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RESEARCH PAPER

EFFECT OF SPACING ON GROWTH AND YIELD OF FIVE BAMBARA GROUNDNUT (*VIGNA SUBTERRANEA* (L) VERDC.) LANDRACES

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ABSTRACT
An experiment was conducted under field conditions to study the effect of spacing on yield of five bambara groundnut landraces in 2008 cropping season. The experimental design was a split plot with bambara groundnut landraces; Nav 4, Nav Red, Black eye, Mottled cream and Burkina as the main plot factor and the three spacings (50 x 20cm, 50 x 30cm, 50 x 40cm) as the subplot factor. Sowing was done on the 17th of May 2008 at two seeds per hill and thinned to one seedling per hill 21 days after sowing (DAS). Growth analysis were carried out at six different sampling periods during which canopy spread, petiole length, leaf area index (LAI), total dry matter were measured. Yield data on number of plants per metre squared, number of pods per plant, number of seeds per pod, mean seed weight as well as harvest index (HI) were also taken at harvest. Results indicated that the lower spacing of (50cm x 20cm) produced significantly (P < 0.05) the greatest pod and grain yield of 3399kg/ha and 1684.7kg/ha respectively. The same treatment also produced significantly higher number of pods than the higher spacing treatments. However, the number of seeds per pod and mean seed weight were not affected by spacing. Although, most vegetative data were not significantly affected by varying plant spacing, leaf area index was significantly highest at 50cm x 20cm than the other treatments. Among the landraces, Mottled Cream recorded significantly the highest shelling percentage of 70.6% and HI of 64.9. Based on high shelling percentage, HI and mean seed weight, Mottled Cream produced the highest seed yield (1656kg/ha). The optimum spacing for the highest pod yield in this study was 50cm x 20cm.

Keywords: *bambara groundnut, harvest index, pod yield, spacing*

INTRODUCTION

Animal protein is very expensive and therefore not easily affordable by the average Ghanaian whose income is very low. The need to find alternative sources of protein which are cheaper and more affordable cannot be overemphasized in preventing malnutrition especially in children. Research priorities need to be reorganised in order to develop our local underutilized crops like bambara groundnut which has a lot to offer in terms of their nutritional value, drought tolerance and relatively high pod yield (Linnerman and Azam-Ali, 1993).

Bambara groundnut has numerous agronomic and nutritional attributes which make it an excellent crop to develop. The protein and carbohydrate content of bambara groundnut are 14-24% and 60% respectively, thus qualifying it as a complete food (NAS, 1979).

Bambara groundnut yields vary considerably among sites, seasons and genotypes (Linnemann and Azam-Ali 1993), with yields averaging 650-850kg/ha as reported by Stanton *et. al*. (1966). However, Collinson *et al.* (1996) have reported yields of up to 4.1t/ha and Sesay *et al*. (2004) obtained seed yield of 2.6t/ha in field trials in Swaziland. Berchie (2010) also reported pod and seed yields of 4.6 and 3.4t/ha respectively. This suggests that bambara groundnut has a potential for high yield.

Not much work has been done on variations in terms of yield among the different bambara groundnut landraces in Ghana. Field observations suggest that bambara groundnut production by subsistence farmers is characterized by low and unpredicted yields and that crop failures are common. A major factor may be because subsistence farmers grow the crop without any recommended spacing. It is in view of these that this experiment was conducted to determine the optimum spacing for the cultivation of bambara groundnut.

MATERIALS AND METHODS

A field experiment was conducted during the major season (May - September) in 2008, at the Plantation Research Farm of the Department of Crop and Soil Sciences, Faculty of Agriculture, Kwame Nkrumah University of Science and Technology, Kumasi (6°43'N, 1°36'W) located in the forest zone of Ghana.

The soil belongs to the Kumasi series or Ferric Acrisol (FOA/UNESCO, 1990) developed over deeply weathered granite. Soil samples from the experimental area were taken from 0-30cm depth and analysed for pH and other chemical-properties. The experimental design was a split plot in a randomized complete block with three replicates. The main plot treatments were the five landraces and the subplot treatments were three population densities. Each plot in a block measured 4m x 3m and was contiguous to one another; the distance between the blocks was one metre.

