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Determine the appropriate planting method and spacing that improve the quantitative agro-morphological traits of three Bambara groundnut landraces

John Mod Bendu[1], Augustine Mansaray[2], Alieu Mohamed Bah[3], Edwin Julius Jeblar Momoh[4]

[1]*(Department of Agriculture and Food Security, EBKUST, MUC, Sierra Leone)*
[2]*(Crops and Natural Resources, Njala Agricultural Research Center, Sierra Leone)*
[3] *(Crop Science, School of Agriculture and Food Sciences, Njala University, Sierra Leone)*
[4]*(Department of Agriculture and Food Security, EBKUST, MUC, Sierra Leone)*

***For Correspondence**

Alieu Mohamed Bah
Crop Science, Njala University, School of Agriculture and Food Sciences, Sierra Leone

abah@njala.edu.sl

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Abstract: *Agro-morphological characterization is the first step for the assessment of genetic variability and the identification of desirable traits of interest in crops. A study was conducted to determine an appropriate planting method and suitable spacing for the improvement of the agro-morphological attributes of three Bambara groundnut cultivars in two agro-climatic zones of Sierra Leone. The treatments consisted of two planting methods, three inter-row spacing, and three Bambara groundnut cultivars.*

The results show that all the agro-morphological traits were not significant with respect to planting methods and spacing at the two locations. For the planting method, the values of these agro-morphological traits were generally higher at Lungi when planting was done on a mound whilst values of these traits were higher when planting was done on a flat in Kabala. The results further show that higher agro-morphological traits were recorded for the narrowest inter-row spacing (50 cm x 10cm) in Lungi contrary to the widest inter-row spacing (50cm x 20cm) in Kabala. In addition, the results show that grain yield and biomass were strongly and positively correlated with the agro-morphological parameters.

I. Introduction

Bambara groundnut (*Vigna subterranea* (L.) Verdc.) is a grain legume belonging to the family papillionaceae and originates from Africa precisely from northeastern Nigeria and northern Cameroon [1]. It is an important grain legume that is mainly grown by subsistence farmers in sub-Saharan Africa in a wide range of agroecological zones [2]. It is the third most important legume crop after cowpea and groundnut [3, 4] and is widely consumed in Southern Africa. The crop has been cultivated in the tropical regions of sub-Saharan Africa and Madagascar for many centuries [5]. In West Africa, Bambara groundnut is mainly cultivated by women, together with maize, millet, or groundnut [6, 7].

The crop is grown for its edible seeds [8, 2, 9] and has been described as a completely balanced diet due to the high carbohydrate (65%) and protein (18%) content of its seeds [10]. The flour obtained from its seeds could provide a viable substitute for conventional flours in the composition of various manufactured products [11]. The immature seeds of Bambara can be boiled or grilled before being eaten, while the mature seeds can be roasted in oil or ground into flour and then mixed with oil or butter to form porridge. The crop can be used in medicine for disease treatment [12] and has high antioxidant activity [13].

Bambara groundnut is used, traditionally, to cure nausea, especially in pregnant women by chewing and swallowing the raw bean [14].

Bambara groundnut is drought tolerant, readily adaptable to different environmental conditions, and possesses the ability to be intercropped making it an important economic crop in many developing countries [15]. This legume has a symbiotic relationship with bacteria (rhizobia) that form root nodules.

In Africa, Bambara groundnut is confined to the dry regions between the desert and the savanna (southern fringe of the Sahara) and adapted to growing in areas of relatively higher temperatures for many leguminous crops [16]. It is not attacked by diseases and pests in any of its production regions. However, in damp conditions, it may be susceptible to various fungal diseases [17]. It has a very low insect pest and disease susceptibility [18].

