pod burial should be borne in mind and in any control measures the use of insecticides which will kill or have residual detrimental effects on the ants avoided. Varieties which do not rely on ants for burial of their pods in the soil should be planted if no suitable insecticides are available.

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APPENDIX 1

Table of analysis of variance for testing the linearlity of regression of petiole length per unit internode length.

Source	d.f	s.s.	m.s.	observed F	Expected F 5%	1%
Total	26	7.00				
Due to linear regression	1	1351.78	1351.78	25.13**	4.24	7.77
Deviation from regression	25	1344.78	53.79			

** Significant at 1% level

APPENDIX 2

Table of analysis of variance for testing the linearity of regression of number of stems per plant per variety.

Source	d.f	s.s.	m.s.	observed F	Expected F 5%	1%
Total	26	2.45				
Due to linear regression	1	1.85	1.85	77.5**	4.24	7.77
Deviation from regression	25	0.60	0.024			

** Significant at 1% level

APPENDIX 3

METEOROLOGICAL DATA

TEMPERATURES JUNE 1968

	TEMPERATURES (°F) 9 A.M.			TEMPERATURES (°F) 3 P.M.		
	Dry bulb	Wet bulb	% R. H	Dry bulb	Wet bulb	% R. H
1	81.3	77.0	82	85.0	78.8	75
2	81.0	77.1	83	81.5	77.8	85
3	80.2	77.0	86	83.0	79.0	83
4	79.8	76.8	86	79.8	77.0	87
5	80.2	77.2	87	77.6	74.6	86
6	81.0	76.4	81	84.0	77.6	74
7	82.6	78.0	81	85.0	77.5	70
8	81.0	77.8	86	84.2	79.0	79
9	80.8	76.7	83	82.4	77.0	77
10	83.8	78.0	76	82.2	77.6	81
11	77.2	75.5	93	76.4	75.2	94
12	78.8	75.6	86	83.0	76.8	75
13	78.0	76.0	91	83.0	77.0	75
14	77.5	75.5	91	77.0	74.0	86
15	78.8	75.0	83	84.4	78.8	77
16	79.8	75.2	80	82.0	77.2	80
17	73.5	71.5	90	82.5	76.0	73
18	78.8	75.8	86	80.2	76.8	85
19	78.0	75.0	86	74.0	73.0	95
20	79.9	75.9	87	83.8	77.0	73
21	78.0	76.0	91	82.0	77.0	79
22	80.0	76.0	83	80.0	75.5	81
23	78.0	75.5	89	82.2	77.2	79
24	79.8	75.6	82	82.8	76.6	74
25	81.0	76.6	81	83.0	77.0	75
26	79.0	75.8	86	82.4	76.6	71
27	82.0	77.0	79	83.0	77.0	75
28	79.8	76.2	84	81.0	76.0	79
29	78.8	73.2	78	83.9	77.5	74
30	75.0	74.4	97	83.0	77.8	78
31	-	-	-	-	-	-
Total	2383.4	2279.3	2549	2454.3	2368.9	2380
Average	79.5	76.0	85	81.7	78.9	79.3

Monthly mean = 82.3 **Source** From the field.

APPENDIX 4

METEOROLOGICAL DATA

TEMPERATURES JULY 1968

	TEMPERATURES (°F) 9 A.M.			TEMPERATURES (°F) 3 P.M.		
	Dry bulb	Wet bulb	% R. H	Dry bulb	Wet bulb	% R. H
1	79.8	76.8	87	81.2	76.0	79
2	76.0	74.6	93	79.4	75.0	81
3	71.0	70.6	98	74.0	73.4	97
4	77.0	73.0	87	76.0	75.0	98
5	73.6	73.4	99	76.0	73.8	90
6	77.0	75.0	91	79.4	76.8	89
7	77.5	75.0	89	79.0	75.0	82
8	75.4	74.0	93	79.4	75.2	82
9	75.8	75.4	98	78.8	75.6	86
10	78.2	74.6	84	81.6	76.8	80
11	77.8	75.2	89	81.6	76.8	80
12	78.4	74.2	81	85.0	77.4	70
13	78.2	75.4	87	81.2	76.8	82
14	76.0	74.0	91	79.0	75.0	82
15	79.2	75.8	85	73.4	73.2	99
16	77.8	74.6	86	79.8	75.2	80
17	78.8	75.6	86	81.4	75.8	77
18	79.4	74.6	79	81.6	75.8	76
19	77.6	75.0	88	78.4	75.4	81
20	75.5	75.0	98	79.8	75.4	81
21	76.9	74.0	87	79.0	74.4	80
22	78.4	76.0	89	83.2	76.4	75
23	79.8	77.0	88	81.4	76.0	77
24	74.6	73.8	96	79.5	75.3	82
25	78.6	74.6	82	80.4	75.4	79
26	78.6	75.6	86	80.6	75.6	79
27	78.0	75.4	88	81.6	78.8	76
28	76.0	73.0	86	80.4	76.4	83
29	74.0	74.0	100	80.0	76.8	86
30	75.2	73.8	93	79.0	75.0	82
31	77.0	75.0	91	79.5	75.3	82
Total	2387.1	2314.0	277.0	2470.4	2264.2	1811
Mean	77.0	74.6	89.4	79.7	73.0	82.2