The main plot treatments were the five landraces (i) Nav 4 (ii) Nav Red (iii) Black Eye (iv) Mottled Cream and (v) Burkina. The sub-plot treatments were the spacings; S1 = 50 cm x 20cm =10 plants/m^2, S2 = 50cm x 30cm = 6.7 plants/m^2, S3 = 50cm x 40cm = 5.0 plants/m^2. Two seeds were sown per hill at a depth of 5cm on May 17, 2008. Thinning was done 21 days after sowing (DAS) to one plant per hill to obtain the desired plant population densities. Weeds were controlled by hand hoeing two weeks after germination and subsequently as and when necessary.

The parameters measured included;

Leaf area index (LAI); where leaf area from three randomly selected plants were determined using leaf area meter (CI-202) and by dividing by the area covered to obtain the LAI.

Dry matter yield; Samplings began at 27 days after sowing (DAS) and continued at 20 days interval till harvest. In all six samplings were taken. Three plants were randomly harvested from the sampling area. For each plant sampled, the roots were cut and discarded and the whole plants weighed fresh and dried in an oven maintained at 70^{0}C for 48 hr for dry weight.

Yield components; The number of pods/m^2 was determined by harvesting ten, seven and five plants each from all the plots for spacings 1, 2 and 3 respectively and the pods counted separately. The pods were first air dried and thereafter oven dried to a constant weight at 70^{0}C for 48 hrs for the dry weight. The dried pods were hand shelled; the husk and seeds were weighed separately. Hundred random seeds were counted from each sample and weighed to determine the 100 seed weight. Number of seeds per pod was determined by randomly counting fifty pods and shelling and counting the seeds in the pods. The number of seeds obtained was divided by fifty to obtain the mean number of seeds per pod. Shelling percentage was determined by dividing the weight of the extracted seed over that of the

