EFFECT OF SOWING DATE, FERTILIZER LEVEL AND INTRA-ROW SPACING ON THE AGRONOMIC CHARACTERS AND YIELD OF BAMBARA GROUNDNUT (*Vigna subterranea* L. Verdcourt)

BY

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A dissertation submitted to the Postgraduate School, Ahmadu Bello University in partial fulfillment of the Requirements for the degree of Doctor of Philosophy in Agronomy

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ZARIA, NIGERIA

FEBRUARY, **1996**

DECLARATION

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

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CERTIFICATION

This dissertation entitled "EFFECTS OF SOWING DATE, Fertilizer LEVEL AND INTRA-ROW SPACING ON THE AGRONOMIC CHARACTERS AND YIELD OF BAMBARA GROUNDNUT (Vigna subterranea L. Vercourt) by Balarabe TANIMU meets the regulations governing the degree of Doctor of Philosophy of Ahmadu Bello University, Zaria, and it is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

This work is dedicated to my Parents, late Alhaji Tanimu Aliyu Rigachikun and Hajiya Inna Halima Abdullahi.

ACKNOWLEDGEMENTS

In the name of Allah, most beneficient, most merciful. All praise be to Him.

I wish to express my sincere gratitude to Dr. V.B. Ogunlela, Professor of Agronomy, Institute for Agricultural Research, Ahmadu Bello University, for his encouragement, valuable suggestions and guidance during the conduct of the experiments and preparation of the manuscript. The same sincere gratitude is also extended to Drs. O.O. Olufajo and E.N.O. Iwuafor for their advice and guidance throughout the period of the study. My sincere appreciation is also extended to Professor J.Y. Yayock who was the initial Chairman of the team that started supervising this work, and wish also to acknowledge here, the guidance received from late Professor Ono Leleji, who was part of the supervisory team.

Sincere appreciation is extend to Professor S.T.O. Lagoke and Dr. E.B. Amans, the former and current Head of Department of agronomy who, in various ways contributed to the success of this work.

I have no words to thank Drs Anita R. Linnemann, L. Aliyu and S.G. Ado who encouraged me and contributed in various ways to make my dreams come true and the entire staff of the Data Processing Unit for the statistical analyses of the data. I also wish to thank

Alhaji M.M. Ahmad, late Muhammad M. Mahammad, and my numerous friends and colleagues for their encouragement and help during the period of the investigation.

I acknowledge the kind assistance of Messrs C.I Nwosu, A. Ishaku, G.A. Unongul and Y. Isa who helped in the collection of data.

The experiments were carried out as one of the approved projects under the IAR's Legumes and Oilseeds Research Programme. I, therefore, thank Professor A.M. Emechebe, the immediate past Leader of the Programme, and the Director of the Institute for Agricultural Research, Samaru.

The effort of Mall. Sani Ishaka and Mrs Victoria Toke Samson who typed this draft manuscript is acknowledged. To my mother, brothers and sisters, to my wives, Amina Lawal and Amina Ibrahim, and the children - Aisha, Late Mahammad Bello and Abdulwahab, I say thank you for your understanding throughout the period of the study.

All praise be to Allah.

ABSTRACT

Field experiments were conducted during the 1986 - 90 rainy seasons at Samaru (11° 11' N; 07° 38'E) to study the effects of sowing date, fertilizer level and intra-row spacing on the agronomic characters and yield of two bambara groundnut varieties. Two separate experiments were conducted in each year. In the first experiment, the effect of fertilizer nutrients (0 and 20kg N/ha; 0, 25 and 50kg K/ha and 0, 11, 22 and 33kg P/ha) was evaluated while the second experiment involved the determination of the best sowing date and the optimum intra-row spacing using two varieties (Pategi-Black and Giwa-White). The earlier experiment was conducted for five years (1986-1990) and the later for four years (1987-1990). The investigation revealed that the application of a starter dose of 20kg N/ha was not essential even on soils with low nitrogen levels (less than 0.05% total N) such as the ones used in this trial. The application of ll-22kg P/ha was found to enhance the performance of the crop significantly and the application of 25kg K/ha also increased the yields of the crop. Grain yields were maximum at 13kg P/ha and 27kg K/ha.

Planting early (in June) resulted in higher yields than late planting (July-August) provided adequate protection against weeds, pests and diseases is given to

the crop. Closely planted bambara groundnuts (5-10cm between stands on ridges 75cm apart) gave higher yields. The Pategi-Black variety yield significantly higher grains than the adapted local variety (Giwa-White). Plant height, plant foliage spread, 100-grain weight and shelling percentage were significantly positively correlated with grain yield in most years. However, the direct contribution of the shelling percentage to the grain yield was negative in all the years. Good management, especially adequate protection of the crop from weeds, pests and diseases is essential for the production of this crop in Samaru given the small stature of the crop which makes it prone to mechanical damage and/or infection.

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CHAPTER 1

INTRODUCTION

1.1 Origin and Distribution

Bambara groundnut (Vigna subterranea L. Verdcourt) is an indigenous African legume which constitutes the third most important pulse crop in the continent after groundnut and cowpeas (Sellscop, 1962). The centre of origin for bambara groundnut has been a matter of discussion, however, it is now generally accepted that wild forms are found from the Jos Plateau and Yola (Northern Nigeria) to Garoua (Cameroon), and possibly in the Central Africa Republic (Hepper, 1970). The crop is now found throughout tropical Africa as well as in Madagascar, Mauritius, Sri Lanka, Indonesia, the Philippines, Malaysia, the United States, New Caledonia, northern Australia, Tropical Central America, Surinam and Brazil (Duke, et al., 1977).

1.2 Growth Habit

Bambara groundnut is a small bunched herbaceous annual, similar to groundnut (Arachis hypogaea L.) in habit. The plant bears numerous erect and long petioled trifoliate leaves produced from small creeping stems (Cobley and Steel, 1976). It shows a wide variation in growth habit, but varieties may be classified into two broad groups: open or spreading types with long trailing stems; and compact or bunched types with short trailing

stems (Doku and Karikari, 1971). Between these extreme types there are gradations, but the general appearance of the plant is a bunch of leaves with long petioles arising from very contracted and much branched stems which form a small crown on the soil surface (Doku and Karikari, 1971). From the crown arises a well developed tap root, free of lateral roots for part of its length, and then producing downwardly growing laterals in profusion. The tap root and its laterals bear thick, sub-globular, weekly striated and effective root nodules (Johnson, 1968). The hairy stems which creep on the surface of the soil branch off in all directions from the central bud which is situated at soil level. Branching starts very early, about one week after germination, and as many as 16 to 20 branches may be produced (Doku and Karikari, 1971). The small yellowish flowers are borne on the small creeping stems quite close to the ground and are normally self-pollinated and are fertilized before opening and, like those of groundnut, the stalks lengthen in a downward direction after the flowers have been fertilized. The young pods are gradually pushed under the ground around and below the plant, where they develop and ripen (Sands, 1931). On germination, the cotyledons remain under the ground, thus exhibiting a hypogeal germination (Stanton et al., 1966).

1.3 Economic Importance and Uses

Total production of bambara groundnut has been estimated to be over 300,000 tones per annum in Africa (Poulter, 1981). The major producing countries include Nigeria (estimated at 100,000 tones per annum), Niger (30,000 tones) and Ghana (20,000 tones) (Rachie and Roberts, 1974). According to Sellschop (1962), the most important leguminous crops in terms of production and consumption in Africa are groundnut, cowpea and bambara groundnut in that order. The production of these crops in Nigeria follows the same pattern. However, the result of a survey in Ghana showed that bambara groundnut was only second to cowpea. Kinyawa (1969) mentioned also that bambara groundnut comes next to groundnut in Western Tanzania in terms of production and consumption. This crop features prominently in traditional farming systems all over the continent of Africa as an intercrop of cereals and root crops, although it is also planted as a sole crop in some areas (Stanton, 1968). In most parts of Africa the crop is grown primarily for home consumption, with excess quantities being sold in local markets (Hepper, 1970).

Bambara groundnut is mainly used for human consumption. The grains are consumed either immature or when fully ripe. Immature grains are consumed fresh or grilled (Rassel, 1960), or they are boiled, either

shelled or unshelled, after which they are eaten alone or mixed with immature groundnut or green maize (Johnson, 1968). Ripe grains are hard and therefore difficult to grind. Usually they are either pounded to flour and boiled to stiff porridge, or soaked and boiled (Johnson, 1968). The porridge keeps well and is traditionally used on long journeys (Holm and Marloth, 1940). Ripe grains are also roasted, broken into pieces, boiled, crushed and eaten as relish. Commercial canning of bambara groundnut is a successful industry in Ghana (Doku and Karikari, 1971; Lartey, 1977). Other methods of processing developed in recent years, are vegetable milk processing (Poulter and Caygill, 1980) and the meal (Lartey, 1977) or rice flour (Obizoba, 1983 and 1984). In Nigeria, Begemann (1987) reported that bambara groundnut is used in preparing 'alale' or 'moin moin', 'kosai' or 'akara', cake, stew and snacks. Bambara groundnut may also be used as an animal feed stuff; the grains are used for livestock (Oluyemi et al., 1976), while the haulms are fed to cattle (Gohl, 1975; Uwaegbute, 1977). However, the comparatively small production of vegetative matter limits the use of bambara groundnut as a fodder (Doku and Karikari, 1971).

1.4 Status of Production in Nigeria

Bambara groundnut is grown in almost all parts of Nigeria, except in the riveraine/swampy areas where

climatic conditions are not conducive for its good performance. It is grown either sole or intercropped with other crops.

Linnemann (1988) reported that the total hectarage of bambara groundnut in the northern parts of Nigeria has declined over the past ten years, while for much of the south, production increased during the same period. Farmers in the north estimated that the present hectarage is approximately 5-20% of the hecterage about a decade ago. The main reason for the decline in production was drought, which resulted in little or no production of the crop for some years. The increase in hectarage in the south was however, attributed to the fact that the crop fetches more money than it used to (Linnemann, 1988). Even though, majority of the farmers produce bambara groundnut primarily for food, they may sell part of their produce when they have produced excess of their food needs or when they are pressed for money to pay taxes, loans or school fees (Linnemann, 1988). The shift in production area from the north to the south may have affected the annual production. Because bambara groundnut is one of the 'neglected crops', research information, especially with regard to Nigeria, is generally scanty because not much work has been done on the crop. The improvement of its germplasm as well as the agronomy of its production both deserve intensive

study if increases in grain and protein yields and quality are to be achieved.

The varieties presently in cultivation are local selections whose yields are generally low and whose adaptation is such that it renders them largely unresponsive to improved management.

1.5 Objectives of the Study

Very little is known about improved bambara groundnut production in Nigeria. Most of the information available are based on experiences reported elsewhere. This study was therefore initiated with the following objectives:

1. To ascertain the best time to plant bambara groundnut in order to achieve optimum grain yield.
2. Determine the optimum amount of phosphorus fertilizer to apply to the crop for optimum grain yield.
3. Determine whether or not the application of potassium and nitrogen is important in the production of bambara groundnut, and
4. Determine the best intra-row spacing to use in the production of bambara groundnut.

CHAPTER 2

LITERATURE REVIEW

Being one of the 'neglected' poor man's crops, bambara groundnut has not received the required research attention it deserved especially in Nigeria where it is believed to be the centre of origin of the crop. Much of the literature review that follows is therefore based largely on results reported elsewhere.

2.1 Grain Yields

Yield comparisons are complex due to the fact that yields in different countries may be expressed differently, in different units such as 'bags', and in terms of shelled or unshelled grain (Hepper, 1970). It is difficult to obtain accurate figures on production and yield of bambara groundnut since most production and consumption are local. Bambara groundnut yields are generally low in Africa with an average of 650-850kg/ha with large differences occurring between countries (Stanton et al., 1966). Grain yields which have been reported for various countries include Congo (Kahemba) 350-650kg/ha; Chad and Cameroon 500kg/ha; Benin 450-650kg/ha; Nigeria (Ogoja) 254-400kg/ha; Zambia 56-112kg/ha; Zimbabwe 3870kg/ha; and Ghana 714-1100kg/ha (FAO, 1959; Johnson, 1968; Hepper, 1970; Karikari and Lavoe, 1977; Linnemann, 1987). The potential yield of bambara groundnut is an important factor for

consideration. Begemann (1987) reported that the yield potential of bambara groundnut in Nigeria ranges between 500 and 2600kg/ha; that of groundnut averages 750kg/ha for Nigeria and 650kg/ha for all of Africa. He reported that the average pulse yield is even less; 204kg/ha for Nigeria and 467kg/ha for all of Africa. He speculated that depending on the variety and the cropping system, bambara groundnut can have a very high yield potential of about 2,500kg/ha. However, the yields of bambara groundnut are difficult to determine and compare because of the diverse intercropping systems.

2.2 Date of Sowing

Date of sowing varies in different countries, but the crop is generally grown during the rainy season. The time of sowing is reported to be a critical factor for bambara groundnut in areas with short duration of rainfall and in areas with clayey soils, where the soil hardens at the onset of dry weather (Holm and Marloth, 1940; Anonymous, 1961; Johnson, 1968). In Nigeria, the time of sowing of bambara groundnut is determined by the importance to which the farmers attaches to this crop. Normally, farmers sow their main food crops such as the cereals first after which subsidiary crops like bambara groundnut are planted (Linnemann, 1988). Sowing should however, be done as soon as the rains have established. For example in March-April in the Western highlands of

Cameroon, in July - August in the Northern Savanna Zone of Cameroon (Westphal, 1981 quoted by Linnemann, 1987). Sowing is done in November - December in Malawi (Anonymous, 1961), Swaziland (Brook et al., 1977) and Zambia (Anonymous, 1989). Late planting results in considerable yield reductions for example, sowing, on December, 14; January, 11; and February 8 in Malawi gave grain yields of 2290, 520 and 40kg/ha respectively (Anonymous, 1961). In Zambia two sowings, in December, and in January, resulted in grain yields of 2,000 and 425kg/ha respectively (Anonymous, 1989). In Zimbabwe, the best time to plant is mid-November, which time coincides with the beginning of the rainy season (Johnson, 1966). In places where the rainy season is of long duration (like Tanzania), planting is done half way through the season to enable the crop mature at the end of the rains (Anonymous, 1961). Since planting of bambara groundnut is mostly done during the rainy season, the time to plant is determined by the on-set of the rains. That is why planting is done between August - September north of the Equator and between September - December south of the Equator (Hepper, 1970). Working in Ghana, Karikari (1969) observed that yields of bambara groundnut were significantly lower during the rainy than the dry season, primarily because of more prevalent problem of pests and diseases in the former.

2.3 Spacing

The use of optimum plant spacing is essential for grain yields, particularly since this would ensure early and good ground cover and the smothering of weeds. In Nigeria, Linnemann (1988) reported that spacing is closely related to cultivation methods. She found that farmers who plant bambara groundnut on the flat use closer spacings than those that plant the crop on ridges. The average spacing on the flat is approximately 35x35cm, with the closest spacing being 20x20cm and the widest 40x40cm. Begemann (1987) reported that farmers planting on ridges generally use a distance of 50-100cm between ridges and 15-30cm between stands. The widest spacing he found was 110cm between ridges and 40cm between stands. In some instances farmers plant bambara groundnut in double or triple rows on beds at a spacing of 15x20cm. In Zimbabwe, however, Johnson (1968) reported that the recommended spacing on the flat is 10-15cm apart in single rows at a distance of 45cm, and 20cm apart in double rows on flat-topped ridges at 90cm distance. In Swaziland, unshelled yields from single rows 1m apart were lowest at 962kg/ha, followed by double rows 1m apart (1113kg/ha), then 50cm rows (1316kg/ha). These differences were significant, whereas no significant effect was found for spacings within the rows of 10, 15 or 20cm (Anonymous, 1979). In Congo, a planting distance

of 40cm square is practiced (Rassel, 1960), while Israeli (1965) quoted by Doku and Karikari (1971) reported a planting distance of 20x50cm at Burkina Fasso.

2.4 Fertilizers

Fertilizer requirements are determined by the natural fertility of the land and the previous cropping history. The number of pods per plant and number of grains per pod of bambara groundnut are both influenced by the fertility of the soil (Rassel, 1960). Nitrogen, phosphorus and potassium are the major nutrient elements required by crops in large quantities from the soil. Potassium deficiency is not as prevalent as those of nitrogen and phosphorus in the Nigerian savannas, except, in the most intensively cultivated areas such as Kano. Being a leguminous crop, bambara groundnut meets it nitrogen requirements by fixing the atmospheric-nitrogen. This implies that phosphorus becomes the most important fertilizer element that has to be applied on this crop in the savanna zones of Nigeria. Although, little or no work has been done in Nigeria, on bambara groundnut fertilizer requirements, experiences elsewhere are compiled as follows. It should be noted that the only work done on bambara groundnut fertilizer requirements found in the literature are on these three principal nutrient elements (N, P and K).

2.4.1 Nitrogen and nitrogen fixation

There are three major forms of nitrogen in mineral soils, organic nitrogen associated with the soil humus, ammonium nitrogen fixed by certain clay minerals and soluble in-organic ammonium and nitrate compounds. Most of the nitrogen in soils is associated with the organic matter. In this form it is protected from rapid microbial release (Brady 1974). Nitrogen tends primarily to encourage above ground vegetative growth and to impart to the leaves a deep green colour. Nitrogen is a regulator that governs to a considerable degree the utilization of potassium, phosphorus and other constituents (Brady, 1974). Plants receiving insufficient nitrogen are stunted in growth and possess a restricted root system. An over supply may delay crop maturation by encouraging excessive vegetative growth.

Using 23 cultivars of bambara groundnut, at Togo Dadson and Brooks (1989) reported that all cultivars nodulated freely with the indigenous rhizobia; and usually produced more nodules and greater nodule dry weight in the low nitrogen than the high-nitrogen (50kg N/ha) treatment. They also found inadequate infectivity or efficacy of the indigenous rhizobia because the high-nitrogen treatment gave higher total dry weight and grain yield than the low-nitrogen nodulated plants. They, therefore, considered necessary the application of high

nitrogen for high grain yield. However, Dadson et al. (1988) reported that inoculating bambara groundnut with rhizobia gave better grain yields than when 50kg N/ha was applied. They concluded that bambara groundnut nodulation and yield in West Africa could be enhanced by inoculation with selected indigenous rhizobia. In a greenhouse study, Gueye (1988) reported that nitrogen supplied at 20ppm N increased shoot dry weight of two bambara groundnut cultivars by about 43%. He also found an increase in the nitrogen content and total nitrogen when 20 or 100 ppm N was applied. The interaction between nitrogen and phosphorus resulted in increased shoot dry weight, nitrogen and phosphorus contents in the plants, and the total nitrogen and phosphorus of bambara groundnut cultivars (Gueye, 1988). Nitrogen fixation of 106 kg/ha by bambara groundnut was recorded by Dennis (1977). Inoculation with soil from an old field in which the crop was grown is recommended when planting in a new field (Stanton et al., 1966). In Zimbabwe, Mukurumbira (1985) found that bambara groundnut had a higher residual nitrogen effect over groundnut and fallow in affecting grain and stover yields of maize. He suggested that the residues from bambara groundnut were mineralized more readily than those from groundnut an accertion which agrees with that of Nnadi and Balasubramanian (1978) who found that about 50 per cent of the total root nitrogen

in bambara groundnut mineralized within 12 weeks.

2.4.2 Phosphorus

Soil phosphorus occurs in two forms, namely, organic phosphorus and inorganic phosphorus. The total phosphorus content of a soil depends on its organic matter content, the parent material and the degree of weathering. The organic phosphorus can be found in the organic matter of the soil and in the organisms living in the soil. The inorganic phosphorus is present in the form of compounds of Ca, Mg, Mn, Fe, Al and clay minerals and as primary apatites and other phosphorus bearing minerals (Sauchelli, 1967). The agronomic value (the quantity of the total amount of phosphorus which is taken up by the plant) of the soil phosphorus depends on its solubility. Factors favouring this solubility are: a good supply of readily decomposable organic matter, pH of between 6.5-7.5, a high level of phosphorus in the soil, a high level of soil moisture and a high silica: sesquioxide ratio (Sauchelli, 1967 and Khasewnel and Doll, 1978). The amount of phosphorus present in the soil solution (and thus available to plants) depends on the equilibrium which exist between phosphates absorbed on colloidal surfaces, together with phosphatic compounds of low solubility (Al^{-} and Fe^{-} phosphates) and the phosphate concentration in the soil solution. Water soluble phosphate fertilizers such as single super

phosphate, after dissolution, form different kinds of crystalline and amorphous products. From these products phosphates dissolve into the soil solution and become free for plant nutrition (Sauchelli, 1967; Khasewnel and Doll, 1978).

