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(Research Article)

Effect of planting method and spacing on the growth parameters of three Bambara groundnut cultivars in two Agro-climatic zones of Sierra Leone

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Abstract

Field trials were conducted in two agro-climatic zones of the country (Lungi and Kabala) to evaluate the effect of planting methods and inter-row spacing on the growth parameters of three Bambara groundnut cultivars. The experiment consisted of a factorial 18 treatment combinations of two planting methods (mound and flat), three inter-row spacing (50 cm x 10 cm, 50 cm x 15 cm, and 50 cm x 20 cm), and three Bambara groundnut cultivars (Lubam1, Lubam 2, and Kabam 1). The study shows that planting Bambara groundnut using mounds produced higher values of the assessed growth parameters compared to planting Bambara groundnut on flat land. The result further shows that the wider inter-row spacing (50 cm x 20 cm) on average recorded the highest value for all the assessed growth parameters. Furthermore, Kabam1 was observed to have recorded the highest value for all the growth parameters in both locations. Thus, for optimum growth parameters to be achieved, it is recommended that Kabam1 should be planted on mound using the inter-row spacing of 50 cm x 20cm.

Keywords: Bambara groundnut; Cultivar; Growth parameter; Inter-row spacing; Planting method; Plant height

1. Introduction

Bambara groundnut is an indigenous African crop that has been cultivated for ages. It is the third most important grain legume after groundnut and cowpea in sub-Saharan Africa. The crop is an important pulse, which is mainly cultivated by small-scale farmers in sub-Saharan Africa in a wide range of agro-climatic zones [1]. Bambara groundnut is grown primarily for its subterranean pods, which can be boiled, roasted, made into flour, and boiled to a thick porridge [2]. Bambara groundnut seeds are rich in protein and help to alleviate nutritional disorders in humans and livestock [3]. It has the ability to fix atmospheric nitrogen through symbiosis with rhizobium bacteria and is therefore beneficial in rotation and intercropping [4]. The crop is common in Africa because of its ability to withstand drought and pests, and produce reasonable yields when cultivated on marginal soils.

The spacing of Bambara groundnut varies from one agro-climatic zone to another in both Eastern and Western Africa. Mkandiwire and Sibugu [3] reported a spacing of 30 cm x 30 cm in Tanzania and 60 cm x 30 cm in West Africa with 10 cm intra-row spacing producing the highest yield and growth parameters. Also, in Zambia, it was shown that planting on flat with a spacing of (30 cm x 30 cm) with or without earthing-up resulted in no significant differences in yield and growth parameters [5] cited by [6]. In a different study, at Ukiriguru in Tanzania, planting on either ridge or flat land resulted in no considerable difference in yield [7].

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Information relating to the growth parameters of Bambara groundnut concerning plant spacing and planting method (seedbed type) in the two agro-climatic zones where the research was conducted is scanty. Identification of an appropriate planting method and suitable plant spacing will encourage farmers in the area to embark on the cultivation of the crop.

Thus, a field experiment was conducted to identify the appropriate planting method and spacing that could improve the growth parameters of the three Bambara groundnut landraces.

2. Material and methods

2.1. Experimental site

The study was conducted under rain-fed conditions in 2018 and 2019 cropping seasons in two agro-climatic zones namely, Lungi (8.5555N, 13.1636W) representing the coastal plain with a mean annual rainfall of 3,911.39 mm, mean annual temperatures of 25.08^{0}C, and mean annual relative humidity of 83.59% and Kabala (9.5797N, 11.4408W) representing the savannah highland with an annual mean rainfall of 2,841.35 mm, mean annual temperatures of 24.86^{0}C, and mean annual relative humidity of 75.86%. The soil properties and locations of the trials are shown in table1 and figure 1 respectively.