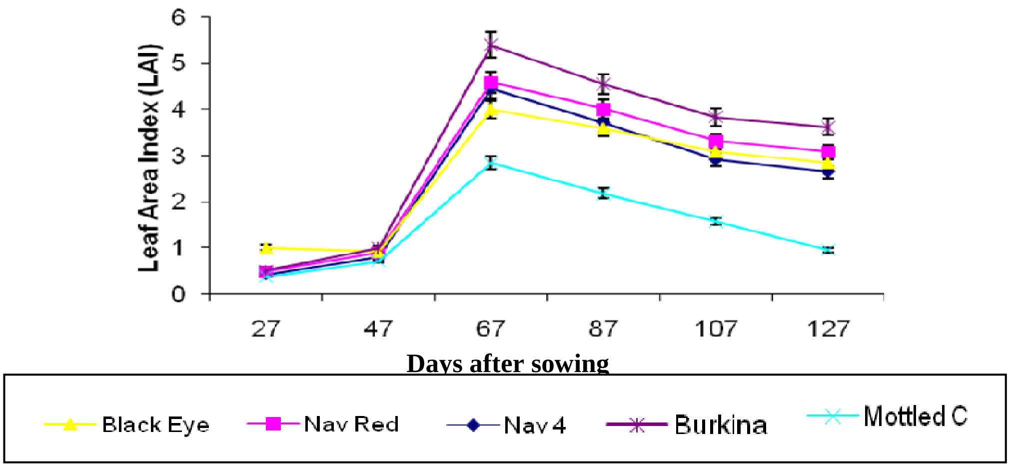

Fig. 1: Changes in LAI of the landrace with time

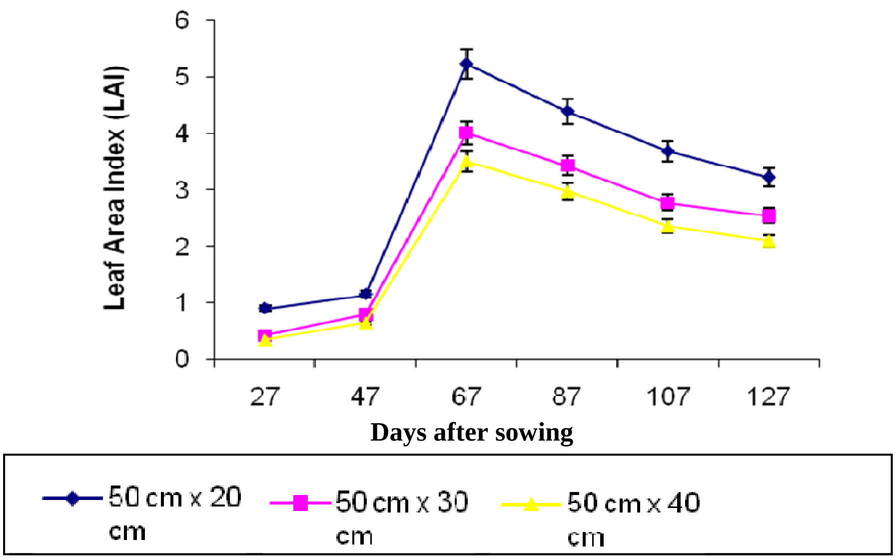

Fig. 2: Effect of plant population on LAI with time

pod dry weight . Seed harvest index (SHI) was calculated by dividing the dry weight of harvested seed per plant by the total plant biomass.

Environmental conditions

During the planting season, the total amount of rainfall recorded was 153.7mm. The average sunshine hours per day was 4.0 and the average ambient temperature was 21.9^{o}C.

RESULTS

Leaf Area Index:

Figure 1 shows the variations in the LAI of the landraces with time. At 27 and 47 DAS, no significant landrace effect was observed. At 67 DAS, Burkina had the greatest leaf area index and this was significantly higher than that of Mottled Cream and Black Eye ($p<0.05$). All other treatment effects were similar. At 87, 107 and 127 DAS, leaf area index of Burkina was still the greatest. Burkina obtained the greatest LAI of 5.4 at 67 DAS.

Figure 2 shows variations in the LAI as affected by plant population. Leaf area index was significantly greatest for the 50cm x 20cm spacing on all sampling dates. No significant difference was, however, observed between the 50 x 30cm and 50 x 40cm spacing at all sampling dates.

Total Dry weight:

Figure 3 shows changes in the total dry weight of the landraces with time. At 27 DAS there was no significant treatment effect among the landraces. At 47 and 67 DAS, the greatest effect was observed in Burkina and this was significantly greater than in Nav Red and Mottled Cream ($p<0.05$). At 107 and 127 DAS sampling, treatment effect of Mottled Cream was significantly lower than that of the Burkina, Nav Red and Black Eye.

Figure 4 shows the effect of plant population on the total dry weight of the landraces with time. Population density effect on total plant dry matter was significant at 107 DAS for 50 x 40cm spacing. The other treatments were not significantly different.

Yield Variables:

Figure 5 shows the changes in the pod numbers with time. Podding occurred earlier in Mottled Cream than the other four landraces. Pod numbers increased in all the landraces after 87 to 107 DAS. At 87 DAS, Mottled Cream produced significantly ($P < 0.05$) greater pod number/plant than the other landraces. The difference between Nav 4 and Nav Red was not significant but either effect was significantly higher than both Black Eye and Burkina. At 107 DAS, Mottled Cream produced the least number of pods, and this was significantly lower than all treatment effects, except that of Nav 4.

Effect of plant population on number of pods per plant with time:

Figure 6 shows the variations in pod numbers as affected by plant population. Population density did not significantly affect number of pods per plant at 87 and 107 DAS sampling occasions. However, at 67 DAS, pod production from the 50 x 20cm spacing was significantly higher than other treatment effects.

Husk and pod yields:

Table 1 shows the effect of spacing on the pod husk and pod yield of the landraces. Husk yield was significantly different at harvest ($P<0.05$). Burkina had the greatest husk weight at harvest (1664.1 kg/ha) even though this was not significantly different from all the landraces except Mottled Cream. Mottled Cream attained the least husk yield at harvest (759.3 kg/ha) (Table 1). No significant difference was observed among the various landraces ($P> 0.05$) with respect to pod yield.