Phosphorus is used in the plant for the formation of essential nucleic acids and proteins, cell division, the formation of fats, grain germination and during the respiration processes (Sauchelli, 1967). Within the plant, phosphorus is a mobile element which does not remain fixed within the tissue in which it was initially deposited (Sauchelli, 1967).

According to Stanton et. al., (1966), it appears to be economical to apply superphosphate at planting time or later at the rate of 60kg/ha. Johnson (1966) recommended a maintenance dressing with superphosphate (19% P_2O_5) 112-170kg/ha after a well-fertilized crop such as maize, and application of compound fertilizer at rate of 225-450kg/ha on soils of low fertility. Trials in Malawi, Nigeria and Swaziland showed that no response was found when single superphosphate was applied at rates up to 336kg/ha P_2O_5/ha (Cumberland, 1978; Anonymous 1989; Nnadi et al., 1981). In some situations phosphate application may even decrease yields (Anonymous 1989). In a green-house experiment, Tanimu (1988) reported that the rates and sources of phosphorus did not affect the P-content

and the P-uptake of bambara groundnut and suggested that phosphorus may have been adequate in the growth medium or that the crop is an efficient phosphorus absorber.

2.4.3 Potassium

The various forms of potassium in soils can be classified on the basis of availability in three general groups: unavailable, readily available and slowly available. A slow change from one form to another does occur (Brady, 1974). This makes possible a fixation and conservation of added soluble potassium and a subsequent slow release of this element when the readily available supply is reduced. This element plays an important part in many of the vital physiological processes in the plant. It is essential in all cell metabolic processes and apparently has a specific role in influencing the uptake of certain other nutrients, in regulating the rate of respiration, in affecting the rate of transpiration, and aiding the action of enzymes, synthesis and translocation of carbohydrate (Foth and Turk, 1972).

The only work on potassium in bambara groundnut that was reported was conducted at Swaziland where the application of 25kg k/ha was found to increase bambara groundnut yields (Anonymous, 1979).

CHAPTER 3

MATERIALS AND METHODS

Investigations were carried out between 1986 and 1990 at Samaru on the effects of date of sowing, fertilizer application and intra-row spacing on bambara groundnut. Two trials were conducted each year, one on fertilizer requirements of bambara groundnut and the other on the suitable sowing date and intra-row spacing for the crop.

3.1 Location

The experiments were sited at Samaru (lat. 11°11'N; long. 07°38'E, 686m above sea level), Nigeria which lies in the northern Guinea Savanna, where rainfall establishes between mid-May to early June and reaches maximum in July/August. Annual rainfall ranges between 800 and 1300mm, with an average of 1000mm (Appendices 1-6). The dry season starts about mid-October to late April. The hottest months are those preceding the rains (March/April) with mean daily temperatures being above 27°C. The coldest months are November to January which period is characterized by the dry harmattan winds from the North East when temperatures average 10-15°C minimum and 21-36°C maximum.

The properties of the soils at the experimental farms are presented in Table 1. A composite random soil sample was collected (0-30cm) from each site before the

commencement of the experiment each year, and analyzed for physical and chemical characteristics. Particle size analysis by the hydrometer method showed soils to be a sandy loam. The pH range (between all fields) was 5.50-6.00 in 1:1 soil-water suspension, and 4.50-5.80 in a 1:1 soil:IN KCl solution. Total N-content, as determined by macro-Kjeldahl extraction (Bremer, 1965), Available phosphorus was determined by Bray 1 method (Bray and Kuss, 1945). Exchangeable cations were determined from a IN ammonium acetate leachate (Black, 1965), using atomic absorption spectrophotometry for calcium (Ca) and magnesium (Mg), and flame photometry for sodium (Na) and potassium (K).

3.2. Treatments and experimental designs

3.2.1 Experiment 1 - Fertilizer experiment

The treatments included factorial combinations of two levels of nitrogen (0 and 20kg N/ha); four levels of phosphorus (0, 11, 22 and 33kg P/ha) and three levels of potassium (0, 25 and 50kg K/ha). The design of the experiment was a randomized complete block with three replications. Nitrogen was applied in the form of calcium ammonium nitrate (26% N), phosphorus in the form of single superphosphate (18% P_2O_5) and potassium as muriate of potash (60% K_2O). The three fertilizers were all applied at planting along grooves made at the sides

of the ridges and were later covered with soil.

3.2.1.1 **Plot size**

Each plot was made up of six ridges and each ridge was 4m long 75cm apart. The four inner ridges constituted the net plot from which yields were measured.

3.2.1.2 **Planting**

Grains were planted by hand using guide ridges and string method in which a pair of marked planting ropes that were placed along the two outermost ridges, and an unmarked one held at either ends and moved from one mark to the next. The marks were made 10cm apart to correspond with the 10cm intra-row spacing used in the fertilizer trial.

3.2.2 Tissue analysis

Samples from each plot of (1) stems with petioles and (2) leaves were separated oven-dried at 70°C, ground with a Wiley mill and sieved with 0.5mm sieve, labelled and stored in plastic containers for subsequent chemical analyses.

3.2.3.1 **Total nitrogen**

Total percentage nitrogen was determined by the micro Kjeldahl method as described by Bremner (1965). 0.20g of the stem and petioles or leaves was weighed and placed in a digestion tube. 15ml of concentrated sulphuric acid (H_2SO_4) was added and the tube gently

swirled until the sample and acid were thoroughly mixed. Some 5g of Kjeldahl catalyst mixture was added and the tube heated cautiously until the solution cleared. A few drops of 30% H_2SO_4 was used to wash isolated sample particles down the neck of the tube and then allowed to cool down. The content of the digestion tube was then transferred into 100ml volumetric flask and diluted with distilled water to where the flask is marked and mixed thoroughly. Some 10ml of 2% boric acid and 4 drops of mixed indicator were placed in a 250ml - Erlenmeyer flask. 10ml aliquot of the digest was transferred into a distillation flask and attached to the distillation apparatus. Thereafter 10ml of 1.0N NaOH was added to the distillation flask containing the digest and distillated. The distillate was then titrated with standard 0.025N H_2SO_4 to pink end point.

The per cent N in the sample was calculated as

$$N = \frac{0.014 \times \text{Titre} \times \text{Vol. of digest} \times \text{Normality of acid} \times 100}{\text{weight of sample} \times \text{Vol. of aliquot used.}}$$

3.2.3.2 **Analysis for P,K,Ca and Mg**

Phosphorus was determined using the vanadomolydo-phosphoric acid yellow method described by Olsen and Dean (1965). Some 0.5g of the ground sample was placed in the digestion tube, 5ml of the HNO_3^- $HClO_4$ acid mixture (2:1 by volume) was added to the digestion tube and mixed. The tube was placed in a fume hood at 150°C and content allowed to digest for 1½ hours. The temperature was then

increased to 230°C and digested for 30 minutes. The digester was then switched off. The tube was removed and 30ml of distilled water added within few minutes of removing it from the digester. More distilled water was added to make up to the mark on the tubes. The P in the solution was determined calorimetrically using a spectrophotometer.

The digested samples used for the P-determination were diluted and used for K, Ca and Mg determination. K was determined by flame photometry (Heald, 1965), while Ca and Mg were determined by atomic absorption spectrophotometry (Pratt, 1965).

Table 1: Physical and chemical properties of the soils of the experimental sites (0-30cm depth).

Soil composition	1986	1987	1988	1989	1990
Mechanical composition (g/kg)					
Clay	80	170	160	60	180
Silt	420	340	300	300	220
Sand	500	490	540	640	600
Chemical composition					
pH (H_2O)	5.80	5.50	5.70	5.90	6.8
pH (KCl_2)	5.00	4.50	5.00	5.20	5.8
Organic carbon (g/kg)	6.0	3.0	5.2	2.0	2.4
Available P (mg/kg)	3.85	5.15	6.51	3.50	8.2
Total N (g/kg)	0.7	0.3	0.4	0.17	0.2
Exchangeable bases (Cmol/kg)					
Ca	1.13	0.44	0.62	2.13	4.25
Mg	0.21	0.26	0.41	0.74	1.23
K	0.09	0.09	0.18	0.15	0.15
Na	0.07	0.07	0.09	0.09	0.01
CEC	4.60	4.20	5.40	5.40	10.2

3.2.2 Experiment II - Sowing date and spacing

The treatments were five sowing dates (SD1; SD2; SD3; SD4; and SD5), four intra-row spacings (5, 10, 15 and 20cm equivalent to 266,600; 133,300; 88,850 and 66,650 plants/ha respectively) and two varieties Giwa white and "Pategi black". The design was a split plot with the dates of sowing occupying the main plots while factorial combinations of varieties and intra-row spacings were randomized in the sub plots. The experiment was replicated three times in all years. (For the various sowing dates see appendix 7).

3.2.2.1 Plot size

The sowing date and spacing experiment however had a plot size of 6m long ridges by 4 ridges that were 75cm apart. The 2 inner ridges made the net plot which was harvested for yields measurement.

3.2.2.2 Bambara groundnut varieties

Giwa-White was used in the fertilizer experiment while Giwa-White and Pategi-Black were used in the sowing date and spacing experiment. Giwa white has white grain coat and yields about 635kg/ha grains while Pategi-Black has black grain coat with grain yields of about 850kg/ha (Tanimu et al ., 1990). The grains were purchased from Giwa (Kaduna State) situated in northern Guinea savanna and Pategi (Kwara State) southern Guinea savanna. The two varieties were not uniform in their growth and

development.

3.3.2.3 Planting

For the sowing date and spacing experiment, sticks were prepared and used to plant at 5, 10, 15 and 20cm being tested. One grain was sown per hole at sowing.

3.3.2.4 Basal fertilizer application

For the sowing date and spacing experiment which had no fertilizers in its treatments, 22kg P, 25kg K and 20kg N/ha were applied each year before planting along grooves made on the sides of the ridges.

The fertilizers were applied as single superphosphate (18% P_2O_5), muriate of potash (60% K_2O) and calcium ammonium nitrate (26% N).

3.4 Cultural Practices

3.4.1 Land preparation

The experimental field was ploughed and harrowed each year after which ridges were made 75cm apart.

3.4.2 Weed, pests and disease control

Weeds were controlled by applying Galex (1:1 mixture of metabromuron and metolachlor) at 4.0 litres/ha immediately after planting for both trials. Thereafter plots were kept weed-free by manual weeding using hoe. Dithane M45 and Benlate at 1kg a.i./ha were applied in 1987, 1988, 1989 and 1990 to control rust and leaf blight caused by Puccinia sp. and colletotrichum sp. respectively.

3.4.3 Harvesting

At harvest, plants from the net plots, including roots, were carefully dug, to recover all mature pods. Pods were detached from the rest of the plant (Haulm) and were washed. The total fresh weight of haulm, was determined. The pods were air dried, weighed and shelled to recover the kernels which were weighed.

3.5 Observation

In order to determine the effects of treatments on growth, periodic measurements of ten randomly tagged plants from the net plots were made.

3.5.1 Plant height

Height was measured from ground level to the tip of the plant at 2 weekly intervals from two weeks after emergence.

3.5.2 Plant foliage spread

The average of two diameters measured as a cross is taken as the foliage spread. This was measured at 2 weekly intervals from two weeks after emergence.

3.5.3 Dry matter production

In 1990, five plants were removed from the boarder ridges of the plot at an internal of two weeks. The leaves were detached from the particles and the stems. These were oven dried and weighed to determine the dry matter distribution between the shoot parts.

3.5.4 Days to first flowering

Days to first flowering were recorded from the time of sowing to when the first flower in each plot was formed.

3.5.5 Haulm yield

The haulm from the net plots were weighed using salter scale after the pods were detached. The plot yields were then extrapolated to haulm yield (kg/ha).

3.5.6 Grain yield

The kernels obtained from the air dried pods of the net plots were weighed with a Mettler balance model 1210 and the value obtained multiplied by a factor to convert to kg/ha.

3.5.7 100-grain Weight

100 grains were counted from each treatment and weighed separately with the Mettler balance model 1210.

3.5.8 Shelling percentage

The shelling percentage was determined as weight of grains/pod weight x 100 for each plot or treatment.

$$\text{i.e Shelling \%} = \frac{\text{weight of grains}}{\text{weight of pods}} \times 100$$

3.6 Statistical Analysis

All the data collected from the experiments were subjected to statistical analysis using the two way analysis of variance method to test the significance of effects and their interactions as described by Snedecor

and Cochran (1967). Mean values were compared using the new Duncan's Multiple Range Test at the 5% level of probability. Correlation and path analysis coefficients among some observations were also calculated in accordance with Dewey and Lu (1959) and Wright (1960). Polynomial response of grain yield to fertilizer levels was also determined as described by Steel and Torrie (1984). Maximum rates were calculated using the formula of Little and Hills (1975).

CHAPTER 4

4. RESULTS

4.1 Effects of nitrogen, phosphorus and potassium fertilizers

4.1.1 Plant height

The main effects of nitrogen, phosphorus and potassium fertilizers on bambara groundnut plant height two weeks after emergence for 1986 to 1990 and the combined data are shown in Table 2. Application of 20kg N/ha did not significantly affect the height of the crop at two weeks after emergence in any of the five years and even when the data were pooled.

Phosphorus application was found to affect the height of the crop significantly only in 1987 and 1988 but not in 1986, 1989 and 1990. In 1987 the application of phosphorus resulted in depressed height, while in 1988 the application of 11kg P/ha resulted in taller plants than when 22kg P/ha was applied.

At two weeks after emergence in 1986 and 1990 the application of 50kg K/ha resulted in plants that were significantly shorter than those that received no potassium application.

Table 2: Effects of nitrogen, phosphorus and potassium fertilizers on bambara groundnut plant height (cm) 2 weeks after emergence at Samaru.

Treatment (kg/ha)	Years					
	1986	1987	1988	1989	1990	Pooled
Nitrogen (N)						
0	8.7	10.7	8.9	8.7	9.2	9.2
20	8.8	10.6	8.7	9.1	9.2	9.3
SE±	0.21	0.14	0.14	0.21	0.15	0.17
Phosphorus (P)						
0	8.6	11.1a	8.9ab	8.6	9.1	9.3
11	8.8	10.5ab	9.2a	9.0	9.2	9.4
22	8.9	10.8ab	8.5b	9.0	9.0	9.2
33	8.7	10.3b	8.6ab	9.1	9.3	9.2
SE±	0.28	0.21	0.21	0.28	0.21	0.24
Potassium (K)						
0	9.1a	10.7	8.3b	8.9	9.5a	9.3
25	8.6ab	10.6	8.9ab	8.9	9.1ab	9.2
50	8.5b	10.7	9.2a	9.0	8.9b	9.3
SE±	0.21	0.21	0.21	0.28	0.19	0.22
Treatment Interactions						
NxP	NS	NS	NS	NS	NS	NS
NxK	*	NS	NS	NS	NS	NS
PxK	NS	NS	**	NS	NS	NS
NxPxK	NS	NS	NS	NS	NS	NS

Means in a column of any set of treatments within a year followed by unlike letter(s) are significantly different at 5% level using DMRT.

In 1988, however, potassium application of this same level significantly enhanced the height of the crop over the no potassium treatment. In 1987 and 1989 the differences in plant height between the various levels of potassium were not statistically significant. The interactions between nitrogen and potassium and between phosphorus and potassium were significant in 1986 and 1988 respectively.

At 0kgN/ha there was no difference among the rates of potassium. However, at 20kg N/ha taller plants were produced by the no-potassium treatment. Comparing the nitrogen rates at similar potassium rates, it was found that at 0kg K/ha the application of 20kgN/ha resulted in the tallest plant. There was no significant difference between the nitrogen rates at 50kg K/ha (Table 3).

There was no difference between the potassium levels at each of the phosphorus levels except at 11kg P/ha when the application of 50kg K/ha produced the tallest plants (Table 4). The tallest plants were produced with the application of 33kg P/ha at 25kg K/ha. However, at 50kg K/ha, the tallest plants were produced with the application of 11kg P/ha.

Table 3: Interactions between nitrogen and potassium on plant height (cm) of bambara groundnut two weeks after emergence at Samaru, 1986.

Nitrogen rate (kgN/ha)	Potassium rate (kgK/ha)		
	0	25	50
0	9.2bc	10.1ab	9.2bc
20	10.5a	8.9c	8.6c
SE± 0.42			

Means values followed by unlike letter(s) differ significantly at 5% level using DMRT.

Table 4. Interactions between phosphorus and potassium on plant height (cm) of bambara groundnut two weeks after emergence at Samaru, 1988.

Phosphorus rate (kgP/ha)	Potassium rates (kgK/ha)		
	0	25	50
0	9.1b	8.4b	9.2b
11	8.5b	8.8b	10.4a
22	8.3b	9.1b	8.1b
33	7.3b	9.5ab	8.9b
SE± 0.36			

Means values followed by unlike letter(s) differ significantly at 5% level using DMRT.

At four weeks after emergence the application of 20kg N/ha did not result in statistically significant differences in the height of the crop in all the years except when the data were pooled. At this stage the control plants were significantly taller than those when 20kgN/ha was applied (Table 5). Phosphorus application at 22kgP/ha enhanced plant height in 1986 significantly. The application of potassium was found to significantly reduce the height of the crop at four weeks after emergence in 1986 only. However, no significant differences were observed in any of the other years.

Table 5: Effects of nitrogen, phosphorus and potassium fertilizers on bambara groundnut plant height (cm) 4 weeks after emergence at Samaru.

Treatment (kg/ha)	Years					
	1986	1987	1988	1989	1990	Pooled
Nitrogen (N)						
0	9.5	15.8	11.7	11.3	10.2	11.7a
20	9.3	13.7	11.6	11.3	10.1	11.2b
SE±	0.21	0.14	0.14	0.14	0.15	0.16
Phosphorus (P)						
0	8.8b	14.0	11.0	11.5	10.1	11.1
11	9.6ab	13.6	11.5	11.5	10.1	11.3
22	9.8a	13.8	11.5	10.9	10.3	11.3
33	9.4ab	13.5	11.8	11.2	10.1	11.2
SE±	0.35	0.21	0.16	0.21	0.21	0.23
Potassium (K)						
0	9.8a	13.8	11.7	11.4	10.3	11.4
25	9.5ab	13.6	11.7	11.3	10.2	11.3
50	8.9b	13.7	11.5	11.1	9.9	11.0
SE±	0.28	0.14	0.13	0.14	0.18	0.17
Treatment Interactions						
NxP	NS	NS	NS	NS	NS	NS
NxK	NS	NS	**	NS	NS	NS
PxK	NS	NS	NS	NS	NS	NS
NxPxK	NS	NS	NS	NS	NS	NS

Means in a column of any set of treatments within a year followed by unlike letter(s) are significantly different at 5% level using DMRT.

The interactions between nitrogen and potassium for plant height were significant in 1988 only. The application of 20kg N/ha produced the tallest plants at 0kg K/ha, whereas the opposite was true at 25 and 50kg K/ha (Table 6). Varying the potassium rates but at the same nitrogen rates, the control plots were significantly shorter than those in which 25kg K/ha was applied. When no potassium was applied, the crop grew tallest in plots where 20kg N/ha was applied.

Table 6: Interactions between nitrogen and potassium on plant height (cm) of bambara groundnut four weeks after emergence at Samaru, 1988.

Nitrogen rate (kgN/ha)	Potassium rate (kgK/ha)		
	0	25	50
0	11.4c	12.0ab	11.7abc
20	12.1a	11.5bc	11.3c

SE ± 0.19

Means values followed by unlike letter(s) differ significantly at 5% level using DMRT.

Table 7: Effects of nitrogen, phosphorus and potassium fertilizers on plant height (cm) at harvest at Samaru.

Treatment (kg/ha)	Years					
	1986	1987	1988	1989	1990	Pooled
Nitrogen (N)						
0	21.0	21.1	19.1	20.2	18.4b	20.0
20	21.4	21.4	19.1	20.4	19.5a	20.4
SE±	0.64	0.36	0.14	0.21	0.28	0.32
Phosphorus (P)						
0	20.4	22.0a	19.5a	21.3	18.9	20.4
11	20.9	20.8abc	19.0ab	20.2	18.8	19.9
22	22.2	21.8ab	19.1ab	19.8	18.8	20.3
33	21.2	20.4c	18.8b	19.9	19.2	19.9
SE±	0.85	0.50	0.21	0.50	0.39	0.49
Potassium (K)						
0	22.0	21.4	19.3	19.8	18.8	20.3
25	21.7	20.9	19.1	20.2	19.0	20.2
50	19.8	21.4	18.9	20.3	19.0	19.9
SE±	0.78	0.42	0.18	0.42	0.34	0.43
Interactions						
NxP	NS	NS	NS	NS	NS	NS
NxK	*	NS	NS	NS	NS	NS
PxK	NS	NS	NS	NS	NS	NS
NxPxK	NS	NS	NS	NS	NS	NS

Means in a column of any set of treatments within a year followed by unlike letter(s) are significantly different at 5% level using DMRT.