Agricultural policy, in developing countries, focuses, to a large extent, on cash crops. This choice has not significantly improved the population's food situation. However, it has encouraged growers to abandon many local crops, which have declined as a result. Because of their nutritional quality, these crops have played a major role in providing a balanced diet for an ever-increasing human population, but have been under-exploited. Their yields have therefore remained low and unstable [19]. Despite the increasing number of scientific reports on Bambara groundnut in Africa [20, 21, and 22] very little bibliographical data is currently available on the distribution, genetic diversity, cultivation method, and uses of this plant in Sierra Leone. Also, despite its great potential, there are not many studies on Bambara groundnut [23]. Moreover, Research has paid little attention to this neglected and underutilized crop species. Thus, there is a need to develop improved varieties for particular agro-ecological conditions or production systems.

Previous studies undertaken were focused essentially on the farming system, notably on the effect of mounding time and the influence of mineral and organic fertilizers on yield [24] but few works by Ouedraogo et al. [10] were interested in the agro-morphological variability description. Agro-morphological characterization is the first step for the assessment of genetic variability and the identification of desirable traits of interest [25]. For many species, this approach remains the most frequently used [26]. In addition, knowledge of genetic resources conservation and utilization process is essential for the establishment of future breeding programs [23].

Several researchers have used various morphological traits to characterize Bambara groundnut accessions [27]. Goli et al. [7] characterized and evaluated a collection of Bambara groundnuts at the International Institute of Tropical Agriculture. The variability between local and exotic Bambara groundnut landraces in Botswana was reported by Karikari [28]). Jonah et al. [29] evaluated seasonal variation and the correlation among yield and yield components in Bambara groundnut accessions in Nigeria. Furthermore, another study, in Nigeria, used multivariate analysis and character association for growth and yield of Bambara groundnut [30]. Shegro et al. [25], also, reported morphological variation in Bambara groundnut in South Africa. However, there are a large number of landraces that are planted in Sub-Saharan Africa and it is important to further assess the variation in this germplasm for use in the breeding program. The research was therefore conducted to determine the planting method and suitable spacing for the improvement of the agro-morphological attributes of three Bambara groundnut cultivars in two agro-climatic zones of Sierra Leone.

II. Materials 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 plains with 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 highlands 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 the locations of the trial areas are shown in table 1 and figure 1 respectively.

