EFFECT OF SEASON OF PLANTING ON GROWTH, FLOWERING, FRUIT SET AND SEED YIELD OF BAMBARA GROUNDNUT

[VOANDZEIA SUBTERRANEA (L.) VERDC.].

By

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A Thesis submitted in partial fulfillment of the requirements for Master of Philosophy degree in Crop Science

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DECLARATION

I do hereby declare that, except for references to other people's 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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ABSTRACT

Studies were conducted on nine (9) bambara groundnut (Voandzeia subterranea) accessions representative of cultivars cultivated in Ghana, Swaziland and Zimbabwe at the University Farms, Legon, on two planting dates.

Time of first flower opening was irrespective of time of planting since photoperiod did not change much. Flowering once initiated did not cease until harvest, except for one cultivar 'Jabajaba'. It was found that double and single flowering peaks occurred in Minor and Major planting seasons respectively except for one cultivar 'Sabliga' which showed no definite peak.

More leaves, hence a greater dry matter yield (DMY) was produced under a higher rainfall condition. The crop, however exhibited a drought resistant character by producing more seed under comparatively drier conditions.

Rainfall and temperature appear to be the two important interactive climatic factors influencing vegetative growth, flowering and yield of bambara groundnut in the tropics. Moderate rainfall coupled with relatively high temperatures over the entire growth period of the crop provides ideal conditions for better yield.

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CECIL SESIE FIAM-COBLAVIE

DEDICATION

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CHAPTER 1

INTRODUCTION

Bambara groundnut [Vigna subterranea (L.) Verdc. syn Voandzeia subterranea (L) Thouars] is an indigenous tropical pulse cultivated throughout south and west Africa. Although it is usually cultivated on subsistence scale, it is the third most important legume both in production and consumption in Africa after groundnut (Arachis hypogaea) and cowpea (Vigna unguiculata) (Wigngaarden, 1988). It is estimated that of the total annual production of 300,000 tonnes, approximately half is produced in West Africa (Coudert, 1984). Studies conducted by the International Trade Centre UNCTAD/GATT in 1982, revealed that its demand in West Africa exceeds the present supply. Increased production will therefore give farmers an additional source of income.

Information on the crop is very scarce and reviews by Linnemann (1987, 1991) and Linnemann and Azam - Ali (1993) have both stressed on the lack of research attention accorded it. There is no reliable source of seed and agronomic information on the crop. This hampers development of improved cultural practices for higher yields.

Although bambara groundnut is known to produce some yield under various growing conditions there is the need to establish the conditions under which the maximum productivity can be achieved. In this regard the cultivar grown, the time of planting of the crop and other agronomic practices are important considerations.

In Ghana, the main cultivated areas are in the Guinea Savannah, the Transition and Coastal Savannah Zones. In the Guinea Savannah and Transition Zones planting is done between early April and early May and again between late August and early September. Cropping is however done once in the Coastal Savannah areas between early April and early May. These planting periods correspond to different climatic conditions especially with respect to rainfall and temperature. Hence bambara groundnut yields may vary considerably among locations, planting periods and daylength for a given cultivar.

The objective for this study is:

To study the effects of season of planting on the performance of nine varieties of bambara groundnut.

CHAPTER 2

LITERATURE REVIEW

Cultivation of legumes and other crops in Ghana and other parts of Africa are done at times that are dictated to a large extent by the onset of rains. But other environmental factors affecting plant growth and development such as daylength, temperature, humidity, solar radiation and wind are invariably ignored. Perhaps rainfall or soil moisture is the most important factor in crop production especially in rainfed agriculture. However these other factors which act simultaneously on the plant in the natural environment have been known to influence general and certain specific plant growth and development processes. (Williams and Joseph, 1976; Salisbury and Ross, 1978).

2.1 Effect of sowing date on crop growth and development

Most local climate and soil conditions each year provide only short periods that are least suited for particular agronomic operations (Raeburn, 1984). Of all the management aspects of growing crops especially cereals and legumes, sowing date is probably the most subjective to variations. This is because of very large differences between seasons even within the range of climate highly suitable for arable culture. Thus the differences in crops performance at different planting dates within season may be attributed to the different environmental conditions notably photoperiod and temperature through which the early stages of plant growth and development proceeds (Hay and Walker, 1989). Effects of early and delayed sowing time in some tropical and temperate crops have been extensively reviewed (Stern and Kirby, 1976; Randhawa, 1980; Duff, 1980; Blacket, 1981; Jones and Allen, 1986). As a result it is now known that delay in sowing beyond a given date results in progressive reduction in the potential yield of crops.

Johnson (1968) reported that the timing of planting in bambara groundnut is critical to final yield. He noted that delaying the sowing date by three (3) weeks caused a yield reduction from 2530 kg/ha to 840 kg/ha in clay soil and from 1420 kg/ha to 200 kg ha in sandy soil.

Feaster (1949) in an experiment using five (5) varieties of soybean observed that planting at 20-day intervals within a major planting season resulted in the number of days from planting to maturity becoming less as planting was delayed. Consequently he noted that the trend in planting time influenced seed yield of early maturing varieties much more than the full-season varieties. He found the interaction of variety and planting date to influence seed yield significantly.

Reports on planting date experiments conducted on cowpea and mungbean by Kamara and Godfrey-Sam-Aggrey (1979), and Schiller and Dogkeaw (1976) respectively revealed that both crops produced taller plants with a corresponding higher grain yield when planted in early September than from other planting dates. This is because they benefitted from sufficient seasonal rainfall and made use of stored moisture.

Green _et al_. (1985) and Knop (1985) have given proofs of yield reduction in winter cereals of the order of 20% when planted outside the normal range of sowing dates.

The results of sowing date experiments have revealed inconsistencies between seasons and sites. For example, it is not unusual for a relatively late sown crop to outyield the control crop sown within what would be considered to be the optimum period. Knop (1985) and Hay and Walker (1989) attributed such discrepancies to soil conditions at different sowing dates and because each developmental stage goes through different environmental conditions especially photoperiod and temperature. Thus generally, crop performance is markedly affected by planting date and optimum time varying between locations or microclimates.