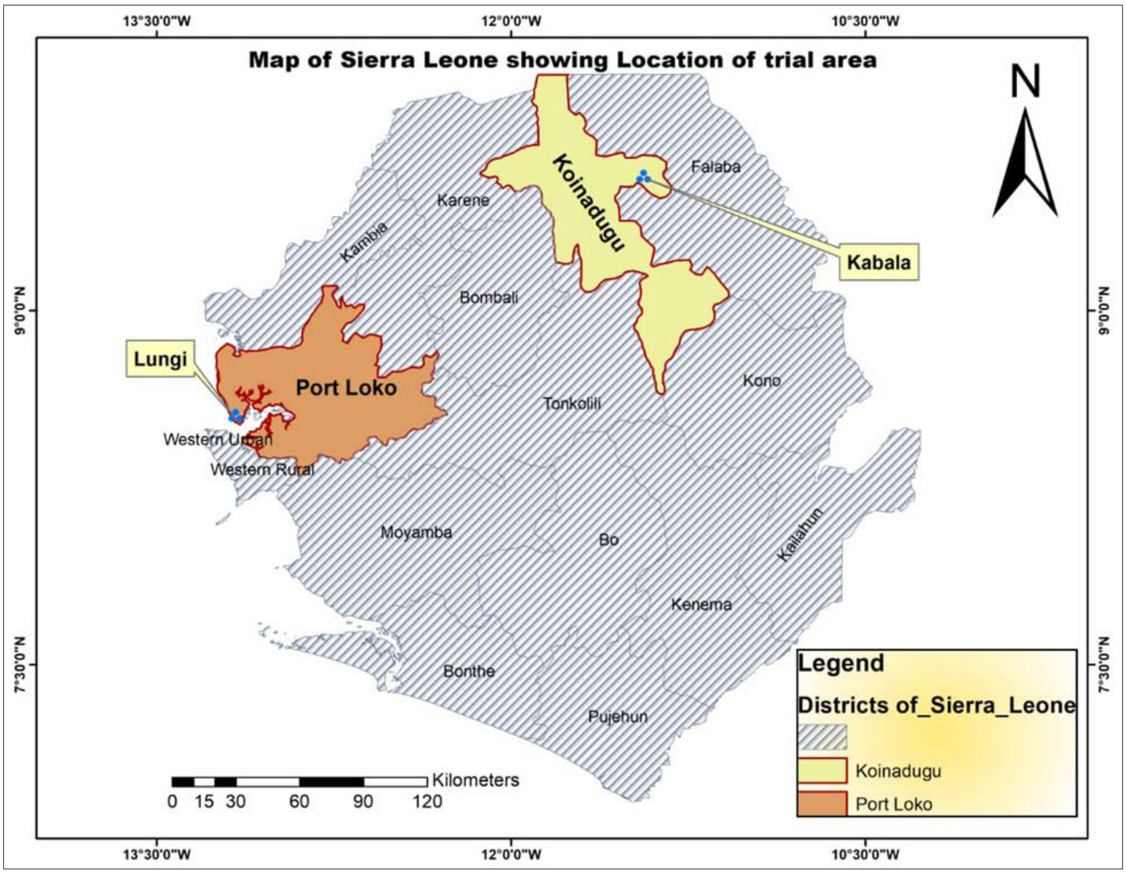

Figure 1 Map of Sierra Leone showing trial locations

2.2. Soil collection and analysis

Soil samples from the two experimental sites were collected at 0~30cm depth using a soil auger during the 2018 and 2019 cropping seasons. The collected samples were bulked, air-dried, and sieved. The bulked soil was used to determine the physical and chemical properties at the Njala University Quality Control Laboratory (NUQCL), Njala, Sierra Leone. The Kjedhal distillation method was used to determine the total nitrogen content [8]. Potassium was extracted by Ammonium Acetate and determined by the flame photometer method. The available Phosphorus was determined by the Bray 1 Method. Soil pH (1:1) was determined using the pH Meter. The soil organic carbon was determined by Walkley-Black procedure. Particle size analysis was done using the hydrometer method.

Table 1 Physicochemical properties of the soil at the experimental sites

Physicochemical property	Lungi				Kabala			
	Initial	Final	Change	% Change	Initial	Final	Change	% Change
pH	4.99	4.65	-0.34	-6.81	5.40	5.18	-0.22	-4.25
Organic carbon (%)	1.83	1.57	-0.26	-14.21	2.06	1.78	-0.28	-13.59
Total Nitrogen (%)	0.10	0.157	0.06	58	0.022	0.07	0.048	218.18
Available Phosphorus (mg /kg soil)	1.58	1.45	-0.04	-2.53	9.07	7.48	-1.59	-17.53
Exchangeable Potassium (mg/kg soil)	2.99	3.16	0.17	5.68	21.79	21.00	-0.79	-3.63
Soil texture	Loamy sand				Loamy sand			

2.3. Land preparation

The land at the two locations was slashed with a cutlass, burnt down, de-stumped, and dug using a hoe, and plots were laid out using a measuring tape, garden line, and pegs.

2.4. Experiment design, treatments, and planting

The experiment was a 3 x 3 x 2 factorial arranged in a randomized complete block design (RCBD) with three replications. The treatments consisted of three Bambara groundnut varieties (Lubam1, Lubam2, and Kabam1), three plant spacings (50 cm x 10 cm, 50 cm x 15 cm, and 50 cm x 20 cm), and two planting methods (Flat and mound). The plot size was 3 m x 3 m. The seeds for the trials were collected from the local farmers at the two zones and seeds were planted in June of each cropping season at the rate of one seed per hill at a depth of 3 cm. Weeding was done at two weeks intervals till harvest. Harvesting was done at the respective maturity dates of the three Bambara groundnut cultivars.

2.5. Data collection

The important growth parameters collected included germination percentage, plant height, canopy width, number of leaves per plant, fresh leaf weight, dry leaf weight, number of stems, fresh stem weight, and dry stem weight. These parameters were determined at 77days after planting (DAP).

The germination percentage was determined by counting the number of germinated seedlings out of the number of healthy seeds sown at 19 days after planting (DAP) at both sites and the result was expressed as a percentage.

Plant height was determined from five randomly selected plants as the length of the main axil from the base of the plant to the tip of the closed terminal leaflet expressed in centimeters using a tape rule. Canopy width was also obtained in centimeters as a mean of five plants randomly selected from each replicate plot using a measuring tape. To carry this out, two small sticks were placed at the widest length between two opposite points of spread. This length was then measured and recorded.

The number of fully opened trifoliate leaves per plant was counted and the mean for five randomly selected plants was then recorded.

Fresh leaf weight was determined by harvesting fresh leaves from five randomly selected plants and weighed on a sensitive scale.

Dry leaf weight was determined by placing the fresh leaves that were harvested from the five randomly selected plants into an oven at 70^0C for 48 hours and the dry weight was recorded.

The number of stems was determined by counting the number of stems of five randomly selected plants and the mean recorded.

Fresh stem weight was determined by weighing the stems harvested from five randomly selected plants. The weight obtained was recorded in kilograms.

Dry stem weight was determined by oven drying the fresh stems and the weight was recorded.

2.6. Data analysis

The data collected were subjected to analysis of variance (ANOVA) using the SAS statistical package [9] and means were separated using the Student Newman-Keuls Test (SNK) at a 0.05 level of significance.