When potassium rates were compared at similar nitrogen rates, it was found that at 0kg N/ha there was no difference between the different K rates (Table 8). However, at 20kg N/ha, the control produced significantly taller plants than when 50kg K/ha was applied. The difference between 0 and 25kg K/ha was not significant. Similarly there was no difference between 25 and 50kg K/ha. When different nitrogen rates were compared at similar K rates, it was found that there was no difference between the nitrogen rates.

Table 8: Interactions between nitrogen and potassium on plant height (cm) at harvest at Samaru, 1986.

Nitrogen rate (kgN/ha)	Potassium rates (kgK/ha)		
	0	25	50
0	20.3ab	22.0ab	20.8abc
20	23.7a	21.5ab	18.9b
SE ± 1.05			

Means values followed by unlike letter(s) differ significantly at 5% level using DMRT.

4.1.2 Plant foliage spread:

Table 9 shows the effect of the various levels of the three fertilizer elements on the plant foliage spread at two weeks after emergence. The application of nitrogen resulted in increased spread of the bambara groundnut foliage only in 1988, however, no significant differences were observed in the rest of the years of experimentation. The application of phosphorus generally did not cause significant differences in the foliage spread of the crop except in 1988 when the application of 11kg P/ha gave significantly widest spread.

No statistically significant differences were found with the application of potassium in 1986 and 1987. However, in 1988, 1989 and 1990 significant differences were observed. In 1988, the application of 50kg K/ha gave significantly better ground cover than 25kg K/ha which in turn was better than when no K was applied.

In 1989 and 1990 the application of 0 and 25kg K/ha respectively gave the widest foliage spread. There were significant interactions between nitrogen and phosphorus in 1988.

Table 9: Effects of nitrogen, phosphorus and potassium fertilizers on bambara groundnut plant foliage spread (cm) 2 week after emergence at Samaru.

Treatment (kg/ha)	Years					
	1986	1987	1988	1989	1990	Pooled
Nitrogen (N)						
0	10.7	15.5	16.5b	16.3	17.8	15.4
20	10.5	15.4	17.3a	16.7	18.2	15.6
SE±	0.14	0.05	0.18	0.36	0.29	0.20
Phosphorus (P)						
0	10.5	15.3	16.4b	15.9	18.4	15.3
11	10.6	15.5	18.1a	16.6	17.6	15.7
22	10.6	15.4	16.7b	17.0	18.0	15.5
33	10.6	15.5	16.5b	16.4	17.9	15.4
SE±	0.14	0.07	0.26	0.50	0.41	0.22
Potassium (K)						
0	10.8	15.4	15.9c	17.1a	18.0ab	15.4
25	10.5	15.4	16.9b	16.5ab	18.6a	15.6
50	10.6	15.5	17.9a	15.8b	17.4b	15.4
SE±	0.14	0.06	0.22	0.42	0.36	0.24
Treatment Interactions						
NxP	NS	NS	*	NS	NS	NS
NXK	NS	NS	NS	NS	NS	NS
PxK	NS	NS	NS	NS	NS	NS
NxPxK	NS	NS	NS	NS	NS	NS

Means in a column of any set of treatments within a year followed by unlike letter(s) are significantly different at 5% level using DMRT.

Application of 20kg N/ha in combination with 11 kgP/ha produced the widest foliage spread (Table 10). There was no significant difference between the nitrogen rates at the other rates of phosphorus. Similarly, there was no difference between the phosphorus rates at 0kg N/ha.

Table 10: Interactions between nitrogen and phosphorus on bambara groundnut foliage spread (cm) at two weeks after emergence at Samaru, 1988.

Nitrogen rate (kgN/ha)	Potassium rates (kgK/ha)			
	0	11	22	33
0	15.8b	17.2b	17.0b	16.2b
20	16.9b	18.9a	16.4b	16.8b
SE± 0.36				

Means values followed by unlike letter(s) differ significantly at 5% level using DMRT.

The effect of nitrogen application on bambara groundnut foliage spread four weeks after emergence was not statistically significant in any of the years of experimentation not even when the data were pooled Table 11).

Phosphorus application did not affect the foliage spread of the crop significantly in any of the years and when the data were pooled.

The application of potassium affected the plant foliage spread significantly only in 1988, when 25kg K/ha resulted in the ground cover more than 0kgK/ha. In 1986, 1987, 1989 and 1990 the application of potassium did not result in significant differences in the foliage spread of the crop.

Table 11: Effects of nitrogen, phosphorus and potassium fertilizers on bambara groundnut spread (cm) 4 weeks after emergence at Samaru.

Treatment (kg/ha)	1986	Years 1987	1988	1989	1990	Pooled
Nitrogen (N)						
0	24.9	26.4	25.9	25.3	26.1	25.7
20	25.8	26.6	26.3	25.3	26.5	26.1
SE±	0.57	0.21	0.24	0.36	0.36	0.35
Phosphorus (P)						
0	24.6	26.7	26.1	25.0	26.5	25.8
11	25.6	26.7	26.1	25.6	27.1	26.3
22	25.9	27.0	26.1	25.0	25.9	26.0
33	25.2	26.0	26.3	25.5	25.7	25.7
SE±	0.78	0.35	0.34	0.50	0.52	0.50
Potassium (K)						
0	26.3	26.8	25.7b	25.5	26.0	26.1
25	25.3	26.3	26.4a	25.4	26.1	25.9
50	24.4	26.4	26.2ab	25.0	26.9	25.8
SE±	0.71	0.28	0.30	0.42	0.45	0.43
Treatment Interactions						
NxP	NS	NS	NS	NS	NS	NS
NxK	NS	NS	NS	NS	NS	NS
PxK	NS	NS	*	NS	NS	NS
NxPxK	NS	NS	NS	NS	NS	NS

Means in a column of any set of treatments within a year followed by unlike letter(s) are significantly different at 5% level using DMRT.

Interactions between the treatment factors were only significant between phosphorus and potassium in 1988. The narrowest foliage spread was recorded at 0kg P/ha with 0kg K/ha (Table 12). The differences between the various phosphorus rates were not significant when compared at similar potassium rates. Similarly, there was no significant difference between the potassium rates at similar levels of phosphorus.

Table 12: Interactions between potassium and phosphorus on bambara groundnut foliage spread (cm) four weeks after emergence at Samaru, 1988.

Phosphorus rate (kgP/ha)	Potassium rates (kgK/ha)		
	0	25	50
0	24.3b	27.2a	26.7a
11	26.3a	26.2ab	25.6ab
22	25.5ab	26.2ab	26.5a
33	26.7a	26.0ab	26.1ab
SE ± 0.59			

Mean values followed by unlike letter(s) differ significantly at 5% level using DMRT.

The effects of the three fertilizer nutrients on foliage spread of bambara groundnut at harvest from 1986 to 1990 and the pooled data over years are shown in Table 13.

Nitrogen fertilizer application was observed to have increased the crop's foliage spread significantly only in 1989 when the application of 20kg N/ha significantly resulted in wider foliage spread than when there was no nitrogen at all. In other years however, no significant effects were observed.

No significant effect was observed with phosphorus application in all the years of the study and when the data were pooled.

Potassium fertilizer application depressed crop foliage spread at harvest significantly only in 1986 while in other years no significant response occurred. The only interaction that was significant was that between phosphorus and potassium in 1989.

Table 13: Effects of nitrogen, phosphorus and potassium fertilizers on bambara groundnut plant spread (cm) at harvest at Samaru.

Treatment (kg/ha)	Years					
	1986	1987	1988	1989	1990	Pooled
Nitrogen (N)						
0	28.1	32.0	33.7	39.6b	45.9	35.9
20	28.9	32.2	34.2	41.9a	47.6	36.9
SE±	0.57	0.28	0.48	1.13	0.88	0.67
Phosphorus (P)						
0	27.8	32.5	33.4	39.2	47.2	36.0
11	28.9	32.1	33.8	42.2	47.4	36.9
22	29.1	32.4	35.1	42.1	46.5	37.0
33	28.2	31.3	33.5	38.9	45.9	35.5
SE±	0.78	0.35	0.68	1.56	1.25	0.92
Potassium (K)						
0	29.5a	32.2	34.0	40.9	45.3	36.4
25	28.5ab	32.0	34.2	40.5	47.5	36.5
50	27.5b	32.0	33.6	40.4	47.4b	36.2
SE±	0.64	0.28	0.59	1.34	1.08	0.79
Treatment Interactions						
NxP	NS	NS	NS	NS	NS	NS
NXK	NS	NS	NS	*	NS	NS
PxK	NS	NS	NS	NS	NS	NS
NxPxK	NS	NS	NS	NS	NS	NS

Means in a column of any set of treatments within a year followed by unlike letter(s) are significantly different at 5% level using DMRT.

The results of the interactions are presented in Table 14. Varying the rates of phosphorus at similar potassium rates, 0kg P/ha had the narrowest spread at 25kg K/ha, while the application of 11 kgP/ha at 50kg K/ha gave the widest spread. When different potassium rates were compared at similar phosphorus levels, it was found that the application of 25kg K/ha produced the narrowest foliage spread at 0kg P/ha.

Table 14: Interactions between potassium and phosphorus on bambara groundnut foliage spread (cm) at harvest, Samaru 1989.

Phosphorus rate (kgP/ha)	Potassium rates (kgK/ha)		
	0	25	50
0	43.2abc	34.8c	39.5abc
11	38.6abc	41.8abc	46.3a
22	44.5ab	42.4abc	39.5abc
33	37.3abc	42.9abc	36.5bc
SE ± 2.72			

Mean values followed by unlike letter(s) differ significantly at 5% level using DMRT.

4.1.3 Dry weight of leaves

Table 15 shows the dry weights of the bambara groundnut leaves/plant at different stages of sampling. At all the stages of sampling, nitrogen was observed to have no significant effect on the dry weights of leaves per plant and even when the data were pooled. The application of phosphorus had varying effects on the dry weights of the leaves but it was only at four weeks after emergence that the differences between the phosphorus treatments were significant. The application of 22kg P/ha was found to enhance the leaf dry weights most at this stage of sampling. At no other stage of sampling was phosphorus found to significantly affect the leaf dry weight of the crop.

Potassium application had no significant effect on the leaf dry weight at all the stages of sampling. In general the dry weights of the bambara groundnut leaves reached its peak at about 10 weeks after emergence. The interactions between the various fertilizer treatments were not significant at all the stages of sampling.

Table 15: Effects of nitrogen, phosphorus and potassium fertilizers on leaves drying weight/plant (g) of bambara groundnut at Samaru, 1990

Treatment (kg/ha)	Weeks after emergence					
	2	4	6	8	10	12
Nitrogen (N)						
0	6.2	42.8	84.9	117.6	134.4	62.1
20	6.4	43.6	96.6	131.5	138.2	70.8
SE±	0.20	2.98	4.95	5.82	4.48	5.67
Phosphorus (P)						
0	6.1	48.7ab	100.2	125.2	135.7	61.3
11	5.7	36.4b	81.9	122.6	139.2	74.5
22	6.9	50.1a	88.5	113.2	138.5	66.0
33	6.2	37.7b	92.5	137.1	131.8	64.1
SE±	0.29	4.22	7.00	8.23	6.33	8.01
Potassium (K)						
0	6.5	45.0	90.1	127.7	138.7	71.7
25	6.3	41.8	91.8	126.3	143.7	63.1
50	6.1	42.9	90.4	119.7	126.5	64.6
SE±	0.25	3.65	6.06	7.13	5.48	6.94
Treatment Interactions						
NxP		NS	NS	NS	NS	NS
NxK		NS	NS	NS	NS	NS
PxK		NS	NS	NS	NS	NS
NxPxK		NS	NS	NS	NS	NS

Means in a column of any set of treatments within a year followed by unlike letter(s) are significantly different at 5% level using DMRT.

4.1.4 Dry weights of stems and petioles

Table 16 shows the dry weights of the stems and petioles of the bambara groundnut at various stages of sampling in 1990. It was only at 8 weeks after emergence that the effect of nitrogen application was significant on the stem and petiole dry weights per plant, when the 20 kg N/ha application resulted in significantly higher dry weights per plant. At the other stages of sampling no significant decrease in the dry weights was observed.

Phosphorus had no significant effect on the stem and petiole dry weights of bambara groundnut at all the stages of sampling.

Similar to nitrogen application, the application of potassium had significant effect only at the 8th week sampling, when the 25kg K/ha had the best dry weights followed by the control and the 50kg K/ha in that order and each was significantly higher than the other.

Table 16: Effects of nitrogen, phosphorus and potassium fertilizers on stem and petiole dry weight/plant (g) of bambara groundnut at Samaru, 1990

Treatment (kg/ha)	Weeks after emergence 2	4	6	8	10	12
Nitrogen (N)						
0	2.8	22.5	69.2	78.8	96.9	138.1
20	2.7	22.0	79.2	95.2	93.0	162.0
SE±	0.11	1.85	3.98	2.36	4.22	11.32
Phosphorus (P)						
0	2.7	25.8	77.4	92.4	79.9	147.9
11	2.7	18.8	69.1	97.4	81.3	154.9
22	2.9	25.0	71.8	98.4	82.1	167.4
33	2.8	19.4	78.5	96.0	100.5	130.0
SE±	0.15	2.62	5.61	4.05	5.97	16.01
Potassium (K)						
0	2.9	24.2	72.1	95.5b	90.7	168.3
25	2.8	21.5	77.6	107.7a	85.1	136.4
50	2.6	21.0	72.8	85.1c	81.9	145.4
SE±	0.13	2.27	4.86	3.51	5.17	13.87
Treatment Interactions						
NxP	NS	NS	NS	NS	NS	
NxK	NS	NS	NS	NS	NS	
PxK	NS	NS	**	NS	NS	
NxPxK	NS	NS	NS	NS	NS	

Means in a column of any set of treatments within a year followed by unlike letter(s) are significantly different at 5% level using DMRT.

The only interaction that was significant was that between phosphorus and potassium at the 8th week after emergence which is presented in Table 17. It was found that at 0kg K/ha the 11 kgP/ha treatment gave the highest stem and petiole dry weights. Dry matter production was at par with each other at this potassium level. At 25kg K/ha level, the 33kg P/ha treatment gave significantly higher stem and petiole dry weights than the other treatment levels. At the 50kg K/ha level however, 22kg P/ha resulted in the highest stem and petiole dry weights than the other treatment levels which were at par with each other. When the different potassium levels are compared at same phosphorus level, it was observed that at 0kg P/ha all the potassium levels were similar in their effects. At the 11 kgP/ha level, the control and 25kg K/ha produced similar effects but significantly different from the 50kg K/ha level. At 22kg P/ha all the potassium levels were similar while at 33kg P/ha level, the 25kg K/ha gave significantly most dry weights than the control and the 50kg K/ha which were at par.

Table 17: Interactions between potassium and phosphorus on the stem and petiole dry weight/plant (g) of bambara groundnut ten weeks after emergence at Samaru, 1990.

Phosphorus rate (kgP/ha)	Potassium rates (kg K/ha)		
	0	25	50
0	92.7bcd	96.8bcd	87.7bcd
11	106.7b	106.3b	79.3cd
22	98.0bc	98.5bc	98.8bc
33	84.5bcd	129.1a	74.4d
SE ± 7.02			

Mean values followed by unlike letter(s) differ significantly at 5% level using DMRT.

4.1.5 Number of days to first flower:

Table 18 shows the effect of nitrogen, phosphorus and potassium fertilizer nutrients on the number of days to first flower production of bambara groundnut. The application of 20kg N/ha was found to have no effect on the period the crop took to produce the first flower except when the results were pooled when the control took longer period to produce flowers.

Like the fertilizer nitrogen, the application of phosphorus did not significantly affect the time the crop took to produce the first flower except in 1989 and also when the results were pooled. The application of 11

kgP/ha was observed to reduce the number of days to flower production significantly in 1989 and when the data were pooled.

Potassium like nitrogen and phosphorus did not significantly affected the number of days to flowering in all the years of experimentation except when the data were pooled. The application of 25kg K/ha reduced the number of days to first flower.

Interactions between the main treatments were not statistically significant in all the years of the trial.

Table 18: Effects of nitrogen, phosphorus and potassium fertilizers on number of days to first flowering of bambara groundnut at Samaru.

Treatment (kg/ha)	Years				
	1987	1988	1989	1990	Pooled
Nitrogen (N)					
0	44	12	48	42	44a
20	44	42	44	42	43b
SE±	0.25	0.13	0.21	0.20	0.20
Phosphorus (P)					
0	44	42	48a	43	44a
11	44	41	46b	42	43b
22	45	42	46b	43	44a
33	44	42	45b	43	44a
SE±	0.35	0.18	0.28	0.28	0.27
Potassium (K)					
0	44	42	47	42	44a
25	44	41	46	42	43b
50	45	42	46	42	44a
SE±	0.28	0.16	0.28	0.25	0.24
Treatment Interactions					
NxP	NS	NS	NS	NS	NS
NXK	NS	NS	NS	NS	NS
PxK	NS	NS	NS	NS	NS
NxPxK	NS	NS	NS	NS	NS

Means in a column of any set of treatments within a year followed by unlike letter(s) are significantly different at 5% level using DMRT.

4.1.6 Number of stands at harvest

The stand establishment of the bambara groundnut is presented in Table 19.

The application of nitrogen reduced the number of stands at harvest in 1987 significantly. In the years 1986, 1988, 1989, 1990 and when the data were pooled nitrogen had no significant effect on stand establishment at harvest. The application of phosphorus significantly reduced the number of stands at harvest only in 1987, while no definite trend was observed in the year 1986, 1988, 1989 and 1990 and when the results were pooled. In 1987, the application of potassium significantly reduced the number of stands at harvest. The interaction between nitrogen and potassium in 1986 was the only interaction that was statistically significant.

Table 19: Effects of nitrogen, phosphorus and potassium fertilizers on stand count/18m^2 at harvest of bambara groundnut at Samaru.

Treatment (kg/ha)	Years					
	1986	1987	1988	1989	1990	Pooled
Nitrogen (N)						
0	65	39a	33	72	61	54
20	64	35b	33	72	63	53
SE±	1.27	1.06	1.84	2.69	2.0	1.77
Phosphorus (P)						
0	64	40a	32	72	63	53
11	66	38ab	32	70	66	54
22	65	35	34	75	61	54
33	63	36ab	35	71	57	52
SE±	1.84	1.49	2.55	3.82	2.83	2.51
Potassium (K)						
0	65	45a	30	71	62	55
25	66	37b	36	75	58	54
50	62	33	33	70	60	52
SE±	1.61	1.34	2.19	3.25	2.45	2.17
Interactions						
NxP	NS	NS	NS	NS	NS	NS
NxK	*	NS	NS	NS	NS	NS
PxK	NS	NS	NS	NS	NS	NS
NxPxK	NS	NS	NS	NS	NS	NS

Means in a column of any set of treatments within a year followed by unlike letter(s) are significantly different at 5% level using DMRT.

The results of the interactions are present in Table 20. The largest number of stands were maintained by the control under 0kg K/ha. The difference between the nitrogen rates under other rates of potassium were not significant. Similarly, there was no difference between the potassium rates at 20kg N/ha.

Table 20: Interactions between nitrogen and potassium on the number of bambara groundnut stands per plot at harvest at Samaru, 1986.

Nitrogen rate (kgN/ha)	Potassium rates (kgK/ha)		
	0	25	50
0	68.8a	65.7abc	59.4c
20	61.2bc	66.8bc	64.8abc

SE± 2.23

Mean values followed by unlike letter(s) differ significantly at 5% level using DMRT.

4.1.5 Haulm yield per hectare

The crop grew most luxuriantly and hence produced the most haulm in 1989 followed by 1990, 1986, 1987 and 1988 in that order with a range of between 1047 to 4197 kg/ha. The application of 20kg N/ha was found to be beneficial in haulm production in all the years of experimentation and when the results were pooled although no significant differences were observed between the application and non application except in 1990 when the

control resulted in significantly higher haulm yield than non application. (Table 21). Applying phosphorus resulted in significant differences only 1990. In other years the differences were statistically not significant. The application of 11 kgP/ha resulted in significantly more haulm than other treatments.

The application of potassium depressed the haulm yield per hectare significantly in 1987. In 1986, 1988, 1989, 1990 and the pooled results the application of potassium tended to reduce the haulm yield even though no significant differences where observed between the levels of the potassium applied.