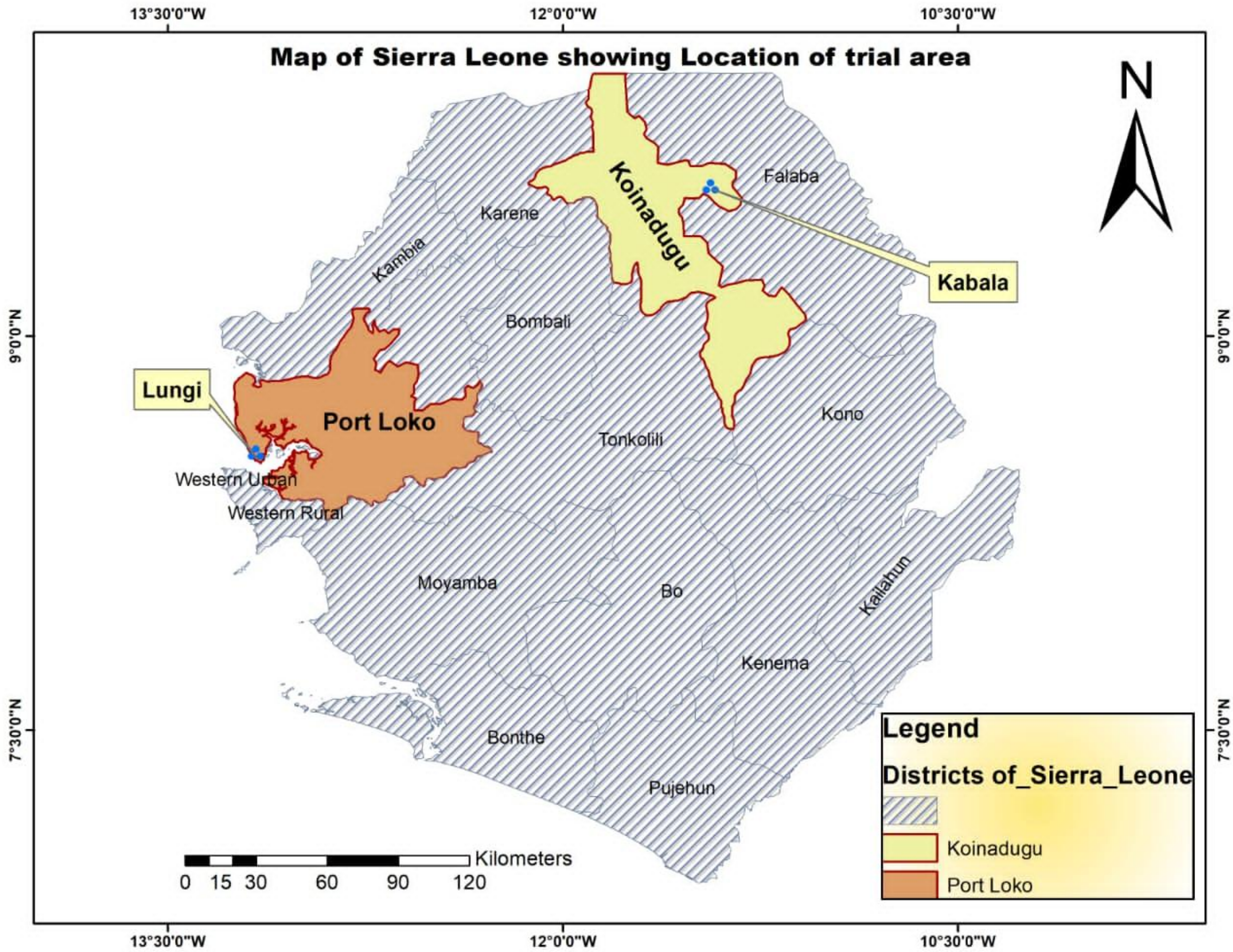

Figure 1 Map of Sierra Leone showing trial locations

2.2 Soil collection and analysis

Soil samples from the two experimental sites were collected at 0~30cm depth using 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 Njala University Quality Control Laboratory (NUQCL), Njala, Sierra Leone. The Kjedhal distillation method was used to determine the total nitrogen content [31]. 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 by the hydrometer method. The results of soil analyses are presented in table 1.

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 cutlass, burnt down, de-stumped, and dug using a hoe and plots laid out using a measuring tape, garden line and pegs.

2.4 Experiment design, treatments and planting

The experiment was a factorial 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 local farmers at the two zones and seeds were sown in June of each cropping season at the rate of one seed per hill at a depth of 3cm. Weeding was done at two weeks intervals till harvest. Harvesting was done at the respective maturity dates of the three Bambara varieties.

2.5 Data collection

The important agro-morphological parameters collected included seed length, seed width, pod length, pod width, and seed size. These parameters were determined after the harvest of each cultivar.

Seed length, seed width, pod length, and pod width were determined from five randomly selected seeds using vernier calipers.

2.6 Data analysis

The data collected were subjected to analysis of variance (ANOVA) and means were separated using the Student Newman-Keuls Test (SNK) at a 0.05 level of significance. Also, a simple correlation coefficient was calculated using the Pearson correlation coefficient to determine the relationships among some of the agro-morphological variables.

III. Results

3.1 Seed length

For seed length, significant differences (P > 0.05) were not observed concerning planting methods, plant spacing, and cultivars at both locations (Table 2). For the planting method, at Lungi, the mound registered a higher seed length (1.52) compared to flat (1.48), even though no significant differences (P>0.05) were recorded. At Kabala, the mound scored a higher seed length (1.50) compared to when planting was done on a flat (1.49) (Table 2).

