Effect of Spacing on Yield of Five Bambara groundnut (*Vigna subterranea* (L.) Verdc.) Landraces in Southern Tanzania

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Abstract

The study was conducted to investigate the effect of spacing on yield of five bambara groundnut landraces under field conditions in 2011/2012 and 2012/2013 seasons. The experimental design was a split plot with bambara groundnut landraces viz NALBAM 1, NALBAM 2, NALBAM 3, NALBAM 4 NALBAM 6, as the main plot factor. Four plant populations with spacing of 50cm x 10cm, 50cm x 15cm, 60cm x 10cm, and 60cm x 15cm were subplot factor. Sowing was done in February 2012 and January 2013 at two seeds per hill and thinned to one seedling at 21 days after sowing. "Fresh consumption" and "dry grain" bambara groundnut groups were under study. The yield, number of pods per plant, number of seeds per plant and 100 seed weight were examined. Significant differences ($P<0.05$) were observed from "fresh consumption" bambara groundnut landraces. The results indicated that the lowest spacing (50cm x 10cm) produced the highest pod yield (1023 kg ha^{-1}) and grain yield (705 kg ha^{-1}) for NALBAM 1 and 1111 kg ha^{-1} and 771 kg ha^{-1} for NALBAM 2 respectively. The "dry grain" of NALBAM 2 under 60cm x 10cm had the highest pod yield (1206 kg ha^{-1}) and grain yield (847 kg $ha^{-}1$) among landraces. On the other hand, NALBAM 3 recorded significantly the highest pod yield (1447 kg $ha^{-}1$) and grain yield (1007 kg $ha^{-}1$) for fresh consumption landraces under spacing 60cm x 10cm. The optimum spacings for the highest pod yield was 60cm x 10cm for NALBAM 2 and 50cm x 10cm for NALBAM 1. Hence, considering the yield obtained spacings of 50cm x 10cm and or 60cm x 10cm are recommended for farmers.

Key words: Bambara groundnut, Landraces, South Eastern Tanzania, Plant spacing, Yield.

1. Introduction

Bambara groundnut (*Vigna subterranea* (L.) Verdc.) has numerous agronomic and nutritional attributes which make it an excellent crop to develop (Dakora and Muofhe, 1995). The protein and carbohydrate content of bambara groundnut are in the range of 18.0 - 24.0 % and 42-70% respectively (Adu-Dapaah *et al*. 2004; Amarteifio *et al*. 1997; Nwokolo, 1996). 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-^{1} and Sesay *et al*. (2004) obtained seed yield of 2.6 t ha^{-1} 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.

Studies from different parts of Africa report large variation in seeding rates (Linnemann, 1992). Earlier studies in highly leached soils of Bukoba in North Western Tanzania (Dunbar, 1969) indicated that farmers sow bambara groundnut at an average spacing of 30cm x 30cm. In West Africa, Ameyaw and Doku (1983) recommended a spacing 60cm x 30cm. Duke et al. (1977) similarly reported seed rate variations from 25 – 75 kg ha^{-1}, with inter row and intra row spacing varying from 30cm – 75cm and 10 – 50cm, respectively.

In South Eastern Tanzania, bambara groundnut is among the legumes grown in the area, mainly for food but also as a source of income. Unfortunately, farmers use local landraces as source of seed and follow their own management practices for cultivating the crop as improved technologies have not been introduced. Compared to other crops, bambara groundnut has been a neglected crop until recently (Azam-Ali *et al*., 2003). Consequently, very few research data have been published on the response of bambara groundnut to plant density. Even the few available reports have been inconclusive (Sticksel *et al*., 2002). Realising the potential and importance of bambara groundnut to the communities in South Eastern Tanzania and the country at large, Naliendele Agricultural Research

Institute has since 2009 embarked on research of the crop including its agronomy. It is within this background that a series of plant population trials have been conducted since 2011/2012 cropping season.

Not much work has been done on variations in terms of yield among the different bambara groundnut landraces in Tanzania. 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 intended to determine the optimum spacing for the cultivation of bambara groundnut in South Eastern Tanzania. This study was conducted to see effect of spacing on yield of five bambara groundnut landraces.

