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EVALUATION OF AGRONOMIC CHARACTERS OF SOYBEAN VARIETIES AND BAMBARA GROUNDNUT LANDRACES CULTIVATED ON DIFFERENT SOILS OF LAKE VICTORIA BASIN

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How to cite:

Ogolla O. Fredrick and Onyango O. Benson (2021). Evaluation of agronomic characters of soybean varieties and Bambara groundnut landraces cultivated on different soils of lake victoria basin *In: Isutsa, D.K. (Ed.) Proceedings of the 7th International Research Conference held in Chuka University from 3rd to 4th December 2020, Chuka, Kenya, p.146-152*

ABSTRACT

Neglect and under-utilization of legumes such as soybeans and bambara groundnuts are the reason for increased food insufficiency in the Lake Victoria basin. Diversification of legumes into the cropping systems of Lake Victoria basin ensures protein rich diets and improved soil fertility. This study was carried out to evaluate agronomic characters of two soybean varieties and two bambara groundnut landraces cultivated on different soils of Lake Victoria basin. Seeds of two bambara groundnut landraces; Kakamega Cream (KAKC) and Busia Brown (BUSB) were collected from farmers in Kakamega and Busia counties, respectively in Kenya. Soil sampling was done at selected farmers' fields with no history of inoculation in Kisumu, Port Victoria, Kendu bay and Karungu within Lake Victoria basin. Screen house experiment was performed in plastic pots with two plants of each cultivar. Randomized Complete Block Design was used. Experiments data were organized into a matrix and subjected to two- and three-way analysis of variance using Genstat 16th Edition and significant means separated using Least Significant Difference at [$LSD_{5\%}$] and Dancun Multiple Range Test. Agronomic characters of BUSB and KAKC landraces differed significant ($p<0.05$). Bambara groundnuts performed better in Port Victoria and Kendu bay soils than Kisumu and Karungu. Agronomic performance of two soybean varieties SB19 and 'Safari' on soils from four sites in Lake Victoria basin was significant ($p<0.05$). Soybeans yield in Port Victoria and Kendu bay soils was better compared to Kisumu and Karungu soils. Agronomic performance of bambara groundnuts and soybeans were influenced by soil type. Port Victoria and Kendu bay soils resulted in better growth compared to Kisumu and Karungu soils. Landrace KAKC and SB19 had better agronomic performers and are recommended to farmer and seed companies for certified seed production.

Keywords: Rhizobia, Nodulation, Effectiveness, Soybeans, Bambara Groundnut

1.0 Introduction

Population in Sub-Saharan Africa may double by 99% by the year 2050 (United Nations Department of Economic and Social Affairs (UNDESA), 2019). Projected rise in population poses challenge of access to food, overall human welfare and economic growth (Food and Agricultural Organization (FAO), 2017). Concerted efforts such as legume diversification aimed sustainable food production in Africa are necessary to ameliorate vulnerability to risks of insufficient food (FAO, 2017; Stagnari *et al*., 2017; Muoni *et al.*, 2019). However, inadequate attention, neglect and/or under-utilization crops such as soybeans and bambara groundnuts have intensified food insufficiency (Oyeyinka *et al.* 2015; Mubaiwa *et al*., 2018). Production of legume crops has declined below potential yield in regions that include Lake Victoria basin (Ojiem *et al*. 2001; Siddique *et al.*, 2012). A soya bean grain has protein (40%), carbohydrate (30%), digestible fiber (10%) and vitamins. It is also rich in minerals including Mg, K, Ca, Fe, Cu, Zn, and anti-oxidants (Meghvansi *et al.*, 2010). Production of soybean in Africa is low due to constrained such as its incompatibility with rhizobia found in African soils (Mpepereki *et al.*, 2000). Further, nodulation in soybean vary with cultivars as some cultivars exclude or restrict nodulation by rhizobia that belong to certain sero-groups of *Bradyrhizobium* spp. (van Berkum *et al*., 2002). However, improved cultivars with ability to freely nodulate with different members of rhizobia under natural conditions or inoculation have been developed by breeding (Mpepereki *et al*., 2000; Sanginga, 2003). Free natural nodulation allows these cultivars to form symbioses with native rhizobial strains. Nonetheless, Okogun and Sanginga (2003) reported that such promiscuous nodulation does not meet the full N demand for the cultivars necessitating inoculation. Currently, there is inconclusive information on the occurrence of indigenous symbionts of soybeans in soils of parts of Lake Victoria basin.