With regards to plant spacing, at Lungi, S1 (50 cm x 10 cm) registered a higher seed length (1.55) followed by S2 (50 cm x 15 cm) (1.51) and S3 (50 cm x 20 cm) (1.46). Conversely, for Kabala, S3 (50 cm x 20 cm) recorded a higher seed length (1.51) followed by S1 (50 cm x 10 cm) (1.50) and S2 (50 cm x 15 cm) (1.48) (Table 2).

About cultivars, Kabam 1 registered a higher seed length (1.55) at Lungi, followed by Lubam 2 (1.50), and Lubam 1 (1.47). On the other hand, for Kabala, Lubam 2 recorded a higher seed length (1.53) followed by Lubam 1 (1.49), and Kabam 1 (1.47) (Table 2). In general, Lungi recorded a slightly higher seed length (1.51) compared to Kabala (1.50). The seed length for Lungi was 0.66% higher than Kabala (Table 2). Furthermore, the three-way interactions among planting method x plant spacing x cultivar concerning seed length at both locations were not significant (P>0.05).

3.2 Seed width

Similarly, as with seed length, there were no significant differences (P>0.05) concerning planting method, plant spacing, and cultivar at both locations (Table 2). For the planting method, at Lungi, the mound recorded a higher seed width (0.53) compared to flat (0.51). On the other hand, at Kabala, the flat scored a higher seed width (0.73) compared to when sowing was done on the mound (0.65) (Table 2).

Concerning plant spacing, at Lungi, S1 (50 cm x 10 cm) registered a higher seed width (0.54) followed by S2 (50 cm x 15 cm) (0.52) and S3 (50 cm x 20 cm) (0.50). Similarly, at Kabala, S1 (50 cm x 10 cm) recorded a higher seed width (0.73) followed by S2 (50 cm x 15 cm) (0.68) and S3 (50 cm x 20 cm) (0.66) (Table 2)

About cultivars, Kabam 1 registered a higher seed width (0.68), at Lungi, followed by Lubam 2, (0.44) and Lubam 1(0.44). Also, for Kabala, Kabam 1 recorded a higher seed width (0.88) followed by Lubam 1 (0.61), and Lubam 2 (0.59). In general, Kabala recorded a slightly higher seed width (0.69) compared to Lungi (0.52). The seed width for Kabala was 25% higher than Lungi (Table 2). Also, the three-way interactions among planting method x plant spacing x cultivar concerning seed width at both locations were not significant (P > 0.05).

3.3 Seed size

For seed size, significant differences (P > 0.05) were not registered relative to planting method and plant spacing at both locations. However, significant differences (P < 0.05) were observed about cultivars at both locations (Table 2). For the planting method at Lungi, the mound registered a higher seed size (2.41) compared to when sowing was done on a flat (2.25). Conversely, for Kabala, the flat recorded a higher seed size (3.22) compared to the mound (3.16). Generally, Kabala registered a higher seed size (3.19) compared to Lungi (2.33). The seed size for Kabala was 27% higher than Lungi.

For plant spacing, at Lungi, S3 (50cm x 20 cm) recorded higher seed size (2.48) followed by S2 (50 cm x 15 cm) (2.35) and S1 (50 cm x 10 cm) (2,15). In the case of Kabala, S2 (50 cm x 15 cm) recorded the highest seed size (3.30) followed by S3 (50 cm x 20 cm) (3.16) and S1 (50 cm x 10 cm) (3.10). On average, Kabala recorded a higher seed size (3.19) compared to Lungi (2.33) (Table 2).

Concerning cultivars, at Lungi, Lubam 2 registered a higher seed size (2.70) followed by Lubam 1 (2.53) and Kabam 1 (1.75). On the other hand, for Kabala, Lubam 1 scored a higher seed size (3.69) followed by Lubam 2 (3.62) and Kabam 1 (2.26). In general, Kabala recorded a higher seed size (3.19) compared to Lungi (2.33) (Table 2). The three-way interactions among planting method x plant spacing x cultivar concerning seed size at both locations were not significant (P > 0.05).