Due to the biological timing by photosensitive crops to daylength effects and variation in sowing dates, their development may be accelerated in order to synchronize their maturity with season (Jones and Allen, 1986). Spring wheat when sown at different dates within a growing season, has the dates of achievement of successive developmental stages occurring about the same time. This results in the ear emergence at the different planting dates maturing at closer dates (Stern and Kirby, 1976). In another experiment Kirby and Appleyard (1984) observed that winter wheat when planted later at different planting dates have their growth and flowering sliding into each other under long days. To this, Kirby and Ellis (1980) assumed that the acceleration of the development is progressively reduced with increasing delay in sowing. Consequently in cereals the number of leaves per stem declines because the length of the period of leaf initiation decreases. This in turn, tends to reduce the maximum number of flowers initiated which is broadly related to the number of leaf nodes.

Despite the effect of both early and late planting on crops the optimum sowing dates of various crops is still subject from year to year to variations, thus making it difficult to predict. This is because plant establishment, the possibilities of pest and disease incidence, drought response pattern to the sowing date among cultivars, has effect on the crop growth (Bingham et al., 1983). Rodger (1982) therefore suggested recommendations based on results of long running series of agronomic experiments which can give mean sowing date for highest yield together with realistic estimates of expected yield penalties for each week of delay in sowing. However, reservation to these recommendations ought to be appreciated as not guarantee of highest yield for a particular season.

2.2 Influence of daylength on plant growth, development and yield.

A spectacular manifestation of organisms is their ability to synchronise their physiological activities with season. Often, these seasonal responses are a reaction of plants to the daily exposure to periods of illumination (Bell and Combe, 1976). Although the length of hours of illumination per day has significant effects upon vegetative development of plants, its most significant influence is on flowering and other reproductive phases of development (Considine and Considine, 1989).

Photoperiodism has been defined in various ways by different researchers. In all these definition a similar view shared by all can be summarized as plant response to recurrent diurnal light periods of illumination at various degrees through natural or artificial light selection. (Hammer, 1940; Webster and Wilson, 1986; Salisbury, 1971, 1981; Salisbury and Ross 1978; Considine and Considine, 1989).

Bell and Combe (1976) explained that in spite of the numerous photoperiodic studies carried out, the real causation of photoperiodic effects is still not well understood. However these studies come to conclusion that photoperiodic effects are not only confined to initiation or prevention of flowering but influence other vegetative and generative morphology. The form of succulence of the leaves, the length of internodes, the development of pigments, frost resistance, the formation of subterranean storage organs, the onset and termination of bud can all be influenced by daylength.

In their experiment on eight (8) groundnut cultivars grown under varying photoperiods, Sengupta et al. (1977) observed that a photoperiod of ten (10) hours accelerated flowering by 5-7 days in 5 cultivars. A further increase in photoperiod delayed the onset of flowering significantly in all cultivars. They thus concluded that 10 hr photoperiod was optimum for accelerating flowering in all cultivars.

Similarly, Laing et al. (1984) in their studies on response of common bean (Phaseolus vulgaris) to photoperiod, observed that photoperiod not only affected time to flowering but also affected the overall balance between reproduction and vegetative growth.

Experiments on 24 local accessions of cowpea collected from Nigeria and Niger between latitude 7.5°N to 13.5°N by Wein and Summerfield (1980), revealed that some photosensitive cultivars originating from 9-11°N did not initiate reproductive primodia unless the days were shorter than 12 hrs and 46 minutes. But generally cultivars from altitude 11°N and above were less sensitive to daylength. This sensitivity they attributed to two distinct photoperiod 'triggers' - long and short respectively. This allows the plant to develop reproductive primordia which flower more or less simultaneously when the natural daylength becomes slightly short. Ojomo (1972) working on some local Nigerian cowpeas (Vigna unguiculata) varieties also showed that short photoperiod treatments induced determinate growth, flowering and fruit formation during long daylength months. He also noted that vegetative growth increased but yield decreased with increase in daylength.

Based on plant response to photoperiod leading to the initiation of flower bud formation, plant fall into three fairly well defined categories; short day (SD) species, day-neutral (DN) species and long day (LD) species. The above categories may be sub-divided since in nature probably no plant throughout its life is adapted strictly to one kind of photoperiod, excepting those growing in equatorial regions. Many plants will tolerate to a considerable extent, a uniform length of day as when grown under such conditions for experimental purposes. Most likely a specific daylength or nightlength is most conducive to one phase of sexual reproduction of particular plants and another or others to succeeding phases (Murneek, 1948). Hence the subdivision of the above categories are qualitative short and long day plants and day neutral plants (Vince-Prue, 1975; Salisbury and Ross, 1978; Salisbury. 1981).

Many studies have indicated that soybean cultivars are quantitative short-day plants and will flower quickly if subjected to sufficiently short photoperiod. Leffel (1961) reported that the flowering and post-flowering phases were shortened by delayed planting and attributed this response to shorter day lengths. Abel (1961) also found that delayed planting reduced the time from 50% flowering to maturity in early cultivars whereas preflowering was shortened by delayed planting in cultivars of medium maturity.

Smith (1941) working on Lespedeza found that plants of short-day types lagged behind those receiving a longer period of illumination and that the vegetation of the short-day types was dark green. Similarly, Doku (1970) found that cowpea plants growing under long days grew taller and appeared more vigorous with broader and greener leaves than those under normal days of 12 hrs. They in turn appeared taller and more vigorous than those under short days.

In general high yields require a long plant maturity period or 'juvenile stage' before flowering begins. According to Van Dobben (1962) when a plant is stimulated by an optimal day length, it has a short juvenile stage, limited in size, opens early and yields are reduced. All these findings indicate the importance of daylength on the growth and yield of photo-sensitive crops.

The influence of length of day is modified and sometimes counteractered by other environmental factors particularly temperature. Temperature interacts with photoperiod to influence the flowering of many plant species. It may reinforce the photoperiodic effect by inducing or inhibiting flowering or it may oppose it (Webster and Wilson, 1986).

