Effect of Sowing Date and Plant Spacing on Growth and Yield of Bambara Groundnut (*Vigna subterranea*)

By

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DEDICATION

To my dear
Father, mother and sister

To my great family
Uncles, aunts, grandmother and late grandfather

To my friends and colleagues

With endless love

Jalal
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I wish to express my deepest gratitude and sincere thanks to my supervisor Prof. Tag El-Din El Shiekh Musa Hago for his support, suggestions, creative direction and scientific guidance. He had been a patient reader, editor and advisor.

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ABSTRACT

An experiment was carried out for one season (2007) in the Experimental Farm of the Faculty of Agriculture at Shambat to investigate the effect of sowing date and plant spacing on growth and yield of Bambara groundnut (*Vigna subterranea* L.). The treatments comprised three sowing dates: first of July, first of August and 15\(^{th}\) of August and four plant spacings (10, 15, 20 and 25cm). The design was randomized complete block design, with four replications. The parameters studied were: vegetative parameters (plant height, number of nodules/plant, nodules dry weight/plant, shoot and root dry weight and number of branches/plant), reproductive parameters (beginning of flowering, day to 50% flowering and number of flowers/plant), yield and yield components (plant density, number of pods/plant, pod set %, weight of pod/plant, shelling % and pod yield (kg/ha) and chemical composition (seed oil and protein contents). The results showed that sowing date significantly affected plant height, number of branches/plant, beginning of flowering, number of flowers/plant, number of nodules/plant, nodules dry weight/plant and shoot and root dry weight. Plant spacing significantly affected nodules dry weight/plant, beginning of flowering, pod set %, weight of pods/plant and pod yield. The results also showed significant effect of the interaction between sowing date and plant spacing on plant height, number of nodules/plant, nodules dry weight/plant, number of branches/plant, number of flowers/plant and beginning of flowering.
ملخص الابروحة

اجريت تجربة حقلية لمسمى واحد (2007) بمزرعة كلية الزراعة بشميات لدراسة تأثير تاريخ الزراعة ومسافات الزراعة على نمو وانتاجية فول ابونقو. كانت المعاملات ثلاثة تواريخ للزراعة: أول يوليو، أول أغسطس، و15 أغسطس واربعة مسافات زراعة (10، 15، 25، 20 سم). استخدم في تنفيذ التجربة تصميم القطاعات الكاملة العشوائية باربعة مكررات. تمت دراسة تأثير المعاملات المختلفة على النمو الخضري ونحو التمري وانتاجية وكذلك التركيب الكيميائي للبذرة. جمعت بيانات عن النمو الخضري (طول النبات وعدد العقد البكتيرية في النباتات والوزن الجاف للعقد البكتيرية في النباتات) وعدد الأفرع للنباتات والوزن الجاف للجماع الخضري والوزن الجاف للذكور. كما جمعت بيانات عن النمو الثمري وبداية الأزهار وعدد الأيام لـ50% أزهار وعدد الأزهار في النباتات. عن الانتاجية (الكثافة النباتية وعدد الفروق في النباتات ونسبة عقد الفروق ونسبة التكشير وانتاجية الفروق) وتحليل الكيميائي لتحديد محتوى البذرة من الزيت والبروتين.

أوضح النتائج أن لتاريخ الزراعة أثر معنوي على طول النباتات وعدد الأفرع للنباتات وبداية الأزهار وعدد الأزهار في النباتات وعدد العقد البكتيرية للنباتات والوزن الجاف للجماع الخضري والذكور. أما مسافات الزراعة فقد أثرت معنوي على الوزن الجاف للعقد البكتيرية وبداية الأزهار ونسبة عقد الفروق وزن الفروق في النباتات وانتاجية الفروق. كما أوضحت النتائج تأثيرًا معنويًا لتناول تواريخ الزراعة ومسافات الزراعة على طول النباتات وعدد العقد البكتيرية في النباتات والوزن الجاف للعقد البكتيرية في النباتات وعدد الأفرع في النباتات وبداية الأزهار وعدد الأزهار في النباتات.
CHAPTER ONE
INTRODUCTION

The Bambara groundnut (*Vigna subterranea* L.) formerly (*Voandzeia subterranea* L.) belongs to the family Leguminosae and originated in the Sahelian region (Begemann, 1988). The common name (Bambara groundnut) actually appears to be derived from a tribe that now lives mainly in Mali; (Efukwa) is the traditional name. Bambara groundnut (also spelled Bambarra in Rhodesia), has many common names such as Congo groundnut, Congo goober, Madagascar groundnut, earth pea, earth groundnut, Baffin pea, njugo bean (S.Africa), Voandzou, nzama (Malawi), indhluba and underground bean. Bambara earthnut is known in the Sudan as “Ful Abun Gawī”. Bambara groundnut is considerably less popular in other parts of the world. Cultivation of the crop is common in all of West Africa, once labeled as “the poor man's crop”.

After the introduction of the peanut (*Arachis hypogaea*), the Bambara groundnut has all but been forgotten by many agronomic researchers. In recent years, Bambara groundnut received resurgence of interest by the scientific community. It is widely accepted that Bambara groundnut is a resource that at the present is grossly underutilized by the developing world. Considering that Bambara groundnut is a popular crop in the whole of sub-Saharan Africa, its cultivation seems to have preceded the introduction of the common groundnut.

In many traditional farming systems, it is found intercropped with cereals (sorghum, millet and maize) and tuber crops (Rassel 1960). Bambara groundnut is an extremely adaptable plant. It is well suited for hot, dry weather and marginal soil and will continue to grow in conditions too dry for sorghum, maize and peanut. It also has the reputation of resisting pests and diseases. Bambara groundnut is
essentially grown for human consumption but is also used as a fodder for livestock (National Academy of Sciences 1979; El Wakeel and Osman, 1992). In Kordofan, farmers plant the crop on sandy soils which are easily worked with hand tools. The infiltration rate is high and soil fertility is low. The crop is generally cultivated on small farms and mainly consumed fresh by humans, the pods are boiled and the seeds are eaten as a snack. The seed contains sufficient quantities of protein, 19% (Johnson, 1968 and Stanton, 1966). Several workers have examined the biochemical composition of the seed; the protein is reported to be higher in the essential amino acid methionine than other legumes (Owusu-Domfeh et al. 1970; Olyemi et al. 1976; Oliveira 1976; Linnemann, 1987).

The plant has good ability to fix atmospheric nitrogen. In Africa, the Bambara groundnut is generally cultivated by women, on small farms. In 1982, world Bambara groundnut production was around 330 000 t (Linnemenn 1994). A total of 150 000-160 000 t, or 45-50% of world production of crop, came from West Africa (Kiwallo 1991). In Burkina Faso Bambara groundnut is the third most important legume crop after peanut and cowpea (Kiwallo 1991). In Ghana according to 1970 Ghana Agricultural Census, there were 2800 hectares of Bambara groundnut under cultivation. In Tanzania Rachie (1979) reported pod yield of 612-1557kg /ha, and in Zimbabwe 843-1567 kg/ha (Johnson, 1968).

The crop has also been introduced into many countries such as India, Malaysia, northern Australia and tropical Central America. However, nowhere outside the African continent has its cultivation assumed any large proportion (Khidir 1976; Marloth, 1940). In the Republic of Botswana, Bambara groundnut has the third highest production of the grain legumes, coming after cowpea and groundnut,
Bambara groundnut was carried to America by slaves, but has never become as popular as the peanut, which has a higher level of protein.