Table 2 Effect of planting method, plant spacing, and Bambara cultivar on seed length, seed width, and seed size with respect to location over two years cropping season

Treatments	Locations: Lungi			Kabala			Mean
	Agro-morphological parameter			**Agro-morphological parameter**			
	Seed length	Seed width	Seed size	Seed length	Seed width	Seed size	
Planting method							
Flat	1.48	0.51	2.25	1.49	0.73	3.22	**1.61 a**
mound	1.52	0.53	2.41	1.50	0.65	3.16	**1.63a**
Mean	**1.50a**	**0.52b**	**2.33 b**	**1.50a**	**0.69a**	**3.19 a**	
Plant spacing							
50 cm x 10cm	1.55	0.54	2.15	1.50	0.73	3.10	**1.60a**
50cm x 15cm	1.51	0.52	2.35	1.48	0.68	3.30	**1.64a**
50cm x 20cm	1.46	0.50	2.48	1.51	0.66	3.16	**1.63a**
Mean	**1.51a**	**0.52b**	**2.33 b**	**1.50a**	**0.69a**	**3.19 a**	
Cultivar							
Lubam1	1.47	0.44	2.53	1.49	0.61	3.69	**1.71a**
Lubam 2	1.50	0.44	2.70	1.53	0.59	3.62	**1.73a**
Kabam 1	1.55	0.68	1.75	1.47	0.88	2.26	**1.43b**
Mean	**1.51a**	**0.52b**	**2.33 b**	**1.50b**	**0.69a**	**3.19 a**	

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

3.4 Pod length

Similarly, there were no significant differences (P> 0.05) in pod length concerning planting method, plant spacing, and cultivar at both locations (Table 3). For the planting method, although there were no significant differences (P>0.05) at both locations, the mound recorded a slightly higher value at Lungi whereas the flat recorded a slightly higher value at Kabala (Table 3). Concerning location, Lungi recorded a higher value (1.71) compared to Kabala (1.63). The pod length for Lungi was 5% higher than Kabala.

About plant spacing, S1 (50 cm x 10 cm) recorded a higher pod length (1.74), at Lungi, followed by S2 (50 cm x 15 cm) (1.72) and S3 (50 cm x 20 cm) (1.67). At Kabala, conversely, S3 (50 cm x 20 cm) registered a higher pod length (1.68) followed by S1 (50 cm x 10 cm) (1.62) and S2 (50 cm x 15 cm) (1.60). On average, pod length was higher in Lungi (1.71) compared to Kabala (1.63) (Table 3).

With regards to cultivar, Kabam 1 recorded higher pod length at both locations. At Lungi, Kabam 1 registered a higher pod length (1.85) followed by Lubam 1 (1.65) and Lubam 2 (1.63). At Kabala, Kabam 1, also scored a higher pod length (1.74) followed by Lubam 2 (1.58) and Lubam 1 (1.57) (Table 3). Furthermore, the three-way interactions among planting methods, plant spacing, and cultivar concerning pod length at both locations were not significant (P >0.05).

3.5 Pod width

Concerning pod width, no significant differences (P>0.05) were observed relative to planting method and plant spacing at both locations. However, significant differences (P<0.05) were recorded about cultivars for Lungi only (Table 3). For the planting method, even though no significant differences (P>0.05) were recorded, the mound registered a higher pod width at both locations. At Lungi, the mound recorded a higher pod width (1.08) compared to when sowing was done on flat (1.07) whilst at Kabala it also registered a higher pod width value (1.41) compared to flat (1.38) (Table 3).