3. Results

3.1. Germination percentage

Concerning germination percentage, significant differences (P < 0.05) were observed regarding planting method, plant spacing, and cultivar (Table 2). For the planting method, the mound recorded a higher germination percentage at both locations. At Lungi, the mound registered a higher germination percentage (68.48%) compared to when planting was done on flat (67.96%). Similarly, at Kabala, the mound recorded a higher germination percentage (79.14%) compared to flat (75.37%). Generally, Kabala registered a higher germination percentage (77.26%) than at Lungi (68.22%). The germination percentage at Kabala was 12% higher than at Lungi (Table 2).

Regarding plant spacing, S3 (50 cm x 20 cm) which is the widest spacing registered a higher germination percentage at both locations. At Lungi, S3 (50 cm x 20 cm) recorded a higher germination percentage (70.50%) followed by S2 (50 cm x 15 cm) (67.88%) and S1 (50 cm x 10 cm) (66.27%). Similarly, at Kabala, S3 (50 cm x 20 cm) registered a higher germination percentage (78.66%) followed by S2 (50 cm x 15 cm) (77.61%) and S1 (50 cm x 10 cm) (75.50%) (Table 2).

Concerning cultivars, Lubam 2 registered a higher germination percentage at both locations. At Lungi, Lubam 2 recorded a higher germination percentage (85.83%) followed by Lubam 1 (63.00%) and Kabam 1 (55.83%). Similarly, for Kabala, Lubam 2 recorded a higher germination percentage (89.88%) followed by Kabam 1 (74.22%) and Lubam 1 139(67.66%). On average, Kabala registered a higher germination percentage (77.23%) compared to Lungi (68.22%). The germination percentage for Kabala was 12% higher than at Lungi (Table 2). Also, the three-way interactions among planting method x plant spacing x cultivar with respect to germination percentage at both locations were not significant (P > 0.05).

3.2. Canopy width

About canopy width, significant differences (P < 0.05) were observed concerning planting method, plant spacing, and cultivar. For the planting method, the mound recorded a higher canopy width at both locations. At Lungi, the mound registered a higher canopy width (34.77) compared to when planting was done on flat (31.87) (Table 2). Similarly, at Kabala, the mound recorded a higher canopy width (54.52) than planting on flat (53.20). In general, Kabala recorded a higher canopy width (53.86) than at Lungi (33.32). The canopy width for Kabala was 38% higher than Lungi.

For plant spacing at Lungi, S1 (50 cm x 10 cm) which is the narrowest spacing registered a higher canopy width (33.59) followed by S2 (50 cm x15 cm) (33.51), and S3 (50 cm x 20 cm) (32.86). Conversely, for Kabala, S3 (50 cm x 20 cm) recorded a higher canopy width (55.02) followed by S2 (50 cm x15 cm) (54.23) and S1 (50 cm x 10 cm) (52.33). Furthermore, Kabala generally recorded a higher canopy width (53.86) compared to Lungi (33.32) (Table 2).

Concerning cultivars, Kabam 1 recorded a higher canopy width at both locations. For Lungi, Kabam 1 registered a higher canopy width (35.13) followed by Lubam 2 (32.46), and Lubam 1 (32.37). Similarly, at Kabala, Kabam 1 registered a higher canopy width (63.12) followed by Lubam 2 (49.57) and Lubam 1 (48.89). In general, Kabala registered a higher canopy width (53.86) compared to Lungi (33.32) (Table 2). The three-way interactions among planting method x plant spacing x cultivar with respect to canopy width at both locations were not significant.

3.3. Plant height

Regarding plant height, significant differences (P < 0.05) were recorded concerning planting method, plant spacing, and cultivar at both locations (Table 2). For the planting method, at Lungi, the mound registered a higher plant height (25.11) compared to when planting was done on flat (23.09). On the contrary, at Kabala, planting on flat recorded a higher plant height (30.17) compared to Kabala (30.07). In general, Kabala registered a higher plant height (30.12) than at Lungi (24.10) (Table 2). The plant height for Kabala was 20% higher than Lungi.

Concerning plant spacing, S1 (50 cm x 10 cm), registered a higher plant height at both locations. At Lungi, S1 (50 cm x 10 cm) recorded a higher plant height (24.58) followed by S2 (50 cm x 15 cm) (24.47), and S3 (50 cm x 20 cm) (23.24). Similarly, at Kabala, S1 (50 cm x 10 cm) recorded a higher plant height (30.38) followed by S2 (50 cm x 15 cm) (30.17), and S3 (50 cm x 20 cm) (29.81). Generally, Kabala recorded a higher plant height (30.12) compared to Lungi (24.10) (Table 2)

Relating to cultivars, Lubam 2 recorded a higher plant height at both locations. At Lungi, Lubam 2 registered a higher plant height (25.16) followed by Lubam 1 (24.41) and Kabam 1 (22.73). Similarly, at Kabala, Lubam 2 registered a higher plant height (30.89) followed by Lubam 1 (30.37) and Kabam 1 (29.10). In general, Kabala recorded a higher plant height (30.12) compared to Lungi (24.10) (Table 2).

Table 2 Effect of planting method, plant spacing, and Bambara groundnut cultivar on germination percentage, canopy width, and plant height in the two locations over two cropping seasons

Locations							
Treatments	**Lungi**			**Kabala**			**Mean**
	Growth Parameters			**Growth Parameters**			
	Germination percentage	**Canopy width**	**Plant height**	**Germination percentage**	**Canopy width**	**Plant height**	
Planting method							
Flat	67.96	31.87	23.09	75.37	53.20	30.17	46.94b
mound	68.48	34.77	25.11	79.14	54.52	30.07	48.68a
Mean	68.22b	33.32b	24.10b	77.26a	53.86a	30.12a	
Plant spacing							
50 cm x 10cm	66.27	33.59	24.58	75.50	52.33	30.38	47.11c
50cm x 15cm	67.88	33.51	24.47	77.61	54.23	30.17	47.98b
50cm x 20cm	70.50	32.86	23.24	78.66	55.02	29.81	48.35a
Mean	68.22b	33.32b	24.10b	77.26a	53.86a	30.12a	
Cultivar							
Lubam1	63.00	32.37	24.41	67.66	48.89	30.37	44.45c
Lubam 2	85.83	32.46	25.16	89.88	49.57	30.89	52.30a
Kabam 1	55.83	35.13	22.73	74.22	63.12	29.10	46.69b
Mean	68.22b	33.32b	24.10b	77.23a	53.86a	30.12a	

Mean in column with the same letter are not significantly different at P > 0.05 (SNK).