Although in some areas farmers have specialized in Bambara groundnut production for cash income, production figures are quite variable, depending on the rainy season. In Sudan savannah zone, it is usually cultivated towards the end of the single long rainy season. It is also grown in small patches in some parts of Western Sudan, Northern and Southern, Kordofan, Darfur States, Bahr el Ghazal and Equatoria Provinces (Khidir, 1976; El Wakeel and Osman, 1992), Eastern Sudan in El Gadarif State. There is no sufficient information regarding the crop production and cultural practices. The objective of this study was to investigate the effect of sowing date and plant spacing on growth and yield of Bambara groundnut.
CHAPTER TWO
LITERATURE REVIEW

2.1 Economic Importance:

Bambara groundnut, in Sudan, is grown in limited areas, principally in northern and southern Kordofan and Darfur, Bahr El Gazal, Equatoria and El Gadarif (El Wakee and Osman, 1992). The crop is locally known as “Abu ngawi”. And there are different “types” such as “Farshay and Tagmala” in Kordofan, “Sanfour” in El Damazeen and El Gadarif (Mustafa, 2007 personal communication). In Kordofan, especially the crop has many local names, depending on the seed color, such as “Chalol” (black−yellow), “Pidee Red” (speckled with black spots), “Kinta” (yellow−white), “Lukoo” (black), “Garshi” (yellow−whitish) and “Malomita” (variously mottled) (El Wakeel and Osman, 1992). Most of the farmers in Kordofan produce the crop for their own household’s need or for local rural markets. Small quantities are for sale out of the area. Other farmers sell their produce to the village merchants who in turn sell it at the rural markets. The crop is purchased by local merchants who sell it at urban markets to consumers (El Wakeel and Osman, 1992).

Bambara groundnut is essentially grown for human consumption. The seed makes a complete food, as it contains sufficient quantities of protein, carbohydrate and fat. On average, the seeds contain 63% carbohydrate, 19% protein and 6.5% oil. Despite the relatively low oil content, some tribes in Congo reportedly roasted the seed and pounded them for oil extraction (KariKari, 1971). Cobley, (1976) reported that the seed contains 4−6% oil, 16−21% protein and 50−60% carbohydrate. Johnson (1968) and Stanton (1966) reported that the seeds contain 19% protein, 59% carbohydrate and 7% ether extract.
Bambara groundnut seeds are consumed in many ways. They can be eaten fresh, or grilled while still immature. In many West African countries, the fresh seeds are boiled with salt and pepper, and eaten as a snack. In East Africa, the seeds are roasted, then pulverized and used to make a soup, with or without condiments. Bread made from Bambara groundnut flour has been reported in Zambia (Linnemann, 1990). Roasted seed can be boiled, crushed and eaten as a relish. Another common use of Bambara groundnut is to make steamed products, such as ‘akara’ and ‘moin–moin’ in Nigeria (Obizoba, 1983). Recently, a trial of Bambara groundnut milk was carried out which compared in flavor and composition with milk prepared from cowpea, pigeon pea and soybean (Brough et al. 1993).

Bambara groundnut has long been used as animal feed, and the seeds have been successfully used to feed chicks (Oluymi, et al. 1976). The haulm was found to be palatable (Doku and Karikari, 1971), and leaves are reported to be rich in nitrogen and phosphorus, and therefore suitable for animal grazing (Rassel, 1960). The gross energy value of Bambara groundnut seed is greater than that of other common pulses such as cowpea, lentil and pigeon pea (FAO, 1982).

The seeds of Bambara groundnut are also used in traditional medicine. Water from the boiled maize and pulse mixture is drunk to treat diarrhea. The leaves are pounded with those of (Lantana trifolia L.), then water is added and the solution used to wash livestock as a preventive against ticks. This solution is also used as a pesticide on vegetable. The leaves can be combined with those of “Niagara” (Mexican marigold) and L. trifolia, pounded, and water added. This mixture can also be used as an insecticide. When applying the solution to vegetables, care needs to be taken to apply it to the ground, and not to pour it on the leaves, as it is
reported to burn them (Begemann, 1988). When dry, the leaves are pounded with salt and used for treatment of mouth disease in cattle.

2.2. Chemical composition:

The chemical composition of Bambara groundnut seeds varies according to type.

Protein varied from 8.2 to 16.6%; carbohydrate from 51.2 to 57.0%; fat from 5.5 to 6.8%; fiber from 5.5 to 6.4% and ash from 3.2 to 4.0%. Mineral content mg/100g ranges as follows: Ca 95.8–99; Fe 5.1–9.9; K 1144.7–1435.5 and Na 2.9–10.6. The dark-seeded (red and black) types tended to have higher nutrient and mineral contents than the light-seeded ones (cream and white), (Gibbons, 1994). Chemical analysis of a local Sudanese types from Kordofan, gave the following composition:

59.63% carbohydrates, 23.89% crude protein, 5.83% fat and 4.30% ash. (By curtsey of Dr. Hashim Abdel Mutalab). It contains about 5% more protein than was reported by Johnson (1968) and Khidir (1976). El Wakeel and Osman (1992) reported crude protein as 18.7% and oil content as 10.8%.

2.3. Botanical Description:

Bambara groundnut is grown for its underground pods. The entire plant is similar to the common peanut, being a low, flat annual with compound leaves of three leaflets. There is also an erect form. Like the peanut, it forms pods and seeds on or just below the ground. To achieve this, the flower stalk elongates and penetrates the soil. The bulbous tip creates a tunnel through which the fertilized ovule, attached just behind the tip, is drawn into the soil. The pods are round, wrinkled, and over ½ inch long. Each contains one or two seeds that are round, smooth, red,
mottled, or black-eyed (Begemann and Mushonga, 1995). There are numerous nitrogen–fixing nodules on the root. Differences in the length of internodes results in bunched, intermediate (semi–bunched) and spreading type. The general appearance of the plant is bunched leaves arising from branched stems which form a crown on the soil surface. Stem branching begins very early, about one week after germination, and as many as 20 branches may be produced. Each branch is made up of internodes, and those near the base are shorter than the more distant ones. The roots form nodules for nitrogen fixation, in association with appropriate rhizobia. Leaf and flower buds arise alternately at each node. The flowers are borne on hairy peduncles, which arise from the node of the stems (Doku and Karikari, 1971). The pod grows first, and reaches its mature size about 30 days after fertilization. The seed develops in the following 10 days. Mean temperature during the season influences the time taken to achieve physiological maturity. The pods usually develop underground, and may reach up to 3.7cm in length, depending on the number of seeds they contain. Most varieties have single-seeded pods, but pods with three seeds were frequently found in ecotypes collected in Congo (Goli and Ng, 1988). Mature pods are indehiscent, often wrinkled, ranging from a yellow to a reddish dark brown color (Begemann and Moshanga, 1995).

2.4. Nodulation:

The average number of nodules per plant reported in Zimbabwe was only 11. This is much lower than that recorded in countries such as Ghana, where the number of nodules per plant ranged from 92 to 318 (Thompson and Dennis, 1977; Mafongoya, 1988). There was no relationship between the number of nodules per plant and the plant
density. One reason for the low nodules number is the fact that most farmers do not inoculate seed with \textit{Bradyrhizobium} at planting.

2.5. Flowering and Maturity:

El Wakeel and Osman (1992) reported that the crop is harvested between 110 to 120 days after sowing. Begemann and Moshanga (1995) reported that number of days to 50\% flowering varies from 37 to 45 days, with the first flowers appearing one week earlier. Flowering starts within 44–60 days after sowing and generally within 80 days, 50\% of plants flower. Bambara groundnut takes about 3-6 months to mature, depending on climatic conditions and the cultivar (Stephens, 1994). Kebadumetse (1994) reported that the cream landrace produced more flowers and also matured earlier than the red landrace.