Bambara grain has 20.6% protein, 56.5% carbohydrate, 6.3% fiber and 6.6% fat (Mazahib *et al.*, 2013). Bambara groundnut has gained prominence as an alternative dietary protein source with numerous agronomic advantages to smallholder farmers (Azam-Ali *et al*., 2001; Mkandawire *et al*., 2007). However, bambara groundnuts have no properly established seed systems and sound agronomic practices for adoption (Hillocks *et al*., 2012; Mubaiwa *et al*., 2018; Feldman *et al.*, 2019). Knowledge of Bambara groundnut with optimal agronomic traits for different soil types remains scarce (Stagnari *et al.*, 2017). Given the variation in physicochemical status of the soils of Lake

Victoria basin (Jaetzold *et al*., 2007), selection of bambara groundnuts with suitable agronomic characters in different soils is necessary towards improving its production.

2 Study Sites and Methods

The study was conducted through glasshouse and screen house pot experiments, laboratory analysis and on farm trials. The screen-house pot experiments were carried out at Jaramogi Oginga Odinga University of Science and Technology research garden. Soil samples used in pot experiments were collected from farmers' fields in Port Victoria in Busia County, Kisumu in Kisumu County, Kendu bay in Homabay County and Karungu in Migori County in Kenya. A map of the sites is shown in Fig. 1 and site characteristics (Table 1). Chemical analysis of collected soil samples was done at Kenya Agricultural and Livestock Research Organization (KALRO) Research laboratories in Nairobi. Molecular analysis of rhizobial isolates was done at the Biosciences East and Central Africa (BecA-ILRI Hub). The glasshouse experiment to evaluate symbiotic status of the isolates was done at Kenya Forestry Research Institute's headquarters at Muguga, Nairobi. Jaramogi Oginga Odinga University of Science and Technology is in Bondo town, Siaya County along Bondo – Usenge road within the lower midland agro-ecological zone characterized by high temperatures, low rainfall and high evaporation rates (Jaetzold *et al*., 2007). The University lies between longitudes of $31^0 32'0''$E - $31^0 57'0''$W and latitudes of $0^0 07'30''$N - $0^0 10'15''$S of the equator at an altitude of about 1440 m above sea level (World Agro-forestry Centre, 2003).

Table 1. **Characteristics of soil of different sampling sites**

Site	Site location	Agro-climatic zones	Soil type
Kisumu	0^0 6′0N $34^0$45′ 0E	Sub-humid lower midland	Clay loam
Karungu	$0^0$51′ 0S 34^0 8′ 60E	Semi-humid lower midland	Clay loam
Kendu bay	$0^0$22′ 0S $34^0$38′ 60E	Semi-humid lower midland	Sandy loam
P. Victoria	0^0 6′ 0N 33^0 58′ 0E	Sub-humid lower midland	Sandy loam

Source: (Jaetzold *et al*., 2007)