3.4. Number of leaves

Concerning the number of leaves, significant differences (P < 0.05) were observed regarding planting method, plant spacing, and cultivar (Table 3). About the planting method, more leaves were produced for the mound at both locations. At Lungi, planting on mound registered a higher number of leaves (52.81) compared to planting on flat (41.71). Also, at Kabala, the mound recorded a higher number of leaves (116.74) than when planting was done on flat (111.25) (Table 3). Generally, Kabala registered a higher number of leaves (114.00) compared to Lungi (47.26). The number of leaves recorded for Kabala was 59% higher than Lungi.

Relating to plant spacing, S3 (50 cm x 20 cm) recorded a higher number of leaves (49.47) followed by S1 (50 cm x 10 cm) (46.83) and S2 (50 cm x 15 cm) (45.48) at Lungi. At Kabala, also, S3 (50 cm x 20 cm) registered a higher number of leaves (128.00) followed by S2 (50 cm x 15 cm) (123.50) and S1 (50 cm x 10 cm) (90.50). In general, Kabala recorded a higher number of leaves (114.00) than at Lungi (47.26) (Table 3).

In the case of cultivars, Kabam 1 recorded a higher number of leaves at both locations. At Lungi, Kabam 1 registered a higher number of leaves (69.13) followed by Lubam 2 (42.01) and Lubam 1 (30.65). Similarly, at Kabala, Kabam 1 registered a higher number of leaves (145.33) followed by Lubam1 (103.33) and Lubam 2 (93.33) (Table 3). Kabala in general recorded a higher number of leaves (114.00) compared to Lungi (47.26). Also, the three-way interactions among planting method x plant spacing x cultivar with respect to the number of leaves at both locations were not significant (P > 0.05).

3.5. Fresh leaf weight

With regards to fresh leaf weight, significant differences (P < 0.05) were observed with respect to planting method, plant spacing, and cultivar. In the case of the planting method, the mound registered a higher fresh leaf weight at both locations compared to when planting was done on flat. In general, Kabala recorded a higher fresh leaf weight (78.52) than Lungi (25.21) (Table 3). The fresh leaf weight for Kabala was 68% higher than Lungi.

Concerning plant spacing, S3 (50 cm x 20 cm) registered a higher fresh leaf weight at both locations. At Lungi, S3 (50 cm x 20 cm) registered a higher fresh leaf weight (26.43) followed by S2 (50 cm x 15 cm) (25.52) and S1 (50 cm x 10 cm) (23.68). Similarly, at Kabala, S3 (50 cm x 20 cm) registered a higher fresh leaf weight (87.77) followed by S2 (50 cm x 15 cm) (84.60) and S1 (50 cm x 10 cm) (63.17). Kabala generally, registered a higher fresh leaf weight (78.51) compared to Lungi (25.21) (Table 3).

Regarding cultivars, Kabam 1 recorded a higher fresh leaf weight at both locations. At Lungi, Kabam 1 registered a higher fresh leaf weight (36.64) followed by Lubam 2 (19.69), and Lubam 1 (19.30). Similarly, in Kabala, Kabam 1 recorded a higher fresh leaf weight (91.48) followed by Lubam 1 (77.33), and Lubam 2 (66.73). In general, Kabala registered a higher fresh leaf weight (78.51) compared to Lungi (25.21) (Table 3). Furthermore, the three-way interactions among planting method, plant spacing, and cultivar with respect to fresh leaf weight at both locations were not significant (P>0.05).

3.6. Dry leaf weight

Concerning dry leaf weight, significant differences (P < 0.05) were observed with respect to planting method, plant spacing, and cultivar. For the planting method, the mound recorded a higher dry leaf weight (10.20) compared to when planting was done on flat (7.16) at Lungi. At Kabala, on the other hand, planting on flat registered a higher dry leaf weight (29.25) than the mound (27.56). Generally, Kabala registered a higher dry leaf weight (28.41) compared to Lungi (8.68). The dry leaf weight for Kabala was 70% higher than at Lungi (Table 3).

Regarding plant spacing, S3 (50 cm x 20 cm) recorded a higher dry leaf weight at both locations. At Lungi, S3 (50 cm x 20 cm) registered a higher dry leaf weight (9.67) followed by S2 (50 cm x 15 cm) (8.55) and S1 (50 cm x 10 cm) (7.82). Similarly, at Kabala, S3 (50 cm x 20 cm) recorded a higher dry leaf weight (31.73) followed by S2 (50 cm x 15 cm) (30.52) and S1 (50 cm x 10 cm) (22.97). Kabala in general registered a higher dry leaf weight (28.41) than at Lungi (8.68) (Table 3).

With respect to the cultivars, Kabam 1 recorded a higher dry leaf weight at both locations. At Lungi, Kabam 1 recorded a higher dry leaf weight (12.53) followed by Lubam 2 (7.18) and Lubam 1 (6.34). Similarly, at Kabala, Kabam1 registered a higher dry leaf weight (32.71) followed by Lubam 1 (28.11) and Lubam 2 (24.40). In general, Kabala registered a higher dry leaf weight (28.41) compared to Lungi (8.68) (Table 3). Also, the three-way interactions among planting method x plant spacing x cultivar with respect to dry leaf weight at both locations were not significant (P>0.05).