Population density, however, had significant effect ($P < 0.05$) on pod yield. Pod yield from the highest density (50 x 20cm) was significantly higher than the other treatment effects. The difference between the medium and the lowest density was however, not significant.

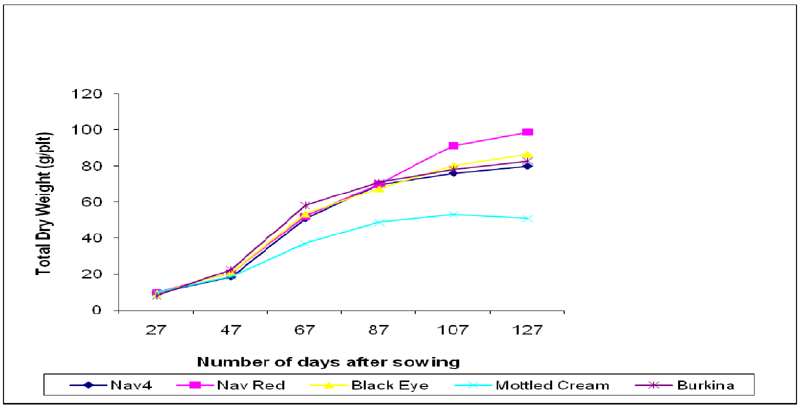

Fig. 3: Changes in the total dry weight of the landraces over time

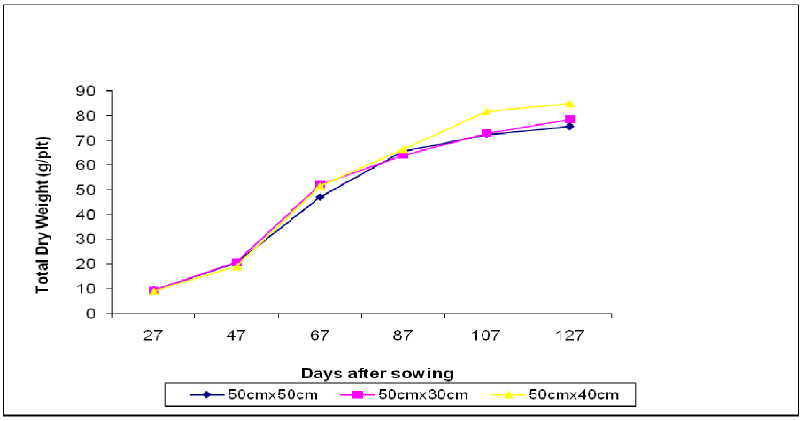

Fig. 4: Effect of plant population density on total dry weight of the landraces.

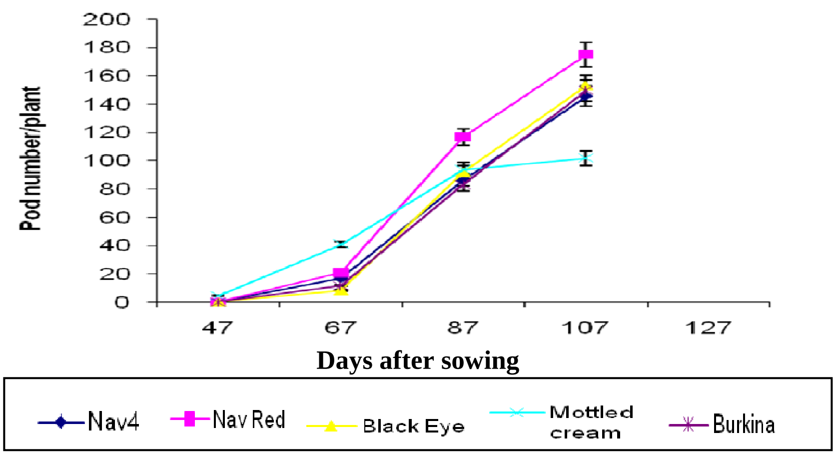

Fig. 5: Changes in the pod numbers of the landraces with time.