Table 21: Effects of nitrogen, phosphorus and potassium fertilizers on haulm yield (kg/ha) of bambara groundnut at Samaru.

Treatment (kg/ha)	1986	Years 1987	1988	1989	1990	Pooled
Nitrogen (N)						
0	3313	1733	1287	3739	3637a	2742
20	3961	1760	1293	3932	2877b	2765
SE±	196.65	173.24	122.49	175.15	172.60	168.82
Phosphorus (P)						
0	3432	1843	1290	3741	3273ab	2716
11	3009	1972	1352	3852	3809a	2799
22	3318	1516	1047	4197	3072ab	2630
33	2790	1556	1432	3552	2875b	2441
SE±	278.10	244.66	173.23	247.63	244.06	237.54
Potassium (K)						
0	3436	2203a	1160	3843	3200	2768
25	3056	1604ab	1287	3695	3553	2639
50	2921	1358b	1408	3968	3019	2535
SE±	240.84	212.13	150.03	165.03	211.36	205.77
Treatment Interactions						
NxP	NS	NS	NS	NS	NS	NS
NxK	NS	NS	NS	NS	NS	NS
PxK	NS	NS	NS	NS	NS	NS
NxPxK	NS	NS	NS	NS	NS	NS

Means in a column of any set of treatments within a year followed by unlike letter(s) are significantly different at 5% level using DMRT.

None of the interactions was statistically significant in all the years.

4.1.7 Grain yield per hectare

The crop yielded most grains in 1989 followed by 1990, 1988, 1986 and 1987 in that order. The yield ranged between 324-2702kg/ha (Table 22). The application of nitrogen did not cause statistically significant differences in the grain yield of the crop in all the years and when the data were pooled. The only exception was 1990 when plots that received 20kgN/ha produced significantly higher grain yield than those that had no nitrogen. In 1986, the application of 11 kgP/ha gave significantly higher yield than 33kg P/ha but was at par with 22kg P/ha and the control while in 1989 22kg P/ha resulted in the higher grain yield than the other phosphorus levels which were at par.

Potassium increased grain significantly in 1986 and 1988 only. In 1986 grain yield was significantly higher using 50kg K/ha compared with the either the control or 25kg K/ha which were at par. In 1988, the application of 25kg K/ha gave the highest grain yield and was at par with 50kg K/ha but higher than the control.

Table 22: Effects of nitrogen, phosphorus and potassium fertilizers on grain yield (kg/ha) of bambara groundnut at Samaru.

Treatment (kg/ha)	Years					
	1986	1987	1988	1989	1990	Pooled
Nitrogen (N)						
0	485	344	1541	2261	1551b	1236
20	478	356	1312	2210	1694a	1210
SE±	28.28	40.38	139.75	178.12	119.81	101.27
Phosphorus (P)						
0	454ab	340	1462	2157ab	1722	1227
11	554a	348	1516	1870b	1821	1222
22	519ab	341	1356	2702a	1547	1243
33	428b	372	1371	2212ab	1397	1156
SE±	40.02	57.13	197.64	251.87	169.40	143.14
Potassium (K)						
0	455ab	398	1193b	2295	1339	1136
25	446b	324	1735a	2311	1744	1312
50	549a	328	1351ab	2100	1784	1222
SE±	34.65	49.50	171.16	218.14	146.71	124.03
Treatment Interactions						
NxP	NS	NS	NS	NS	*	NS
NxK	NS	NS	NS	NS	NS	NS
PxK	NS	NS	*	NS	NS	NS
NxPxK	NS	NS	NS	NS	NS	NS

Means in a column of any set of treatments within a year followed by unlike letter(s) are significantly different at 5% level using DMRT.

The interaction between phosphorus and potassium was significant in 1988 while that between phosphorus and nitrogen was significant in 1990. Table 23 shows the interaction between the fertilizer treatments. Varying potassium levels at similar phosphorus rates, the highest grain yield was obtained from the application of 25kg K/ha at 11 kgP/ha. However, when different phosphorus levels, were compared at similar potassium levels, there were no differences between the phosphorus rates at all the levels of potassium.

Table 23: Interactions between phosphorus and potassium on bambara groundnut grain yield (kg/ha) at Samaru, 1988.

Phosphorus rate (kgP/ha)	Potassium rates (kgK/ha)		
	0	25	50
0	947.1a	1714.3ab	1725.8ab
11	1394.9ab	2432.3a	720.2b
22	1538.0ab	1435.5ab	1095.0b
33	893.3b	1357.9ab	1863.1ab
SE ± 342.3			

Mean values followed by unlike letter(s) differ significantly at 5% level using DMRT.

Table 24 shows the interaction between nitrogen and phosphorus on grain yield in 1990. Comparing the effect of nitrogen rates at different phosphorus levels, the application of 20kg N/ha at 0kg P/ha resulted in the best grain yield. When neither nitrogen nor phosphorus was applied, the grain yield was lower compared to all other treatments. The application of 20kgN/ha at 0 and 11 kgP/ha and the application of 11 and 22kg P/ha at 0kg N/ha resulted in the best yields of grain.

Table 24: Interactions between nitrogen and phosphorus on bambara groundnut grain yield (kg/ha) at Samaru, 1990

Nitrogen rate (kgN/ha)	Phosphorus rates (kgP/ha)			
	0	11	22	33
0	1250.9b	1736.2ab	1728.0ab	1487.65ab
20	2193.9a	1907.5ab	1367.9ab	1305.8ab
SE± 239.57				

Mean values followed by unlike letter(s) differ significantly at 5% level using DMRT.

4.1.8 100-grain weight

100-grain weight was highest in 1987 followed by 1986, 1988, 1990 and 1989 in that order and ranged between 57.10 to 84.40 grams in 1989 and 1987 respectively (Table 25).

Nitrogen application resulted in significant differences in 1989 only when the 20kg N/ha caused a significant reduction in the weight of the 100 - grains. In the other years of experimentation the application of nitrogen did not cause significant differences and even when the data were pooled. In 1988 the application of 22kg P/ha gave the highest grain weight. In 1990, the application of 11 kgP/ha gave the highest grain weight even though differences between the levels of phosphorus applied were not statistically significant, except in 1990 when it was followed by 0, 22kg P/ha and were at par with each other but was significantly different from the 33kg P/ha treatment. In 1986, 1987 and 1990 phosphorus application did not cause significant differences in the 100-grain weight of the crop. Potassium application resulted in significant differences in 1989 only when the application of 25kg K/ha gave the highest 100-grain weight. The differences were not significant in the other years of experimentation and when the data were pooled.

Table 25: Effects of nitrogen, phosphorus and potassium fertilizers on 100-grain weight (g) of bambara groundnut at Samaru.

Treatment (kg/ha)	Years					
	1986	1987	1988	1989	1990	Pooled
Nitrogen (N)						
0	77.5	78.4	75.6	63.4a	70.1	73.0
20	77.0	84.4	73.9	57.2b	66.2	71.8
SE±	1.49	2.62	1.63	1.77	2.28	1.95
Phosphorus (P)						
0	76.5	79.8	72.7ab	60.3	71.8ab	72.2
11	78.2	82.9	74.4ab	62.3	74.3a	74.4
22	78.4	79.1	79.6a	58.0	65.6ab	72.1
33	76.3	83.8	72.3b	60.6	60.8b	70.8
SE±	2.05	3.75	2.30	2.48	3.22	2.76
Potassium (K)						
0	78.3	81.0	73.7	57.9b	66.4	71.5
25	76.0	82.8	77.1	65.9a	70.0	74.4
50	77.7	80.4	73.4	57.1bc	68.1	71.3
SE±	1.77	3.25	1.99	2.12	2.79	2.38
Treatment interactions						
NxP	NS	NS	NS	NS	NS	NS
NxK	NS	NS	NS	NS	NS	NS
PxK	NS	NS	NS	NS	NS	NS
NxPxK	NS	NS	NS	NS	NS	NS

Means in a column of any set of treatments within a year followed by unlike letter(s) are significantly different at 5% level using DMRT.

In all the years of study the interactions between the treatment factors were not significant.

4.1.9 Shelling percentage

This parameter was determined in 1986, 1988, and 1990 and ranged between 40.20 in 1988 to 59.60 in 1986 (Table 26).

Nitrogen application was observed to depress the shelling percentage significantly in 1986 while no differences were observed in 1988, 1990 and when the results were pooled.

Phosphorus application did not cause significant differences between the treatments in the three years.

Potassium application enhanced the shelling percentage in 1986. In 1986, the application of 50kg K/ha significantly increased the shelling percentage In 1988 and 1990, potassium application did not cause significant differences between the treatments on shelling percentage. None of the interactions between the treatments were significant in all the three years of observation.

Table 26: Effects of nitrogen, phosphorus and potassium fertilizers on shelling percentage of bambara groundnut at Samaru.

Treatment (kg/ha)	Years			
	1986	1988	1990	Pooled
Nitrogen (N)				
0	58.4a	40.8	45.2	48.1
20	53.5b	40.8	45.5	46.6
SE±	1.63	0.66	1.25	1.18
Phosphorus (P)				
0	54.9	41.4	42.1	46.1
11	55.8	40.5	45.9	47.4
22	53.3	41.2	46.6	47.0
33	59.6	40.2	46.7	48.8
SE±	2.26	0.93	1.76	1.65
Potassium (K)				
0	57.5c	40.5	47.1	48.4
25	50.9b	41.2	45.0	45.7
50	59.3a	40.7	43.9	48.0
SE±	1.98	0.81	1.53	1.44
Treatment Interactions				
NxP	NS	NS	NS	NS
NxK	NS	NS	NS	NS
PxK	NS	NS	NS	NS
NxPxK	NS	NS	NS	NS

Means in a column of any set of treatments within a year followed by unlike letter(s) are significantly different at 5% level using DMRT.

4.1.10 Correlation

Tables 27, 28 and 29 show the result of correlation study carried out to determine the association between some of the parameters. The analyses show that there was a significant positive association between grain yield and shelling percentage in 1986, 1987 and 1990. All other associations were not statistically significant.

In 1988, however, the association between the parameters in question were only significant and positive between grain yield and 100-grain weight and grain yield with shelling percentage.

In 1989, plant spread had significant positive association with plant height so also spread with haulm yield and plant height with haulm yield. 100-grain weight and shelling percentage were also found to have significantly associated with grain yield.

Table 27: Simple correlation coefficients between bambara groundnut grain yield, plant height, plant foliage spread, haulm yield 100-grain weight and shelling percentage as affected by fertilizer treatments at Samaru.

Variables	1	2	3	4	5	6
1986 Rainy Season						
1. Grain yield	1.000					
2. Plant Height	-0.130	1.000				
3. Plant Spread	0.098	0.448*	1.000			
4. Haulm Yield	-0.121	0.285	0.206	1.000		
5. 100-grain	0.154	-0.069	-0.196	0.158	1.000	
6. Shelling %	0.424*	-0.371	-0.421	-0.048	-0.055	1.000
1987 Rainy Season						
1. Grain yield	1.000					
2. Plant Height	-0.332	1.000				
3. Plant Spread	0.170	0.696**	1.000			
4. Haulm Yield	0.256	-0.080	0.059	1.000		
5. 100-grain	0.312	-0.335	-0.199	0.121	1.000	
6. Shelling %	0.477*	0.188	-0.103	0.023	0.054	1.000

* Significant at 5% level

** Significant at 1% level.

Table 28: Simple correlation coefficients between bambara groundnut grain yield, plant height, plant foliage spread, haulm yield 100-grain weight and shelling percentage as affected by fertilizer treatments at Samaru.

	Variables	1	2	3	4	5	6
1988 Rainy Season							
1.	Grain yield	1.000					
2.	Plant Height	-0.103	1.000				
3.	Plant Spread	0.050	0.373	1.000			
4.	Haulm Yield	0.398	0.040	-0.185	1.000		
5.	100-grain	0.547**	-0.124	0.232	0.107	1.000	
6.	Shelling %	0.527**	0.164	0.177	-0.271	0.258	1.000
1989 Rainy Season							
1.	Grain yield	1.000					
2.	Plant Height	-0.061	1.000				
3.	Plant Spread	-0.049	0.910**	1.000			
4.	Haulm Yield	-0.011	0.494*	0.591**	1.000		
5.	100-grain	0.436*	0.041	-0.033	-0.172	1.000	
6.	Shelling %	0.501*	-0.058	0.002	0.083	0.339	1.000

* Significant at 5% level

** Significant at 1% level.

Table 29: Simple correlation coefficients between bambara groundnut grain yield, plant height, plant foliage spread, haulm yield 100-grain weight and shelling percentage as affected by fertilizer treatments at Samaru, 1990.

	Variables	1	2	3	4	5	6
1.	Grain yield	1.000					
2.	Plant Height	-0.083	1.000				
3.	Plant Spread	0.240	0.151	1.000			
4.	Haulm Yield	0.332	-0.262	0.103	1.000		
5.	100-grain	0.342	-0.114	0.146	0.380	1.000	
6.	Shelling %	0.681**	0.286	-0.304	0.038	-0.062	1.000

* Significant at 5% level

** Significant at 1% level.

4.1.11 Path coefficient analyses

The path analyses (Figure 1, 2 and 3) showed that plant height had large positive direct contribution on grain yield in 1987, 1988 and 1989 while plant foliage spread had its own in 1986 and 1987. This is expected because the more the vegetative growth, the more the grain yield would be provided adequate time and environmental factors prevail. It also agrees with Hoffman (1971) who observed that plant height can be used to predict crop yield.

Although there were significant positive correlations between grain yield and shelling percentage, the direct positive contributions to the yield by the shelling percentage were negative except in 1986. The direct contributions of 100-grain weight to the yield were negative in 1987 and 1988 but positive in 1986, 1989 and 1990. This shows that the contribution of the shelling percentage to the grain yield must have been through the other parameters recorded such as plant height and plant spread which had positive direct contribution to the grain yield in most of the years of the study. Haulm yield which had negative non significant correlation with grain yield had negative direct contribution to grain as in indicated in the path

coefficient analyses. This shows that the photosynthate was used mainly to increase the crops vegetation rather than the grain yield.

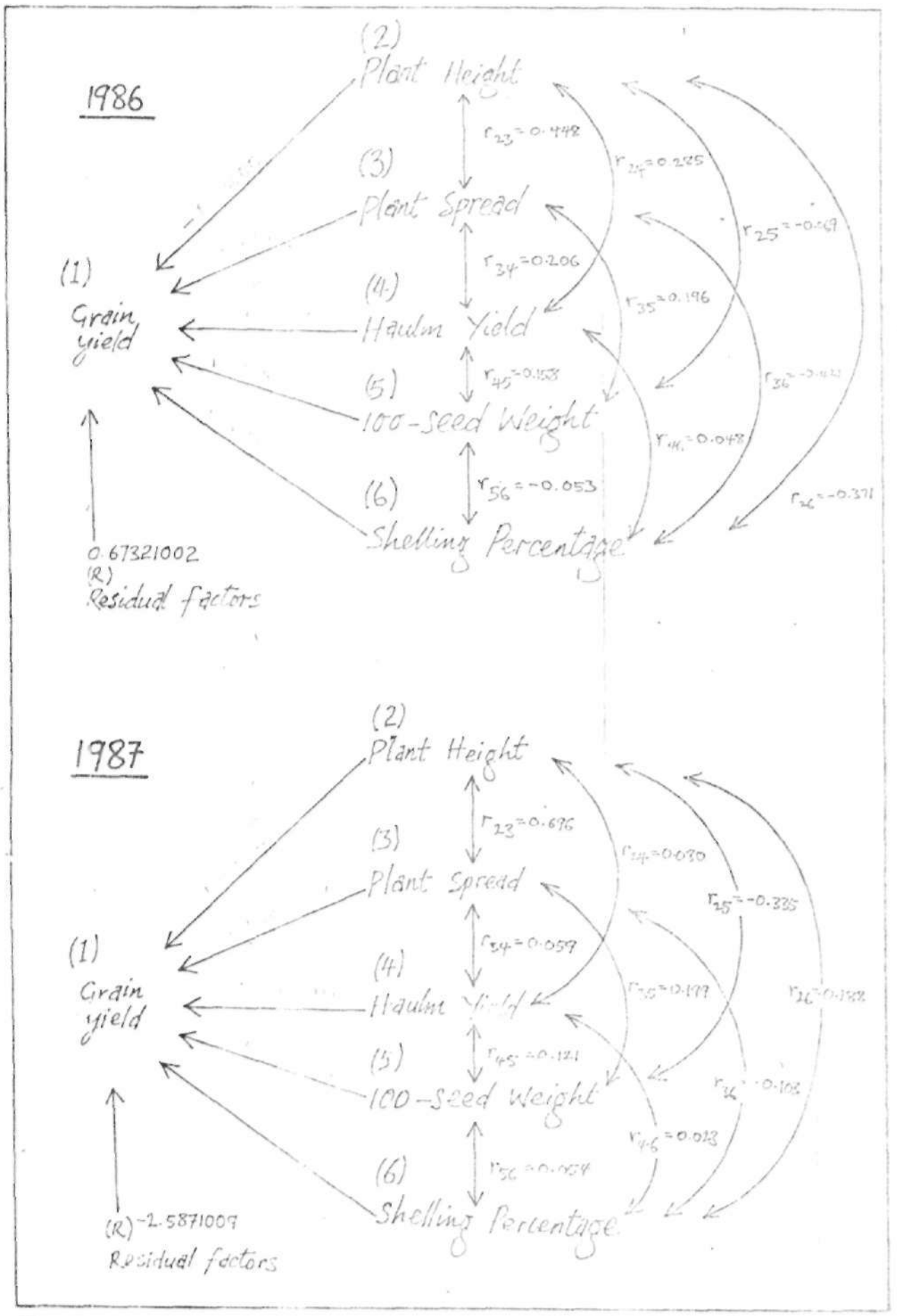


Fig. 1 : Path coefficient diagram relating grain yield to plant height, plant spread, haulm yield, 100-seed weight and shelling percentage

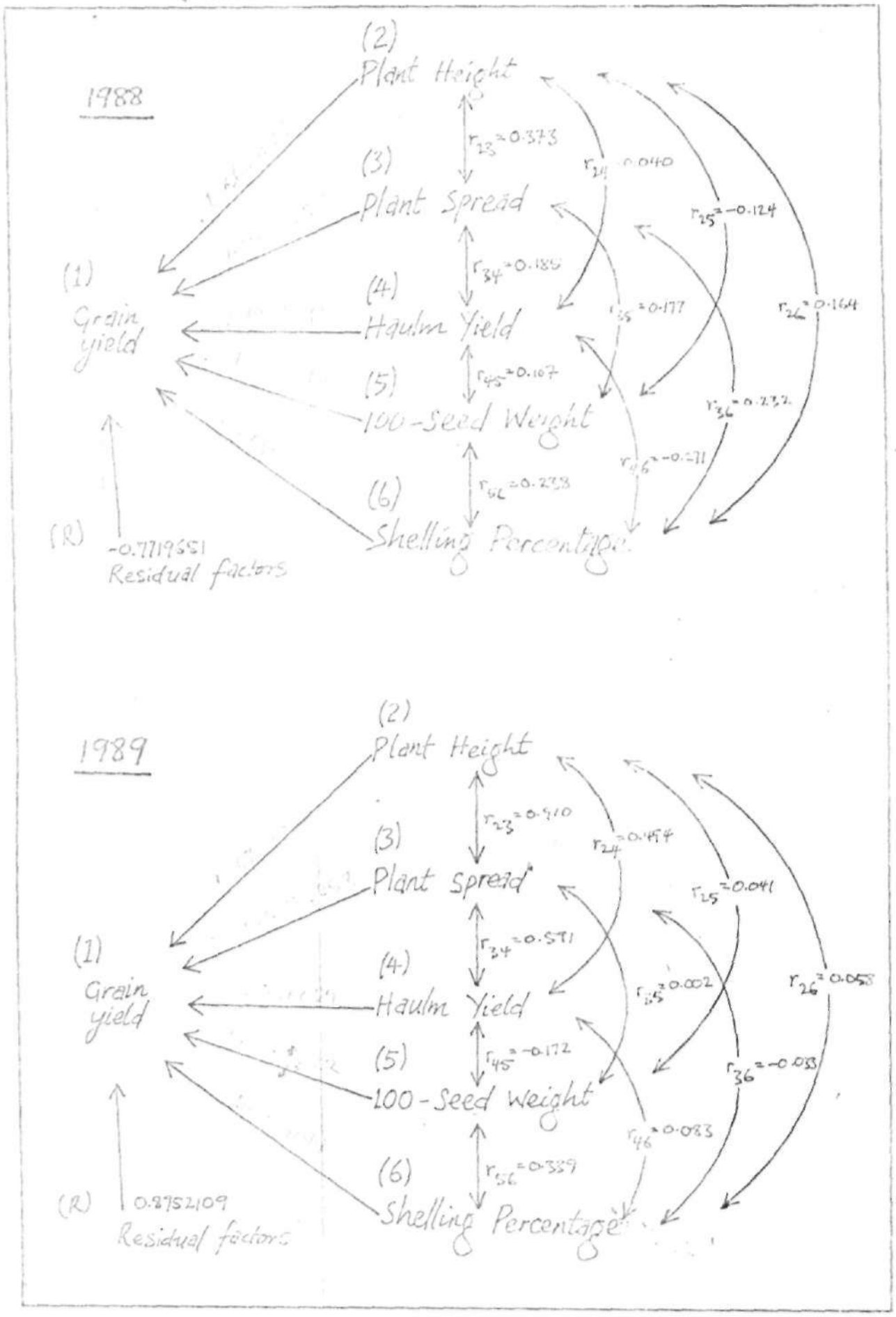


Fig. 2.: Path coefficient diagram relating grain yield to plant height, plant spread, haulm yield, 100-seed weight and shelling percentage of bambara groundnut in 1988 and 1989.