2. Materials and methods

2.1 Experimental site

The study was executed at Naliendele Agricultural Research Institute in Mtwara district during the 2011/2012 and 2012/2013 cropping seasons under rain fed conditions. Naliendele is located at 10^{o} 22'S and 40^{o} 10'E, 120 m above sea level and receives mean annual rainfall of 950 mm with monthly mean temperature of 27^{o}C and average relative humidity of 86%. The site is characterized by a unimodal type of rainfall. The soil texture of the site is loamy sand.

2.2 Experiment design and planting materials

The experimental design was a split plot in a randomized complete block design. Plant spacings were assigned as main plot whereas varieties were assigned in sub plots. Two sets of bambara groundnut landraces were used in the study under different plant spacing during 2011/2012 and 2012/2013

cropping seasons. The first set of landraces comprised of *NALBAM 1* and *NALBAM 2*; whereas the second set consisted of NALBAM *3, NALBAM 4* and *NALBAM 6*. The first set of landraces has been selected and is suitable for using the kernels when they are dry whereas the second one is for fresh consumption. The spacing treatments included 50cm and 60cm between rows; and 10 and 15 between plants within rows. The different spacing gave a range of plant population from 111 111 to 200 000 plants per hectare. For each set, the landraces and plant spacing were combined in a complete randomised block design in four replications. The trials were sown on-station in research fields at Naliendele Agricultural Research Institute on 20th February 2012 and 28th January 2013 and harvested in July 2012.

2.3 Data collection

During the study, initial and final plant stand were recorded. At harvesting number of pods per plant were recorded from which pod yield per hectare, 100 seed mass, shelling percentage and grain yield per hectare were calculated.

2.4 Data analysis

Data was analysed using the analysis of variance (ANOVA) from GenStat® Version 16 (VSN International, UK). Thereafter, means were separated using Duncan's Multiple Range Test in GenStat® at the 5% level of significance.

3. Results and discussion

3.1 The Bambara groundnuts Suitable for Dry Consumption

3.1.1 The percentage of 100 seed mass and shelling

None of yield parameters had a significance difference across the cropping seasons and also among the tested plant populations. A hundred (100) seed mass of the landraces ranged between 52 g and

60 g. Shelling percentage ranged between 68 – 70. Moreover there were no significant differences on high numbers of 100 seed mass as well as shelling percentage, which obtained from treatments with low plant populations.

3.1.2 Number of pods per plant

There was a significant difference ($P< 0.05$) on number of pods per plant among the tested plant populations. The highest number of pods per plant (24 pods) was observed from the spacing of 60cm x 15cm with plant population of 111 111 per hectare. This implies that, large plant spacing favours individual yield component. These results agree with ones obtained by Mkandawire and Sibuga (2001) who found the same trend. Their results revealed that increasing plant population density reflected negatively on pod yields; 9-plant m^{-2} produced the highest pod yields, while the 66 plants m^{-2} pod production was lowest. Awal and Lija, 2015 working with groundnuts and Edje *et al.* (1971) working with beans reported a decrease in number of pods plant $^{-1}$ with increase in plant population. Usually with increase in plant population, the combined demand for plant nutrients and light results into competition of these resources.

3.1.3 Grain yield

The effect plant population of landraces yield and other attributes are presented in Tables 1 and 2. There was no significance ($P\leq0.05$) on pod yield and seed yield/ha in both seasons, due to the increase in plant population was observed. During 2011/2012 cropping season, The NALBAM 1 which spaced at 50cm x 10cm had the highest pod yield (1023 kg ha^{-1}) as well as highest grain yield (705 kg ha^{-1}). On the other hand, the highest pod yield (1111 kg ha^{-}1) and grain yield (771 kg ha^{-}1) were obtained from NALBAM 2 by spacing of 60cm x 10cm produced. The results showed that highest plant population for NALBAM 1 (200 000 plants ha^{-1}), gave the highest grain yield as compared to other plant densities. On the other hand, NALBAM 2 had its highest grain yield from plant population with 166 667 plants ha^{-1}. The difference between the plant densities with the highest grain yield from the two landraces

may be happen, due to their genotypic features. The NALBAM 1 is a bunch type, whereas NALBAM 2 is a spreading type. Hence, competition for resources increased in NALBAM 2 with increased plant population. These results, was supported by Sesay and Yarmah (1996), who conducted a field experiment on the effects of plant densities ranging from 23,000 to 444,000 plants/ha at an inter-row spacing of 30 cm. Sesay and Yarmah (1996) reported that they did not achieve the desired plant density, probably because of plant competition, especially at the higher plant densities, and that the highest pod yield was obtained at plant densities ranging between 220,000 and 260,000 plants ha^{-1}.