Table 3 Effect of planting method, plant spacing, and Bambara groundnut cultivar on the number of leaves, fresh leaf weight, and dry leaf weight in the two locations over two cropping seasons

Locations							
Treatments	**Lungi**			**Kabala**			**Mean**
	Growth Parameters			**Growth Parameters**			
	Number of leaves	**Fresh leaf weight**	**Dry leaf weight**	**Number of leaves**	**Fresh leaf weight**	**Dry leaf weight**	
Planting method							
Flat	41.71	20.20	7.16	111.25	76.81	27.56	47.45b
mound	52.81	30.22	10.20	116.74	80.22	29.25	53.25a
Mean	47.26b	25.21b	8.68b	114.00a	78.52a	28.41a	
Plant spacing							
50 cm x 10cm	46.83	23.68	7.82	90.50	63.17	22.97	42.83c
50cm x 15cm	45.48	25.52	8.55	123.50	84.60	30.52	53.03b
50cm x 20cm	49.47	26.43	9.67	128.00	87.77	31.73	55.51a
Mean	47.26b	25.21b	8.68b	114.00a	78.51a	28.41a	
Cultivar							
Lubam1	30.65	19.30	6.34	103.33	77.33	28.11	44.18b
Lubam 2	42.01	19.69	7.18	93.33	66.73	24.40	42.22c
Kabam 1	69.13	36.64	12.53	145.33	91.48	32.71	64.64a
Mean	47.26b	25.21b	8.68b	114.00	78.51a	28.41a	

Mean in column with the same letter are not significantly different at P > 0.05 (SNK).

3.7. Number of stems

About the number of stems, significant differences (P<0.05) were observed with regards to planting method, plant spacing, and cultivar (Table 4). For the planting method, more stems were registered for the mound at both locations. At Lungi, planting on mound registered a higher number of stems (6.03) compared to planting on flat (5.93). Also, at Kabala, the mound recorded a higher number of stems (7.25) compared to when planting was done on flat (6.70) (Table 4). Generally, Kabala recorded a higher number of stems (6.98) compared to Lungi (5.98). The number of stems recorded for Kabala was 14% higher than at Lungi.

Similarly, regarding plant spacing, more stems were registered for S3 (50 cm x 20 cm) at both locations. At Lungi, S3 (50 cm x 20 cm) registered a higher number of stems (6.11) followed by S1 (50 cm x 10 cm) (5.95) and S2 (50 cm x 10 cm) (5.88). Also, at Kabala, S3 (50 cm x 20 cm) registered a higher number of stems (7.38) followed by S2 (50 cm x 15 cm) (7.11) and S1 (50 cm x 10 cm) (6.44). In general, Kabala recorded a higher number of stems (6.98) compared to Lungi (5.98) (Table 4).

With respect to cultivars, more stems were recorded for Kabam 1 (6.33) followed by Lubam 1 (5.94) and Lubam 2 (5.67) at Lungi. On the contrary, at Kabala, Lubam 1 registered a higher number of stems (7.16) followed by Lubam 2 (7.00) and Kabam 1 (6.77) (Table 4). Kabala in general recorded a higher number of stems (6.98) compared to Lungi (5.98). Also, the three-way interactions among planting method x planting spacing x cultivar with respect to the number of stems at both locations were not significant (P > 0.05).

3.8. Fresh stem weight

Concerning fresh stem weight, significant differences (P < 0.05) were observed concerning planting method, plant spacing, and cultivar. For planting method, the mound recorded a higher fresh stem weight at both locations compared to planting on flat (Table 4). In general, Kabala recorded a higher fresh stem weight (18.34) than Lungi (6.42) (Table 4). The fresh stem weight for Kabala was 65% higher than Lungi.

Pertaining to plant spacing, S3 (50 cm x 20 cm) registered a higher fresh stem weight at both locations. At Lungi, S3 (50 cm x 20 cm) recorded a higher fresh stem weight (7.16) followed by S1 (50 cm x 10 cm) (6.26) and S2 (50 cm x 15 cm) (5.83). Similarly, at Kabala, S3 (50 cm x 20 cm) recorded a higher fresh stem weight (20.33) followed by S2 (50 cm x 15 cm) (19.64) and S1 (50 cm x 10 cm) (15.04). Kabala generally, registered a higher fresh stem weight (18.34) compared to Lungi (6.42) (Table 4).

With regards to cultivars, Kabam 1 recorded a higher fresh stem weight at both locations. At Lungi, Kabam 1 registered a higher fresh stem weight (10.04) followed by Lubam 1 (4.86) and Lubam 2 (4.35). Similarly, in Kabala, Kabam 1 recorded a higher fresh stem weight (25.04) followed by Lubam 1 (15.88), and Lubam 2 (14.08). In general, Kabala registered a higher fresh stem weight (18.33) compared to Lungi (6.42) (Table 4). Furthermore, the three-way interactions among planting method x plant spacing x cultivar with respect to fresh leaf weight at both locations were not significant ($P > 0.05$).

3.9. Dry stem weight

Regarding dry stem weight, significant differences ($P < 0.05$) were observed with respect to planting method, plant spacing, and cultivar. About the planting method, the mound recorded a higher dry stem weight compared to when sowing was done on flat at both Lungi and Kabala. Generally, Kabala recorded a higher dry stem weight (6.09) compared to Lungi (2.18). The dry stem weight for Kabala was 64% higher than Lungi (Table 4).