Concerning plant spacing, although no significant differences (P>0.05) were recorded at Lungi, S1 (50 cm x 10 cm) scored a higher pod width (1.10) followed by S2 (50 cm x 15 cm) (1.07) and S3 (50 cm x 20 cm) (1.04). At Kabala, both S1 (50 cm x 10 cm) and S2 (50 cm x 15 cm) registered a similar higher pod width (1.40) compared to S3 (50 cm x 20 cm) (1.39). In general, Kabala registered a higher pod width value (1.40) compared to Lungi (1.07). The pod width for Kabala was 24% higher than Lungi (Table 3)

Concerning cultivars, at Lungi, Kabam 1 registered a higher pod width (1.42) followed by Lubam 1 (0.91) and Lubam 2 (0.89). At Kabala, also, Kabam 1 recorded a higher pod width (1.46) followed by Lubam 1(1.40) and Lubam 2 (1.32). Generally, Kabala scored a higher pod width (1.39) compared to Lungi (1.07) (Table 3). In addition, the three-way interactions among planting methods x plant spacing x cultivar concerning pod width at both locations were not significant.

Table 3 Effect of planting method, plant spacing, and Bambara cultivar on pod length and pod width with respect to location over two years cropping season

Treatments	Locations				Mean
	Lungi		**Kabala**		
	Agro-morphological parameter		**Agro-morphological parameter**		
	Pod length	Pod width	Pod length	Pod width	
Planting method					
Flat	1.69	1.07	1.67	1.38	**1.45a**
mound	1.73	1.08	1.59	1.41	**1.45 a**
Mean	**1.71 a**	**1.08b**	**1.63 a**	**1.40a**	
Plant spacing					
50 cm x 10cm	1.74	1.10	1.62	1.40	**1.47a**
50cm x 15cm	1.72	1.07	1.60	1.40	**1.45 a**
50cm x 20cm	1.67	1.04	1.68	1.39	**1.45 a**
Mean	**1.71a**	**1.07b**	**1.63a**	**1.40a**	
Cultivar					
Lubam1	1.65	0.91	1.57	1.40	**1.38 b**
Lubam 2	1.63	0.89	1.58	1.32	**1.36 b**
Kabam 1	1.85	1.42	1.74	1.46	**1.62 a**
Mean	**1.71a**	**1.07b**	**1.63 a**	**1.39a**	

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

3.6 Correlation matrix among Agro-morphological variables

There were lots of significant correlations among the agro-morphological traits (Table 4). The correlation matrix showed that grain yield had a very strong, positive correlation with number of pods (r= 0.99, P =0.02) and seed size (r= 0.97, P= 0.13). Biomass was positively correlated with 100 seed weight (r=0.99 p = 0.02), canopy width (r= 0.88, p= 0.31), plant height (r = 0.91, P = 0.25), number of stems (r= 0.74, P 0.46), seed length (r = 0.99, P = 0.05), seed width (r = 0.85, P 0.35), pod length (r= 0.96, P = 0.16) and pod width (r = 0.76, P = 0.44). Furthermore, 100 seed weight correlates positively with biomass yield (r= 0.99, P = 0.02), canopy width (r – 0.89, P = 0.28), plant height (r=0.93, P 0.25), number of leaves (r = 0.84, P 0.30), number of stem (r = 0.77, R = 0.43), seed length (r = 0.99, P 0.03), seed width (r= 0.83, P = 0.37), pod length (r = 0.95, p = 0.18) and pod width (r=074, P = 46). Seed length correlates positively with biomass yield (r=0.99. P = 0.05), 100 seed weight (r = 0.99, P = 0.03), canopy width (0.92. P = 0.25), plant height (r = 0.94, P = 0.20), number leaves (r= 0.81, P = 0.39), number of stem (r= 0.80, P 0.40), seed width (0.80, r = 0.40), pod length (r = 0.94, r = 0.21) and pod width (r =0.70, P= 0.49). Seed width correlates positively with biomass yield (r = 0.85, P = 0.35), 100 seed weight (r = 0.83, P = 0.37), canopy width (r = 0.50, P = 0.66), plant height (R = 0.57, P= 0.60), number of leaves (r = 0.99, P= 0.01), seed length (r = 0.80, P = 0.40), pod length (r=0.95, P =0.18), and pod width (r = 0.98, P 0.09). Pod length correlates positively with biomass yield (r = 0.96, P = 0.16), 100 seed weight (r =0.95, P 0.18), canopy width (r= 0.73, P =0.47), plant height (r 0.78, P = 0.42), number of leaves (r= 0.96, P = 0.17), number of stem (r= 0.55, P =0.62), seed length (r= 0.94, P = 0.21), seed width (r= 0.95, P =0.18), and pod width (r=0.90, P= 0.28). In addition, pod width was positively correlated with biomass yield (r = 0.76, P= 0.44), 100 seed weight (r= 0.74, P = 0.46), number of leaves (r = 0.98, P 0.10), seed width (r = 0.98, P = 0.09) and pod length (r =0.90, P = 0.28).