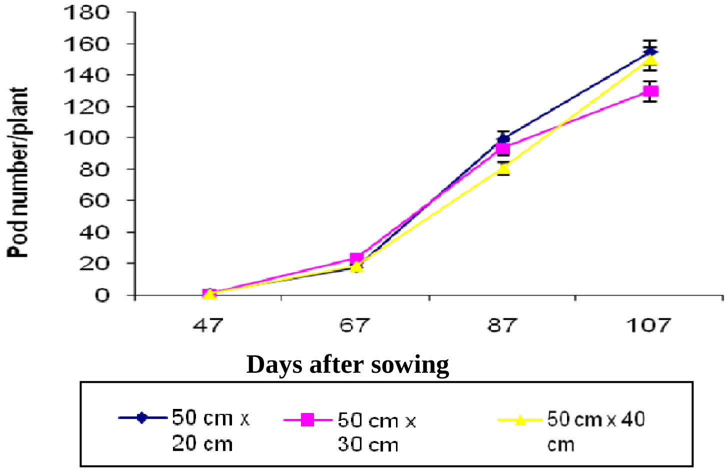

Fig. 6: Effect of plant population density on pod numbers of landraces

Table 1: Effect of spacing on husk and pod yield of five bambara groundnut landraces

Treatment	Husk dry wt (kg/ha)	Pod Yield (kg/ha)
Landraces		
Nav 4	1229.0	2517.4
Nav Red	1472.4	3281.5
Black Eye	1 538.3	2531.1
Mottled Cream	759.3	2379.8
Burkina	1664.1	3219.0
LSD (5%)	***597.2***	***NS***
Spacing (cm)		
50 x 20	1548.1	3399.0
50 x 30	1262.8	2733.4
50 x 40	1187.2	2224.3
LSD (5%)	***275.4***	***610.2***
CV (%)	**13.4**	**14.6**

NS - not significant, LSD – Least Significant Difference, CV – coefficient of variation

Mottled Cream produced significantly lower husk dry weight than Nav Red, Black Eye and Burkina. Husk yield of 50 x 20cm spacing was significantly higher than the medium and the lowest density treatments.

Seed yield:
Table 2 shows the effect of spacing on seed yield and components of the landraces. There was no significant difference (P >0.05) among the landraces with respect to seed yield. However, spacing (plant density) showed a significant effect on seed yield. The greatest yield was produced by the closest spacing, (which has the largest plant population), and this effect was significantly higher than the other treatments. Seed yield of the medium population density, (50 x 30cm spacing) was also significantly hig-

her than that of the lowest population density (50 x 40cm) spacing.

Results in Table 2 showed that both landrace and population density did not significantly (P > 0.05) affect seed number per pod. Number of seeds per pod averaged 1-2.

antly different from Burkina. All other treatment differences were not significantly different. Spacing did not significantly (P > 0.05) affect pod harvest index.

Seed harvest index was again greatest in the Mottled Cream and this was significantly

Table 2: Effect of spacing on seed yield and components of bambara groundnut landraces

Treatments	Seed Yield (Kg/ha)	Seed No./Pod	100 Seed wt ((g)
Landraces			
Nav 4	1254.5	1.0	41.1
Nav Red	1519.7	1.0	44.3
Black Eye	1235.8	1.0	45.5
Mottled Cream	1656.4	2.0	68.0
Burkina	1322.6	1.0	37.0
LSD (5%)	**NS**	**NS**	**7.4**
Spacing (cm)			
50 x 20	1684.7	1.2	47.5
50 x 30	1422.3	1.2	47.3
50 x 40	1084.4	1.2	46.7
LSD (5%)	**214.2**	**NS**	**NS**
CV (5%)	**9.7**	**0.0**	**4.2**

Mottled Cream recorded the greatest hundred seed weight (68.0g) which was significantly higher than the other treatments. Burkina produced the least 100 seed weight even though was not significantly lower than that of Nav Red and Nav 4 only. Spacing did not significantly (P> 0.05) affect seed weight.