A number of individually distinct processes occur during the development stages from floral initiation to fruiting and maturation in most plants. Under different environmental conditions coupled with individual plants these processes differ significantly. While some plants may require only an initial induction, other plants will require an appropriate provision of continuous photoperiod and temperature. The former are known as photoperiod inductive species while the latter are photoperiod dependent. For the photoperiod-inductive species, once maximally induced, all responsive apices become reversibly oriented towards flower production and it is believed that the resumption of vegetative growth is possible after flowering (Benier et al., 1981). However, in the case of the photoperiod dependent plants when its requirements are met it may be shown in terms of flower number produced, vegetative growth abnormalities, days to anthesis and fruit development as demonstrated in 'Biloxi' soybeans (Hammer, 1940), tomato (Leamer and Wittwer, 1953; Aung, 1976) and okra (Nwoke, 1980; Tenga, 1984). Accelerated developments of initiated floral buds and initiation of larger flower numbers are the outcome in the above mentioned examples when thermo- or photo-induction is extended. In the case of tulips, chrysanthemums and other various flowering plants, Nitsch (1965) showed that other flower parts like the calyx, corolla, stamens, and pistol may also have their individual photoperiod requirements for optimal development.

2.3. Influence of water supply on plant growth and development

Rainfall is among the most important climatic factors influencing crop growth in the tropics. Many physiological activities in the plant are affected as a result of poor or lack of rainfall. Among processes affected are cell growth, wall synthesis, protein synthesis, photochlorophyll formation, stomatal opening, carbon dioxide assimilation, respiration, xylem conductance and sugar level (Hsasio et. al., 1976).

Bambara groundnut produces satisfactory yield in areas with low rainfall (Doku and Karikari, 1971; Duke, 1978; Purseglove, 1962). However, information on plant water relations and low moisture availability effects on yield characters such as, flower formation, pollen fertility and branch and pod formation is very scarce. Elia and Mwandamele (1986), determined the experimental effects of water deficits in bambara groundnut and observed that although the crop grows well in areas of marginal rainfall, yields are higher if there is sufficient water.

Wien et al. (1979), noted drought stress to be one of the major factors limiting yield in tropical crops. In soybean, drought stress affects flower induction and pollen grain production so pod-fill is reduced (Sepaskhah, 1977; Shaw and Laing, 1966). In cowpeas, Hiler et al. (1972), found the flowering stage susceptible to imposed stress, while Summerfield et al. (1976), found that exposure to stress during vegetative stage reduced leaf area and significantly reduced yield. Generally water stress may cause injury to plants ranging from mild reduction in growth with negligible lasting effects to severe disorders which may result in death of plant.

2.4. Effects of temperature on plant growth and development.

Seasonal variation in performance of a given crop is most likely to reflect variable rainfall and the incidence of pest and disease in the tropics because variation in mean highest and lowest temperature in a month between year is generally small being about 4°C (Raeburn, 1984). However, temperature has been reported to affect the flowering behaviour in some bambara groundnut varieties. Nishitani and Inouye (1981) reported that certain bambara groundnut genotypes may not flower at a temperature of about 30°C irrespective of photoperiod, while mean temperature during planting period, influences the time taken to achieve physiological maturity in the crop (Linnemann and Azam-Ali, 1993).

Temperature effects on flowering plants may either be direct or indirect. Direct effect on floral initiation have been recorded in bulb plants and other vegetables. For example in onions, cool night temperatures encourage better bulb formation, but at the same time they also induce bulb to flower (Sinnadurai, 1992). Andrew (1935), working on two lima bean varieties showed that the plants fruit inconsistently due to temperature variations. He observed that 'Henderson' gave better yield than 'Fordhook' under higher temperatures. However when they were grown under relatively high humidity and low temperature, 'Fordhook' often out-yielded 'Henderson'.

On plant growth and development it has been noted that an increase in air temperature for example for tomatoes accelerated development resulting in an earlier yield whereas lower temperatures results in a late crop often with high yields (Klapwijk, 1969). In an experiment conducted on response of soybeans to planting date it was observed that temperature effects were apparent only in the absence of a strong photoperiodic response (Lawn and Byth, 1972). Studies on temperature treatment ranging from 1°C to 43.5°C for several plant species by Berry and Raison (1981) revealed that the effects have been mainly on sex expression. Within the range of normal growth, low temperatures promote femaleness while high temperatures favour maleness.

Certain crop plants require a specific promotion of flower initiation by a previous cold treatment termed vernalization for normal initiation and development of flower buds. In the absence of sufficient chilling, flowering may be irregular, flower bud may be shed or may fail to reach full development before bud open (Webster and Wilson, 1986). This phenomenon has been considered to be an indirect effect of temperature on flowering because it often requires an appropriate photoperiod or subsequent high temperature for full expression of the effect (Bernier _et al_., 1981). Perception sites for vernalisation has been reported to be more than that for photoperiodic response. Some perception sites include the stem tip or apical meristem (Bidwell, 1974; Bernier et al., 1981), leaves (Salisbury, 1971; Bidwell, 1974), and root (Bidwell, 1974).

CHAPTER 3

MATERIALS AND METHODS

Two experiments were conducted at the University of Ghana Farm, Legon during the minor planting season (July-October, 1992) and major season (April-June, 1993) using nine bambara groundnut cultivars. Climatic conditions which prevailed during period of experimentation are presented in Table 1.

Table 1: Climatic data for Legon during period of study

Monath & Year	Temperature (°C)		Total Rainfall	Relative Humidity
Expt. I (1992)	Min.	Max.	(mm)	
July	22.5	27.1	55.7	82.5
August	21.9	27.8	8.5	77.0
Sept.	22.7	29.1	8.2	75.5
Oct.	23.7	30.8	35.1	75.0
Expt. II (1993)				
April	24.5	32.3	96.2	72.5
May	25.1	31.8	49.0	72.7
June	23.7	30.0	81.4	77.0
July	23.3	27.6	4.1	78.5

Source: Ghana Meteorological Service Dept. Accra (1993).

3.1. Bambara groundnut cultivars

Nine bambara groundnut cultivars from Ghana,Swaziland and Zimbabwe were used in the experiment. There were seven cultivars from Ghana. These were obtained from both Northern and Southern Ghana. These were 'Sabliga', 'Piele balgu', 'Chichele balgu' 'Zhei', 'Piele kargu', and 'Chichele kargu' from Northern Ghana and 'Jabajaba' from Southern Ghana. 'Zimbabwe' and 'No.1 Swaziland' which were exotic varieties were obtained from Zimbabwe and Swaziland respectively. Some characteristics of bambara groundnut cultivars used in the study are presented in Table 2.