Table 1: Means of yield and other variables of dry consumed bambara groundnut genotypes under different plant populations during 2011/2012 cropping season.

Genotype and Population	Pod yield (kg ha^{-1})	100 mass wt. (g)	Final stand	Initial stand	No. of pods $plant^{-1}$	Shelling (%)	seed yield (kg ha^{-1})
NALBAM1 P1	861	53	45	46	14	68	587
NALBAM1 P2	1023	56	48	48	14	69	705
NALBAM1 P3	998	55	36	39	19	70	699
NALBAM1 P4	928	60	43	45	13	69	637
NALBAM2 P1	910	57	47	48	13	70	636
NALBAM2 P2	949	55	43	44	16	69	655
NALBAM2 P3	853	53	53	54	17	70	594
NALBAM2 P4	1111	54	37	38	16	70	771
Mean	955	55.5	43.8	45.0	15	69	661
CV%	18.85	7.0	16.25	16.74	19.15	2.5	18.5
LSD (Genotypes x Population)	265	5.7	10.5	11.1	4.3	2.6	180
P=0.05 (Genotypes)	ns	ns	ns	ns	ns	ns	ns
P=0.05 (Population)	ns	ns	ns	ns	*	ns	ns
P=0.05 (Geno. x Population)	ns	ns	**	**	ns	ns	ns

Key: ns = non-significant, P1 = 50cm x 10cm, P2 = 50cm x 15cm, P3 = 60cm x 10cm, P4 = 60cm x 15cm

During 2012/2013, there was no any difference in pod yield for NALBAM 1 with respect to plant populations with spacing of 50cm x 10cm and 50 cm x 15 cm, since both of spacing of sowing had pod yield of 1000 kg ha^{-1}. Nevertheless, the spacing of 50cm x 10cm gave the highest grain yield of

696 kg ha^{-1}. The highest pod and grain yielding of spacing for NALBAM 2 were also 50cm x 10cm with pod yield of 1125 kg $ha^{-1}$and grain yield of 790 kg ha^{-1}. The increase in grain at higher plant densities was mainly due to increased number of plants per unit area, which was able to compensate for the reduction in the number of pods plant $^{-1}$ at greater plant populations. Guriqbal *et al.* (2011), in study of mung bean, found grain yield increase in higher plant populations; they found higher grain yields were obtained at 40 plants m^{-2} as compared to low plant densities.

During the two cropping seasons, there was no significance difference (P≤0.05) in 100 seed mass and shelling percentage was obtained from the tested landraces and population. Also there was no significance difference on landraces x population interaction for pod yield, seed yield, shelling percentage and 100 seed mass, this means that, bambara groundnut population increase influenced both landraces performance equally.

Table 1: Means of yield and other variables of dry consumed bambara groundnut genotypes under different plant populations during 2012/2013 cropping season.

Genotype and Population	Pod yield (kg ha^{-1})	100 mass wt. (g)	Final stand	Initial stand	No. of pods $plant^{-1}$	Shelling (%)	seed yield (kg ha^{-1})
NALBAM1 P1	875	52	43	48	14	70	609
NALBAM1 P2	1000	52	57	52	15	70	696
NALBAM1 P3	1000	52	49	55	15	69	688
NALBAM1 P4	844	55	46	50	17	68	575
NALBAM2 P1	938	53	46	50	13	70	651
NALBAM2 P2	1125	58	53	55	19	70	790
NALBAM2 P3	875	54	55	50	15	70	615
NALBAM2 P4	1206	58	46	51	24	70	847
Mean	969	55	49	50	16	70	673
CV%	17.5	7.1	27.3	18.7	18.3	2.2	16.7
LSD (Genotypes x Population)	249.7	5.7	19.8	14.1	4.4	2.3	165.2
P=0.05 (Landrace)	ns	ns	ns	ns	*	ns	ns
P=0.05 (Population)	ns	ns	ns	ns	**	ns	ns
P=0.05 (Landrace x Population)	ns	ns	ns	ns	ns	ns	ns