Monthly mean = 85.8

Source From the field.

APPENDIX 5

METEOROLOGICAL DATA

TEMPERATURES AUGUST 1968

	TEMPERATURES (°F) 9 A.M.			TEMPERATURES (°F) 3 P.M.		
	Dry bulb	Wet bulb	% R. H	Dry bulb	Wet bulb	% R. H
1	78.8	75.0	85	80.0	75.0	79
2	76.0	74.0	91	81.0	76.8	87
3	78.8	75.0	85	77.4	75.0	89
4	78.8	76.2	88	83.0	76.8	75
5	79.8	76.0	85	81.6	76.2	77
6	80.0	77.0	87	79.0	76.0	86
7	74.8	74.2	97	77.0	74.9	74
8	77.9	75.2	87	79.5	76.7	85
9	79.0	76.0	86	79.9	76.9	86
10	79.0	76.0	86	83.4	77.4	76
11	79.9	76.9	86	81.2	72.4	84
12	78.8	77.0	92	77.5	75.0	89
13	77.0	75.0	91	79.4	76.8	89
14	78.8	75.5	86	80.8	77.5	86
15	75.2	74.0	94	77.0	74.5	88
16	77.5	75.0	88	79.0	76.0	86
17	78.0	76.0	91	76.8	74.8	91
18	79.0	76.6	89	78.2	74.4	83
19	79.4	77.0	89	78.4	75.2	86
20	76.0	75.0	95	79.8	76.8	86
21	77.8	75.0	85	79.8	76.0	83
22	76.5	75.0	93	77.0	75.2	92
23	76.0	75.2	96	77.5	75.5	91
24	76.0	75.5	98	79.6	76.0	84
25	79.7	76.6	87	78.4	75.0	85
26	79.5	75.2	80	82.5	78.0	82
27	78.8	75.8	81	74.0	73.0	95
28	80.0	76.0	83	81.4	77.8	85
29	78.4	74.4	82	81.4	77.5	84
30	76.3	74.3	91	71.8	75.2	93
31	74.8	74.0	96	79.0	76.4	89
Total	2416.3	2339.6	2747	2457.3	2355.2	2639
Mean	77.9	75.5	88.6	79.2	76.0	85.1

Monthly mean = 86.9

Source From the field.

APPENDIX 6

METEOROLOGICAL DATA

TEMPERATURES DECEMBER 1968

	TEMPERATURES 9 A.M.			TEMPERATURES 3 P.M.		
Days	Dry bulb	Wet bulb	% R. H	Dry bulb	Wet bulb	% R. H
1	82.7	78.4	82	87.2	78.6	67
2	82.5	78.0	73	87.0	80.0	73
3	82.5	78.0	81	88.8	79.2	64
4	84.0	79.0	79	84.0	78.5	77
5	81.4	78.0	86	86.4	78.0	67
6	82.6	77.8	80	75.4	71.4	82
7	81.8	78.8	87	87.6	80.0	71
8	81.2	76.8	82	86.5	78.5	69
9	82.4	76.4	75	84.4	76.6	69
10	81.8	77.0	76	84.6	78.2	74
11	81.6	77.0	81	86.6	78.0	67
12	79.4	76.0	77	85.6	77.5	68
13	81.4	76.6	80	84.4	76.2	67
14	82.4	77.6	80	88.4	79.4	66
15	80.2	76.2	83	84.0	77.0	72
16	79.8	77.0	88	84.4	78.4	76
17	81.0	77.0	83	86.5	78.0	67
18	81.2	77.4	84	84.5	77.4	69
19	77.4	75.4	91	85.0	78.0	72
20	80.4	76.8	84	85.4	77.4	69
21	84.0	73.0	57	87.0	77.0	67
22	83.0	77.5	77	87.0	77.7	65
23	79.6	76.5	86	84.4	79.6	80
24	79.6	74.5	73	85.4	77.4	69
25	83.0	77.8	78	86.0	77.4	67
26	80.5	76.2	81	85.2	78.0	72
27	84.4	77.0	70	84.4	78.8	77
28	85.4	77.8	70	82.4	77.0	77
29	81.5	77.2	82	85.7	78.6	72
30	82.4	78.4	83	86.0	78.6	71
31	85.5	77.0	67	89.0	77.6	59
Total	2,536.6	2,387.7	2,456	2,631.2	2342.0	2,182
Mean	81.8	77.0	79.2	84.9	75.5	70.4