Table 2: Some Characteristics of bambara ground cultivars used in Study

Cultivar	Growth Habits	Seed Colour	Testa Pattern
Sabliga	Spreading	Yellowish brown	No pattern
Piele balgu	Semi bunch	Medium brown	Stripped
Chichele balgu	Spreading	Medium brown	Spotted
Zhei	Spreading	Reddish brown	No pattern
Piele kargu	Semi bunch	Medium brown	Spotted
Chichele kargu	Spreading	Medium brown	Stripped
Jabajaba	bunch	Cream	No pattern
Swaziland	Spreading	Reddish brown	No pattern
Zimbabwe	Spreading	Reddish brown	No pattern

3.2. Minor Season Experiment

This study was carried out to evaluate nine bambara groundnut cultivars during the off-season of 1992, from July to September, 1992. The soil type used was the reddish brown, sandy clay belonging to Toje series. Ploughing and harrowing of the field were undertaken on 22nd and 25th of June 1992 respectively. Phosphate fertilizer, triple superphosphate, at the rate of 140 kg/ha P_2O_5 was applied uniformly to all plots and worked into the soil a day prior to planting. A randomized complete block design was used with 4 replicates 45cm apart. Plants within a row were also 45 cm apart. Seeds were inoculated with peat-based Bradyhizobuim strain TAL 169 before sowing. Seeds were sown at one seed per hill.

The plots were weeded manually at four weeks after planting and again three weeks later. Supplementary irrigation was applied three times a week until flowering and thereafter once weekly. Diathane M45 at the rate of 4g/l and cymbush at the rate of 1.6m/l were tank-mixed and applied three times at three weekly intervals after sowing to control fungal and insect infestation.

3.3 Major Season Experiment

This experiment was undertaken during the major planting season of 1993, from April to June 1993 to evaluate the performances of nine bambara groundnut cultivars. The soil type used was the dark reddish brown, sandy loam soil belonging to Toje series. Ploughing and harrowing were undertaken on 30th and 31st March 1993, respectively. Triple superphosphate fertilizer at a rate of 140 kg/ha P_2O_5 was uniformly worked into the soil as in Experiment I. However, there were six rows-plots with the rows 40 cm apart and plants 30 cm apart within a row. Cultural practices were similar to those in Experiment I.

3.4. Data Collection

Data was collected from five randomly selected plants from the two middle rows in each plot. These were tagged when plants were three weeks old in both experiments.

Crop maturity was detected by slight browning of leaves. All cultivars matured between three to four months after planting with the exception of 'Sabliga'.

In both experiments, measurements and records were taken on number of leaves, leaf area, base spread, number of days to flowering, number of flowers per plant, total dry weight, number of pods per plant, number of seeds per plant, seed yield and 100- seed weight.

Data obtained from these measurements were subjected to a statistical analysis. This involved using analysis of variance and then seperating means using the t-test.

i. <u>Number of leaves per plant</u>

The total number of leaves on each record plant at 8 weeks after sowing.

ii. Leaf area per plant

The length and width of three leaflets were measured and their means calculated for each record plant. Their leaf areas were determined by multiplying the resultant product (length x breadth) by a factor of 0.69 (Edje and Osiru, 1987). These leaf areas were then multiplied by the number of leaves per plant to obtain the leaf area per plant.

iii. Base spread (cm)

Base spread of plant was measured as the widest distance between two opposite points on record plants.

iv. Number of days to flowering

This was recorded as the number of days from sowing to time of first flower opening on record plants.

v. Number of flowers per plant

Flowers were counted daily over a period of 60 days.

vi. Total dry weight

The dry weight was obtained as the dry weight of shoots and root system of each record plant.

vii. Number of pods per plant

All pods from each record plant were counted including unfilled pods.

viii. Number of seeds per plant

The number of wholesome seeds from each record plant.

ix. Seed yield per plant

Wholesome seeds from each record plant were weighed after drying.

x. 100 - seed weight (g)

This was recorded as the weight of hundred (100) seeds obtained from each plot after drying.

xi. Harvest index was determined by expressing as a percentage seed yield per plant to the dry matter produced.

CHAPTER 4

RESULTS

4.1 Effect of planting time on plant growth

4.1.1 Number of leaves, leaf area and base spread

A higher number of leaves was generally produced during the major planting season (Experiment II) than during minor season (Experiment I) (Table 3). In four cultivars 'Chichele balgu', 'Zhei', 'Sabliga' and 'Zimbabwe' differences were significant ($P < 0.05$). However, the highest number of leaves per plant was in the minor season in the cultivar 'Sabliga'. There were significant differences among cultivars for each growing season. 'Sabliga' gave the highest leaf number in the minor season while 'Chichele balgu' gave the highest in the major season.

No significant differences in the leaf area occured between the two planting times. However within a planting time, the cultivars showed significant differences. 'Jabajaba' gave the lowest leaf area and 'Sabliga' the highest. With respect to base spread, except for Piele kargu and Zimbabwe no significant differences were observed between the major and minor seasons.

4.1.2 Dry matter yield (DMY)

Differences in dry matter yield between the two planting times were significant ($P < 0.05$) with more dry matter produced in the major planting season (Experiment II) than in the off-season

(Experiment I) (Table 4). In both experiments, 'Jabajaba' and 'Sabliga' gave the lowest and highest DMY, respectively. Cultivar 'Sabliga' produced over three times as much DMY as 'Jabajaba'. Significant differences in DMY were present among cultivars within Experiments.

Table 3 Influence of time of planting on leaf production and leaf area per plant.

Cultivar	No. of leaves			Leaf area (cm^2)		
	Expt. I	Expt. II	Signi-ficance	Expt. I	Expt. II	Signi-ficance
Chichele balgu	74	93	*	45.03	44.01	NS
Jabajaba	41	46	NS	32.76	33.69	NS
Zhei	54	88	**	40.53	47.49	NS
Piele kargu	59	54	NS	48.90	47.88	NS
Chichele kargu	75	76	NS	54.75	56.93	NS
Piele balgu	55	48	NS	38.73	39.86	NS
Sabliga	95	83	*	60.56	59.58	NS
Swaziland	52	54	NS	51.00	52.26	NS
Zimbabwe	72	90	*	43.80	45.99	NS
L S D 5%	39.8	44.3		8.13	7.89	

NS, Not significant
*, **, Significant at 5% and 1% respectively.