2.6. Breeding System:

Cobley (1956) stated that the flowers are cleistogamous and that self-pollination is the rule. Observations at Shambat indicated that the flowers open from 7 a.m. onwards and that the two flowers in the axil of a leaf do not open at the same time (Khidir, 1976). The extent of cross-pollination depends on insect activity, and amounts to 60–80\%. Doku (1968) studied flowering pollination and pod formation and reported that the pollen matures and the stigma becomes receptive before it is fully open. He demonstrated that pollination is carried out by two species of ants (\textit{Pheidol megacephala} and \textit{Monomorium phoaraonis}) and suggested that some incompatibility exists among varieties. He stated that cross-pollination may be greater in strains or varieties with a more open habit than in the bunch types.
2.7. Environmental Requirements:

2.7.1. Climate:

Bambara groundnut grows best in climates suitable for peanut. It needs bright sunshine, high temperatures, at least 4 months free of frost, and frequent rains to grow best. The plant, however, is highly adaptable and tolerates harsh conditions better than most crops. It yields under conditions too dry for peanuts (Stephens, 1994). Bambara groundnut growing areas are located in semi-arid tropics. Rainfall is the most limiting factor. Manjarrez and Morteo (1999) reported that Bambara groundnut is commonly found in warm and tropical areas where the annual rainfall ranges from 600-1400 mm, and the crop shows high adaptability to low rainfall. It is one of the two most drought tolerant legumes after cowpea.

2.7.2. Soil:

Generally, the crop tolerates the harsh conditions of low rainfall, dry spells and poor soils. Manjarrez and Morteo (1999) reported that, Bambara groundnut can grow in poor soil where no other crop can survive. The crop thrives better in deep, well-drained soils with a light, friable seedbed, but it is usually grown in relatively poor soils, mainly in monoculture. Martin (1959) and Johnson (1967) reported loose sandy or loamy soils are best and heavy soils are unsuitable. However, nitrogen-rich soils tend to encourage vegetative growth and to give lower yields of larger-sized seeds.
2.8. Cultural Practices:
2.8.1. Sowing Date:

Time of planting is critical, generally the best time of sowing is as soon as soil becomes well moistened (Johnson, 1967). In Sudan (Kordofan region), El Wakeel and Osman (1992) reported that, the crop is usually planted after the first effective rains (about 15 mm or more), or as soon as soil moisture is conductive. The most common planting occurs between early and mid July, some farmers plant late in July (3rd week). Hepper (1963) reported that in N. Cameroon’s sowing takes place in May when the rains begin.

In western Kenya, Begemann and Moshana (1995) reported that Bambara groundnut is normally planted in March and harvested in August. Johnson (1965-66) studied different planting dates and soil textures: He reported that 30/ November planting date gave 2530 lb/acre on clay soil and 1420 lb/acre on sand soil. At 7/December the clay soil gave 135 lb/acre and the sand soil gave 1100 lb/acre. 14/ December gave 1230 lb/acre on clay and 391 lb/acre on sand and at 21/December the clay soil gave 838 lb/acre and sandy soil gave 195 lb/acre. Collinson, et al. (2000) also stated that: the highest pod yields were achieved at the earliest sowing date, with a maximum of 2.87 and 1.42 t/ha for the red- and cream-seeded type representing pod harvest indices of 0.56 and 0.34, respectively. A 30 day delay in sowing caused more than 60% reduction in pod yield, and a further 30 day delay resulted in no pods at all. Similarly, in 1995 successive delays in sowing caused dramatic yield declines, and maximum yield was much lower, at 0.44t/ha. In 1996 there was no significant difference in pod yields between the two early sowing dates for the red-seeded and yields were again lower in 1994 with a maximum of 1.02 t ha-1. Differences in dry mater production between sowing dates and years were attributed mainly to differences in amount
and distribution of rainfall and to declining temperatures towards the end of the season.

2.8.2. Land Preparation:

Soil should be ploughed 7″– 9″, deep (Valentine, 1963). If ridging equipment is available, the making of flat- topped ridges with 36″ centers is recommended where the land is susceptible to water logging or where the soil is shallow. In Sudan (Kordofan region), El Wakeel and Osman (1992) reported that the bushes and vegetation are cut and the field is cleared before onset of rains (El Wakeel and Osman, 1992).

2.8.3. Spacing and Seed Rate:

In Sudan El Wakeel and Osman, (1992) reported that planting is on flat rows spaced most commonly about 30×30cm and the range of plant spacing is 20-50×15-30cm. de Schlippe (1956) reported that a seed rate of about 150Ib./acre is considered sufficient using rows that are 2-3 feet apart and 0.5 feet between the plants. Johnson (1967) reported that it is probably best to plant 4-6″ apart in single rows 18″ apart on the flat or in double rows 8″ apart on ridges with 36″ centers. The required Seed rate will be 125-170Ib./acre required at 4inch spacing or 80-115Ib./acre at 6″ spacing. El Wakeel and Osman (1992) reported that a high plant population is essential for good yield and the crop should be planted in rows to assist subsequent cultivation. Usually 2-3 seeds/hole are planted at 2″ depth (De Chlippe, 1956). Ridges are especially recommended if the land is susceptible to water logging.

2.8.4 Intercropping:

In Ghana, the crop is always grown at high densities, in pure stand and in rotation with cereals. Sometimes it is grown in mixed stands of Bambara and peanut or yams (Doku, 1969). The majority of the farmers
in Kordofan plant watermelon between the rows of Bambara groundnut at late flowering stage “relay cropping” (El Wakeel and Osman, 1992).

2.8.5 Fertilization:

Bambara groundnut improves the nitrogen status of the soil (Mukurumbira, 1985). Farmers do not normally apply chemical fertilizers to Bambara groundnut. The nitrogen requirement is met by natural N fixation, as indicated by several nodulation studies (Doku, 1969; Somasegaran et al., 1990). Yield increase as a result of phosphate or potassium application has not been confirmed (Johnson, 1968; Nnadi et al. 1981). Grant (1988) reported that, a decline in soil fertility was the major reason for the decrease in Bambara groundnut yield. Soils on which the crop is usually grown are generally coarse-textured sand, and largely deficient in nitrogen, phosphorus and sulphur.

2.8.6 Rotation:

Under most traditional farming systems, Bambara groundnuts are grown as a mixed crop in combination with maize, small grains, beans or groundnuts (Ghana, 1962; Priestley and Greening, 1950). El Wakeel and Osman (1992) reported that, almost all farmers (95%) in Kordofan indicated that the crop is cultivated for 1 to 2 years and then be followed by millet. Other rotations mentioned were:

- Bambara-Sesame-Millet
- Bambara-Millet-Sesame
- Bambara-Sorghum-Sesame

Generally the crop was reported to benefit the subsequent crops in the rotation.
2.8.7. Weed Control:

Mafongoya (1988) reported that the crop is weeded at 2-3 weeks after planting. El Wakeel and Osman (1992) reported that most of the farmers weed twice, very rarely three times. The first weeding occurs at about 2 weeks from germination or 3 weeks from planting. The second weeding is at about early flowering (after 5 weeks from planting). At the second weeding the rows are usually earthened up to promote peg penetration and fruit development.