4.1.12 Nutrient concentration in plant tissue

The effect of nitrogen, phosphorus and potassium fertilizer on the concentration of nutrients in leaf tissue of bambara groundnut in 1990 is presented in Table 30. Although application of nitrogen seems to increase the leaf tissue contents of N,P,K and Mg relative to the control, the difference was not significant.

Applied phosphorus also did not significantly influence the concentration of nutrients tested in this study.

Potassium application was also not effective in significantly increasing nutrient concentration in the leaf tissue.

Concentration of nutrients in stem and petioles as affected by levels of fertilizers in 1990 is presented in Table 31. Nitrogen fertilization did not significantly result in any difference in nutrient concentration in stem tissue. Fertilizer P and K were also statistically similar in nutrient concentration with the control. There was no definite trend of either increase or decrease in nutrient concentration with increment in fertilizer levels.

Neither the concentration of nutrients in leaf nor in the stem were significantly affected by either first or second order interactions between the factors studied.

Table 30: Effects of Nitrogen, Phosphorus and Potassium fertilizers on nutrient concentrations (Cmol/kg) in leaf of bambara groundnut at Samaru, 1990.

Treatment (kg/ha)	Nutrients				
	N	P	K	Ca	Mg
Nitrogen (N)					
0	1558.0	62.7	292.6	448.5	95.9
20	1592.0	64.4	293.9	429.6	103.1
SE±	25.18	1.65	8.93	13.87	3.04
Phosphorus (P)					
0	1546.0	62.3	295.1	426.3	101.2
11	1594.0	60.9	301.1	439.7	101.2
22	1626.0	66.9	291.1	442.3	92.9
33	1535.0	63.9	285.6	447.9	100.8
SE±	35.64	2.33	12.62	19.62	4.30
Potassium (K)					
0	1530.0	62.2	284.8	422.1	94.2
25	1582.0	64.2	298.9	432.8	101.4
50	1613.0	64.3	296.5	462.2	102.9
SE±	30.91	2.02	10.93	16.99	3.73
Treatment Interactions					
NXP	NS	NS	NS	NS	NS
NXK	NS	NS	NS	NS	NS
PXK	NS	NS	NS	NS	NS
NXPXK	NS	NS	NS	NS	NS

Means in a column of any set of treatments within a year followed by unlike letter(s) are significantly different at 5% level using DMRT.

Table 31: Effects of nitrogen, phosphorus and potassium fertilizers on nutrient concentrations (Cmol/kg) in stem and petiole of bambara groundnut at Samaru, 1990.

Treatment (kg/ha)	Nutrients				
	N	P	K	Ca	Mg
Nitrogen (N)					
0	1250.0	67.6	418.8	170.5	153.0
20	1295.0	73.2	414.2	199.7	150.7
SE±	39.04	2.68	9.68	3.89	5.26
Phosphorus (P)					
0	1272.0	68.5	421.8	162.2	146.4
11	1288.0	68.3	411.4	162.2	164.1
22	1287.0	73.6	408.8	165.2	149.8
33	1244.0	71.3	423.9	170.7	147.1
SE±	59.23	3.79	13.68	5.50	7.44
Potassium (K)					
0	1267.0	69.7	412.9	164.0	147.5
25	1238.0	68.0	407.4	159.3	161.2
50	1313.0	73.5	429.2	171.9	146.9
SE±	47.80	3.28	11.84	4.75	6.44
Treatment Interactions					
NXP	NS	NS	NS	NS	NS
NXK	NS	NS	NS	NS	NS
PXK	NS	NS	NS	NS	NS
NXPXK	NS	NS	NS	NS	NS

Means in a column of any set of treatments within a year followed by unlike letter(s) are significantly different at 5% level using DMRT.

4.1.13 Regression

The expected grain yield response to phosphorus levels is presented in Figure 4. For all the years a quadratic response was found to give the best fit. Parabolic curves were observed for 1986 and 1987. In 1989 the curve levelled after 22kg P/ha. Maximum yield was obtained at 15.8, 7.9, 7.9, 27.2 and 5.5kg P/ha in 1986, 1987, 1988, 1989 and 1990 respectively. The mean maximum yield was obtained at the rate of 12.7kg P/ha.

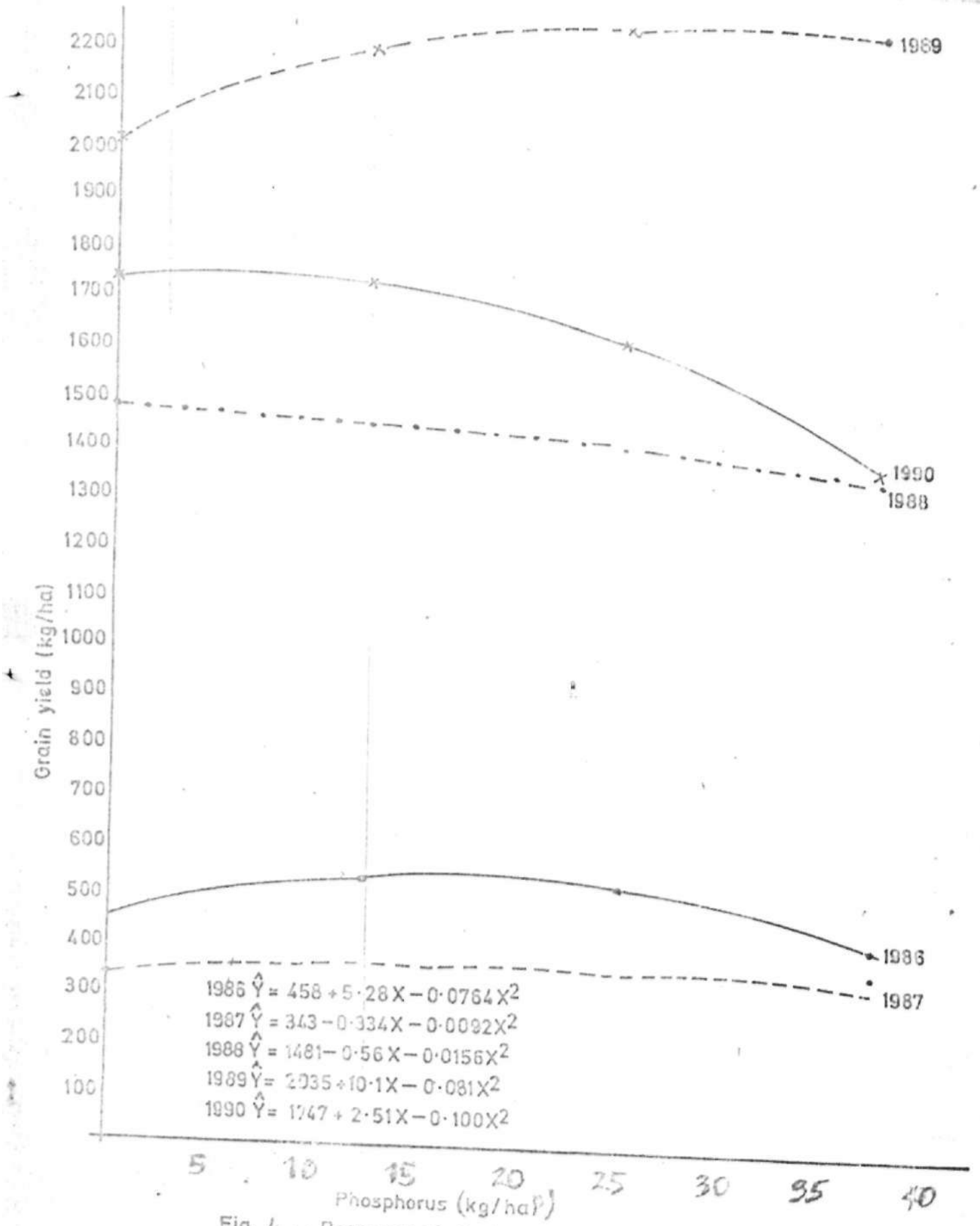


Fig. 4 : Response of Grain yield to Phosphorus

Figure 5 shows the expected response of bambara groundnut grain yield to potassium application. Throughout the period of the experiments, there was a quadratic response to K levels. In 1986 and 1987 there was a depression in yield with K application up to 25kg K/ha after which the yield steadily increased. An inverse response was obtained in 1988 and 1989 at which the yield increased up to 25kgK/ha and declining thereafter. In 1990 the yield levelled off at 37.5kgK/ha.

Maximum yield was obtained at 14.5, 36.3, 27.2, 14.3 and 40.2kgK/ha in 1986, 1987, 1989 and 1990 respectively. The average maximum yield was obtained at 26.2kg K/ha.

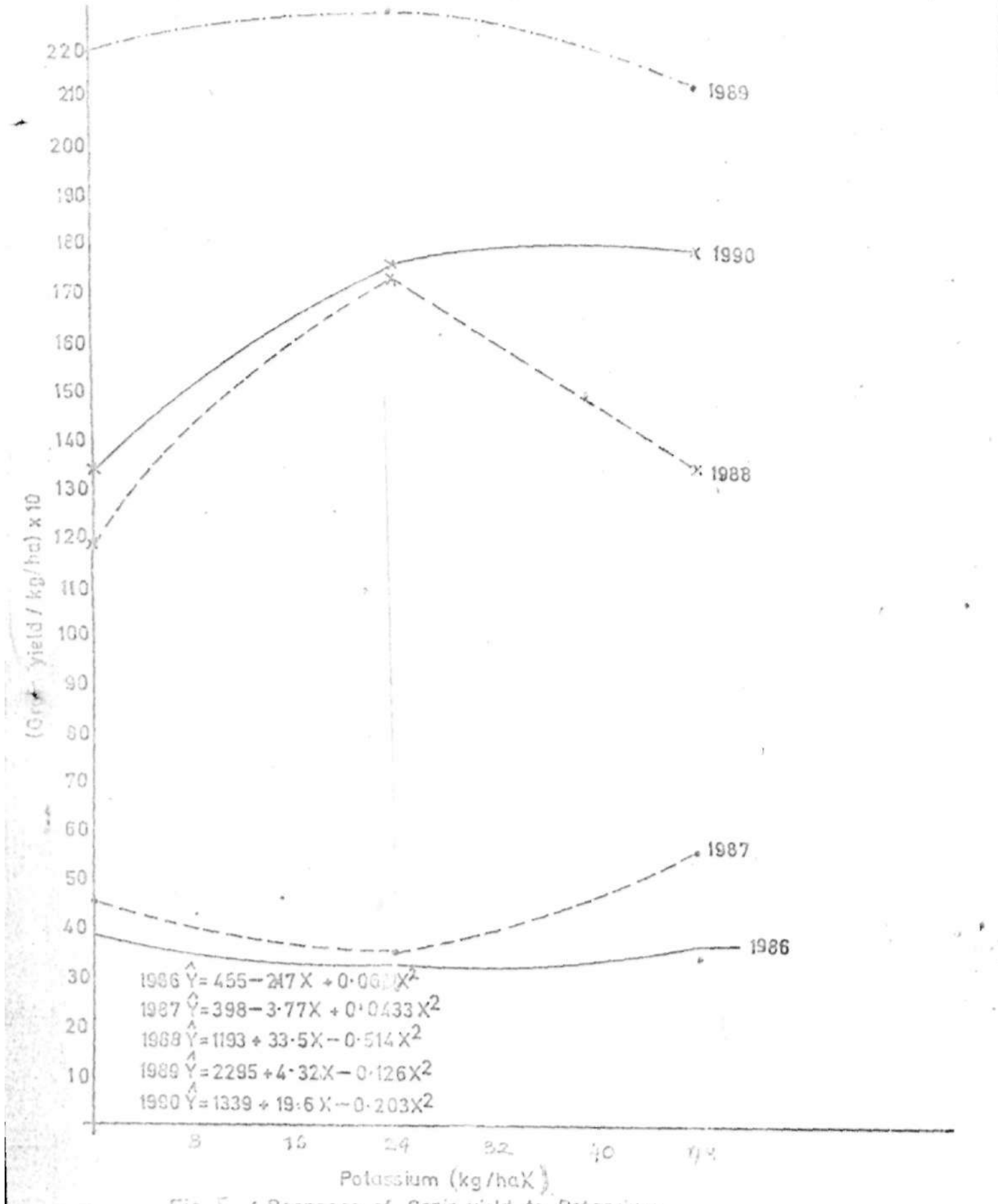


Fig. 5 : Response of Grain yield to Potassium

4.2 Experiment II - Effects of sowing Date, Intra-row spacing and varieties.

4.2.1 Plant height

Table 32 shows the effect of sowing date and intra-row spacing on the height of bambara groundnut varieties two weeks after emergence from 1987 to 1990. Except in 1990, none of the treatments had any significant effect on the crop's height at two weeks after emergence. In 1990, planting on the second sowing date resulted in tallest plants. Intra-row spacing did not cause significant differences in the results in all the years of the study. There were no significant differences between the two varieties in their height at this stage and in all the years of experimentation.

Table 32: Effects of sowing date and intra-row spacing on plant height (cm) 2 weeks after emergence of two bambara groundnut varieties at Samaru.

	Years			
Treatment	1987	1988	1989	1990
Sowing date				
SD1	10.95	10.70	10.13	10.01bc
SD2	11.08	11.03	10.50	11.16a
SD3	11.00	10.48	10.72	9.83c
SD4	11.05	11.15	10.83	10.47ab
SD5	11.03	10.93	10.18	10.53ab
SE±	0.075	0.232	0.178	0.238
Intra-row spacing (cm)				
5	11.01	10.86	10.66	10.60
10	11.19	10.59	10.41	10.39
15	10.93	10.75	10.31	10.12
20	10.96	11.23	10.51	10.49
SE±	0.067	0.208	0.159	0.213
Variety				
Giwa-White	10.98	10.97	10.52	10.29
Pategi-Black	11.07	10.75	10.42	10.514
SE±	0.005	0.147	0.113	0.150
Interactions				
SDxS	NS	NS	NS	NS
SDXV	NS	NS	*	NS
SXV	NS	NS	NS	NS
SDxSxV	NS	NS	NS	NS

Means in a column of any set of treatments within a year followed by unlike letter(s) are significantly different at 5% level using DMRT.

Interactions between the various treatments were not significant in all the years except in 1989 when the interaction between the date of sowing and the varieties was found to be significant. The performance of the varieties at the different dates of sowing, showed that variety Giwa-white grew to virtually same height at all the dates with the exception of the last date of sowing when the plants were significantly shorter (Table 33). Pategi-Black also grew to the same height for all the sowing dates except for the first sowing date when it grew shorter than at all dates. Comparing the dates of sowing across the varieties however, it was only on the first sowing date when Pategi-Black plants were significantly shorter than those of Giwa-white and on last date of sowing when the Giwa-white plants grew significantly shorter than Pategi-Black plants.

Table 33: Interactions between sowing date and varieties of bambara groundnut on plant height (cm) two weeks after emergence at Samaru, 1989.

	Sowing Dates				
Variety	SD1	SD2	SD3	SD4	SD5
Giwa - white	10.8a	10.7a	10.6a	10.8a	9.7bc
Pategi-Black	9.5c	10.3ab	10.8a	10.8a	10.6a
SE± 0.25					

Means with unlike letter(s) differ significantly at 5% level using DMRT.

The effects of the dates of sowing and intra-row spacings on the two bambara groundnut varieties four weeks after emergence are presented in Table 34. In the four years of the experimentation, it was in 1989 and 1990 that the plant heights were statistically different for the different sowing dates. The plant were observed to have grown tallest in 1987, 1990, 1988 and 1989 in descending order. The plants grew tallest in plots sown on fourth date of sowing in 1989 and on last date of sowing in 1990.

Intra-row spacing significantly affected the bambara groundnut height four weeks after emergence only in 1987 when sowing at 10cm between stands resulted in the tallest plants. Sowing in 1988, 1989 and 1990 resulted in no significant differences between the intra-row spacings.

Differences between the two varieties were not statistically significant in all the years of experimentation.

Table 34: Effects of sowing date and intra-row spacing on plant height (cm) 4 weeks after emergence of two bambara groundnut varieties at Samaru.

	Years			
Treatment	1987	1988	1989	1990
Sowing date				
SD1	13.4	12.3	11.6b	11.3b
SD2	13.6	12.7	12.0ab	13.2a
SD3	13.5	12.5	12.2a	13.1a
SD4	13.3	12.4	12.4a	13.7a
SD5	13.5	12.3	11.9ab	13.9a
SE±	0.09	0.16	0.18	0.39
Intra-row spacing (cm)				
5	13.5ab	12.4	12.1	13.2
10	13.6a	12.5	12.0	13.1
15	13.3b	12.2	12.0	12.8
20	13.5ab	12.5	12.0	13.1
SE±	0.08	0.15	0.16	0.35
Variety				
Giwa-white	13.5	12.6	11.9	13.2
Pategi-Black	13.5	12.3	12.1	12.9
SE±	0.01	0.10	0.12	0.25
Interactions				
SDXS	NS	NS	NS	NS
SDXV	*	NS	NS	NS
SXV	NS	NS	NS	NS
SDXSXV	NS	NS	NS	NS

Means in a column of any set of treatments within a year followed by unlike letter(s) are significantly different at 5% level using DMRT.

The interaction between sowing dates and varieties was found significant in 1987 only (Table 35). Comparing the dates of sowing on the varieties, it was found that none of the dates planted with Giwa-white variety had significantly taller plants than the others at four weeks after emergence. However, for the last but one planting Patego-Black plants were considerably shorter than plants for the other dates. Comparing the two bambara groundnut varieties at any one particular date at four weeks after emergence showed that it was only on last but one planting that in respect of the planting date that Giwa-white plants grew significantly taller than Patego-Black.

Table 35: Interactions between sowing date and varieties of bambara groundnut on plant height (cm) four weeks after emergence at Samaru, 1987.

Variety	Sowing dates				
	SD1	SD2	SD3	SD4	SD5
Giwa-White	13.6a	13.5a	13.3ab	13.6a	13.5a
Patego-Black	13.3ab	13.7a	13.7a	13.1b	13.6a
SE± 0.13					

Means with unlike letter(s) differ significantly at 5% level using DMRT.

Table 36 shows the effect of date of sowing and intra-row spacing on two bambara groundnut height at harvest. The crop growth differed significantly at the various dates of sowing in 1988, 1989 and 1990. The crop grew tallest in 1988 followed by 1987, 1989 and 1990 in that order. In 1990, plots planted with bambara groundnut on last date had the tallest plants. It was followed by the fourth, first, third, and second date of sowing in that order. In both 1988 and 1989 the differences in height at harvest between the dates of sowing were also significant, planting on the first and second dates resulted in the tallest plants.

The differences as a result of the effect of intra-row spacing on the plant height at harvest were not significant in all the years.

The differences between the two varieties were not statistically significant in all the years. No significant interaction among the treatment factors were found.

Table 36: Effects of sowing date and intra-row spacing on plant height (cm) at harvest of two bambara groundnut varieties at Samaru.

	Years			
Treatment	1987	1988	1989	1990
Sowing date				
SD1	15.9	18.7a	14.7a	14.4bc
SD2	15.9	19.1a	14.7a	12.7d
SD3	15.9	13.0c	14.6a	13.5cd
SD4	15.9	13.0c	14.5a	15.7ab
SD5	15.9	14.1b	14.1b	16.1a
SE±	0.07	0.18	0.10	0.47
Intra-row spacing (cm)				
5	15.9	15.9	14.5	14.3
10	15.9	15.6	14.5	14.3
15	15.9	15.5	14.5	14.5
20	15.9	15.4	14.6	14.7
SE±	0.07	0.16	0.09	0.42
Variety				
Giwa-white	15.9	15.4	14.5	14.2
Pategi-Black	15.9	15.8	14.6	14.7
SE±	0.04	0.11	0.06	0.30
Interactions				
SDxS	NS	NS	NS	NS
SDXV	NS	NS	NS	NS
SXV	NS	NS	NS	NS
SDxSxV	NS	NS	NS	NS

Means in a column of any set of treatments within a year followed by unlike letter(s) are significantly different at 5% level using DMRT.