Key: ns = non-significant, P1 = 50cm x 10cm, P2 = 50cm x 15cm, P3 = 60cm x 10cm, P4 = 60cm x 15cm

3.2 Fresh Suitable Consumed Bambara groundnuts

3.2.1 Number of pods per plant, 100 seed mass and percentage shelling

During the cropping seasons 2011/2012 and 2012/2013, none of above yield components showed significant differences (P≤0.05) during the two cropping seasons and also among the plant densities. Number of pods per plant, 100 seed mass and percentage shelling were in the range of 68 – 71 g, 11 – 17 pods per plant and 68 – 71% respectively. Although there was no significant difference, most of low plant population treatments found to outperform treatments with high plant populations. Also, from this study, there was no significance difference landrace x population interaction for number of pods per plant, shelling percentage and 100 seed mass was observed, this means that, bambara groundnuts population increase influenced both landraces performance equally.

3.2.2 Pod/grain yield

The effect of plant population on landraces pod/grain yield and other attributes is presented in Tables 3 and 4. During 2011/2012 experiment, significance difference (P≤0.05) in pod yield among the tested landraces was obtained, although there was no significance difference (P≤0.05) in seed yield among the tested landraces. There was highly significance difference (P≤0.01) in pod and grain yield among the tested landrace populations. In all the three tested landraces (NALBAM 3, NALBAM 4 and NALBAM 6) the highest pod and seed yielding spacing was P4 (60cm x 10cm) with pod yield of 1568 kg ha $^{-1}$ and grain yield of 807 kg ha $^{-1}$ for NALBAM 3. For NALBAM 4 the highest pod and seed yield was 1321 Kg/ha and 824 kg ha $^{-1}$ respectively with the same spacing of 60cm x 10cm. Also the spacing of 60cm x 10cm was superior to other plant populations for NALBAM 6, the highest pod and seed yield was 1334 kg ha $^{-1}$ and 807 kg ha $^{-1}$ respectively. Generally, the results imply that, increase in plant population densities increases plant pod/grain yield. This might be attributed to the efficient utilization of growth resources

and the use of optimum plant densities. The result revealed that 200,000 plants per hectare as optimum plant density for landrace NALBAM 1 and 166, 667 for NALBAM 2. In agreement with these results Agasimani and Hosmani (1989) who worked on different groundnut populations, he found that in groundnut 20cm x 15 cm spacing recorded the highest pod yield of 4.09 tons ha^{-1}, which was at par with 20cm x 10 cm spacing and significantly superior over wider spacing of 40 x 20 cm (3.14 tons ha-1). Also, Annadurai *et al.* (2009) reported that, closer spacing of peanut at 25cm x 10 cm significantly gave higher pod and haulm yield of 2694 and 4397 kg ha^{-1} respectively as compared to 30 cm x 10 cm spacing.

Table 2: Means of yield and other variables of fresh consumed bambara groundnut genotypes under different plant populations during 2011/2012 cropping season.

Genotype and Population	Pod yield (kg ha^{-1})	100 mass wt. (g)	Final stand	Initial stand	No. of pods $plant^{-1}$	Shelling (%)	seed yield (kg ha^{-1})
NALBAM3 P1	874	68	43	45	14	69	632
NALBAM3 P2	1196	69	28	30	14	68	677
NALBAM3 P3	884	72	37	41	15	70	615
NALBAM3 P4	1568	73	26	28	15	69	807
NALBAM4 P1	858	73	37	43	11	69	591
NALBAM4 P2	976	79	36	38	13	71	735
NALBAM4 P3	1060	75	38	41	14	69	731
NALBAM4 P4	1321	75	24	26	17	70	824
NALBAM6 P1	704	69	45	48	13	68	641
NALBAM6 P2	954	71	31	33	15	70	636
NALBAM6 P3	942	73	36	39	11	71	665
NALBAM6 P4	1334	71	29	31	15	70	807
Mean	1056	73	34	37	14	69	697
CV%	13.37	10.8	20.4	17.2	29.9	2.5	18.7
LSD (Landraces x Population)	203.1	11.4	10.0	9.1	5.9	2.5	187.3
P=0.05 (Landraces)	*	ns	ns	ns	ns	ns	ns
P=0.05 (Population)	**	ns	**	**	ns	ns	**
P=0.05 (Geno. x Population)	ns	ns	ns	ns	ns	ns	ns