Table 4 Correlation matrix among some agro-morphological traits

Pearson Correlation Coefficients, N = 3
Prob> |r| under H0: Rho=0

Agro-morphological Characteristics

	YD	BY	100SW	NP	CW	PH	NL	NS	SL	SWT	PL	PW	SS
YD	1.00	-0.65	-0.62	0.99	-0.22	-0.30	-0.94	0.01	-0.58	-0.95	-0.82	-0.98	0.97
		0.54	0.56	0.02	0.85	0.80	0.20	0.99	0.60	0.19	0.38	0.10	0.13
BY	-0.65	1.00	0.99	-0.62	0.88	0.91	0.86	0.74	0.99	0.85	0.96	0.76	-0.79
	0.54		0.02	0.57	0.31	0.25	0.33	0.46	0.05	0.35	0.16	0.44	0.41
100SW	-0.62	0.99	1.00	-0.59	0.89	0.93	0.84	0.77	0.99	0.83	0.95	0.74	-0.77
	0.56	0.02		0.59	0.28	0.23	0.36	0.43	0.03	0.37	0.18	0.46	0.43
NP	0.99	-0.62	-0.59	1.00	-0.18	-0.26	-0.93	0.05	-0.55	-0.94	-0.80	-0.98	0.91
	0.02	0.57	0.59		0.88	0.82	0.23	0.96	0.62	0.22	0.40	0.12	0.15
CW	-0.22	0.88	0.89	-0.18	1.00	0.99	0.52	0.97	0.92	0.50	0.73	0.37	-0.41
	0.85	0.31	0.28	0.88		0.05	0.64	0.15	0.25	0.66	0.47	0.75	0.72

Pearson Correlation Coefficients, N = 3
Prob> |r| under H0: Rho=0

Agro-morphological Characteristics

	YD	BY	100SW	NP	CW	PH	NL	NS	SL	SWT	PL	PW	SS
PH	-0.30	0.91	0.93	-0.26	0.99	1.00	0.59	0.94	0.94	0.57	0.78	0.44	-0.48
	0.80	0.25	0.23	0.82	0.05		0.59	0.20	0.20	0.60	0.42	0.70	0.67
NL	-0.92	0.86	0.84	-0.93	0.52	0.59	1.00	0.30	0.81	0.94	0.96	0.98	-0.99
	0.20	0.33	0.36	0.23	0.64	0.59		0.79	0.39	0.01	0.17	0.10	0.07
NS	0.01	0.74	0.77	0.05	0.97	0.94	0.30	1.00	0.80	0.29	0.55	0.14	-0.19
	0.99	0.46	0.43	0.96	0.15	0.20	0.79		0.40	0.81	0.62	0.90	0.87
SL	-0.58	0.99	0.99	-0.55	0.92	0.94	0.81	0.80	1.00	0.80	0.94	0.70	-0.73
	0.60	0.05	0.03	0.62	0.25	0.20	0.39	0.40		0.40	0.21	0.49	0.47
SWT	-0.95	0.85	0.83	-0.94	0.50	0.576	0.99	0.291	0.80	1.00	0.95	0.98	-0.99
	0.19	0.35	0.37	0.22	0.66	0.60	0.01	0.81	0.40		0.18	0.09	0.06
PL	-0.82	0.96	0.95	-0.80	0.73	0.78	0.96	0.55	0.94	0.95	1.00	0.90	-0.92
	0.38	0.16	0.18	0.40	0.47	0.42	0.17	0.62	0.21	0.18		0.28	0.25
PW	-0.98	0.76	0.74	-0.98	0.37	0.44	0.98	0.14	0.70	0.98	0.90	1.00	-0.99
	0.10	0.44	0.46	0.12	0.75	0.70	0.10	0.90	0.49	0.09	0.28		0.02
SS	0.97	-0.79	-0.77	0.97	-0.41	-0.48	-0.99	-0.19	-0.73	-0.99	-0.92	-0.99	1.00
	0.13	0.41	0.43	0.15	0.72	0.67	0.07	0.87	0.47	0.06	0.25	0.02	