Shelling percentage, Pod and Seed Harvest Indices:

Table 3 shows the effect of spacing on the shelling percentage and harvest indices of the landraces. Shelling percentage of Mottled Cream was the highest, and this was significantly higher than all other treatment means. Plant spacing did not significantly affect shelling percentage.

Pod harvest index was significantly higher for Mottled Cream than the other landraces (64.9) except Burkina. This was however not significhigher than all other treatment effects. The other treatment differences were not significant (P>0.05). Medium population density resulted in the greatest seed harvest index, but this was significantly different from the largest population density (50 x 20cm).

DISCUSSION

The results showed that the LAI increased with population density. The highest leaf area was recorded at a population density of 10 plants / m^2 and this was observed for all the landraces. The leaves might have intercepted much solar radiation than the plants at other densities resulting in greater growth and leaf expansion. The increase in LAI resulted in high yield at the spacing used. It therefore appears that the closest-spaced plants were the most effective in the interception of light and resulting in greater dry matter production. At the initial stages, there was some wastage of incident solar radiation on

Table 3: Effect of spacing on shelling % and harvest indices of five bambara groundnut landraces

Treatment	Shelling %	Pod HI	Seed HI
Landraces			
Nav 4	50.3	45.0	22.5
Nav Red	47.4	43.9	20.9
Black Eye	50.4	40.9	20.4
Mottled Cream	70.6	64.9	44.7
Burkina	41.7	54.0	22.4
LSD (5%)	**11.8**	**15.0**	**9.5**
Spacing (cm)			
50 x 20	50.5	48.0	23.9
50 x 30	53.8	49.2	27.8
50 x 40	51.9	52.4	26.8
LSD (5%)	**NS**	**NS**	**3.7**
CV (%)	**6.2**	**3.4**	**2.3**

bare soil at the lower plant densities thus affecting dry matter accumulation.

This result agrees with findings of Egli (1988), Funnah and Matsebella (1985) and Nakagawa *et al*. (1988) who observed soybean yield to increase with density up 20 plants/m^2, beyond which the reduction in individual plant yield could not be adequately compensated for by increase in number of plants per unit area.

Among the landraces, Nav Red and Burkina produced the highest leaf area indices compared to the three landraces (Fig 1). This suggests that, Nav Red and Burkina developed a larger photosynthetic surface area leading to greater interception of more solar radiation and hence production of more photosynthates for storage in the various organs. But the high LAI did not necessarily result in higher yields. This agrees with Weber *et al.* (1966) in soybean that greater LAI may not necessarily lead to higher yields because of excessive competition for resources, especially light. Even though Mottled Cream produced the lowest LAI and the lowest dry matter, it produced greater seed yield than the other four landraces, though the difference was not significant. This landrace might have partitioned more of its assimilate to the economic sink (pods). Furthermore, this landrace has a different leaf orientation and shape, colour and thickness which might have resulted in intercepting more solar radiation and efficient utilization to produce more photosynthates and partitioning to the pods.

Increasing plant population reflected positively on pod number produced per unit area. The 10 plants/m^2 treatment produced the greatest number of pods (5503 pods/ha), followed by the medium density treatment, while the 5 plants/m^2 treatment produced the lowest. Again 10 plants/m^2 stand produced the significantly greatest pod yield. Cumberland (1978) reported higher pod yield in bambara groundnut at 14 than at 7 plants/m^2. Similarly, Mkadawire and Sibuga (2002) reported high pod yields at population densities of 22 than at 9 plants/m^2, although they again reported lower pod yield with increase in plant density up to 66 plants/m^2. The results showed that the densities tested did not lead to any severe interplant competition, thus suggesting a linear relationship between density and yield. This agrees with Funnah and Matsebella, (1985) and Egli, (1988) in soybean that, crop yield increases in direct proportion to increase in plant density when there is hardly any interplant competition.

The components that determine seed yield are influenced by the amount of solar radiation intercepted by the green crop canopy and the amount of photosynthates produced during the grain filling period, provided that nutrient and soil moisture levels are adequate. Thus the higher LAI produced at the higher densities might have led to the production of the higher seed yields.