Table 4 Influence of time of planting on base spread and dry matter production of bambara groundnut

Cultivar	Base spread (cm)			Dry matter yield(g)		
	ExptI	ExptII	Signi-ficance	ExptI	ExptII	Signi-ficance
Chichele balgu	63.8	71.1	NS	148.50	192.78	*
Jabajaba	35.8	39.0	NS	63.93	71.41	NS
Zhei	58.6	67.2	NS	109.68	197.31	**
Piele kargu	52.4	47.0	*	145.30	138.40	NS
Chichele kargu	64.9	62.6	NS	167.34	177.73	*
Piele balgu	41.9	43.8	NS	154.20	155.49	NS
Sabliga	60.3	66.8	NS	208.91	231.35	NS
Swaziland	91.6	52.2	NS	158.73	168.94	NS
Zimbabwe	32.7	73.1	*	150.35	195.80	*
L S D 5%	23.82	33.94		26.93	39.47	

NS, Not significant
*, **, Significant at 5% and 1% respectively.

4.2 Effect of planting time on flowering characteristics

The number of days to first flower opening during the minor and major seasons varied between 34 to 38 and 32 to 35 days respectively (Table 5. The cultivar 'Jabajaba' was the earliest to flower in both Experiments. Flowering in all cultivars, once initiated did not cease until harvesting except for 'Jabajaba'. Differences in flowering date among cultivars and also between seasons for a cultivar were not significant.

Two distinct pattern of flowering were observed (Fig 1a and Fig 1b). In the minor season two peaks were observed for all varieties except for 'Jabajaba' and Sabliga'. The first and second peaks occured between 15-21 days and 27-39 days respectively after first flower openings. For 'Jabajaba' only a single peak was observed and corresponded to the period of first flowering peaks for the other varieties. No peak was identified for 'Sabliga' as flowering continued to increase till harvest.

In the major season, a single peak period was observed between 20-40 days after first flower opening, except for 'Sabliga' as was observed during the minor season. Two cultivars 'Piele Balgu' and 'Sabliga' produced significantly higher numbers of flowers in the minor season than in the major season. For 'Sabliga' flower production during the minor season was about five times higher than that in major planting season. Differences among some cultivars within experiments were also significant for number of flowers per plant produced (Table 5).

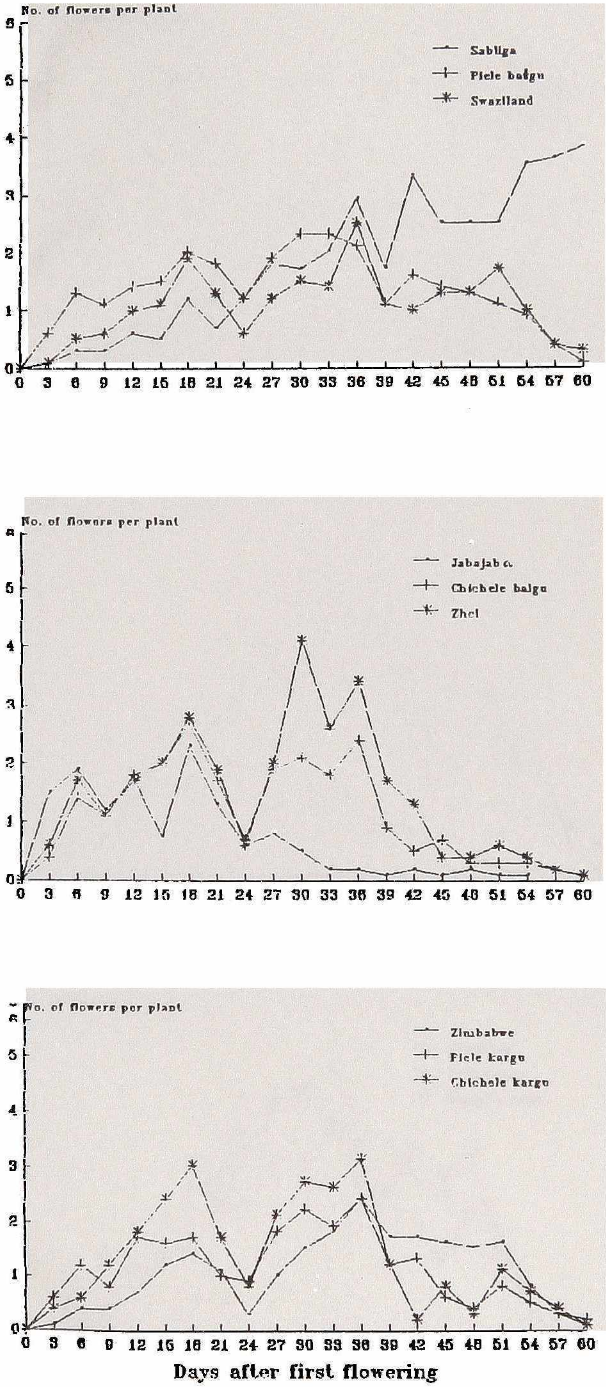

Fig. 1a Frequency of flower production during the minor season (July - October 1992)