2.8.8. Pests and Diseases:

Bambara groundnut has a reputation for resisting pests, and compares favorably with other legumes such as groundnut or cowpea in this regard. In humid environments, however, fungal diseases such as Cercospora leaf spot, Fusarium wilt and Sclerotium rot are common (Billington, 1970; Begmann, 1988). In such circumstances, spraying with the fungicide benlate (1kg/ha) has proved beneficial. Viral diseases are widespread in most environments, especially in areas where other grain legumes such as cowpea are grown. Combination of unusually heavy virus attack and Cercopora leaf spot on one particular accession (TVSU 218) resulted in zero yields during a trial at Kaboinse, Burkina Faso (Goli et al. 1991). The crop appears to be rarely attacked by pests. Termites were the main insect pest observed by some farmers. Their damage does not seem to be severe enough to require control measures. Rats and rabbits were also mentioned to attack the crop. Shelled seeds are susceptible to attack by Bruchids in the store, but unshelled pods can store for years with no damage (El Wakeel and Osman, 1992).
2.8.9. Harvesting:

Bambara groundnut harvesting is similar to the peanut harvesting. The plant is pulled from the soil exposing the nuts which grow beneath the ground. For the bunched-habit type, most pods remain attached to the root crown. Detached pods left in the ground are collected manually. In a dry environment, harvesting takes place when the entire foliage dries up. In humid regions, however, pod-rotting or early seed germination in the pod may take place while the leaves are still partially green. Harvesting is then recommended before full foliage drying. El Wakeel and Osman (1992) reported that usually, the crop is harvested between 90 to 100 days after sowing. Mature nuts are harvested between 110 to 120 days from planting. Harvesting is done when the leaves turn yellow, and the crop is then dried under the sun for five to seven days then the pods are stripped off and left in the sun to dry.

2.8.10. Shelling and Storage:

Shelling percentage ranges from 18 to 22%, and shell thickness from 0.35 to 0.47mm. El Wakeel and Osman (1992) reported a shelling out-turn of 66.9%. The Cream and white-seeded types have thinner shells and seed coats (Kebadumetse, 1994). Traditionally the crop is shelled by hand, using a flat stone or brick. The crop is ready for shelling when the pods rattle upon shaking. However, shelling should take place only when the nuts are required for rations, sale or seed. Bambara groundnuts, store well in the pod but they are extremely susceptible to weevil damage after shelling. On average 2–2½ bags unshelled pods give one bag shelled seeds (Johnson, 1967). Seed to be used for next season’s planting are retained in sacks which are exposed to sunlight over roofs of huts (straw sheds locally known as Rakuba). Few farmers dress the stock
with Alder, while the majority mix or overlay the stock with ash, against store pests.

2.8.11. Yield:

Yield is one of the most important aspects to be considered in efforts to improve the level of production. Current yields are generally low, ranging from 400kg/ha to just under 1400kg/ha of unshelled seed (Begemann and Moshana, 1995). El Wakeel and Osman (1992) reported that the low yield is almost certainly attributable to low plant populations and late planting. In Sudan average yield obtained by farmers is estimated to be around 952 kg/ha of unshelled nuts. In good years with adequate rainfall the yield can reach up to 1904kg/ha, while in bad years of severe moisture stress as low as 404.6 kg/ha are obtained. Yield variability and low yields are due to erratic rainfall, poor agronomic practices, low soil fertility, lack of improved strains and lack of inputs. Mafongoya (1988) reported that Bambara groundnut yields generally range from 400–1400kg/ha. Kebadumetse (1994) reported that, lower yields have always been recorded for the cream-seeded types.
CHAPTER THREE
MATERIALS AND METHODS

3.1. Study area:

A field experiment was carried out during the summer of 2007/08 season, to study the effect of sowing date and plant spacing on growth and yield of Bambara groundnut (*Vigna subterranea* L.). The study was conducted at the Demonstration Farm of the Faculty of Agriculture, University of Khartoum at Shambat (latitude 15°40", N, longitude 30°32"E and altitude 380m above Sea level). The locality is in the semi-arid zone with hot summer, a mild winter and short rainy season during the period July -September. The average annual rainfall is about 150-180mm, and the daily mean maximum and minimum temperatures range between 40-21°C in summer and 25-15°C in winter respectively. Some meteorological data at the experimental site during the experimental period are shown in (Appendix 1). Saeed (1968) described the soil as heavy brown cracking clay (48-54% clay), low in nitrogen and with an alkaline reaction (pH 7.5-8.0).

3.2. Experiment:

The experimental area was disc ploughed, followed by disc harrowing and then levelled and ridged. The experimental area was then divided into plots each 5×5meters in area. Each plot contained seven ridges with 70 cm space between ridges.

The treatments consisted of three sowing dates first July, first August and 15th August, designated as *S*₁, *S*₂ and *S*₃ respectively and four intra-plant spacings (10, 15, 20 and 25 cm). The experimental design used was randomized complete block design, with four replications.
Seeds of a local Bambara groundnut type were sown in holes at the rate of four seeds/hole. Irrigation was applied immediately after sowing and second irrigation was done after 5 days from the first irrigation to facilitate seedling emergence. Subsequent irrigations were given at 10-14 days intervals depending on rainfall and weather conditions. Weeding was carried out by hand using a hand hoe (naggama) after 21 days from sowing and then whenever it was necessary.

3.3. Data Collection:

3.3.1. Vegetative parameters:

The vegetative parameters were measured on five plants randomly taken from the two outer ridges in each plot, to determine the following:

3.3.1.1. Plant height:

Plant height was taken every week starting at one month from sowing. Five plants were tagged at random in each plot. Plant height was measured from the soil surface to the tip of the plant and average plant height was recorded.

3.3.1.2. Number of nodules/plant:

Number of nodules per plant was determined at the 7th week from sowing. Plants were dug out carefully when the soil was wet to avoid loss of nodules. Any detached nodules were collected from the holes. The roots were then washed gently with tap water and nodules were separated from roots by means of forceps and counted, and mean number of nodules was calculated.
3.3.1.3. Nodules dry weight/plant:

Nodules dry weight was determined after the nodules were air dried in the laboratory for one week and weighed by using sensitive balance (Mettler AAA 160L).

3.3.1.4. Shoot and root dry weight:

Shoot and root dry weights were determined at two stages, the first after one month from sowing and the second at maturity. The shoots and roots of the sampled plants were separated and then dried under the sun for two weeks. Shoots and roots were then weighed by using sensitive balance and mean weights were obtained.

3.3.1.5. Number of branches/plant:

This parameter was determined once at harvesting, five plants were tagged at random in the yield area (2.1m²). The number of branches on each of the sampled plants was counted and mean number of branches per plant was recorded.

3.3.2. Reproductive parameters:

3.3.2.1. Start of flowering:

Start of flowering was recorded as number of days from sowing to appearance of the first flower and then mean time for each treatment was obtained.

3.3.2.2. Days to 50% flowering:

Days from sowing until the time when 50% of the plants in each plot flowered were counted for each plot, and the mean time was calculated.
3.3.2.3. Number of flowers/plant:

The total number of flowers per plant was counted at the maximum flowering stage. Five random plants tagged from central ridges in each plot were used for this purpose. The mean flower number per plant was obtained.

3.3.3. Yield and yield components:

Final yield and yield components were determined on one sowing date only (1/7), because the plants from other two sowing dates (1/8 and 15/8) could not complete their growth until maturity due to termite damage.

Yield and yield components were determined from an area of 2.1m² in the middle three meters in the central three ridges in each plot. After the four month from sowing (when the leaves turned brown and started to fall off) plants in the yield area of each plot (2.1m²) were dug out manually when the soil was suitably wet, detached pods left in the ground were also collected. Then pods were separated from the plant roots, cleaned and dried under the sun for two weeks.

3.3.3.1. Plant density at harvest:

The number of plants in the yield area was counted and the number of plants/m² was then determined.

3-3-3-2 Number of pods per plant:

Pods of five individual plants randomly taken from the yield area in each plot were counted; the mean number of pods per plant was recorded.
3.3.3.3. Percentage of pod set:
At harvesting time, number of pods of the plants used for determining number of flowers was counted. Percentage of pod set was calculated according to the following formula:

$$\text{Percentage of pod set} = \frac{\text{Number of pods/plant}}{\text{Number of flowers/plant}} \times 100$$

3.3.3.4. Weight of pods per plant:
Pods of the above-mentioned plants were dried under the sun for two weeks then weight of pods per plant was determined, using sensitive balance.