4.2.2 Plant foliage spread

Table 37 shows the effect of sowing date and intra-row spacing on foliage spread at two weeks after emergence of the two bambara groundnut varieties at Samaru. In 1989 and 1990 the date of sowing has had a significant effect on the foliage spread. In 1988 and 1990 the late the planting the more the spread.

The effect of the intra-row spacing on the foliage spread at two weeks after emergence was not significant in all the years of the study,

Differences between the two varieties in the foliage spread of the crop at two weeks after sowing were not statistically significant in all the years of experimentation.

Table 37: Effects of sowing date and intra-row spacing on plant foliage spread (cm) 2 weeks after emergence of two bambara groundnut varieties at Samaru.

	Years			
Treatment	1987	1988	1989	1990
Sowing date				
SD1	13.4	12.3	11.6b	11.3b
SD2	13.6	12.7	12.0ab	13.2a
SD3	13.5	12.5	12.2a	13.1a
SD4	13.3	12.4	12.4a	13.7a
SD5	13.5	12.3	11.9ab	13.9a
SE±	0.09	0.16	0.18	0.39
Intra-row spacing (cm)				
5	13.5ab	12.4	12.1	13.2
10	13.6a	12.5	12.0	12.8
15	13.3b	12.2	12.0	12.8
20	13.5ab	12.5	12.9	13.1
SE±	0.08	0.15	0.16	0.35
Variety				
Giwa-white	13.5	12.6	11.9	13.2
Pategi-Black	13.5	12.3	12.1	12.9
SE±	0.01	0.10	0.12	0.25
Interactions				
SDxS	NS	NS	NS	NS
SDXV	*	NS	NS	NS
SXV	NS	NS	NS	NS
SDxSxV	NS	NS	NS	NS

Means in a column of any set of treatments within a year followed by unlike letter(s) are significantly different at 5% level using DMRT.

The effects of date of sowing and intra-row spacing on the foliage spread four weeks after emergence of two bambara groundnut varieties at Samaru are shown in Table 38. Significant differences in the foliage cover as a result of dates of sowing were observed in all the years of experimentation. In both 1987 and 1988, late planting resulted in smaller plants however, in 1989 and 1990 this trend was not the case. In 1987, and 1988, the foliage spread was widest in plots planted on the second date of planting. In general, the year of experimentation did not result in much disparity between the ground cover of the two bambara groundnut varieties at four weeks after emergence.

The differences in the bambara groundnut foliage spread at four weeks after emergence were only significantly affected by the intra-row spacing in 1989 when plots planted with bambara groundnut at 5cm intra-row spacing had significantly wider spread than 20cm. In all the years of experimentation, Pategi-Black and Giwa-White were not significantly different.

Table 38: Effects of sowing date and intra-row spacing on plant foliage spread (cm) 4 weeks after emergence of two bambara groundnut varieties at Samaru.

	Years			
Treatment	1987	1988	1989	1990
Sowing date				
SD1	23.5a	23.1a	22.4b	29.8a
SD2	23.6a	23.4a	22.9a	26.6b
SD3	22.7b	23.2a	22.7b	23.5c
SD4	23.0ab	22.9ab	23.7a	27.7b
SD5	23.0b	22.4b	16.5c	27.1b
SE±	0.15	0.23	0.33	0.55
Intra-row spacing (cm)				
5	23.5	23.0	22.0a	26.7
10	22.2	23.2	21.8ab	26.7
15	23.1	23.0	21.8ab	27.2
20	23.2	22.7	21.0b	27.2
SE±	0.14	0.21	0.30	0.33
Varieties				
Giwa-white	23.1	23.0	21.5	26.7
Pategi-Black	23.2	23.0	21.8	27.2
SE±	0.10	0.15	0.21	0.29
Interactions				
SDxS	NS	NS	NS	NS
SDXV	NS	NS	NS	*
SXV	NS	NS	NS	NS
SDxSxV	NS	NS	NS	NS

Means in a column of any set of treatments within a year followed by unlike letter(s) are significantly different at 5% level using DMRT.

The interaction between the various treatment factors were only significant between varieties and dates of sowing in 1990. Comparing the two varieties at similar dates of sowing, it was found that it was only on the last sowing date that the Pategi-Black variety had significantly more foliage spread than the Giwa-White variety (Table 39). On all other dates however, no significant differences were observed between the two varieties.

Comparing the different dates of sowing, with a variety, it was found that Giwa-White had significantly largest spread at the first of date of sowing followed by second, and fourth which were at par with each other and significantly higher than at third date of sowing. The Pategi-Black too had significantly largest spread on first date of sowing followed by fourth and the last date which were at par, with each other and significantly higher than at the second date which too was significantly higher than at third date of planting.

Table 39: Interactions between sowing date and varieties of bambara groundnut on plant foliage spread (cm) 4 weeks after emergence at Samaru, 1990.

Variety	Sowing dates				
	SD1	SD2	SD3	SD4	SD5
Giwa-White	29.8a	27.1b	24.1cd	26.4b	26.0bc
Pategi-Black	29.8a	26.1bc	22.9d	29.0ab	28.1ab
SE± 0.775					

Means with unlike letter(s) differ significantly at 5% level using DMRT.

Table 40 shows the effects of sowing date and intra-row spacing on foliage spread of two bambara groundnut varieties at harvest at Samaru. The effects of date of sowing on the crop's foliage spread were found to be significant in all the years. In 1987, sowing on the last date gave plants with the largest foliage spread. It was followed by fourth, first, second and third dates in that order. In 1988, planting early resulted in better foliage cover such that the first planting had the widest foliage spread followed by the second, third, fourth and last dates in that order.

In 1989, 1990 however, planting on fourth date had the widest foliage cover. It was followed by the third, second, first and last dates in that order.

The effects of intra-row spacing on the foliage spread at harvest did not significantly affect the spread of the crop.

At harvest, the Pategi-Black variety and the Giwa-White variety were not significantly different in all the years of the experimentation. The various interactions among the treatment factors were not statistically significant in all the years of the study also.

Table 40: Effects of sowing date and intra-row spacing on foliage spread (cm) at harvest of two bambara groundnut varieties at Samaru.

	Years			
Treatment	1987	1988	1989	1990
Sowing date				
SD1	33.6c	55.6a	40.0a	30.6ab
SD2	33.5c	54.5c	40.3a	28.4bc
SD3	32.7d	36.1b	40.3a	27.9cd
SD4	34.1b	34.8c	40.4a	33.1a
SD5	35.0a	25.9d	36.3b	27.7c
SE±	0.14	0.42	0.20	0.92
Intra-row spacing (cm)				
5	33.8	41.8	39.6	31.2
10	33.9	41.5	39.6	29.4
15	33.6	41.0	39.4	29.0
20	33.8	41.5	39.3	28.6
SE±	0.12	0.38	0.18	0.82
Variety				
Giwa-white	33.7	41.2	39.3	29.2
Pategi-Black	33.85	41.7	39.6	29.8
SE±	0.09	0.27	0.13	0.58
Interactions				
SDxS	NS	NS	NS	NS
SDXV	NS	NS	NS	*
SXV	NS	NS	NS	NS
SDxSxV	NS	NS	NS	NS

Means in a column of any set of treatments within a year followed by unlike letter(s) are significantly different at 5% level using DMRT.

4.2.5 Number of days to first flowering

The effects of sowing date and the spacing between stands on the number of days to the first flower produced by the two bambara groundnut varieties at Samaru are in Table 41. Sowing dates in all the years of the study were found to have significantly affected the number of days to first flower production. In the year 1987 and 1990 planting late resulted in delayed flower production. In the year 1988, it was found too that planting on the last date of sowing resulted in delayed flower production. Planting on the last date of sowing in 1989 too delayed the flower production.

The spacing between stands did not significantly affect the number of days taken to produce the first flower by the two bambara groundnut varieties in all the years of the study. The two varieties did not differ significantly in the time they took to produce the first flower in all the years of experimentation. The interactions between the treatment factors were not statistically significant in all the years.

Table 41: Effects of sowing date and intra-row spacing on number of days to first flowering of two bambara groundnut varieties at Samaru.

	Years			
Treatment	1987	1988	1989	1990
Sowing date				
SD1	44c	44a	42d	42cd
SD2	44c	41b	42c	40d
SD3	44c	41b	42c	42cd
SD4	46b	41b	44b	44b
SD5	48a	44a	46a	49a
SE ±	0.26	0.26	0.18	0.22
Intra-row spacing (cm)				
5	45	42	44	43
10	45	42	43	43
15	45	42	43	43
20	45	42	43	43
SE±	0.23	0.23	0.16	0.19
Variety				
Giwa-white	45	42	43	43
Pategi-Black	45	42	43	43
SE±	0.16	0.16	0.11	0.14
Interactions				
SDxS	NS	NS	NS	NS
SDXV	NS	NS	NS	NS
SXV	NS	NS	NS	NS
SDxSxV	NS	NS	NS	NS

Means in a column of any set of treatments within a year followed by unlike letter(s) are significantly different at 5% level using DMRT.

4.2.4 Stand count at harvest

The effects of dates of sowing and the spacing between stands on the number of stands harvested of the bambara groundnut varieties at Samaru are in Table 42. In all the years of the study sowing date has caused significant differences in the number of stands. In the rainy season of 1987, most stands were harvested from plots planted on the first date of sowing more than the third, and second. In 1988 when the highest number of stands were harvested compared to the other years, the last but one planting had the highest number of stands harvested followed by the first, second, third and last dates in that order. Second planting was more than the third and the last in 1989. In 1990 however the last had significantly higher number of stands followed by the fourth and the first which was at par but significantly higher than at the third which was higher than the first sowing.

The spacing between stands affected the number of stands harvested in all the years significantly. The 5cm intra-row spacing had the highest number of stands harvested and was followed by 10cm, 15cm and 20cm spacings in that order in all the years of the experimentation.

Pategi-Black variety had significantly more stands harvested than Giwa-White in 1988.

Table 42: Effects of sowing date and intra-row spacing on stand count/18m^2 at harvest of two bambara groundnut varieties at Samaru.

Treatment	Years			
	1987	1988	1989	1990
Sowing date				
SD1	59a	119bc	66ab	59ab
SD2	43c	111c	69a	48c
SD3	44c	98d	53c	52b
SD4	58ab	147a	66bc	60a
SD5	53abc	62e	45c	65a
SE ±	3.64	3.83	3.03	2.60
Intra-row spacing (cm)				
5	70a	171a	80a	63a
10	56b	108b	61b	61ab
15	40c	82c	53b	55bc
20	38c	68d	45c	49c
SE±	3.25	3.43	2.71	2.33
Variety				
Giwa-white	49	89b	58	55
Pategi-Black	53	125a	62	59
SE±	2.30	2.43	1.92	1.65
Interactions				
SDxS	NS	NS	NS	NS
SDXV	NS	NS	NS	NS
SXV	NS	NS	NS	NS
SDxSxV	NS	NS	NS	NS

Means in a column of any set of treatments within a year followed by unlike letter(s) are significantly different at 5% level using DMRT.

The various interactions between the treatment factors were only statistically significant in 1990 when sowing date significantly interacted with the two varieties. The results of the interactions are presented in Table 43. Comparing the varieties at similar sowing dates, on the last but one planting Pategi-Black had significantly higher number of stands at harvest than Giwa-White. On other dates however, the differences between the two varieties were not significant. Comparing the dates of sowing with a variety. Giwa-White planted on the last date had significantly higher stand count at harvest than other planting date. Pategi-Black planted on the third and the second dates of planting had significantly lowest number of stands at harvest than other dates of sowing.

Table 43: Interactions between sowing date and varieties of bambara groundnut on the number of stands/18m^2 at harvest at Samaru, 1990.

Variety	Sowing dates				
	SD1	SD2	SD3	SD4	SD5
Giwa	57.2bc	49.2c	50.3c	49.8c	69.8ab
Pategi-Black	60.8abc	46.9c	53.6c	73.0a	61.0abc
SE± 5.21					

Means with unlike letter(s) differ significantly at 5% level using DMRT.

4.2.5 Haulm yield

The effects of sowing date and intra-row spacing on the haulm yields of the two bambara groundnut varieties are shown in Table 44. Significant differences were observed between the various sowing dates. The haulm yield was highest on the last but one planting in 1987, the first planting in 1988, and 1989.

Significant differences between the intra-row spacings were found in 1988 and 1989 when the 5cm intra-row spacing had significantly more haulms than the 15 and the 20cm spacings.

Pategi-Black had significantly more haulm than Giwa-White in 1987, 1988, and 1989. The differences were not significant in 1990.

Table 44: Effect of sowing date and intra-row spacing on haulm yield (kg/ha) of two bambara groundnut varieties at Samaru.

	Years			
Treatment	1987	1988	1989	1990
Sowing date (SD)				
SD1	825d	5239a	5580a	3816a
SD2	3369b	3957b	4362b	3716a
SD3	1970c	1783c	1980c	3216ab
SD4	4412a	1609c	1788c	3106ab
SD5	858d	1095c	1212c	2968b
SE±	272.3	219.7	284.2	154.7
Intra-row spacing(s)				
5	2430	3369a	3743a	3007
10	2436	2994ab	3138ab	3327
15	2292	2436bc	2706bc	2977
20	1974	2118c	2356c	2977
SE±	183.5	196.5	254.2	138.3
Variety (V)				
Giwa-White	2440b	2061b	2290b	2963
Pategi-Black	2533a	3396a	3682a	3218
SE ±	166.3	175.0	190.6	110.7
Treatment Interactions				
SD X S	NS	NS	NS	NS
SD X V	NS	NS	NS	NS
S X V	NS	NS	NS	NS
SDX S X V	NS	NS	NS	NS

Means in a column of any set of treatments with a year followed by unlike letter(s) are significantly different at 5% level using DMRT.

4.2.6 Grain yield

The effects of sowing date and spacings between stands on the grain yield per hectare of the two bambara groundnut varieties at Samaru are in Table 45. Grain yield was highest in 1990 followed by 1989, 1988 and 1987 in that order and ranged between 137-1142kg/ha.

Sowing date in all the years of experimentation was found to cause significant yield differences of the crop. In 1987, the grain yield was highest when the crop was sown on last but one date i.e. later in the season, in 1988 and 1989 sowing early June resulted in the highest yield of the crop while in 1990 the second planting resulted in the highest grain yield. In 1987, the fourth sowing was followed by second, third, last and first sowing in that order. In 1988 and 1989, the trend is the same i.e. the later the planting the less the grain yield.

Table 45: Effects of sowing date and intra-row spacing on grain yield (kg/ha) of two bambara groundnut varieties at Samaru.

Treatment	Years			
	1987	1988	1989	1990
Sowing date				
SD1	137d	873a	930a	636c
SD2	561b	654b	727b	1142a
SD3	328c	297c	330c	896b
SD4	735a	268c	298c	867b
SD5	143d	182c	202c	529d
SE ±	45.3	36.6	47.3	25.7
Intra-row spacing (cm)				
5	405	561a	623a	836
10	406	499ab	523ab	915
15	382	406bc	451bc	751
20	329	353c	392c	755
SE±	30.5	32.7	42.3	23.0
Variety				
Giwa-white	340b	343b	381b	737
Pategi-Black	422a	566a	613a	891
SE±	28.7	23.1	29.9	16.3
Interactions				
SDxS	NS	NS	NS	NS
SDXV	NS	*	*	*
SXV	NS	NS	NS	NS
SDxSxV	NS	NS	NS	NS

Means in a column of any set of treatments within a year followed by unlike letter(s) are significantly different at 5% level using DMRT.

Unlike in the case of the dates of sowing, the intra-row spacings affected the grain yield per hectare significantly only in 1988 and 1989. In 1988 and 1989 and the pooled data the effects of the intra-row spacing on the grain yield were significant and followed the same trend. The 5cm spacing between stands resulted in the highest grain yield per hectare more than the 10, 15 and 20cm.

The grain yield differences between the two varieties were significant in all the years of the experimentation except in 1990. The Pategi-Black variety yielded more grain than Giwa-White.

The sowing date by variety interactions was significant in 1988, 1989 and 1990 (Table 46) comparing the two varieties against the sowing date, grain yield of Pategi-Black was significantly higher than that of Giwa-White in all date except the last date of sowing.

Table 46 shows the interaction between the dates of sowing and varieties on the grain yield of bambara groundnut per hectare in 1989. The comparison of the two varieties against the dates of sowing revealed that Pategi-Black planted on the first and second, yielded significantly higher than variety Giwa-White sown on the same dates. The yields of the two varieties were similar on the other dates.

Table 46 shows the interaction between varieties and dates of sowing on grain yield in 1990. Comparing the two varieties on different sowing dates, it was found that variety Giwa-White yielded significantly highest when planted on the second followed by the first, last, first and third plantings which were at par. Variety Pategi-Black on the other hand yielded most grain on the third followed by fourth and second which were at par with each other but significantly higher than when planted on the first and last dates. On the fourth and third variety Pategi-Black yielded more grain than the Giwa-White variety. On other dates however, the two varieties yielded similar grains however, the yield differences were not significant even though the Pategi-Black was higher in yield. Comparing the sowing dates against for the varieties however revealed that with respect to the yield of variety Giwa-White differences were significant except for the two last dates of sowing. The same was also true for variety Pategi-Black.

Table 46: Interactions between sowing date and varieties of bambara groundnut on the grain yield (kg/ha) at Samaru, 1988, 1989 and 1990.

Varieties	Sowing Dates				
	SD1	SD2	SD3	SD4	SD5
1988					
Giwa-White	694c	418d	238ef	192f	173f
Pategi-Black	1052a	890b	356dc	343dc	191f
SE± 51.7					
1989					
Giwa-White	771b	465c	265d	214d	192d
Pategi-Black	1090a	989a	395cd	381cd	212d
SE± 66.9					
1990					
Giwa-White	632b	1242a	570bc	617bc	625bc
Pategi-Black	641bc	1041ab	1223a	1118a	432c
SE± 143.2					

Means with unlike letter(s) differ significantly at 5% level using DMRT.

4.2.7 100-Grain Weight

The effects of sowing dates and spacings between stands on 100-grain weight of the two bambara groundnut varieties at Samaru are shown in Table 47. The dates of sowing were found to have significantly influenced the 100-grain weight of the crop in all the years of the study. In 1987, the third planting was highest but was at par with the fourth, second and the first and were significantly different from the last sowing. In 1988, planting on the third gave significantly highest 100-grain weight followed by the fourth, last and the first sowings in that order.

In 1989 however, the early planting in June resulted in the highest 100-grain weight. Late sowing was observed to significantly reduce the 100-grain weight in the year. In 1990 the second had the highest followed by the first, fourth, third and last in that order.

The spacing between stands was found to have no significant effect on the 100-grain weight in all the years of the experimentation.

Differences between the two varieties were not significant in all the years of experimentation. The interactions between the treatment factors were not significant.

Table 47: Effects of sowing date and intra-row spacing on 100-grain weight (g) of two bambara groundnut varieties at Samaru.

Treatment	Years			
	1987	1988	1989	1990
Sowing date				
SD1	73.0a	48.7c	76.3a	60.7a
SD2	74.9a	60.3b	56.4b	62.5a
SD3	78.3a	70.9a	54.7b	51.7b
SD4	77.7a	67.3ab	44.4c	60.1a
SD5	59.8b	56.4bc	51.0bc	44.8c
SE ±	2.61	2.00	2.32	2.19
Intra-row spacing (cm)				
5	73.2	59.8	56.9	57.2
10	72.5	51.3	55.0	57.0
15	71.5	60.5	56.4	54.9
20	73.8	61.4	57.9	54.6
SE±	2.34	1.78	2.07	1.96
Variety				
Giwa-white	74.1	59.9	56.3	56.6
Pategi-Black	71.4	61.5	56.9	55.2
SE±	1.65	1.26	1.47	1.39
Interactions				
SDxS	NS	NS	NS	NS
SDXV	NS	NS	NS	NS
SXV	NS	NS	NS	NS
SDxSxV	NS	NS	NS	NS

Means in a column of any set of treatments within a year followed by unlike letter(s) are significantly different at 5% level using DMRT.