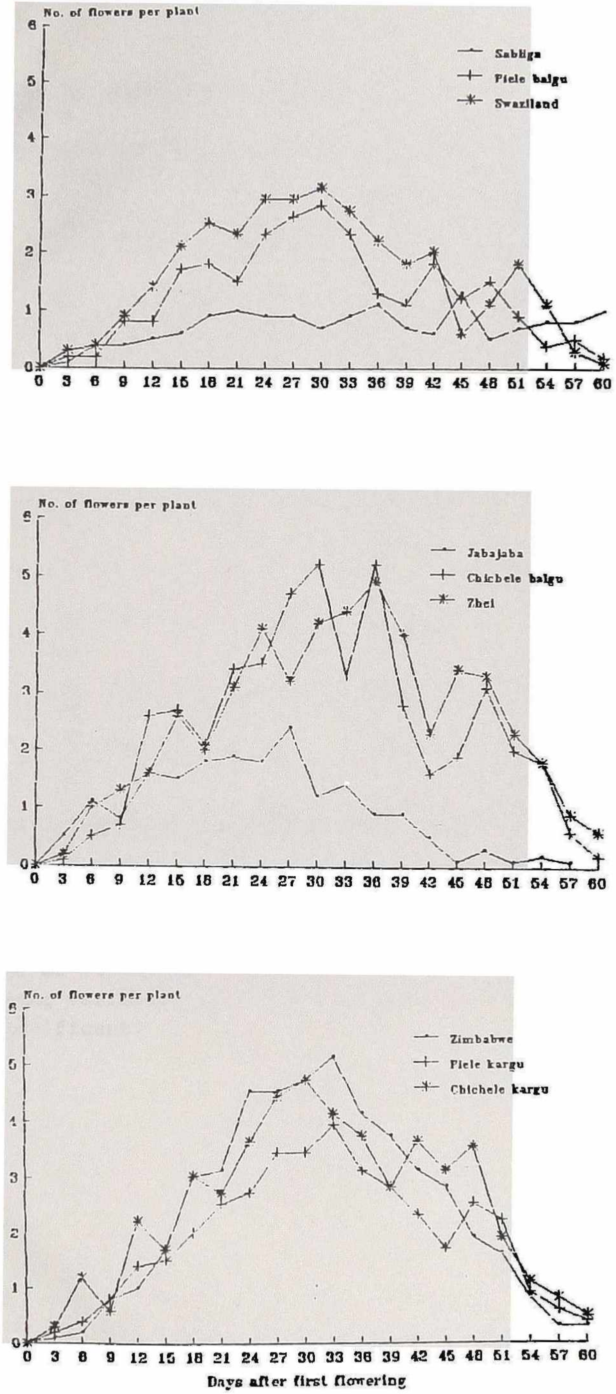

Fig. 1b Frequency of flower production during the Major season (April-July 1993)

Table 5 Effect of time of planting on number of days to first flowering and number of flowers per plant

Cultivar	Days to flowering		No. of flowers/plant		
	Expt.I	Expt.II	Expt.I	Expt.II	Significance
Chichele balgu	37 [a]	34	122.2	156.4	*
Jabajaba	34	32	58.4	79.5	*
Piele kargu	35	34	127.3	130.9	NS
Chichele kargu	37	35	149.5	162.4	NS
Piele balgu	35	33	129.7	158.8	*
Sabliga	38	33	153.1	26.0	**
Swaziland	37	34	101.8	122.0	NS
Zimbabwe	35	33	101.8	112.6	NS
Zhei	35	34	151.6	166.0	NS
L.S.D 5%	NS	NS	54.16	87.31	

NS, Not significant

*, **, Significant at 5% and 1% respectively

a, Differences among varieties and also between Experiments I and II were not significant.

Table 6 Seed yield per plant and harvest index of bambara groundnut planted at different seasons.

Cultivar	Yield/plant (g)			Harvest Index (%)		
	Expt.I	Expt. II	Significance	Expt.I	Expt. II	Significance
Chichele balgu	35.12	23.55	NS	27.52	22.80	NS
Jabajaba	28.62	29.49	NS	47.30	42.47	NS
Zhei	46.34	29.35	*	29.66	18.14	*
Piele kargu	28.65	22.62	NS	25.28	27.56	NS
Chichele kargu	31.14	20.48	NS	20.71	19.32	NS
Piele balgu	26.01	11.48	NS	19.89	20.74	NS
Sabliga	13.12	6.61	NS	15.57	13.23	NS
Swaziland	36.60	17.95	*	18.18	17.64	NS
Zimbabwe	22.51	18.78	NS	18.27	14.99	NS
L S D 5%	22.23	11.20				

NS, Not significant
*, Significant at 5%.

4.3 Effect of time of planting on seed yield and components of seed yield

4.3.1 Seed Yield

The variety 'Sabliga' produced the lowest yield per plant in both experiments (Table 6). Probably it was harvested too early. However, seed yield was generally low in all varieties in both experiments. The Harvest index was higher in the monor season than in the major season in all cultivars except for 'Piele kargu' and 'Piele balgu'. In both experiments, 'Jabajaba' and 'Sabliga' gave the highest and lowest harvest index respectively.

Table 7 Effect of time of planting on number of pods per plant and Fertility Coefficient

Cultivar	No. of pods/plant			Fertility coefficient (%)		
	Expt.I	Expt.II	Signi-ficance	Expt.I	Expt.II	Signi-ficance
Chichele balgu	49.8	28.3	*	40.8	18.1	**
Jabajaba	48.6	36.2	*	61.2	62.0	NS
Zhei	64.7	36.5	**	42.6	21.9	*
Piele kargu	44.3	25.1	*	34.2	19.2	**
Chichele kargu	49.3	30.3	*	33.0	18.7	*
Piele balgu	35.3	15.6	**	27.2	26.5	NS
Sabliga	30.6	10.3	*	19.9	39.6	**
Swaziland	62.4	33.8	**	56.6	30.0	*
Zimbabwe	52.4	24.2	**	48.9	24.4	**
L S D 5%	23.87	16.32		19.63	12.81	

NS, Not significant
*, **, Significant at 5% and 1% respectively.

4.3.2 **Components of seed yield**

Differences in the number of pods per plant among cultivars were significant ($P < 0.05$) in both Experiments (Table 7). For all cultivars, the number of pods formed in the minor season was greater than in the major season. The fertility coefficient, or the number of pods produced as a proportion of number of flowers was greater in the minor season than in the major season. The cultivar 'Jabajaba' and 'Piele Balgu' had similar fertility coefficients in both planting times. Only 'Sabliga' had a higher fertility coefficient during the major season than during the off season.

Most pods contained only one seed with a few containing two seeds. The cultivar 'Zhei' and 'Sabliga' produced the highest and lowest number of seeds respectively in both experiments (Table 8).

Results on 100 - seed weight (Table 8) indicate that there were no significant differences between seasons. The highest weight was observed in the cultivar 'Chichele balgu' in both experiments and the lowest in 'Zimbabwe' in both experiments.