Table 4 Effects of planting method, plant spacing, and Bambara ground cultivar on the number of stems, fresh stem weight, and dry stem weight in the two locations over two cropping seasons

Locations							
Treatments	**Lungi**			**Kabala**			**Mean**
	Growth Parameters			**Growth Parameters**			
	Number of stems	**Fresh stem weight**	**Dry stem weight**	**Number of stems**	**Fresh stem weight**	**Dry stem weight**	
Planting method							
Flat	5.93	4.87	1.79	6.70	18.13	5.98	7.23b
mound	6.03	7.96	2.57	7.25	18.54	6.19	8.09a
Mean	5.98b	6.42b	2.18b	6.98a	18.34a	6.09a	
Plant spacing							
50 cm x 10cm	5.95	6.26	1.88	6.44	15.04	4.96	6.76c
50cm x 15cm	5.88	5.83	2.11	7.11	19.64	6.52	7.85b
50cm x 20cm	6.11	7.16	2.55	7.38	20.33	6.77	8.38a
Mean	5.98b	6.42b	2.18b	6.98a	18.34a	6.08a	
Cultivar							
Lubam1	5.94	4.86	1.73	7.16	15.88	5.04	6.77b
Lubam 2	5.67	4.35	1.55	7.00	14.08	4.43	6.18c
Kabam 1	6.33	10.04	3.26	6.77	25.04	8.79	10.04a
Mean	5.98b	6.42b	2.18b	6.98a	18.33a	6.09a	

Mean in column with the same letter are not significantly different at $P > 0.05$ (SNK).

Concerning plant spacing, S3 (50 cm x 20 cm) registered a higher dry stem weight at both locations. At Lungi, S3 (50 cm x 20 cm) registered a higher dry stem weight (2.55) followed by S2 (50 cm x 15 cm) (2.11) and S1 (50 cm x 10 cm) (1.88). Similarly, at Kabala, S3 (50 cm x 20 cm) recorded a higher dry stem weight (6.77) followed by S2 (50 cm x 15 cm) (6.52) and S1 (50 cm x 10 cm) (4.96). Generally, Kabala registered a higher dry stem weight (6.08) compared to Lungi (2.18) (Table 4).

Pertaining to the cultivars, Kabam 1 recorded a higher dry stem weight at both locations. At Lungi, Kabam 1 recorded a higher dry stem weight (3.26) followed by Lubam 1 (1.73) and Lubam 2 (1.55). Similarly, at Kabala, Kabam1 recorded a higher dry stem weight (8.79) followed by Lubam 1 (5.04) and Lubam 2 (4.43). In general, Kabala registered a higher dry stem weight (6.09) compared to Lungi (2.18) (Table 4). Also, the three-way interactions among planting method x plant spacing x cultivar with respect to dry stem weight at both locations were not significant (P>0.05).

4. Discussion

The identification of an appropriate plant spacing, planting method, and suitable cultivar is essential for maximizing the growth parameters of any crop.

Significant differences were recorded concerning germination percentage, canopy width, and plant height relating to planting method with the mound recording the highest value for the assessed growth parameters in the two locations compared to when planting was done on flat land. This result concords with the findings of Valenciano et al.[10] and Neumann et al. [11] concerning the effect of planting method on the germination percentage of common beans and peas respectively. These authors reported that planting common beans on raised beds enhances fast emergence of the seeds. The possible reason for the above observation could be that planting on mound may provide a more conducive environment for seed germination compared to flat. In the case of canopy width, a higher value was recorded when planting was done on the mound compared to flat probably because the growth factors such as moisture, air, nutrients, and optimum temperature were efficiently utilized when planting was done on the mound compared to flat.

The reported higher plant height when planting was done on the mound compared to flat could be because mounds have loose soil, more aeration, and drainage that is less compacted, which are effective in enhancing seed emergence and inducing vigour for plant growth as reported by Bakht et al. [12]. Also, Chassot and Richner [13] opined that mounds have loose soil which may promote root penetration or growth of crops. Furthermore, Willis et al. [14] reported higher plant height when planting was done on mounds due to the deeper penetration of water and suppression of evaporation losses. Furthermore, Venkateshwarlu [15] showed that planting on mound results in uniform rainwater recharge of the profile and increased moisture for extended times. Mounds, therefore, appear to overcome drought effects due to dry spells during the rainy season.

Relating to the effect of plant spacing on percentage germination, canopy width, and plant height, significant differences were recorded with Kabala recording higher values for the three parameters. For percentage germination, the widest spacing S3 (50 cm x 20 cm) recorded the highest percentage germination. This result agrees with Tuarira and Moses [16] who reported a higher percentage of seed germination of fava beans when planted using wider inter and intra-row spacing. For plant height, the narrowest spacing S1 (50 cm x 10 cm) recorded a slightly higher value at both locations compared to the widest spacing. The higher plant height reported for the narrow spacing at both locations could be due to an increase in competition among plants in narrow spacing. This observation concords with the findings of Khalil et al. [17] and Singh et al. [18], who indicated that the denser plant population increased the plant height of the fava bean due to competition among plants for light thus, result in taller plants. On the contrary, higher plant height was recorded in Kabala for wider spacing probably because wider spacing reduces competition between plants for nutrients, light, and moisture which enhances growth. This result is in concordance with the findings of Khan et al. [19] who reported higher competition among plants in narrow plant spacing. Furthermore, Ibrahim [20]; Bodnar et al. [21], and Karaye and Yakubu [22] also reported a reduction in plant height at increased plant density probably due to competition for soil moisture and nutrients. In addition, Katona et al. [23] also reported an increase in height of onions with wider spacing.