4.2.8 Shelling Percentage

Table 48 shows the effect of sowing date and intra-row spacings on the shelling percentage of the two bambara groundnut varieties.

Neither the sowing date nor the spacings between stands had any statistically significant effect on the shelling percentage of the two varieties of bambara groundnut used in the study.

Table 48: Effect of sowing date and intra-row spacing on shelling percentage of two bambara groundnut varieties at Samaru.

Treatment	Years			
	1987	1988	1989	1990
Sowing date (SD)				
SD1	55.3	58.3	60.3	55.3
SD2	56.7	57.8	56.8	56.9
SD3	53.6	59.7	57.2	54.8
SD4	54.2	58.7	58.7	55.3
SD5	53.7	56.8	59.3	57.0
SE±	2.2	2.0	1.6	1.9
Intra-row spacing(s)				
5	55.8	57.6	59.8	54.7
10	53.6	58.3	58.9	54.6
15	54.9	58.4	58.3	53.8
20	54.6	56.6	57.4	55.7
SE±	1.8	1.7	1.0	0.9
Variety (V)				
Giwa-White	53.6	59.7	58.3	53.9
Pategi-Black	54.5	59.5	59.4	55.1
SE ±	0.8	0.9	0.8	1.0
Treatment Interactions				
SD X S	NS	NS	NS	NS
SD X V	NS	NS	NS	NS
S X V	NS	NS	NS	NS
SDX S X V	NS	NS	NS	NS

Means in a column of any set of treatments with a year followed by unlike letter(s) are significantly different at 5% level using DMRT.

4.2.9 Regression

The expected grain yield response to sowing date is presented in Figure 6. A quadratic response was found to give the best fit while a parabolic curve levelled at late July. For the four years of the study therefore, planting late July was found to have produced the highest levels of grain yield per hectare. Figure 7 shows the expected response of bambara groundnut grain yield to intra-row spacing when grain yield was declining with increasing intra-row spacing. The narrower the gap between the stands, the higher the grain yield produced. Maximum yield was obtained with 5cm space between stands.

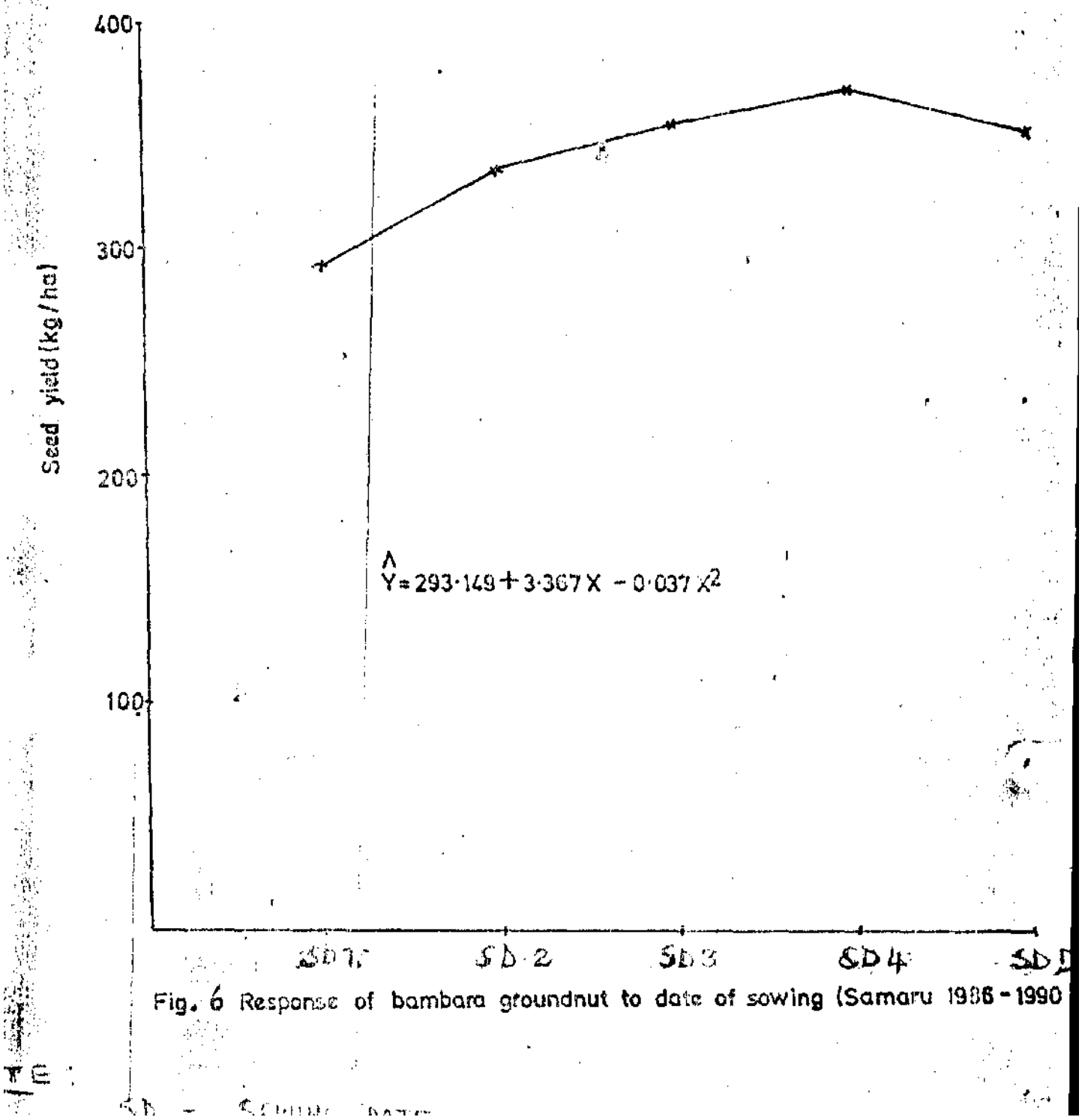


Fig. 6 Response of bambara groundnut to date of sowing (Samaru 1986 - 1990

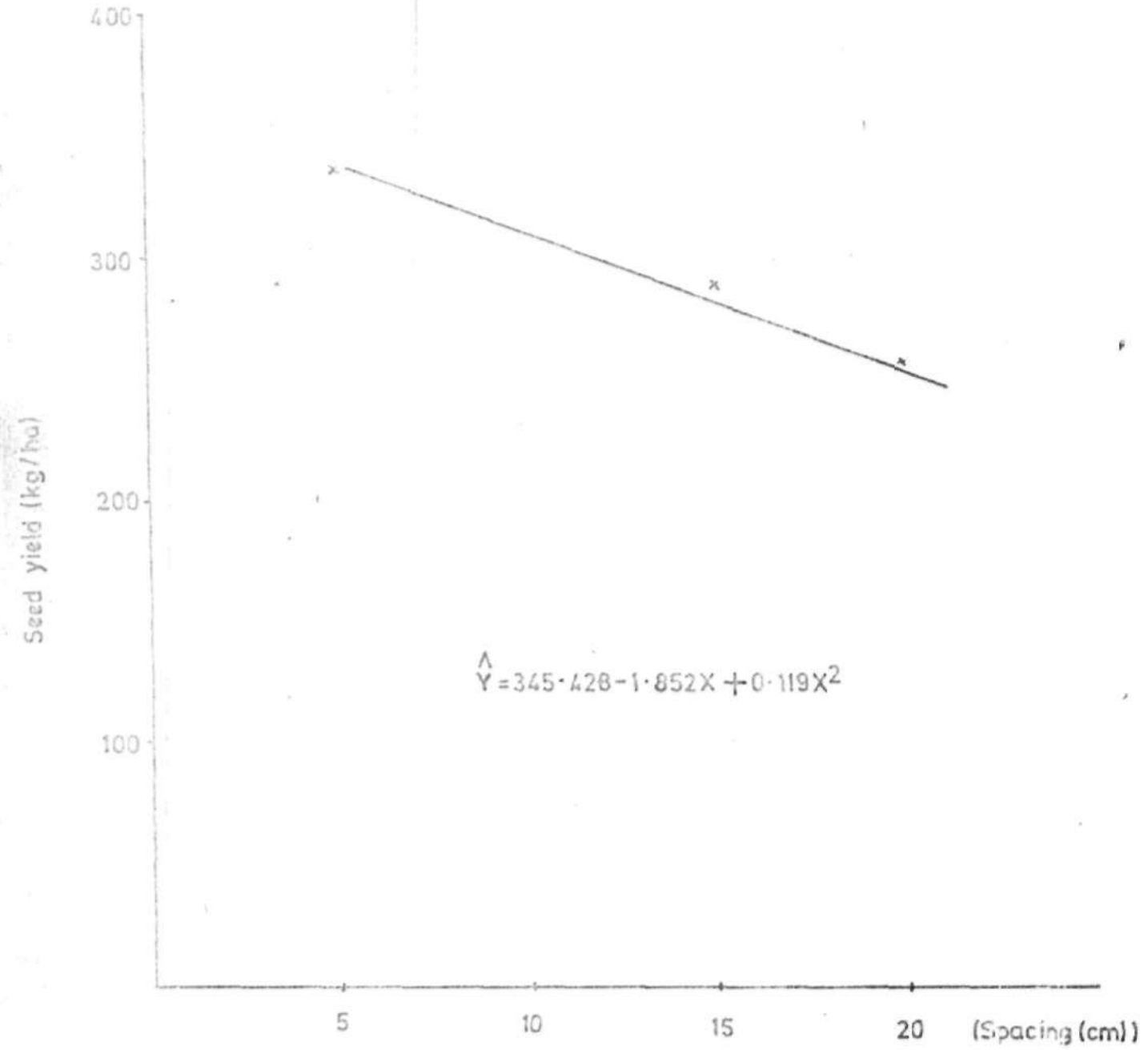


Fig. 7 Response of bambara groundnut seed yield to spacing between stands. Samaru 1987—1990

CHAPTER FIVE

DISCUSSION

The general performance of the bambara groundnut in 1988, 1989 and 1990 was satisfactory however, the incidence of the fungal infection by Colletotrichum sp and Puccinia spp which affected the crop in 1987 resulted in considerably lower yields. In 1986, the performance of the crop in terms of grain yields was not satisfactory too. The likely reason may have been the weather condition. The rainfall ceased in September in 1986 such that nothing was received in October which may have limited the growth and subsequent yield of the crop.

5.1 Effects of Nitrogen

5.1.1 Vegetative growth

The application of 20kg N/ha in all the years of the experimentation did not significantly affect the vegetative growth of the crop measured in terms of plant height, plant foliage spread dry weights of stems/petioles, leaves and haulm yield except at certain stages of the crops growth in some years. It is universally agreed that bambara groundnut, like other leguminous plants, fixes its own nitrogen with the aid of Rhizobium spp. According to Styn (1975) if nitrogen is applied to legume, it tends to take it up instead of using Rhizobia nitrogen and nodulation is reduced. However, there is no authoritative statement on whether

or not the symbiotically fixed nitrogen is sufficient to meet the requirements of the crop. For example, Dadson and Brooks (1989) reported that bambara groundnut nodulated freely with indigenous rhizobia and usually produced more nodules and greater nodule dry weight in low-nitrogen (25kgN/ha) than in high-nitrogen (50kg N/ha) treatment. With the high-nitrogen treatment they observed inadequate infectivity or efficacy of the indigenous rhizobia because the high-nitrogen treatment gave higher total dry weight and grain yield than the low-nitrogen nodulated plants. Dadson et al. (1988) believed that symbiotic fixation was sufficient for bambara groundnut yield in West Africa provided that inoculation with selected indigenous rhizobia has been done. The application of 20kg N/ha as a starter dose in Samaru (Northern Guinea Savanna), may therefore, be irrelevant even if the nitrogen level in the soil is low as is the case with the soils used for the study. (Table 1). Bambara groundnut is believed to have originated in Nigeria and this implies that our soils are rich in the local rhizobia strains and hence inoculation may be irrelevant. Another fact that the grains are large hence the food stored is enough to support the crop early, up to the time it would start fixing the nitrogen it requires while photosynthesing. This lack of response by legumes to nitrogen application especially in terms of

their vegetative growth was observed on soyabean (Abaver, 1983); groundnut (Anonymous, 1991) and cowpeas (Yayock, 1975).

5.1.2 Yield and yield character

The 20kg N/ha starter dose did not affect the grain yield of the bambara ground in all the years of the study indicating that either the crop can fix its own nitrogen necessary for its survival or that the crop is efficient in the absorption of the nutrient from even the subsoil layers and from a wide area of the rooting zone. From the studies (Linnemann, personal communication) of the rooting of the crop done at the Department of Tropical Crop Science, Agricultural University in the Netherlands, it was found that the roots of bambara groundnut are longer and spread more than those of groundnut (Arachis hypogeae L.). Although the 20kg N/ha dose applied did not influence the yield of bambara groundnut in Samaru on soils that are very low in their nitrogen contents, the application of higher dose of nitrogen may influence the yield of the crop since in most of the years of the experimentation, the grain yields have not been impressive. For example, Dadson and Brooks (1989) found that a high nitrogen treatment (50kg N/ha) gave higher total dry weight and grain yield than low-nitrogen treatment (25kgN/ha). In other legumes such as soyabean, cowpea and groundnut several workers have also reported

that symbiotic nitrogen fixation alone could not sustain high yields and, therefore, there is a need for supplemental nitrogen (Boswell and Anderson, 1976; Kuwahava et al., 1986; Jana et al., (1990) and Mahalle et al., 1991). They reported that the initial application of 10 to 20kgN/ha to be beneficial to yield of the crops. On the contrary, many studies have shown lack of response of these legumes to nitrogen fertilization (Rachie and Sylvestre, 1977); and Kalia et al., 1984).

The shelling percentage and the 100-grain weight were significantly reduced by the application of the 20kg N/ha starter dose in 1986 and 1989 respectively. The likely reason for this may be that the nitrogen may have been used for the production of proteins i.e. may have rather improved the quality of the grains than the quantity and hence the smaller grain size and especially because the N in the shoot is low.

5.2 Effect of Phosphorus

5.2.1 Vegetative growth

The application of between 25kg to 50kg P_2O_5/ha was observed to have significantly increased the vegetative growth of the crop during the period of the study. The results of the soil analysis indicate that there were low levels of phosphorus in all the soils used. Phosphorus plays a key role in the physiological processes of root production, nodulation and N-fixation (Sankar et al.,

1984). The fact that phosphorus is a constituent of every living cell, phospholipids, nucleoprotein and is found extensively in the young growing parts, emphasizes the importance of the nutrient in the growth and yield of the crop. The increase in the vegetative growth as a result of the application of phosphorus could have been due to the low level of available phosphorus in the soil, which may have been as a result of the low soil pH. Agboola and Obigbesan (1977), Lombin (1979) and Pal et al., (1983) found increases in the vegetative growth of cowpeas, groundnut and soyabean respectively. Rates ranging between 6kg to 128kg P/ha were used in their studies.

5.2.2 Yield and yield characters

For high yields of legumes in general, the application of various quantities of phosphorus have been recommended for legumes in Nigeria. For example 17kg, 24kg and 27kg P/ha have been recommended for cowpea, groundnut and soyabean respectively. Bambara groundnut may not be an exception only that research into the nutrient requirements of the crop has just commenced and hence the lack of any recommendation. The application of 11-22kg P/ha was found to significantly increase the yield of grains and the yield characters of this crop (e.g 100-grain weight and shelling percentage) in the period of the study. This corroborates the findings of

Johnson (1968) who recommended the use of 112-170kg P_2O_5/ha and Stanton et al. (1966) who reported that it was economical to use 60kg P_2O_5/ha on this crop. This observed bambara groundnut yield response to phosphorus in Samaru may have been as a result of the low-available-P in the soil or the high-P required for the various physiological processes in the crop. On the contrary Cumberland (1978) and Nnadi et al, (1981) reported that no response was found with the application of up to 33kg P_2O_5/ha on this crop. In some cases phosphate application even decreased yields (Anonymous, 1979). In a green-house trial, Tanimu (1988) observed that rates and sources of phosphorus did not significantly affect the P-content and the P-uptake of bambara groundnut.

5.3 Effect of Potassium

Legumes have high potassium requirements but potassium fertilizers are rarely justified for rain-fed grain legumes in semi-arid regions (Doku, 1977).

Potassium has been said to be in abundance in most of the Savanna soils except in places where the soils have been intensively cultivated (Lombin 1979). Although potassium may not be lacking in our soils, its availability may be low since potassium can be in readily available, slowly available or unavailable form. Potassium is a nutrient which plants generally exhibit luxury consumption of its utilization. These and some

other characteristics of potassium may greatly affect the influence of potassium as a treatment on bambara groundnut.

5.3.1 Vegetative Growth

The application of potassium has had varying effects on the vegetative growth and development of this crop but in general, the application of potassium was found to have no effect on the vegetative growth of bambara groundnut. In most cases decline in the vegetative growth characters were observed with the application of potassium eventhough the extent of the decline were not significant. From the results of the soil analysis the level of available potassium in the soils used were in most better than those of nitrogen and phosphorus. This may have caused the non response of the crop to the applied potassium.

5.3.2 Yield and yield characters

At the Institute for Agricultural Research (IAR), potassium application has been recommended for legumes in the Sudan savanna soils of Nigeria. For example 25kg and 20kg K_2O/ha have been recommended for groundnut and soyabean respectively (Anonymous, 1984).

Potassium application in this study was found to significantly increase the grain yield in 1986 and 1988 when the application of 50kg and 25kg K/ha increased the grain yield respectively. In these years the levels of

potassium were found to be low in the soil compared to the other years. This corroborates a finding where the application of 21kg K/ha was observed to increase yield of the crop (Anonymous, 1979). The application of 25kg K/ha was observed to be beneficial to 100-grain weight and shelling percentage of the bambara groundnut generally.

5.3.4. Nutrient contents

In common with other leguminous crops bambara groundnut, requires virtually no nitrogen addition because of its capacity to manufacture its own nitrogen. Hence the non significant response in N content with or no addition, indicating that the external N was translated internally. The savannah soils are generally high in native K, Ca and Mg thus the concentration of these elements were not significantly affected by fertilizer addition. Although savannah soils are inherently low in phosphorus due to low pH and organic matter contents, the crop did not respond to applied P probably because of the relative high amounts of residual phosphate.

5.5 Interactions

Significant interactions were recorded involving nitrogen x potassium on plant height and phosphorus x potassium on foliage spread. Other interaction N x P x K was not significant for any of the vegetative growth

character. In most cases for the interaction between N x K, it was found that the application of 20kg N/ha at 0kg P/ha resulted in the tallest plants. This is normal because nitrogen is known to primarily encourage above ground vegetative growth and impart to shoot, deep green coloration. For the P x K interactions, it was observed that the two nutrients had a direct reciprocal effect i.e. a high dose of phosphorous at low potassium resulted in more foliage spread and vice visa.

5.6 Effects of sowing date

The recommended sowing dates for cowpea, groundnut and soyabean are mid-July to first week of August, early when the rains are established and between June 15 to 25 respectively. In order to determine the most appropriate time to plant bambara groundnut plantings were done on the dates indicated in appendix 7.

5.7.1 Vegetative growth

Plant height was found to be affected by the date of sowing at harvest in 1988, 1989 and 1990. In both 1988 and 1989 sowing in late June resulted in the tallest plants while in 1990, planting in the second week of August resulted in the tallest plants. This means that planting early would give the plant enough time to grow vegetatively. Plant foliage spread was found to have been affected by the dates of sowing at harvest in all the years. In 1987 and 1990 late sowing (late July to

early August), had the widest spread while in 1988 and 1989, the later the sowing, the narrower the spread. In effect, the earlier the planting, the more would be the vegetative growth, which is very logical. Contrary to this would have been due to the disease infection which severely affected the crop in 1987 and to some extent in 1990. This confirms the findings of Lawal (1988) who reported that planting early (June 24) resulted in better stand establishment dry matter yield and shoot height. Iheanetu (1988) also found a decrease in the number of flowers, pod number and grain yield of soyabean with delayed sowing (August 8). Atuk (1987) reported that sunflower plant height at harvest, number of grains per plant decreased with delayed sowing while leaf area per plant increased with delayed sowing. He attributed the increase in the leaf area per plant with delayed sowing to the prevalent of diseases early in the rainy season which must have reduced the amounts of leaves.