Monthly mean = 74.8

Source: From the field.

APPENDIX 7

METEOROLOGICAL DATA

TEMPERATURES JANUARY 1969

	TEMPERATURES (°F) 9 A.M.			TEMPERATURES (°F) 3 P.M.		
Days	Dry bulb	Wet bulb	% R. H	Dry bulb	Wet bulb	% R. H
1	82.4	76.4	77	86.4	78.6	70
2	80.5	77.2	85	84.6	79.2	72
3	80.0	76.4	84	87.6	79.2	68
4	86.0	77.5	67	87.4	75.4	56
5	80.6	76.8	83	82.8	71.4	55
6	80.4	77.0	85	87.4	75.8	57
7	79.6	70.0	84	87.4	79.4	69
8	81.0	77.2	83	88.0	79.2	67
9	81.0	77.0	87	87.6	79.4	69
10	80.2	77.2	87	85.5	77.5	69
11	29.8	76.2	85	33.2	75.2	68
12	80.3	76.6	83	86.2	77.8	68
13	80.4	76.6	83	86.0	76.6	64
14	80.0	77.2	88	86.8	76.8	67
15	79.0	76.6	89	86.5	78.0	67
16	82.0	78.2	84	85.2	78.8	75
17	80.0	76.8	86	86.2	78.6	70
18	82.0	79.0	87	85.0	74.0	57
19	80.0	77.0	87	84.6	74.6	61
20	76.0	75.8	99	84.0	75.0	64
21	78.4	75.4	86	85.8	78.0	70
22	79.0	76.4	89	86.4	76.4	67
23	79.6	76.0	84	87.4	78.4	66
24	81.6	76.4	78	87.4	89.4	69
25	81.0	77.0	83	86.6	77.2	64
26	86.2	78.6	83	83.7	73.7	76
27	84.0	77.2	73	79.0	76.4	89
28	78.6	76.8	92	87.3	74.4	53
29	80.2	73.6	72	87.0	67.0	31
30	78.4	68.0	56	87.4	73.4	50
31	82.0	77.7	82	86.0	75.8	61
Total	2,498.4	2,371.8	2,571	2,662.4	2,384.6	1,997
Mean	80.6	76.5	83	85.9	76.9	64

Monthly Mean = 73

Source From the field.

APPENDIX 8

METEOROLOGICAL DATA

TEMPERATURES FEBRUARY 1969

	TEMPERATURES (°F) 9 A.M.			TEMPERATURES (°F) 3 P.M.		
Days	Dry bulb	Wet bulb	% R. H	Dry bulb	Wet bulb	% R. H
1	80.4	75.4	79	82.0	73.6	66
2	79.0	77.4	89	85.0	76.8	67
3	79.0	77.0	87	88.0	79.6	68
4	80.8	77.6	86	87.4	78.8	67
5	80.2	76.2	83	89.4	79.4	63
6	80.8	77.2	84	87.6	79.0	67
7	83.4	78.4	79	86.5	78.7	70
8	82.0	78.4	85	87.6	78.8	66
9	82.6	77.6	79	86.0	78.3	70
10	84.6	78.6	76	87.6	78.0	64
11	83.4	78.4	79	88.8	79.2	64
12	83.8	79.6	83	89.2	79.6	65
13	82.8	79.4	86	88.6	78.6	63
14	83.4	78.6	80	88.4	78.6	63
15	81.5	76.7	80	88.4	78.6	63
16	82.0	77.6	82	87.3	78.5	67
17	84.5	78.9	77	86.8	79.0	65
18	83.4	76.4	72	88.0	78.6	65
19	84.2	78.8	77	89.6	79.0	61
20	84.0	78.4	77	87.4	77.2	62
21	83.0	78.5	82	89.8	79.8	63
22	82.0	78.0	83	81.4	77.6	84
23	85.2	80.0	79	85.2	77.6	74
24	86.0	79.5	75	86.2	77.2	65
25	82.4	76.4	78	88.4	79.0	65
26	84.8	77.8	72	86.8	76.6	61
27	84.2	77.8	78	82.6	77.4	78
28	84.4	79.2	79	88.4	79.0	65
29	-	-	-	-	-	-
30	-	-	-	-	-	-
31	-	-	-	-	-	-
Total	2,321.8	2,183.8	2246	2,438.4	2,192.1	1,861
Mean	83.0	78.0	80	87.1	78.3	66