In general, an increase in plant height with plant density is attributable to the density stimulated intra plant competition for available plant growth resources. In the case of canopy width, the widest spacing S3 (50 cm x 20 cm) recorded a higher value at Kabala whilst in Lungi, the narrowest spacing S1 (50cm x 10 cm) recorded the highest. The reported higher canopy width for the wider spacing conforms to the findings of Malamiand Samaila [24] who reported a higher canopy width in their work with cowpea by using the intra-row spacing of 50 cm x 75 cm. The reason for this is because of the reduced competition for sunlight and available nutrients. The result also agrees with the findings of Obidiebube et al. [25] and Ibrahim [26] who reported intense competition for light and nutrients by closely spaced crops compared to widely spaced crops.

Relating to the cultivar effect on germination percentage and plant height, Lubam 2 registered the highest value for the two parameters at both locations. One possible reason for this could be attributed to the genetic constitution of the cultivar. For canopy width, Kabam1 recorded the highest canopy width at both locations.

In general, the variability in response among cultivars in terms of emergence appears to indicate that seeds are inconsistent when it comes to germination quality, which is probably due to their health, physiological condition, and size.

Furthermore, the values of the assessed parameters were higher in Kabala compared to Lungi probably due to the variability in the soil and rainfall pattern.

Concerning the number of leaves, fresh leaf weight, and dry leaf weight, higher values were recorded for the mound at both locations compared to when planting was done on flat. These results concord with the findings of Kaur [27] and Parkash [28], who reported a significantly higher number of leaves of turmeric when planted on mounds compared to flat planting. The reason for these observations could be because the leaves of mound-planted crops remained photosynthetically active for a longer period compared to the leaves of flat-planted crops [29].

Concerning spacing, the number of leaves, fresh leaf weight, and dry leaf weight were higher for the wider spacing regime S3 (50 cm x 20 cm) compared to the narrow spacing regime S1 (50 cm x 10cm). This result is similar to the findings of Weerasinghe et al. [30]. These authors reported that increasing plant competition due to narrow spacing significantly decreases seedling leaf number, fresh leaf weight, and dry leaf weight. Furthermore, Mari et al. [31] and Rizk [32] also reported that lower planting density resulted in a higher number of leaves per plant. A similar trend was also reported by Singh and Sachan [33] who also associated a higher number of leaves with wider spacing. The reason for this observation could be because wider spacing allows space for vertical and horizontal expansion of leaves which leads to the production of a greater number of leaves per plant than close spacing. Moreover, wider plant spacing enables the plant to intercept more photosynthetically active radiation owing to a better geometric situation that might result in vigorous plant growth and a greater number of leaves.

For cultivars, Kabam 1 recorded the highest value at both locations concerning the number of leaves, fresh leaf weight, and dry leaf weight. The reason could be because of the genetic characteristic of the cultivars.

Relating to the number of stems, fresh stem weight, and dry stem weight, significant differences were recorded for planting method, spacing, and cultivar. For the planting method, the mound recorded a higher value at both Lungi and Kabala compared to flat planting. The reason for this observation could be because the stems of mound-planted crops remained photosynthetically active for a longer period compared to the stems of flat-planted crops [29].

Concerning spacing, the wider spacing S3 (50 cm x 20 cm) was observed to have recorded higher values of the number of the stem, fresh stem weight, and dry stem weight at both Lungi and Kabala. The production of more stems, at wider spacing, could be attributed to low competition among plants for growth factors, which effectively increases the number of stems. Moreover, wider plant spacing allows the plant to intercept more radiation as a result of the better geometric situation that might result in vigorous plant growth and hence a greater number of stems. The result is in line with Mekkei [34] who reported that the number of stems per plant could be increased by increasing inter and intra-row spacing of plants.

5. Conclusion

The result shows that the values of the majority of the growth parameters were higher in both locations when planting was done on the mound except for plant height and dry leaf weight. For these parameters, higher values were recorded for the mound at Lungi whilst Kabala recorded higher values when planting was done on flat. Concerning plant spacing, higher values were recorded at both Lungi and Kabala when the wider spacing regime was used. In the case of cultivars, Kabam 1 on average recorded higher values at both locations. In general, the values of all growth parameters were higher in Kabala compared to Lungi.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that they have no conflict of interest.

References

[1] Ntundu WH., Shillah SA., Marandu W Y F, Christiansen JL. 2006. Morphological diversity of 418Bambara groundnut (Vignasubterranea (L.) Verdc.) landraces in Tanzania. Genetic resources and crop evolution. 2006; 53:367-378.

[2] Swanevelder CJ. Bambara-food for Africa: Bambara groundnut. National Department of Agriculture, South Africa. 1998; 12 .

[3] Mkandawire FL, Sibuga K.P.Yield response of Bambara groundnut to plant population and seedbed type. African Crop Science Journal. 2002; 10: 39-49.

[4] Egbe OM, Bar-Nyam AN. Pigeon pea-sorghum intercropping in Southern Guinea 425Savanna effects of planting density of pigeon pea. Nature and Science. 2010; 8:156- 167.

[5] KannaiyanJ. Review of research work on minor legumes. Msekara Regional Research Station, Chipata; 1988.

[6] Linnemann A R. Bambara groundnut literature: a revised and updated bibliography. 430Tropical Crops Communication 17. Wageningen Agricultural University, The Netherlands, 1992;123

[7] Tanzania Ministry of Agriculture, Ukiriguru research station annual report. 1970; 115.

[8] Unkovich M, Herridge D, Peoples M, Cadisch G, BoddeyB,Giller K, Alves B, Chalk P. Measuring Plant-Associated Nitrogen Fixation in Agricultural Systems. Australian Center for International Agricultural Research, ACIAR, Australian Government: Canberra, Australia, 2008.