The higher seed yield could again be attributed to the higher number of pods produced at the closest density, since other components such as seed number per pod and mean seed weight were not significantly affected by the plant population. This result has demonstrated, once again, the importance of seed number per unit area as a major determinant of seed yield as reported by Yunusa and Ikwele (1990).

It could be deduced from the results that, the 10 plants/m^2 stand is the optimum population density for high pod and grain yield in bambara groundnut, under the conditions of this study. Berchie (2010) evaluating the effect of spacing on two bambara groundnut landraces observed that Nav 4 at 50cm x 20cm (10 plants/m^2) produced significantly greatest pod yield compared to the other spacings. “Tom” a more spreading type however, produced the highest pod yield at 50cm x 30cm even though this was not significantly different from 50cm x 20 cm and 50cm x 40cm.

The number of pods produced per unit area and the pod filling period constitute two important factors that determine the seed yield of leguminous crops. However, with Mottled Cream, the number of pods produced was lowest than the other landraces, yet it produced higher seed yield than the other landraces. This may be attributed to the early maturing nature of this landrace. Berchie *et al.* (2010) in a study to evaluate the yield of three early maturing bambara groundnut landraces; Mottled Cream, Zebra coloured and Burkina observed that Mottled Cream was the earliest maturing landrace. Karikari (2000) had observed that early maturing landraces were high yielding because they emerged rapidly, flowered earlier and had probably enough time to fill the pods.

Mottled Cream exhibited determinate growth habit while the other four landraces exhibited typical indeterminate growth habit. Linnerman (1991) showed that fruit development is influenced by length of photoperiod. However, photoperiod did not change during the growing season. Therefore, in this study photoperiod did not influence podding or seed yield. Doku and Karikari (1970); Linneman and Azam-Ali (1993), indicated that most cultivars of bambara groundnut require 40 days for pod and seed development. Hence indeterminate flowering is likely to result in low yield since all flowers produced 40 days before harvesting will not result in mature seeds.

Differences among genotypes have also been attributed to growing season. Ofori (1996) reported that under adequate moisture conditions, the plant produces flowers over a long period and the spreading types produce flowers throughout the growing season. The greater seed yield produced by Mottled Cream could also be attributed to the average 2 seeds/pod, large pod size and heavier seed weight. This was shown in the high shelling percentage of Mottled Cream. Again, Mottled Cream produced significantly the lowest husk dry weight indicating that most of its photosynthates produced was converted to seed production than the husk.

Shelling percentage is a reflection of pod filling efficiency and high shelling percentage values indicate effective pod filling. The density treatment did not have any significant effect on the shelling percentage. However, among the landraces Mottled Cream recorded significantly the highest shelling percentage of 70.6%. This may be due to efficient partitioning of assimilates to the seed rather than the husk.

The density treatment did not have any significant effect on pod HI (PHI). However, among the landraces Mottled Cream (PHI = 64.9) and Burkina (PHI = 54.6) were most productive and this may be due to the production of lower above ground dry matter by these landraces. With respect to seed HI, the intermediate density of 6.7 plants/m^2 was significantly more productive. It has been postulated (Daniel *et al*., 2001) that a sparse stand will use water in the soil more rapidly than a dense stand and will therefore have a greater partitioning factor for grain. Seed harvest index (SHI) for Mottled Cream was 44.7. This value was highly and significantly more productive than the other four landraces, again showing the inherent ability of Mottled Cream to partition most of the dry matter produced into the grain. High economic yields are pre-determined by dry matter production and partitioning into various sinks of which the grain is the most important. Therefore, any attempt to manipulate plant spacing to maximize yield and cultivar assessment for higher yield are considered successful if subsequent growth characteristics support dry matter partitioning in seed.

CONCLUSION

The results of this study revealed that spacing positively influenced bambara groundnut growth and grain yield. The treatment with the greatest plant density of 10 plants/m^2 produced the greatest dry matter, recorded the highest leaf area index and produced the greatest seed yield compared to the other treatments. Thus, 50cm x 20cm spacing is recommended for the cultivation of bambara groundnut under the conditions of this experiment.

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