3.3.3.5. Shelling percentage:
Sample of 10g of pods was randomly taken from pod yield of each plot then shelled. Seeds were then weighed and shelling percentage was calculated according to the formula:

$$\text{Shelling percentage} = \frac{\text{Weight of seeds}}{\text{Weight of pods}} \times 100$$

3.3.3.6. Pod yield/ha:
The weight of pods in the yield area in each plot was recorded, and then transformed to pods yield per hectare.
3.3.4. Chemical analysis:

3.3.4.1. Seed oil and protein content:

Ten grams of seeds were taken from the yield of each plot and used to determine the oil percentage by the Soxhlet method and protein percentage by the micro-Kielfdal method. (Appendix 2 and 3).

3.4. Statistical Analysis:

Analysis of variance (ANOVA) was performed on the data according to the method described by Gomez and Gomez (1984) for randomized complete block design. Means were separated using Duncan's Multiple Range Test (DMRT).
4.1. Vegetative parameters:

4.1.1. Plant height:

The effect of sowing date and plant spacing on plant height is presented in Table (1). Analysis of variance showed significant effect of sowing date on plant height at all the stages studied, where S1 and S2 gave similar 15.73 and 17.37 cm, but had significantly taller plants than S3 gave 11.82. Plant spacing treatments had no significant effect on plant height, although 10 cm spacing gave slightly taller plant than the other spacing. The interaction between sowing date and plant spacing had significant effect on plant height.

4.1.2. Number of Nodule per plant:

The results showed that at 53 days from sowing, sowing date significantly affected nodule number per plant (Table 2), where S3 gave the highest nodule number 5 nodules and S2 the lowest number 3 nodules. Plant spacing showed no significant effect on nodule number, but 25 cm spacing showed the greatest number of nodule per plant than others, while 20 cm spacing gave the lowest nodule number. The interaction between sowing date and plant spacing had significant effect on number of nodule per plant.
Table (1). Effect of sowing date and plant spacing on plant height (cm):

<table>
<thead>
<tr>
<th>Spacing(cm)</th>
<th>30</th>
<th>38</th>
<th>Plant age (days)</th>
<th>45</th>
<th>53</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sowing date</td>
<td>10</td>
<td>15</td>
<td>20</td>
<td>25</td>
<td>Mean</td>
</tr>
<tr>
<td>S1</td>
<td>17.65</td>
<td>17.73</td>
<td>17.35</td>
<td>17.60</td>
<td>17.93</td>
</tr>
<tr>
<td></td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>a</td>
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<tr>
<td></td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>a</td>
</tr>
<tr>
<td>S3</td>
<td>11.50</td>
<td>9.70</td>
<td>10.78</td>
<td>10.90</td>
<td>10.72</td>
</tr>
<tr>
<td></td>
<td>b</td>
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<td>b</td>
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<td>b</td>
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<tr>
<td></td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>a</td>
<td>a</td>
</tr>
</tbody>
</table>

SE for sowing date ± = 0.40 0.43 0.46 0.50
SE for plant spacing ± = 0.46 0.49 0.53 0.56
SE interaction ± = 0.80 0.85 0.91 0.99
C.V% = 11.69 11.69 12.02 12.69

Means followed by the same letter (S) within a row or column, for the same sowing dates are not significantly different at 0.05 according to DMRT.
4.1.3. Nodule Dry weight:

The effect of sowing date and plant spacing on nodule dry weight is presented in Table (3). The analysis of variance showed no significant effect at 53 days from sowing of plant spacing. However, S1 gave the smallest nodules with regard to sowing dates; whereas 20cm gave the smallest nodule dry weight as compared to other spacings. There were significant effects of interaction between the two factors on nodule dry weight.

4.1.4. Shoot dry weight:

The results in Table (4) show that at 30 days from sowing, S1 and S2 gave significantly greater shoot dry weight than S3, while there was no significant difference between S1 and S2. At 38 days both S1 and S2 gave similar but greater shoot dry weight than S3 although the difference was not significant. Plant spacing did not affect shoot dry weight significantly at both stages. Interaction between sowing date and plant spacing had significant effect on shoot dry weight at 30 days.

4.1.5. Root dry weight:

The results in Table (5) show that at 30 days from sowing, S2 and S3 gave similar, but significantly higher root dry weight than S1, while at 38 days there was no effect of sowing date on this parameter. Plant spacing showed no significant effect on root dry weight at 30 days and 38 days from sowing. Interaction between sowing date and plant spacing showed significant effect on root dry weight at 30 days.
Table (2). Effect of sowing date and plant spacing on number of nodules/plant:

<table>
<thead>
<tr>
<th>Sowing date</th>
<th>Plant spacing (cm)</th>
<th>Means</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>S1</td>
<td>4.05</td>
<td>4.20 ab</td>
</tr>
<tr>
<td>S2</td>
<td>4.93 ab</td>
<td>3.75 b</td>
</tr>
<tr>
<td>S3</td>
<td>5.10 a</td>
<td>5.30 a</td>
</tr>
<tr>
<td>Mean</td>
<td>4.69 a</td>
<td>4.42 a</td>
</tr>
</tbody>
</table>

SE for sowing date ± = 0.59
SE for plant spacing ± = 0.68
SE interaction ± = 1.17
C.V% = 53.16

Means followed by the same letter (s) within a row or column are not significantly different at 0.05 according to DM4RT.
Table (3): Effect of sowing data and plant spacing on nodules dry weight/plant (mg):

<table>
<thead>
<tr>
<th>Sowing date</th>
<th>Plant spacing (cm)</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10</td>
<td>15</td>
<td>20</td>
<td>25</td>
<td>Means</td>
</tr>
<tr>
<td>S1</td>
<td>1.43 b</td>
<td>2.63 ab</td>
<td>2.15 ab</td>
<td>1.53 b</td>
<td>1.93 b</td>
</tr>
<tr>
<td>S2</td>
<td>3.65 a</td>
<td>2.10 ab</td>
<td>1.13 b</td>
<td>2.53 ab</td>
<td>2.35 ab</td>
</tr>
<tr>
<td>S3</td>
<td>2.73 ab</td>
<td>2.78 ab</td>
<td>1.85 b</td>
<td>2.88 ab</td>
<td>2.56 a</td>
</tr>
<tr>
<td>Mean</td>
<td>2.60 a</td>
<td>2.50 a</td>
<td>1.71 ab</td>
<td>2.31 a</td>
<td></td>
</tr>
</tbody>
</table>

SE for sowing date ± = 0.47

SE for plant spacing ± = 0.54

SE interaction ± = 0.93

C.V.% = 81.86

Means followed by the same letter (S) within a row or column are not significantly different at 0.05 according to DMRT.
4.1.6. **Number of Branches/plant:**

The effect of the treatments on the number of branches per plant is presented in Table (6).

The statistical analysis showed significant effect of sowing date on number of branches, where S1 and S2 gave similar but significantly higher number of branches per plant compared to S3. Plant spacing had no significant effect on number of branches. The interaction between sowing date and plant spacing significantly affected number of branches/plant.

4-2 **Reproductive parameters**

4.2.1. **Start of flowering**

The results show that sowing date and plant spacing had significant effects on days to the start flowering (Table 7).