Table 8 Effect of planting time on seed number and weight

Cultivar	No. of seeds/plant			100 - seed weight(g)		
	Expt.I	Expt.II	Significance	Expt.I	Expt. II	Significance
Chichele balgu	41.2	26.8	*	40.86	43.95	NS
Jabajaba	40.0	30.6	*	30.24	30.33	NS
Zhei	57.6	31.2	*	32.53	35.79	NS
Piele kargu	34.4	20.2	*	36.73	38.12	NS
Chichele kargu	39.5	23.2	*	34.65	34.34	NS
Piele balgu	34.3	14.6	**	30.67	32.25	NS
Sabliga	20.1	7.3	**	32.52	30.63	NS
Swaziland	60.1	31.5	**	28.85	28.39	NS
Zimbabwe	43.4	23.6	*	27.48	29.36	NS
L S D 5%	19.45	18.53				

NS, Not significant

*, **, Significant at 5% and 1% respectively

CHAPTER 5

DISCUSSION

5.1 Effect of planting time on plant growth

The development of leaves in bambara groundnut appears to be influenced by climatic factors especially rainfall and temperature. The crop is known to be moderately tolerant to drought (Doku and Karikari, 1970). However, the higher number of leaves produced in the major planting season (Experiment II) than in the minor season may be attributed to the higher average rainfall and temperature experienced in the major planting season. Rainfall distribution in both experiments showed a decline in amount from different optima; being almost twice as high in the major season as in the minor season. Again, the decline was sharper in Experiment I and over a longer period before rising. Consequently this might have resulted in an increase in physiological processes such as cell growth, wall synthesis, stomata opening, carbon dioxide assimilation and photochlorophyll formation in the plants to enhance more vegetative growth (Hsasio et al., 1976) in the major season than in the minor season. Elia and Mwandemele (1986), in their studies on bambara groundnut, showed that insufficient rainfall affect the number of branches and leaves produced. They also observed that during periods of high rainfall resulting in sufficient soil water uptake, the crop branched more profusely with more leaves being produced than under low rainfall.

For both experiments, the photoperiod was between 12hr and 12¼ hrs. This may not have had much differential influence on leaf production. In a green house experiment using a bambara groundnut cultivar from West Africa, Linnemann (1992) reported that day length of 10 hr to 16hr did not produce significant differences in the number of leaves produced.

Differences in leaf area among the cultivars may largely be influenced by differences in genotype rather than the season in which the crop was grown as there was no significant differences when the two Experiments were compared. However, Experiments conducted by Linnemann (1991) on the crop revealed that leaf area development responds to photoperiod with longer photoperiod above 14 hr resulting in larger leaf area than photoperiod under 10 hours or 12 hours.

The crop canopy may intercept more light for a much more efficient photosynthesis. The cultivars 'Zimbabawe', 'Chichele balgu' and 'Sabliga' which had the highest base spread values may thus have more efficient photosynthetic systems.

Results on dry matter yields showed that vegetative growth was much influenced by rainfall. Rainfall values were lower in the minor season than in the major season and even with supplementary watering, dry matter yield correspondingly followed a similar pattern. In other studies, insufficient water availability to plants affected hormone levels Cohen (1975), and especially reduced gibberellin levels (Kapuya, 1972). Many researchers (Lukasi, 1975; Castro and Bergenmann, 1973; Mange, 1971; Foda et al., 1973), have found that gibberellic acid significantly increases branching and stem elongation, mainly through internode length and hence higher leaf production. Therefore the reduced rainfall in the minor season might have affected dry matter yield.

Nicholls and May (1963) have also demonstrated that gradually increasing water stress in barley appreciably retarded differentiation in both leaf and spikelet primordia. Retardation in differentiation therefore likely affected branch and leaf formation in those cultivars which showed significant differences ('Chichele balgu', 'Zhei', 'Sabliga' and 'Zimbabwe') with respect to amount of water received. This is thus reflected in the amount of DMY produced.

Apparently the number of leaves produced per plant appeared to be reflected in the amount of dry matter yield and growth habits. Generally, the higher the number of leaves, the more its spread and the higher the dry matter yield. Thus on account of rainfall distribution in both planting periods, being more favourable in the major season (Expt. II), the higher number of leaves recorded for all cultivars with the exception of 'Sabliga' and 'Piele kargu' resulted in a good spread with greater dry matter yield.

The influence of photoperiod during the two planting periods on DMY may not be significant since it did not appear to have any influence on leaf production. However, observation by Lawn (1989) showed that photosensitive cultivars of bambara groundnut gave lower DMY under a photoperiod of 10 hr than 12 hr. This is because plant under the longer photoperiod took longer time to mature than those under shorter photoperiod.

5.2. Influence of time of planting on flowering date, pattern and duration

For all the cultivars, it appeared that the number of days to first flower opening was not influenced by sowing date. For each cultivar, however, plants flowered a few days earlier in the major rainy season than in the minor rainy season. Doku and Karikari (1970), working on three bambara groundnuts found that for all cultivars, the number of days between date of emergence and commencement of flowering was not influenced by season. The variation in days to first flower opening may probably be due to the intensity of illumination. Canham (1964) defined light conditions in terms of three parameters as the quality of light, the intensity of illumination and length of time which influences flowering in plants. Taking the period through sowing to flowering into consideration, it will be observed that the change in light hours between the first and second Experiments was decreasing during the minor planting season and increasing during the major planting season (Table 1). Thus this variation in light concentration hours coupled with probably varying intensity and quality due to the presence or absence of cloud cover could have resulted in differences in number of days to first flowering. Linnemann (1991) has demonstrated that flowering in bambara groundnut was generally delayed under long photoperiod.

Rainfall distribution when too low could be a regulatory mechanism to slow down crop growth activities by accumulation of many metabolites which could produce secondary effects inhibiting flowering (Salisbury and Ross, 1978). Thus water and temperature conditions in the major season appeared to have been more favourable for flowering than in the minor season probably accounting for the higher number of flowers produced in most varieties. However, relative humidity values did not differ much in both experiments to influence flowering pattern. This effect of water stress on flowering production obtained was similar to results by Sepaskhah (1977) and Shaw and Laing (1966) who observed that decrease in amount of rainfall seriously affected flower formation and number in soybeans.

The double peaks in flowering observed in the minor season after the first 36 days after flowering could not result in more flowers being produced than in the major season. Thus, over the entire period of growth more flowers were produced in the major season than in the minor season. The second flowering peak in the minor season may probably be due to the increase in rainfall from 8.2 to 35.1 mm during the second month of flowering. Flower production in 'Sabliga' appeared to have been influenced greatly by rainfall as it produced the highest and lowest flower numbers in the minor and majoir seasons respectively. This may probably be in direct response to the time of planting. High rainfall may have an adverse effect on its flower production. In this same variety the absence of a flowering peak in both experiment may be an indication of it being a long season variety. Cultivars like 'Zhei', 'Piele kargu' and 'Chichele kargu' which did not give clear differences were probably not influenced by planting time.