Key: ns = non-significant, P1 = 50cm x 10cm, P2 = 50cm x 15cm, P3 = 60cm x 10cm, P4 = 60cm x 15cm

During 2012/2013 cropping season, there was highly significance difference (P≤0.01) in pod and grain yield among the tested landraces and their populations. The highest pod and grain yield in all the three tested landraces were obtained from the spacing of 60 cm x 10 cm, for NALBAM 3 the highest pod yield was 1444 kg ha $^{-1}$ while grain yield was 1007 kg ha $^{-1}$. NALBAM 4 gave the highest pod yield of 1100 kg ha^{-1} and grain yield of 764 kg ha $^{-1}$. Furthermore, NALBAM 6 had the highest pod yield of 1063 kg ha^{-1} and grain yield of 757 kg ha $^{-1}$ from the spacing of 60cm x 10cm. These results conquer with findings by Edje and Mavimbela (2014), who observed that, seed yield (kg ha^{-1}) decreased significantly (P < 0.01) with increase in plant spacing.

Table 3: Means of yield and other variables of fresh consumed bambara groundnut genotypes under different plant populations during 2012/2013 cropping season.

Genotype and Population	Pod yield (kg ha^{-1})	100 seed mass (g)	Final stand	Initial stand	No. of pods plant^{-1}	Shelling (%)	seed yield (kg ha^{-1})
NALBAM3 P1	841	68	61	63	15	69	575
NALBAM3 P2	1125	69	57	58	14	68	760
NALBAM3 P3	931	71	74	76	16	70	652
NALBAM3 P4	1444	73	54	56	15	70	1007
NALBAM4 P1	756	70	62	64	12	69	524
NALBAM4 P2	875	79	67	68	13	69	600
NALBAM4 P3	906	74	78	79	16	70	631
NALBAM4 P4	1100	74	57	58	17	70	764
NALBAM6 P1	800	66	62	63	14	69	552
NALBAM6 P2	869	76	56	58	15	70	604
NALBAM6 P3	906	71	88	82	11	70	633
NALBAM6 P4	1063	69	47	48	15	71	757
Mean	968	71	63	64	14	69	672
CV%	14.2	10.8	25.9	26.4	25.9	2.6	14.8
LSD (Landraces x Population)	198.1	11.1	23.6	14.1	5.3	2.6	142.5
P=0.05 (landraces)	**	ns	ns	ns	ns	ns	**
P=0.05 (Population)	**	ns	**	**	ns	ns	**
P=0.05 (Geno. x Population)	ns	ns	ns	ns	ns	ns	ns

Key: P1 = 50cm x 10cm, P2 = 50cm x 15cm, P3 = 60cm x 15cm, P4 = 60cm x 15cm

4. Conclusion

Since bambara groundnut yields vary considerably among sites, seasons and genotypes these recommendations are solely for South eastern Tanzania. Basing on the findings from the two cropping seasons, the recommended spacing for NALBAM 1 and NALBAM 2 bambara groundnut landraces, which are more suitable for grain, should be planted at 50cm x 10cm for optimum yield. On the other hand, NALBAM 3, NALBAM 4 and NALBAM 6, which are more suitable for fresh consumption, should be planted at the spacing of 60cm x 10cm for optimum yield; this is due to the results obtained in 2011/12 and 2012/13 cropping seasons, as this planting spacing was observed to have consistent high pod yields. Further experiments of the same are encouraged to be conducted elsewhere with more range of plant population densities per hectare.

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