Monthly mean = 73

Source From the field.

APPENDIX 9

METEOROLOGICAL DATA

HOURS OF SUNSHINE

MONTHS

Days	June 1968	July 1968	August 1968	December 1968	January 1969	February 1969
1	-	4½	10.0	8.0	7.0	7.2
2	5.25	-	10.25	8.0	6.0	4.5
3	6.0	Nil	7.25	-	5.5	8.0
4	2.75	1½	5.25	5.5	6.5	6.0
5	3.50	-	1.25	8.5	9.0	5.5
6	7.50	-	8.0	4.5	6.5	6.5
7	9.0	-	8.0	7.5	-	7.0
8	2.0	2½	1.0	7.5	6.5	9.0
9	-	-	6.5	8.5	7.0	-
10	5.0	5½	2.0	9.5	8.5	6.5
11	0.5	5½	8.5	9.5	5.5	8.0
12	1.5	5	-	4.0	6.0	7.5
13	3.5	-	8.5	-	8.0	-
14	-	-	8.0	9.0	7.5	-
15	-	5	4.0	5.0	8.0	-
16	-	5	4.0	-	7.5	8.0
17	1.0	3	-	9.0	8.0	6.0
18	0.5	6½	-	8.5	6.0	9.0
19	Trace	5¼	-	6.0	7.5	9.0
20	8.25	-	6.0	8.0	7.0	8.0
21	5.0	-	4.0	8.0	6.0	-
22	-	7½	10.5	8.5	2.0	7.0
23	1.5	5	8.0	6.5	7.5	5.5
24	6.0	-	-	8.5	8.0	5.5
25	6.5	-	8.0	7.5	8.5	4.5
26	5.5	-	-	(-)	-	8.5
27	9.0	-	6.0	4.5	7.5	9.5
28	-	-	Trace	7.5	-	-
29	4.5	-	-	5.5	4.0	-
30	3.0	-	6.0	3.5	5.5	-
31	-	-	-	9.0	7.0	-
Total	99.9	62.3	141.00	195.5	174.0	156.2
Mean	4.3	4.8	6.4	7.2	6.7	7.1

Source Dept. of Geography Legon.

(About 300 yards away from experimental plot).

APPENDIX 10

METEOROLOGICAL DATA

RAINFALL (INCHES)

Days	RAINY SEASON				DRY SEASON			
	June 1968	July 1968	Aug. 1968	Sept. 1968	Nov. 1968	Dec. 1968	Jan. 1969	Feb. 1969
1	1.52	0.15	-	0.13	-	-	-	-
2	0.06	6.43	-	0.05	-	-	-	0.32
3	0.15	0.10	-	Trace	-	-	-	-
4	0.09	1.71	-	0.08	-	-	-	-
5	0.01	0.07	0.08	0.05	0.45	-	-	-
6	-	-	0.93	0.05	-	-	-	-
7	-	0.05	0.13	0.07	-	-	-	-
8	0.86	0.16	-	-	-	-	-	-
9	Trace	0.11	-	0.09	-	-	-	-
10	0.78	-	Trace	0.09	0.48	-	-	-
11	0.29	-	0.23	-	-	-	-	-
12	0.23	-	0.20	-	Trace	-	-	-
13	0.05	-	0.08	-	-	-	-	-
14	0.41	0.40	0.18	2.52	-	-	-	-
15	0.20	0.98	-	0.24	0.18	-	- -	-
16	0.15	0.02	Trace	0.89	-	-	-	-
17	Trace	-	"	Trace	-	-	-	-
18	0.30	0.10	"	"	-	-	-	-
19	0.44	1.27	-	0.32	-	-	0.18	-
20	-	-	-	2.00	1.55	-	-	-
21	0.08	-	0.05	-	0.04	-	-	-
22	-	-	0.74	-	-	-	-	-
23	0.46	0.16	0.37	-	-	-	-	-
24	-	0.04	-	0.37	-	-	-	-
25	1.17	-	-	-	-	-	-	-
26	-	-	-	2.37	-	-	Trace	-
27	Trace	-	0.98	Trace	1.17	-	1.09	-
28	0.19	1.05	0.02	-	Trace	-	-	-
29	0.97	0.59	0.01	0.88	-	-	-	-
30	0.01	-	0.40	Trace	-	-	-	-
31	-	-	0.17	-	-	-	-	-
Total	8.42	13.30	4.57	11.37	3.87	0.00	1.27	0.32