The number of pods formed in relation to number of flowers produced in all cultivars shows that not all fertilized flowers could develop into fruits. This may suggest that growth and fruit production of crops is strongly influenced not only by genetical but also environmental factors. At harvest it could be observed that there were a few flowers on the crop as well as pods at different stages of development.

When the crop is grown during periods of high rains, most of the flowers are not capable of developing into fruits thereby reducing the chances of a good harvest. Hence even though flowers produced in the minor planting season were generally lower than in the major planting season pods formed from them were much greater in number. Studies on other crops have however shown that low rains resulting in water stress increase abortion in both flowers and pollen (Shaw and Laing, 1966; Sionit and Kramer, 1977) in soybeans. This resulted in lower pod formation and hence lower pod number.

5.3 Effect of planting time on seed yield

Although seed yield was generally low in all cultivars, the variations in yield between the two Experiments may be attributed largely to the number of seeds produced per plant. It has however been reported that the crop may vary considerably between sites, seasons and genotype (Linnermann and Azam-Ali, 1993). These considerations might also have accounted for the observed variations in the same genotype. The significant yield differences observed in the interaction between culitivars 'Zhei' and 'Swaziland' with planting date indicate that the cultivars do not behave alike over the same period. This is similar to the result of Doku and Karikari

(1970) who working on three cultivars of bambara groundnut cropped at different times (rainy and dry seasons) found that high rains tend to adversely affect yield. Knop (1985) ascribed this to the fact that crop grown at different dates pass through slightly different times and therefore are exposed to different environmental stages which determine yield.

It has been suggested that varieties with more open habits resemble the wild strain of the crop and that cultivated varieties which are indigenous are more compact (Hepper, 1963). Thus when varieties are grown under conditions of relatively higher rains the open types are more adversely affected and produce poorer seed yield. Mayeux (1990) has shown that groundnut yield are usually greatest when plant population densities are relatively high and that even under favourable conditions of growth lower plant densities cannot compensate enough by increasing yield per pod.

In their experiment on day length sensitivity in bambara groundnut, Harris and Azam-Ali (1992) suggested that irrespective of other variables like rainfall distribution, yield of photosensitive cultivars vary with planting date. Although photoperiod appears to have had no significant influence on seed yield in both experiments, Linnermann (1991) has shown that fruit development leading to seed yield may be influenced by photoperiod. Trials of cultivars from different locations in West Africa exposed to several daylength treatments (12 h or less and 14 h or more) showed that long photoperiod delayed or even prevented fruit set in cultivars with day neutral or delayed flowering, hence lowering yield.

From Figure 1, it could be observed that all the flowering peaks, with the exception of 'Sabliga' fell within 20 days after first flower opening. In the second Experiment none of the peaks fell within the twenty days after first flowering. This may account for the poorer seed yield since most of the flowers could not develop into mature seeds before harvesting. Results thus obtained is similar to studies conducted by Doku and Karikari (1970) and Linnermann and Azam-Ali (1993) on flowering and pod formation in bambara groundnut, that flowers matured into fruits forty days after opening.

Dry matter yield (especially during the main planting season) was not reflected in seed yield. This may be because although the total yield of dry matter is likely to be closely correlated to the leaf area duration it does not necessarily contribute equally to the harvest yield of the economic product during all stages of the growth period (Webster and Wilson, 1986). The harvested yield will also depend on the distribution of dry matter between the useful and other parts of the plant. This may be affected by the 'sink' capacity of the useful parts to accept photosynthates as well as the ability of the leaves to supply it (Hay, 1982).

The number of pods formed was greater than number of seeds in all cultivars because at the time of harvesting there were pods with immature seeds. The variations observed in pod number as against seeds per plant among cultivars in both Experiment, may be explained as follows. If a constant duration for pod filling is forty (40) days i.e. thirty days for pod maturity and subsequent ten (10) days for seed development, (Doku and Karikari, 1970; Linnemann and Azam-Ali, 1993), then for useful flowering in which flowering leads to matured pod formation should end forty (40) days before plant is harvested. This means only flowers produced during the first twenty (20) days after first flowering had enough time to develop into matured pods in this experiment.

It may be noted that the crop is relatively more adapted to drier conditions like what prevailed during the minor planting season, hence the higher pod number.

Fruit abortion may also be responsible for the low number of seeds as compared to flowering. According to Saraguchi et al. (1954), inadequate nutrition to develop grain has been held responsible for the vast majority of grain abortion and that abortions are mechanisms which control the number of pod that a plant is able to carry as suggested by Carter and Hopper (1942).

The small difference between treatments for the 100-seed weight seemed to suggest that the weight of seeds produced was not influenced by variation in photoperiod and other environmental factors such as rainfall and temperature and that amount of assimilate stored in each seed was not very much influenced by these factors.

CHAPTER 6

SUMMARY AND CONCLUSION

The growth, flowering, fruit-set and yield of nine (9) bambara groundnut [Voandzeia subterranea (L.) Verdc.] cultivars from Ghana, Swaziland and Zimbabwe were studied in two field Experiments at the University Farm, Legon. The treatments were set up in a randomized complete block Design with four replications.

The experiment revealed the following:

In the major planting season where rainfall values were higher than in the minor season, the crop generally produced a higher number of leaves resulting in a larger canopy formation. Dry matter yield was also generally higher under this condition. However differences in leaf area among cultivars appeared to be genotypic in origin.

Flowering in the crop was not influenced by sowing date and once initiated , continued until harvest.

Flowering pattern responded to rainfall distribution. Single flowering peaks were produced when rainfall was moderate over the entire growth period (Experiment II) and double peaks were produced when rainfall distribution fluctuated (Experiment I) during the growth period.

Heavy rainfall seems to have adverse effect on the crop performance resulting in poor yields. Under this conditions seed formation is reduced since most of the flowers produced by the crop was shed.

With the crop flowering until harvest some flowers produced after a period of plant growth did not get enough time to develop into fruits under both seasons.

CHAPTER 7

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APPENDIX

Daylength during experimental period July-October (Minor Season) and April - July 1993 (Major Season)