5.7.2 Yield and yield characters

Except in 1987, the grain yield was higher when the crop was planted early. This is expected because planting early would give the plant time to grow a lot of vegetation which would in turn vegetatively fully and produce adequate flowers which result in higher grain production. The exception to this, i.e 1987 may have been due to the severe fungal infection which resulted in

the low yields of the crop especially with the early planting. The late planted crops may have escaped the disease and since the crops were sprayed with fungicides after the disease was noticed may also have protected the late sown crops from the disease and hence the higher yields of the late planting. The 100-grain weight was higher with early planting than with the late-sown crop. Like explained above, the early planting had provided time for the plant to grow produce flowers and grains before the cessation of rains. i.e. a adequate time was provided for the crop to manufacture food from the source (green surfaces) and translocate it to the sink (grains) and hence larger grains and subsequent higher 100-grain weights. These corroborate the findings of Iheanetu (1988) who reported that early sown (June 24) soyabean out yielded the late sown crop (July 22) by 33.3%. Atuk (1988) reported a decrease in the number of grains per head and grain yield per plant by 35.3% and 27.3% respectively as a result of delayed sowing from July 2 to July 30. Lawal (1988) reported sorghum yield decrease of 15.06% as a result of delayed sowing from July 15 to August 6.

5.8 Effect of Intra-row spacing

5.8.1 Vegetative growth

The recommended intra-row spacings for groundnut, cowpea and soyabean are 20cm, 25-30cm and 5cm respectively.

In general, the closer the intra-row spacing the more the vegetative growth. This is so because there are more plants per unit area at any point in time. Since more plants are found, more vegetation would result. This however, was not always true especially in 1987 when the disease incidence was most severe. The result of the infection was generally stunted growth and/or reduced growth and discoloration of the photosynthetic organ (leaves). Another reason may be that with increase in intra-row spacing, the crop had more space to grow and cover and hence better vegetative growth.

5.8.2 Yield and yield characters

Grain yield was found to decrease with increase in intra-row spacing in all the four years of the study. This means that the closer the intra-row spacing the more the number of plants per unit area hence the higher the yield per unit area. This is not always true for most crops. It is an established fact that yield of crop plants within a certain range of population are always similar because those plants would always be able to compensate for the reduced number of plants. Research on

this crop is still at a tender stage, therefore, bambara groundnut may not be one of these crops, especially given its status which is very small. The small statue of this crop may mean that it requires a small area for its optimum performance.

The 100-grain weight did not follow the same trend. It was observed in the four years, that the wider the spacing the higher was the 100-grain weight. This may be because the wider the spacing the more the space for any one crop hence the more soil area for its root system to explore for mineral nutrition and the less the competition for the nutrients, moisture and sunlight. This implies that more carbohydrate is produced in the source and translocated to the sink (grains) and therefore the higher was the grain weight. In Zimbabwe, Johnson (1968) recommended a spacing of 10-15cm in single rows at a distance of 45cm and 20cm apart in double rows on flat topped ridges at a distance of 90cm. Anonymous (1979) recorded 962kg/ha of unshelled bambara groundnut when planted on rows spaced 1m apart and 1316kg/ha when planted on rows spaced 50cm apart.

5.9 Varietal Differences

5.9.1 Vegetative growth

Although varietal differences were in most cases insignificant, the Pategi-Black variety did grow more luxuriant than Giwa-White variety. The differences

between the two varieties may be genetic. The other reason may be adaption. Pategi-Black is a variety from the southern Guinea Savanna where rainfall is higher compared to the Giwa-White which is adapted to the northern Guinea where the rainfall is far less than that in the Southern Guinea. The Pategi-Black variety has had significantly more established stands than the Giwa-White variety. So the fact that more stands were established means that the vegetative growth would have been better for the Pategi-Black variety.

5.9.2 Yield and yield characters.

The Pategi-Black variety yielded significantly more grain than the Giwa-White variety. The genetic make up of the Pategi-Black may caused the difference and its better yield than the Giwa-White. Another reason could be the number of stands harvested. There were significantly higher number stands of the Pategi-Black harvested than the Giwa-White variety.

5.10 Correlations

Except in 1988 and 1990, plant height significantly positively correlated with plant foliage spread. The plant height and plant foliage spread were also found to have significant positive correlation with haulm yield in 1989. This is expected because the more the height the more would be the leaves and hence the more spread and subsequently the more the haulm yield. 100-grain weight

was significantly positively correlated with grain yield in 1988 and 1989, while shelling percentage was significantly positively correlated with grain yield in all the five years of experimentation. Negative non-significant correlation was observed between plant height and grain yield in most of the years.

CHAPTER SIX

SUMMARY AND CONCLUSIONS

Investigations were carried out for four years in Samaru to observe the effects of date of sowing, intra-row spacing and fertilizer levels on the yield and agronomic characters of two bambara groundnut varieties. Vegetative growth was luxuriant in all years although fungal infection was severe in 1987 which resulted in reduced growth and yield of the crop. Grain yield was best in 1988, 1989 and 1990 essentially as a result of favourable rainfall distribution (Appendices 2, 3, 4, and 5) and timely protective measures employed to control weeds, pests and diseases.

Timely or early planting when the rains were established (June) resulted in the best grain yield of bambara groundnut in 1988, 1989 and 1990 when the crop yielded best. Late planting (late-July to early August) reduced yield significantly.

Closely spaced plants (5cm) gave the best yields of the grains and haulms of the crop planted on ridges 75cm apart. This inter-row spacing is however, not the best because the 75cm distance between the ridges seemed too wide given the statute of the crop and the weed problem associated with the crop.

The Pategi-Black variety yielded more grain than the local Giwa-White variety in most of the years of the

experimentation.

The application of 20kg N/ha as a starter dose did not affect both the grain and haulm yields of the crop, however, the application of 11-22kg P/ha and 25-50kg K/ha were found to enhance the grain and haulm yields of bambara groundnut at Samaru. Maximum yields were obtained when 13kg and 26kg K/ha were applied.

There was a significant positive correlation between grain yield and shelling percentage in all the five years. The degree of association between 100-grain weight and grain yield was significantly positive in 1987-1989. In 1989 plant height was significantly correlated with plant spread and haulm yield.

Using the path coefficient analyses, it was observed that plant height and spread had direct positive contribution to grain yield while haulm yield and shelling percentage had direct negative contributions to the grain yield in most years of the experimentation.

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Appendix 1: Rainfall distribution (cm) at 10-day interval in Samaru during the period of study (1986 - 90).

Month	Days	1986	1987	1988	1989	1990
May	1-10	11.2	0	0	39.3	80.3
	11-20	18.4	0	35.4	20.5	25.8
	21-31	29.5	135.7	59.0	53.2	17.2
June	1-10	35.3	85.1	47.3	55.4	20.4
	11-20	22.6	16.2	17.2	21.0	62.1
	21-30	24.1	45.2	68.7	48.0	73.2
July	1-10	52.9	52.3	50.8	26.9	67.8
	11-20	49.4	106.4	48.2	31.5	84.6
	21-31	191.3	118.0	82.5	101.3	69.5
August	1-10	50.6	105.4	100.4	55.1	109.2
	11-20	94.9	75.2	107.9	29.8	44.7
	21-31	176.6	87.4	194.2	85.5	101.4
September	1-10	56.4	33.0	76.5	78.7	54.6
	11-20	81.2	57.1	71.0	29.9	58.8
	20-30	75.3	12.0	44.8	9.7	18.1
October	1-10	0	42.6	114.7	51.9	0
	11-20	0	0	0	1.0	0
	21-21	0	0	0	0	0
Total		969.7	972.2	1156.7	738.7	892.7

Source: Meteorological Station, Samaru.

Appendix 2 Samaru Meteorological Observation in 1986

MONTH	Rainfall (mm)		Number of Days of Rain		Relative Humidity (%)				Air Temperatures (°C)						SUNSHINE HOURS	
	1986	1928 to 1986	1986	1928 to 1986	1986		1938 - 1986		- 1986			1938 - 1986			1954-1986	
					AM	PM	AM	PM	MIN	MAX	MEAN	MIN	MAX	MEAN	1986	1954-1986
January	0.0	0.1	0	0.1	23.1	17.1	17.7	14.1	12.7	29.6	21.2	13.8	30.1	22.0	8.5	8.5
February	0.0	1.0	0	8.2	18.8	16.9	15.3	11.1	15.9	34.6	25.3	15.9	32.6	24.3	9.6	9.1
March	0.0	6.4	0	0.9	35.4	19.0	25.6	14.7	18.9	35.5	27.2	19.4	35.2	27.4	7.1	8.2
April	5.8	36.0	1	3.9	54.6	26.6	46.6	28.2	21.4	37.5	29.5	21.6	15.8	28.7	8.4	7.9
May	59.1	119.1	6	9.8	59.8	39.0	63.9	43.9	21.7	34.4	28.1	21.2	33.0	27.4	8.0	8.1
June	82.0	152.8	9	12.4	71.2	55.2	72.7	57.1	20.5	30.0	25.3	20.0	30.7	25.4	7.8	7.7
July	293.6	222.2	17	16.3	62.1	67.7	79.8	66.4	19.7	27.9	23.8	19.5	28.5	23.9	6.2	6.1
August	322.1	268.8	17	19.9	81.7	71.1	81.6	69.5	18.0	28.6	23.7	19.2	27.8	23.5	6.9	5.6
September	205.7	210.9	16	16.0	75.6	67.4	76.0	63.3	19.1	28.9	24.0	19.1	29.3	24.2	7.8	7.0
October	0.0	35.1	0	3.8	56.8	49.9	59.5	43.1	17.6	31.1	24.4	17.6	31.4	24.8	8.5	8.6
November	0.0	1.0	0	0.2	36.1	26.4	28.4	21.3	14.2	31.5	22.9	15.2	31.5	23.4	8.6	9.0
December	0.0	0.1	0	0.0	25.0	21.9	21.1	16.7	12.6	27.0	19.8	13.7	30.2	22.0	7.0	8.8
Total	968.3	1053.9	66	83.5	-	-	-	-	-	-	-	-	-	-	94.4	94.6
Mean	-	-	-	-	51.7	39.9	49.0	37.5	17.6	31.4	24.6	18.0	31.3	24.8	7.9	7.9

Appendix 3 Samaru Meteorological Observation in 1987

	Rainfall (mm)		Days of Rain		Relative Humidity (%)				Air Temperatures (^{o}C)						SUNSHINE HOURS	
MONTHN	1987	1928 to 1987	1987	1928 to 1987	1987 AM	1987 PM	1938 - 1987 AM	1938 - 1987 PM	1987 MIN	1987 MAX	1987 MEAN	1938 - 1987 MIN	1938 - 1987 MAX	1938 - 1987 MEAN	1986	1954-1986
January	0.0	0.1	0	0.1	21.4	18.8	17.8	14.2	12.5	30.5	21.5	13.8	30.1	22.0	9.2	8.5
February	0.0	1.0	0	0.2	11.8	10.3	15.2	11.1	16.3	33.1	24.7	15.9	32.7	24.3	8.9	9.1
March	0.0	6.3	0	0.8	26.7	16.3	25.6	14.7	19.6	34.9	27.3	19.4	35.2	27.4	6.5	8.1
April	5.8	35.5	0	3.8	18.5	9.9	45.8	29.7	21.7	36.3	29.0	21.6	35.8	8.7	7.0	7.9
May	135.7	119.9	7	9.8	50.6	25.1	63.5	43.4	22.2	36.7	29.7	24.2	33.0	7.4	9.0	8.2
June	146.8	154.1	13	12.4	76.5	60.5	72.8	21.1	30.7	25.9	20.0	30.7	25.5	5.5	7.6	7.7
July	276.7	222.9	18	16.3	79.8	65.0	79.8	66.4	20.2	30.1	25.2	19.5	28.5	23.9	7.6	6.2
August	268.3	269.1	23	19.9	85.4	72.4	8.2.7	69.6	19.8	29.2	24.5	19.2	17.9	23.6	6.0	5.6
September	102.1	210.2	8	15.8	75.9	63.2	76.0	63.2	26.4	30.4	25.4	40.1	29.4	14.2	8.0	7.1
October	42.6	35.4	3	3.7	53.9	44.0	59.3	43.1	17.5	31.0	24.3	17.6	31.4	24.8	8.6	8.6
November	0.0	1.1	0	0.2	22.7	18.9	28.3	21.2	12.4	31.8	22.1	15.1	31.5	23.3	9.0	9.0
December	0.0	0.1	0	0.0	24.0	19.2	21.2	16.8	12.5	29.9	21.4	13.6	30.2	22.0	8.8	8.8
Total	972.2	1055.7	72	83.0	-	-	-	-	-	-	-	-	-	-	96.2	94.8
Mean	-	-	-	-	45.6	35.3	48.9	37.4	18.0	32.4	25.1	18.0	31.4	24.8	8.0	7.9

Appendix 4 Miterorological Observations at Samaru in 1988

	Rainfall (mm)		Days of Rain		Mean Relative Humidity (%)		Mean Air Temperature (^{o}C)		Sunshine (Hrs)	
MONTH	1988	1928 to 1988	1988	1928 to 1988	1988	1938-1988	1988	1938-1988	1988	1954 to 1988
January	0.0	0.1	0	0.1	20.4	16.2	21.2	22.0	6.5	8.5
February	3.5	1.0	2	0.2	16.1	13.2	23.8	24.3	8.3	9.1
March	0.0	6.3	0	0.8	18.2	20.2	28.4	27.4	7.0	8.1
April	34.6	35.5	5	3.8	37.9	36.8	29.2	28.8	7.9	7.9
May	94.4	119.3	7	9.7	49.5	53.4	28.7	27.5	8.0	8.2
June	133.2	154.2	14	12.5	67.6	65.1	25.4	25.5	7.3	7.7
July	181.5	222.2	14	16.3	75.3	73.2	23.8	23.9	5.4	6.2
August	402.5	275.7	20	19.9	78.7	75.7	23.4	23.6	5.6	5.6
September	192.3	211.0	17	15.9	71.8	68.7	24.3	24.2	6.5	7.0
October	114.7	37.3	1	3.7	41.8	51.0	23.4	24.8	9.4	8.6
November	0.0	1.0	0	0.2	22.0	24.7	21.9	23.9	10.1	9.0
December	0.0	0.1	0	0.0	23.1	19.1	20.0	21.9	7.3	8.0
Total	1156.7	1063.7	80	83.0	-	-	-	-	89.3	94.7
Mean	-	-	-	-	43.6	43.2	24.5	24.8	7.4	7.9

Appendix 5 Samaru Meteorological Observation in 1989

MONTH	Rainfall (mm) 1989	Rainfall (mm) 1928 to 1989	Number of Days of Rain 1989	Number of Days of Rain 1928 to 1989	Relative Humidity (%) 1989 AM	Relative Humidity (%) 1989 PM	Relative Humidity (%) 1928 - 1989 AM	Relative Humidity (%) 1928 - 1989 PM	Air Temperatures (°C) 1989 MIN	Air Temperatures (°C) 1989 MAX	Air Temperatures (°C) 1989 MEAN	Air Temperatures (°C) 1938 - 1989 MIN	Air Temperatures (°C) 1938 - 1989 MAX	Air Temperatures (°C) 1938 - 1989 MEAN	SUNSHINE HOURS 1989	SUNSHINE HOURS 1954-1989
January	0.0	0.1	0	0.1	25.6	17.7	18.2	14.4	10.1	25.2	17.7	21.0	30.0	21.9	10.1	8.5
February	0.0	0.9	0	0.2	17.5	14.2	15.3	11.3	13.4	28.0	20.6	24.2	32.5	24.2	6.2	9.0
March	0.0	6.1	0	0.8	15.5	12.4	25.2	14.7	17.5	34.7	26.1	27.4	35.2	27.4	8.7	8.1
April	15.0	35.1	1	3.8	37.0	20.0	45.6	27.5	20.0	36.8	28.4	28.7	35.8	28.7	9.2	7.9
May	113.0	119.2	12	9.7	61.8	43.8	63.4	43.2	20.4	33.1	26.8	27.5	33.1	27.5	7.7	8.1
June	124.4	153.8	11	12.4	72.3	58.0	72.8	57.3	20.0	30.7	25.4	25.5	30.7	25.5	7.3	7.7
July	154.6	221.2	14	16.3	78.9	63.2	79.9	66.3	19.6	29.4	24.5	19.5	28.5	24.0	6.7	6.2
August	170.4	274.1	20	19.9	81.7	71.0	81.7	69.8	19.3	28.0	23.7	19.2	27.9	23.6	5.8	5.0
September	118.3	209.5	14	15.8	78.4	66.9	76.1	63.5	19.2	29.8	24.9	19.1	29.4	24.2	6.5	7.0
October	52.9	37.5	5	3.7	51.9	42.4	58.8	42.9	16.5	30.6	23.6	17.6	31.4	24.7	8.5	8.6
November	0.0	1.0	0	0.2	19.3	18.5	27.9	21.1	12.7	31.1	21.9	15.2	31.5	23.3	9.3	9.0
December	0.0	0.1	0	0.0	19.3	17.4	21.2	16.9	12.9	28.6	19.9	13.6	30.1	21.9	8.0	8.7
Total	748.6	1058.6	77	82.9	-	-	-	-	-	-	-	-	-	-	94.0	93.8
Mean	-	-	-	-	46.6	37.1	48.8	37.4	16.8	30.5	23.6	21.6	31.3	24.7	7.8	7.2

Appendix 6 Samaru Meteorological Observation in 1990

	Rainfall (mm)		Number of Days of Rain		Relative Humidity (%)				Air Temperatures (°C)						SUNSHINE HOURS	
MONTHN	1990	1928 to 1990	1990	1928 to 1990	1990		1938 - 1990		1990			1938 - 1990			1990	1954 to 1990
					AM	PM	AM	PM	MIN	MAX	MEAN	MIN	MAX	MEAN		
January	0.0	0.1	0	0.1	17.9	13.6	18.5	14.6	12.6	31.1	21.6	21.6	30.0	21.9	7.8	8.5
February	0.0	0.9	0	0.2	13.1	10.1	15.5	11.5	15.2	30.1	27.7	24.0	32.4	24.2	7.7	9.0
March	0.0	6.0	0	0.8	9.1	9.0	25.8	14.8	18.5	35.4	25.8	27.2	35.4	27.4	7.8	8.1
April	0.0	34.5	0	3.8	45.9	23.0	37.7	27.9	23.0	37.2	30.1	28.5	35.8	28.7	8.4	7.9
May	123.3	119.3	12	9.8	68.5	50.5	64.4	44.0	21.7	32.7	27.2	27.3	33.1	27.5	7.5	8.1
June	155.7	153.9	12	12.4	75.8	60.7	74.0	58.3	20.6	31.2	25.9	25.4	30.7	25.5	7.3	7.7
July	221.9	221.2	15	16.3	80.4	65.5	81.2	67.3	19.6	28.7	19.5	28.5	24.0	24.0	6.4	6.2
August	255.3	273.8	16	19.8	81.4	66.6	83.0	70.9	19.5	28.9	24.2	19.2	27.9	23.6	6.3	5.0
September	131.5	208.3	12	15.7	75.9	62.2	77.3	64.5	19.6	30.6	25.1	19.1	29.4	24.2	6.1	7.0
October	0.0	36.9	0	3.6	58.8	46.8	59.7	43.6	18.5	32.8	25.7	17.6	31.3	24.7	8.4	8.0
November	0.0	1.0	0	0.2	31.0	26.4	28.4	21.5	15.5	33.7	24.6	15.2	31.6	23.3	9.3	9.0
December	5.0	0.2	1	0.0	26.2	20.5	21.6	17.2	14.6	33.0	23.9	13.6	30.2	22.0	8.8	8.7
Total	892.7	1056.1	69	82.7	-	-	-	-	-	-	-	-	-	-	96.9	93.1
Mean	-	-	-	-	48.7	37.9	48.9	38.0	18.3	31.9	25.1	21.5	31.2	24.7	7.7	7.8

Appendix 7: The following are the dates when the experiments were planted in the various years of the study.

Sowing Dates	1987	1988	1989	1990
SD1	June 9	June 9	June 9	June 11
SD2	June 23	June 23	June 23	June 25
SD3	July 12	July 14	July 14	July 13
SD4	July 26	July 28	July 28	July 27
SD5	August 12	August 11	August 11	August 13

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Previous Qualifications

Institutions Attended	Period	Certificate/Diploma/Degree
LEA Primary School, Rigachikun	1963-69	Leaving School Certificate
Govt. Sec. School Zaria	1970-74	W.A.S.C.
SBS/ABU., Zaria	1974-75	IJMB Certificate
Ahmadu Bello University, Zaria	1975-78	B.Sc. (Agriculture)
	1980-82	M.Sc. (Agronomy)

Posts Held Since award of first Degree:

Organization	Period	Position
Kaduna State Ministry of Agriculture	1979	Agric. Officer II
Ahmadu Bello University, Zaria.	1979-81	Graduate Assistant
	1981-83	Assistant Res. Fellow
	1983-88	Research Fellow II
	1988-date	Research Fellow I

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Admission Number: PhD/Agric/9285/83-84.