Plants sown on first August (S2) flowered significantly later than those on first July (S1) or 15th of August (S3), the latter two sowings showing no significant differences. On the other hand, plants spaced at 10cm flowered earlier than all others, the difference being significant in comparison to 15cm spacing only. The rest of the spacings showed no significant difference in flowering time. The interaction between sowing date and plant spacing had significant effect on time of flowering.
Table (4): Effect of sowing date and plant spacing on shoot dry weight (g):

<table>
<thead>
<tr>
<th>Spacing (cm)</th>
<th>Sowing date</th>
<th>Plant age (days)</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>Mean</th>
<th></th>
<th></th>
<th></th>
<th>Mean</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td>10</td>
<td>15</td>
<td>20</td>
<td>25</td>
<td>Mean</td>
<td>10</td>
<td>15</td>
<td>20</td>
<td>25</td>
<td>Mean</td>
</tr>
<tr>
<td>S1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S2</td>
<td></td>
<td>4.85</td>
<td>3.40</td>
<td>4.45</td>
<td>3.95</td>
<td>4.16</td>
<td>4.90</td>
<td>4.73</td>
<td>3.23</td>
<td>4.68</td>
<td>4.38</td>
</tr>
<tr>
<td>S3</td>
<td></td>
<td>3.45</td>
<td>3.25</td>
<td>4.00</td>
<td>5.10</td>
<td>3.95</td>
<td>4.85</td>
<td>5.13</td>
<td>4.63</td>
<td>4.18</td>
<td>4.69</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>3.71</td>
<td>3.47</td>
<td>3.60</td>
<td>3.87</td>
<td>4.30</td>
<td>4.43</td>
<td>3.80</td>
<td>3.84</td>
<td>3.84</td>
<td>3.84</td>
</tr>
</tbody>
</table>

SE for sowing date ± = 0.29
SE for plant spacing ± = 0.34
SE interaction ± = 0.58
C.V% = 31.95

Means followed by the same letter (S) within a row or column are not significantly different at 0.05 according to DMRT.
Table (5): Effect of sowing date and plant spacing on root dry weight (g):

<table>
<thead>
<tr>
<th>Spacing (cm)</th>
<th>Plant age (days)</th>
<th></th>
<th></th>
<th></th>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10</td>
<td>15</td>
<td>20</td>
<td>25</td>
<td>Mean</td>
<td>10</td>
<td>15</td>
<td>20</td>
<td>25</td>
<td>Mean</td>
<td></td>
</tr>
<tr>
<td><strong>Sowing date</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S1</td>
<td>0.20</td>
<td>0.18</td>
<td>0.15</td>
<td>0.18</td>
<td>0.18</td>
<td>0.18</td>
<td>0.23</td>
<td>0.15</td>
<td>0.25</td>
<td>0.20</td>
<td></td>
</tr>
<tr>
<td>S2</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
<td>0.23</td>
<td>0.25</td>
<td>0.23</td>
<td>0.23</td>
<td></td>
</tr>
<tr>
<td>S3</td>
<td>0.25</td>
<td>0.20</td>
<td>0.20</td>
<td>0.25</td>
<td>0.23</td>
<td>0.23</td>
<td>0.28</td>
<td>0.20</td>
<td>0.30</td>
<td>0.25</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>0.22</td>
<td>0.19</td>
<td>0.18</td>
<td>0.21</td>
<td>0.21</td>
<td>0.21</td>
<td>0.19</td>
<td>0.25</td>
<td>0.19</td>
<td>0.25</td>
<td></td>
</tr>
</tbody>
</table>

Means followed by the same letter (S) within a row or column are not significantly different at 0.05 according to DMRT.

SE for sowing date ± = 0.012
SE for plant spacing ± = 0.014
SE interaction ± = 0.02
C.V% = 24.36

SE for sowing date ± = 0.018
SE for plant spacing ± = 0.020
SE interaction ± = 0.03
C.V% = 31.93
4.2.2. Days to 50% flowering:

The results show that none of the treatments had significant effect on time to 50% flowering (Table 8).

However, Plants sown on the first of July (S1) reached 50% flowering earlier than others. Also plants sown at 10cm spacing also reached 50% flowering earlier than other spacings. There was no significant interaction of the treatments on time to 50% flowering.

4.2.3. Number of flowers/plant:

The results show that sowing date and spacing had significant effect on number of flowers per plant (Table9). Plants sown on the first of July (S1) and 15th August (S3) scored higher number of flowers per plant than others. On the other hand, plants spaced at 10cm spacing gave lower number of flowers per plant than others. The interaction between treatments had significant effect on number of flowers per plant.

4.3. Yield and yield components:

Table (10) shows the effect of plant spacing on yield and components, of one sowing date only (1/7) because the plants in the other sowing dates (1/8 and 15/8) were completely lost before the yield stage due to termite attack (Fig.7).
### Table (6) Effect of sowing date and plant spacing on number of branches/plant:

<table>
<thead>
<tr>
<th>Sowing date</th>
<th>Plant spacing (cm)</th>
<th>Means</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10</td>
<td>15</td>
</tr>
<tr>
<td>S1</td>
<td>4.55 ab</td>
<td>4.45 ab</td>
</tr>
<tr>
<td>S2</td>
<td>4.67 abc</td>
<td>6.65 a</td>
</tr>
<tr>
<td>S3</td>
<td>3.55 bc</td>
<td>3.75 bc</td>
</tr>
<tr>
<td>Mean</td>
<td>4.25 a</td>
<td>4.95 a</td>
</tr>
</tbody>
</table>

SE for sowing date ± = 0.41
SE for plant spacing ± = 0.48
SE interaction ± = 0.82
C.V% = 37.51

Means followed by the same letter (S) within a row or column are not significantly different at 0.05 according to DMRT.
4.3.1. Plant density at harvest:

Table (10) shows that plant spacing had no significant effect on plant density. However, 25cm spacing gave markedly lower plant density than others.

4.3.2. Number of pods/plant:

Plant spacing had no significant effect on the number of pods/plant; but 10cm spacing gave higher number of pods per plant than others (Table 10).

4.3.3. Percentage of pod set:

Plant spacing treatments had significant effect on pods set%. The results showed that 10cm spacing gave higher percentage of pods set than others (Table 10).

4.3.4. Weight of pods/plant:

The results in (Table 10) showed that plant spacing had significantly affected weight of pods per plant, where 10cm and 15cm spacings gave comparable, but remarkably higher pod weight than 20cm and 25cm spacings.

4.3.5. Shelling percentage:

The results showed that plant spacing did not affect shelling percentage but 10cm and 15cm spacings gave slightly lower shelling percentage than others (Table 10).
Table (7) Effect of sowing date and plant spacing on days to start of flowering:

<table>
<thead>
<tr>
<th>Sowing date</th>
<th>10</th>
<th>15</th>
<th>20</th>
<th>25</th>
<th>Means</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>45.75 bc</td>
<td>59.00 ab</td>
<td>42.75 bc</td>
<td>48.25 bc</td>
<td>49.94 b</td>
</tr>
<tr>
<td>S2</td>
<td>53.50 abc</td>
<td>62.25 a</td>
<td>57.75 ab</td>
<td>58.00 ab</td>
<td>57.88 a</td>
</tr>
<tr>
<td>S3</td>
<td>44.00 c</td>
<td>50.50 abc</td>
<td>52.25 abc</td>
<td>50.50 abc</td>
<td>49.32 b</td>
</tr>
<tr>
<td>Mean</td>
<td>47.75 b</td>
<td>57.25 a</td>
<td>52.25 ab</td>
<td>52.25 ab</td>
<td></td>
</tr>
</tbody>
</table>

SE for sowing date ± = 1.98

SE for plant spacing ± = 2.29

SE interaction ± = 3.96

C.V% = 15.15

Means followed by the same letter(s) within a row or column are not significantly different at 0.05 according to DMRT.
Table (8) Effect of sowing date and plant spacing on time to 50% flowering:

<table>
<thead>
<tr>
<th>Sowing date</th>
<th>Plant spacing (cm)</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10</td>
<td>15</td>
<td>20</td>
<td>25</td>
<td>Means</td>
<td></td>
</tr>
<tr>
<td>S1</td>
<td>77.75 a</td>
<td>81.00 a</td>
<td>81.25 a</td>
<td>81.75 a</td>
<td>80.44 a</td>
<td></td>
</tr>
<tr>
<td>S2</td>
<td>82.75 a</td>
<td>81.50 a</td>
<td>79.00 a</td>
<td>81.25 a</td>
<td>81.13 a</td>
<td></td>
</tr>
<tr>
<td>S3</td>
<td>80.75 a</td>
<td>81.25 a</td>
<td>81.25 a</td>
<td>81.75 a</td>
<td>81.25 a</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>80.41 a</td>
<td>81.25 a</td>
<td>80.50 a</td>
<td>81.58 a</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SE for sowing date ± = 0.74

SE for plant spacing ± = 0.86

SE interaction ± = 1.48

C.V.% = 3.66

Means followed by the same letter (s) within a row or column are not significantly different at 0.05 according to DMRT.
4.3.6. **Final pod yield:**

The results in (Table 10) show that plant spacing had affected final pod yield significantly, where 25cm spacing gave significantly lower yield than others. Moreover, 15cm spacing gave remarkably higher yield than 10cm and 20cm spacings, but the difference was not significant.

4.4. **Chemical analysis:**

4.4.1. **Seed oil content (%):**

The results show that none of the plant spacing treatments had significant effect on oil content (Table11).

4.4.2. **Seed protein content (%):**

Table (11) shows that protein content was not significantly affected by plant spacing treatments. However, the results show that 20cm spacing gave higher protein content than others.
Table (9) Effect of sowing date and plant spacing on number of flowers/plant:

<table>
<thead>
<tr>
<th>Sowing date</th>
<th>Plant spacing (cm)</th>
<th></th>
<th></th>
<th></th>
<th>Means</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10</td>
<td>15</td>
<td>20</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>S1</td>
<td>8.80 ab</td>
<td>10.65 ab</td>
<td>11.45 a</td>
<td>11.43 a</td>
<td>10.58 a</td>
</tr>
<tr>
<td>S2</td>
<td>7.60 b</td>
<td>8.30 ab</td>
<td>8.40 ab</td>
<td>8.80 ab</td>
<td>8.28 b</td>
</tr>
<tr>
<td>S3</td>
<td>10.48 ab</td>
<td>9.03 ab</td>
<td>10.75 ab</td>
<td>10.25 ab</td>
<td>10.13 a</td>
</tr>
<tr>
<td>Mean</td>
<td>8.96 b</td>
<td>9.33 a</td>
<td>10.20 a</td>
<td>10.16 a</td>
<td></td>
</tr>
</tbody>
</table>

SE for sowing date ± = 0.55
SE for plant spacing ± = 0.64
SE interaction ± = 0.82
C.V.% = 22.96

Means followed by the same letter (S) within a row or column are not significantly different at 0.05 according to DMRT.
Table (10) The effect of plant spacing on the yield and yield components:

<table>
<thead>
<tr>
<th>Plant spacing (cm)</th>
<th>Plant density</th>
<th>Number of pods/plant</th>
<th>% of pod set</th>
<th>Weight of Pods/plant (g)</th>
<th>Shelling %</th>
<th>Pod yield (Kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>11.25 a</td>
<td>5.00 a</td>
<td>65 a</td>
<td>7.88 a</td>
<td>12.5 a</td>
<td>177.50 ab</td>
</tr>
<tr>
<td>15</td>
<td>11.00 a</td>
<td>3.00 a</td>
<td>30 b</td>
<td>7.35 a</td>
<td>12.5 a</td>
<td>317.50 a</td>
</tr>
<tr>
<td>20</td>
<td>11.75 a</td>
<td>3.50 a</td>
<td>32 b</td>
<td>3.98 b</td>
<td>13.0 a</td>
<td>192.50 ab</td>
</tr>
<tr>
<td>25</td>
<td>8.00 a</td>
<td>3.50 a</td>
<td>44 ab</td>
<td>4.10 b</td>
<td>13.0 a</td>
<td>115.00 b</td>
</tr>
</tbody>
</table>

SE± = 0.73, C.V% = 28.13

Means followed by the same letter(s) within a row or column are not significantly different at 0.05 according to DMRT.
Table (11): Effect of plant spacing on seed oil and protein contents (%):

<table>
<thead>
<tr>
<th>Plant spacing(cm)</th>
<th>Oil</th>
<th>Protein</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>5.53 a</td>
<td>24.93 a</td>
</tr>
<tr>
<td>15</td>
<td>5.26 a</td>
<td>24.56 a</td>
</tr>
<tr>
<td>20</td>
<td>5.33 a</td>
<td>26.33 a</td>
</tr>
<tr>
<td>25</td>
<td>5.66 a</td>
<td>24.33 a</td>
</tr>
</tbody>
</table>

Means followed by the same letter (s) within a row or column are not significantly different at 0.05 according to DMRT.
(Fig.1): Bambara groundnut after one week from germination.

(Fig.2): Healthy Bambara groundnut plant after 6 weeks from germination (before flowering stage).
(Fig.3): Bambara groundnut roots
(Fig.4): Bambara groundnut plant: stem, branches and pods.
and nodules.

(Fig.5): Bambara groundnut seeds and shells.
(Fig.6): Bambara groundnut plants showing chlorosis symptoms after 6 weeks (A) and after 10 weeks (B) from germination.

(Fig.7): Bambara groundnut plants showing termite damage after 6 weeks from germination
5-1 The effects of treatments on the vegetative growth:

Sowing date and plant spacing treatments had significant effects on some of the parameters of vegetative growth studied, while they had no effects on the others.

The results revealed that the effect of sowing date treatments on plant height was significant and plant height was increased by the first sowing date (1/7). This increase may be due to the favourable effect of early planting. El Wakeel and Osman (1992) stated that the crop is usually planted after the first effective rains or as soon as soil moisture is conductive. On the other hand, non significant effect of plant spacing treatments on plant height may be attributed to generally poor plant growth which might have removed competition between plants.

Number of nodules per plant was significantly affected by sowing date treatments but was not affected by plant spacing treatments.

In Sudan, El Wakeel and Osman (1992) reported that the crop is usually planted after the first effective rains. The most common planting occurs between early and mid July. Johnson (1967) reported that time of planting is critical; generally the best time of sowing is as soon as soil becomes well moistened. Grant (1988) reported that decline in soil fertility is the major reason for the decrease in Bambara groundnut yield.

Non significant effect of plant spacing treatments, observed in this study could be attributed to termite's damage and the unfavorable soil texture. El Wakeel and Osman (1992) reported that termites were the main insect pest that affects plant growth and yield. Johnson (1967) and Martin (1959) reported that loose sandy or loamy textural soils are best and heavy soils are unsuitable for Bambara groundnut.
Thompson and Dennis (1977) reported that the average number of nodules per plant was 11 nodules, which is much higher than the number observed in this study. A possible reason for the low nodules number is the fact that the seeds were not inoculated with *Bradyhizobium* at planting; Rabih (1999) reported that factors such as soil physical factors, chemical factors and microbiological factors influence nodulation. El.kan (1961) reported that lack of nodulation can also be due to root secretions by some leguminous species which inhibit nodulation. In this study, the third sowing date (15/8) showed higher number of nodules per plant.