IV. Discussion

The identification of an appropriate planting method and a suitable inter-row spacing is an important criterion that could improve the agro-morphological attributes of Bambara groundnut cultivars.

From the result, no significant differences were recorded for seed length, seed width, and pod length concerning planting methods, inter-row spacing, and cultivar in both Lungi and Kabala. The above observation contradicts the findings of Gezahegn and Tesfaye [32] concerning pod width. These authors reported significant differences in pod width concerning inter-row spacing for faba bean. The non-significant differences observed concerning both seed length and seed width could probably be because of the similarity in the shape of the seeds. For seed size, and pod width also, there were no significant differences concerning both planting method and inter-row spacing; however, significant differences were recorded regarding cultivar. This could have been due to genetic variability among the cultivars assessed. These variations in the crop's yield components with cultivar differences imply that there is variability among the Bambara groundnut accessions in terms of their yield potential, which corroborates with the findings [33]. Values for seed size, seed width, and pod width were higher in Kabala than in Lungi. On the contrary, seed length and pod length were higher in Lungi than in Kabala.

Seed yield being a polygenic trait is greatly influenced by its component characters. Therefore, direct crop selection based on yield could be misleading. Studies on the character-association are of great importance for the improvement of Bambara groundnut. The estimates of coefficients of correlation are important for a better understanding of the relationship between yield components and their relative contributions to yield. The correlation coefficient is an essential parameter in plant breeding since it measures the degree of genetic or non-genetic association between two or more characters [30]. In this study, the correlation coefficients between Bambara groundnut yields and some yield components (number of pods and seed size) were positively correlated which implies that the higher the number of pods and seed size the higher the yield. These results are in agreement with those obtained by Ouedraogo et al. [10]. These are the characteristics that contribute to Bambara groundnut seed yield, hence crucial for yield improvement. Bambara groundnut farmers would prefer high-yielding varieties to secure food. The positive correlation between seed length and seed width will also be crucial for farmers as they will prefer seeds with big sizes. Therefore, these two parameters are important for size improvement. This result is in concordance with the study of Valombola et al. [34].

From this study, important traits for yield improvement are seed parameters such as seed length, seed width, pod length, pod width, and a hundred seed weight. Environmental variations also indicate the role of the environment on yield and yield-related traits. A better understanding of the relationship between the yield-related components will provide an appropriate way of improving the yield of crops. Correlation among different components indicates the complementary functional influence of these traits on grain yield and their adaptability to different location

V. Conclusion

The agro-morphological parameters (Pod width and seed length) were significantly higher when planting was done on the mound at both locations. Similarly, Pod length, seed size, and seed width were higher when planting was done on a mound at Lungi. However, the value of these parameters (pod length, seed size, and seed width) was higher when planting was done on a flat at Kabala. About inter-row spacing, higher values for the agro-morphological parameters were recorded with the narrow inter-row spacing (50cm x 10cm) at Lungi. On the contrary, at Kabala, higher agro-morphological parameters were recorded using the wider inter-row spacing (50cm x 20cm). Furthermore, there was a strong and positive correlation between Bambara groundnut yields and some agro-morphological characters (number of pods and seed size)

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