Source: From Dept. of Geography. (About 300 yards away from experimental plot).

APPENDIX 11

ANALYSIS OF VARIANCE FOR SEASONAL PRODUCTION OF FLOWERS

Source	df	s.s.	m.s.	observed F.	Required F. 5%	1%
Total	35	372641.77				
Blocks	5	108.00	21.0	0.13	2.60	3.86
Variety	2	44298.00	22149.0	133.60**	3.38	5.57
Season	1	227895.00	227895.0	1375.35**	4.24	7.77
Variety & Season	2	51202.00	25601.0	154.50**	3.38	5.57
Error	25	4141.77	165.7			

** Significant at 1% level

APPENDIX 12

ANALYSIS OF VARIANCE FOR SEASONAL PRODUCTION OF PODS

Source	df	s.s.	m.s.	observed F.	Required F. 5%	1%
Total	35	70996.9				
Blocks	5	10.1	2.2	0.06	2.60	3.66
Variety	2	65867.9	32934.0	829.6**	3.38	5.57
Season	1	3823.2	3823.2	96.3**	4.24	7.77
Variety & Season	2	302.5	151.3	3.81*	3.38	5.57
Error	25	993.2	39.7			

* Significant at 5% level

** Significant at 1% level

APPENDIX 13

ANALYSIS OF VARIANCE TABLE OF THE NUMBER OF PODS PER PLANT IN PRESENCE AND ABSENCE OF ANTS

Source of variation	d.f.	ss.	m.s.	observed	Reqd. F 5%	1%
Total	47	104936.8				
Blocks	3	105.4	35.1	1.26	2.67	3.97
Variety	5	98630.1	19726.0	709.6**	2.51	3.66
Ants/No ants	1	3493.6	3493.6	125.7**	4.15	7.50
Variety x ants/no ants	5	1790.3	358.1	12.9**	2.15	3.66
Error	33	917.4	27.8			

** Significant at 1% level.

APPENDIX 14

ANALYSIS OF VARIANCE TABLE OF THE NUMBER OF "DISCS" PER PLANT IN PRESENCE AND ABSENCE OF ANTS

Source of variation	d.f.	ss.	m.s.	observed	Reqd. F 5%	1%
Total	47	8773.0				
Blocks	3	17.1	5.7	0.35	2.67	3.97
Variety	5	3106.5	621.3	37.65**	2.51	3.66
Ants/no ants	1	3348.4	3348.4	202.93**	4.15	7.50
Variety x ants/no ants	5	1756.0	351.2	21.28**	2.51	3.66
Error	33	545.0	16.5			

** Significant at 1% level.

APPENDIX 15

ANALYSIS OF VARIANCE TABLE OF MEAN OF PODS AND "DISCS"

Source of variation	d.f	ss.	m.s	observed f	Reqd.F 5%	Reqd.F 1%
Total	47	74442.0				
Blocks	3	92.1	30.7	1.7	2.67	3.97
Variety	5	73736.5	14747.3	823.9**	2.51	3.66
Ants/no ants	1	0.1	0.1	0.01	4.15	7.50
Ants/no ants x variety	5	22.1	4.4	0.25	2.51	3.66
Error	33	591.2				

** Significant at 1% level.

APPENDIX 16

Analysis of variance table for difference in weight between lower seed and upper seed.

Source	d.f.	s.s.	m.s.	observed F	Regd. F 5%	1%
Total	47	8858.14				
Block	3	1.74	0.58	0.01	2.67	3.97
Variety	5	8315.44	1663.09	23.98**	2.51	3.66
Lower seed vs. upper seed	1	269.79	269.79	6.36*	4.15	7.50
Lower seed vs. upper seed x variety	5	46.43	9.29	0.14	2.51	3.66
Error	33	224.74	68.10			

* Significant at 5% level

** Significant at 1% level