Number of branches per plant was affected by sowing date. In this study the average number of branches per plant ranged from 4 to 5 branches per plant. The first sowing date (1/7) gave greater number of branches than the others. This could be attributed to a longer growing period, which encouraged branching. Doka and Karikari (1971) reported that Bambara groundnut may produce about 20 branches per plant. On the other hand, number of branches per plant was not affected by plant spacing treatments. This is possibly due to poor growth of the plants as mentioned earlier.

The results showed that the effect of sowing date treatments on shoot and root dry weight was significant at 30 days from sowing. It was observed that there was considerable loss of plant leaves during the later growth period which might have reduced and thus masked the effect of sowing date on this parameter. Moreover, the lack of effect of spacing on shoot dry weight may be attributed to the generally poor plant growth observed in this study.

5-2 The effect of treatments on the reproductive parameters:

Both sowing date and plant spacing significantly affected time to flowering. In this study, time to flowering ranged between 44-62 days from sowing. Plants sown
on both first of July and 15\textsuperscript{th} August flowered earlier than those sown on first of August.

Plants spacing treatments significantly affected time to flowering. Results showed that plants spaced at 10cm flowered earlier than all others. Kebadumetes (1994) stated that flowering in Bambara groundnut started within 44-60 days after sowing. Begemann and Moshana (1995) stated that the number varies from 37 to 45 days, with the first flowers appearing one week earlier.

Number of days to 50\% flowering was not significantly affected by the treatments. Similar result was reported by Kebadumetes (1994). In this study, days to 50\% flowering ranged between 77-82 days. The results showed that plants sown on first of July reached 50\% flowering earlier than those sown on first or 15\textsuperscript{th} August. Plants sown at 10cm spacing reached 50\% flowering earlier than those sown at 25cm spacing only.

5-3 The effect of treatments on the yield and yield components:

Pods set\% was not significantly affected by plant spacing treatments: This could be attributed to the heavy soil texture which might have obstructed peg penetration and pod formation inside the soil. Johnson (1967) reported that heavy soils are unsuitable for Bambara groundnut.

The results showed that plant spacing treatments did not have significant effect on final yield, this could be attributed to the low plant population, resulting from termite's damage. In this study it was observed that termites attacked the crop and led to reduction in yield and yield components. On the other hand, plants showed signs of chlorosis after 6 weeks from emergence and then partial or complete leaf damage occurred as the season progressed.

In this study, the crop gave a lower yield (115 to 317kg/ha) than the average reported by other workers. El Wakeel and Osman (1992) reported that average
yield obtained by farmers is estimated to be around 952kg/ha of unshelled pods. In good years with adequate rainfall the yield can reach up to 1904kg/ha, while in bad years severe moisture stress can reduce yield to as low as 404kg/ha. Begemann and Moshana (1995) reported that current Bambara groundnut yields are generally low ranging from 400kg/ha to just under 1400kg/ha of unshelled nuts. Kebadumetes (1994) reported that lower yield have always been reported for the cream-seeded types.

A number of investigators explained the factors which reduce the yield of Bambara groundnuts. In Sudan El Wakeel and Osman (1992) stated that low yields are due to late planting, erratic rainfall and low soil fertility, and that the crop is usually planted after the first effective rains (about 15mm or more). Collinson, et al (2000) reported that the highest pod yields were achieved at the earliest sowing date.

5.4. Seed chemical composition:

In this study plant spacing treatments did not significantly affect seed oil and protein content. Average oil content ranged between 5.26% and 5.66% and protein content from 24.33% to 26.33%. Abdel Mutalab (personal communication), reported that analysis of a local Sudanese type from Kordofan, gave 23.89% crude protein and 5.83% fat. Gibbons (1994) reported that chemical composition of Bambara groundnut seeds varies according to type, the dark-seeded (red and black) type tended to have higher nutrient and mineral contents than the light-seeded ones (cream and white). He also stated that protein varied from 8.2% to 16.6% and fat from 5.5% to 6.8%. El Wakeel and Osman (1992) reported crude protein content as 18.7% and oil content as 10.8%. Johnson (1968) and Stanton (1966) stated that Bambara groundnut seed contains about 19% protein.
SUMMARY AND CONCLUSION

An experiment was carried out during the summer of (2007/08) season, in the Experimental Farm of Faculty of Agriculture at Shambat to investigate the effect of sowing date and plant spacing on growth and yield of Bambara groundnut (Vigna subterranea L.).

The treatments comprised three sowing dates (first of July, first of August and 15th of August) and four plant spacing (10, 15, 20 and 25cm).

The design was a randomized complete block design with four replications.

Effect of the different treatments on vegetative growth, reproductive growth, yield components and chemical composition of Bambara groundnut was studied.

- Results showed that sowing date treatments affected all the studied parameters, but the effect was not significant in some of them.
- The effect of plant spacing treatments was significant in nodules dry weight/plant, beginning of flowering, pod set % and pod yield.
- The pest plant spacing investigated in this study was 15cm.
- The interaction between the treatments was not significant in all growth, yield components and seed chemical parameters.
- The results indicated that lack of response to the treatments may be due to late planting and low plant density (loss of plants by termites) or due to unfavourable soil conditions at the experimental site (soil textures).

Further studies are needed regarding the influence of different varieties or types of Bambara groundnut, sowing methods, fertilization, intercropping and mixtures with cereal crops on growth and yield of Bambara groundnut under rainfed and irrigated conditions.
REFERENCES


Appendix (1)

Mean monthly temperature (C°) and rainfall (mm) at Shambat for months from June to December of 2007.

<table>
<thead>
<tr>
<th>Months</th>
<th>Temperature (C°)</th>
<th>Rainfall (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>June</td>
<td>40.8</td>
<td>0.1</td>
</tr>
<tr>
<td>July</td>
<td>35.7</td>
<td>1.3</td>
</tr>
<tr>
<td>August</td>
<td>35.3</td>
<td>24.7</td>
</tr>
<tr>
<td>September</td>
<td>38.0</td>
<td>0.1</td>
</tr>
<tr>
<td>October</td>
<td>39.7</td>
<td>0.1</td>
</tr>
<tr>
<td>November</td>
<td>36.1</td>
<td>Nil</td>
</tr>
<tr>
<td>December</td>
<td>32.7</td>
<td>Nil</td>
</tr>
</tbody>
</table>

Source: Shambat Metrological Station season of 2007.
Appendix (2)

Determination of total seed oil

Total oil was determined according to the A.O.A.C method (1984). Two grams sample was extracted with petroleum ether BP 60-80 C° for 8 hr. in soxhlet apparatus. The oil content was calculated according to the following equation:

\[
\text{Oil } \% = \frac{W_2 - W_1}{W_s} \times 100
\]

Where:

- \( W_1 \) = Weight of empty flask
- \( W_2 \) = Weight of flask with oil
- \( W_s \) = Weight of sample
Appendix (3)

Determination of total seed protein:

The protein content of the sample was determined by the micro-kjedahl technique according to the A.O.A.C method (1984). 0.2g of sample was weighted accurately into micro-kjedahl flask, 0.4g catalyst mixture and 3.5 ml of concentrated sulphuric acid were added, the sample content were heated on an electric heater for 2 hr and cooled, then the contents were placed into the distillation apparatus. Twenty milliliters of 40% NaOH were added, the ammonia evolved was received in ten milliliters of 2 % boric acid solution. The trapped ammonia was titrated against HCL (0.02 N) using universal indicator (methyl red + bromo cresol green), the total nitrogen and protein were calculated using the following formula:

\[
N \% = \frac{\text{Volume of HCL} \times N \times 14 \times 100}{\text{Weight of sample} \times 1000}
\]

Protein \% = N \% \times 6.25

Where:

N % = crude nitrogen
N = normality of HCL
14 = equivalent weight of nitrogen
1000 = to convert from g to 100g
6.25 = constant factor