[9] SAS Institute Inc. The SAS system for windows. Release 9.4 Cary (NC): SAS Institute; 2014.

[10] Valenciano JB, Casquero PA, Boto JA, Guerra M. Effect of sowing techniques and pesticide application on dry bean yield and harvest components. Field Crops 441Research. 2006; 96: 2-12.

[11] Neumann A, Wchmidtke K, Rauber R. Effects of crop density and tillage system on grain yield and N uptake from soil and atmosphere of sole and intercropped pea and oat. Field Crops Research. 2007; 100: 285-293.

[12] Bakht JM, Shafi H, Rehman R, Uddin J, Anwar S. Effect of planting methods on 446growth, phenology, and yield of maize varieties. Pakistan Journal of Botany. 2011; 43:1629-1633.

[13] Chassot A, Richner W.Root characteristics and phosphorus uptake of maize seedlings in a bi-layered soil. Agronomy Journal. 2002; 94:118-127.

[14] Wills WO, Haas HJ, Robins JS. Moisture conservation by surface. Soil Science Society of AmericaJournal. 1963; 27: 577-580.

[15] Venkateswarlu, J. Efficient resource management systems for drylands of India. In: Stewart, B.A. (Eds). Advances in Soil Science. 1987; 7: 165-227.

[16] Tuarira M, Moses M. 2014.Effects of plant density and planting arrangement in green bean seed production. Journal of Global Innovations in Agricultural and 456Social Sciences. 2014;2: 152-157.

[17] KhalilSK, Wahab A, Rehman A, Muhammad F, Wahab S, Khan AZ, Zubair M, 458Shah MK, Khalil I, Amin R. Density and planting date influence phenological development assimilate partitioning and dry matter production of faba bean. Pakistan Journal of Botany. 2010; 42: 3831-3838.

[18] Singh AK, Bhatt BP, Sundaram PK, Gupta AK, Singh D. 2013. Planting geometry to optimize growth and productivity in faba bean (Viciafaba L.) and soil fertility. 463Journal of Environmental Biology. 2013; 34: 117.

[19] Khan H, Iqbal M, Ghaffoor A, Waseem K.Effect of various plant spacing and 465different Nitrogen levels on the growth and yield of onion. Online Journal of 466Biological Sciences. 2002;2:545-547.

[20] Ibrahim A I.Effect of grass mulch and plant spacing on growth and yield of garlic (Allium sativum L). B.Sc. project. Department of Agronomy, ABU Zaria; 1994

[21] Bodnar JL, Schumacher B, Uyenaka S.Garlic production in Ontario Omafra 469Factsheet, Canada. 1998; p. 8

[22] Karaye AK,Yakubu AI. Influence of intra-row spacing and mulching on weed 471growth and bulb yield of garlic (Allium sativum L.) in Sokoto, Nigeria. African 472Journal of Biotechnology. 2006; 5: 260-264.

[23] Kantona RL, Abbeyb RG, Hillac MA, Tabil ND. Density affects plant development and yield of bulb onion (Allium cepa L.) in Northern Ghana. Journal of Vegetable 475Crop Production. 2003; 8:15-25.

[24] MalamiB S, Samaila M. Effects of inter and intra row spacing on growth characteristics and fodder yield of cowpea (Vignaunguiculata (L) walp.Var. kanamado) in semi-arid north-western Nigeria. Nigerian Journal of Basic and Applied Sciences. 2012; 20: 125-129.

[25] Obidiebube EA, Eruotor PG, Akparaobi SO, Achebe UA. Effects of spacings on the growth and yield of Bambara groundnut (Vignasubterranea (l) verdc.) in rainforest zone of Delta State. Global Journal of Agricultural Research. 2019; 7:9-13.

[26] Ibrahim SE. Agronomic studies on irrigated soybeans in Central Sudan: Effect of 484sowing date on grain yield and yield components. International Journal of Agricultural Science. 2012; 2: 766-773.

[27] Kaur S. Effect of spacing and farmyard manure levels on growth and yield of flat and ridge planted turmeric (Curcuma longa L.). MSc Thesis, Punjab Agricultural University, Ludhiana; 2001.

[28] Parkash O. Effect of planting methods and plant population on growth, yield and quality of turmeric (Curcuma longa L.) MSc Thesis. Punjab Agricultural University, Ludhiana-141004; 2014.

[29] Bhimjibhai AR. Effect of land configuration and soil conditioners on growth and yield of turmeric (Curcuma lugoma L.). Doctor of Philosophy (Agriculture) Navsari Agricultural University, Navsari-396450, Gujarat State, India; 2011.

[30] Weerasinghe SS, Fordhan R, Babik I,RumpelJ. The effect of plant density on onion established from multi-seeded transplants. 7thint'l.Symp.on timing field 497production of vegetables, Skiemicwice, Poland. ActaHorticulturae. 1994; 371: 97- 104.

[31] Mari JA, Mondal L, Fuentes P, Cristo M, Martinez J, Donate M. Effect of transplanting density of the cultivar Yellow Granex Hybrid on yield and bulb size. 501Centro-Agricola. 1997; 24: 50-55.

[32] Rizk FA. Productivity of onion plant (Allium cepa L.) as affected by method of 503planting and NPK application. Egyptian Journal of Horticulture. 1977; 24: 219- 228.

[33] Singh SR, Sachan BP. Evaluation of different bulb size, spacing and varieties for higher seed yield and yield attributing traits on onion (Allium cepa L.).Crops ResearchHisar. 1999; 17: 351-355

[34] Mekkei ME. 2014. Effect of intra-row spacing and seed size on yield and seed quality of faba bean (Viciafaba L.). International Journal of Agriculture and Crop Sciences 2014; 7: 665 -670