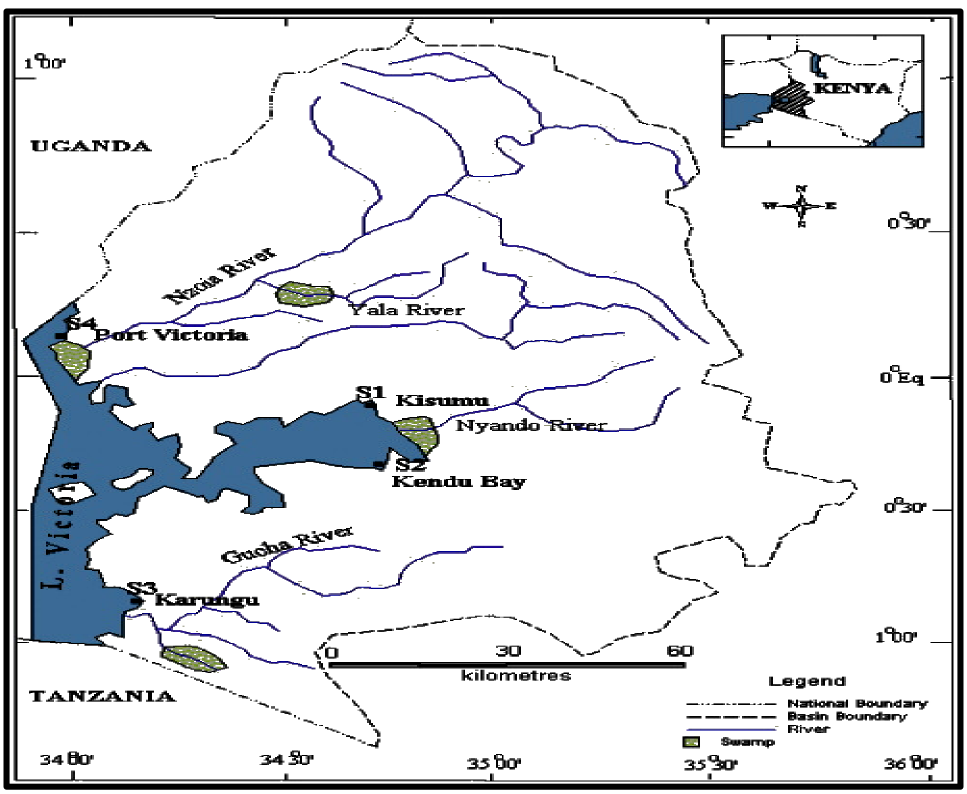


Fig. 12. A map showing four sites within Lake Victoria basin where soil samples used to trap rhizobia were obtained.

2.0 Agronomic Characterization of the two Legumes on Lake Victoria Soils

Seeds of two bambara groundnut landraces; Kakamega Cream (KAKC) and Busia Brown (BUSB) were collected from farmers in Kakamega and Busia Counties in Kenya respectively. A prior survey was done to select the farmer- preferred landraces. Attributes considered during selection included early maturity, superior cooking quality and taste. This was done to improve the exploitation of farmer held varieties with a view of future validation through varietal testing programmes. The survey involved a questionnaire designed to establish the commonly cultivated and farmer-preferred bambara groundnut varieties in Kisumu, Siaya, Busia, Vihiga and Kakamega counties. These sites were selected following previous reports by Ambede *et al*. (2012) and Ngugi *et al*. (1995) that the counties were engaged in bambara groundnut cultivation. Identification of the farmers who participated in the survey was done randomly, but was guided by availability of the crop in the homestead and a history of cultivation. Seeds of two soybean varieties (promiscuous SB19 and specific Safari) were selected for trials based on their host specificity or promiscuity. Guidance on released soybean lines was obtained from Kenya Agricultural and Livestock Research Organization (Kibos Centre) research officers in charge of legumes. In addition, a field survey was conducted to determine farmer-preferred soybean lines in Lake Victoria basin. Certified clean seed materials of SB19 were obtained from Tropical Soil Biology and Fertility Institute (TSBF), Maseno Centre. Variety 'Safari' is farmer-held in Lake Victoria basin and was obtained from farmers in Kakamega County following the survey. Seed collection was done randomly with the assistance of TSBF and KALRO extension officers, who also helped in varietal identification. Figure 2 shows the morphology of the seeds of bambara groundnuts and soybeans used in this study.

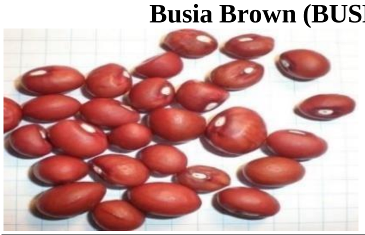
Variety/Landrace	Size	Coat colour	Eye colour
SB19 (Promiscous) 	Small	Cream	Brown
Safari (Specific) 	Large	Bronze	Brown
Kakamega Cream (KAKC) 	Large	Cream	Grey
Busia Brown (BUSB) 	Large	Brown	White

Fig. 2. Morphology of soybean varieties and bambara groundnut landraces used in trapping rhizobia and evaluating their symbiotic efficiency.

2.1 *Soil Sampling*

Soil sampling was done at selected farmers' fields with no history of inoculation in Kisumu, Port Victoria, Kendu bay and Karungu within Lake Victoria basin. The site characteristics are listed in Table 6. At each sampling point, 4 kg of soil was collected from a depth of 5 - 20 cm using a shovel. To avoid cross contamination, the shovel was sprayed in between sampling with 5% sodium hypochlorite solution in a wash bottle, rinsed with water three times and dried using a sterile cloth. Within each site, four replicate samples were collected within an area of 10 m^2 by randomly sampling four corners. The soils were placed in brown paper bags and put in bucket containers away from sunlight. Each soil sample was divided into two lots (1 kg and 3 kg) and used for soil chemical analysis and in glasshouse experiments to trap resident rhizobia using soybeans and bambara groundnut plants respectively.

2.2 Chemical Analysis of Soil Samples

Soil samples used in chemical analysis were air dried, crushed using a wooden roller and passed through a 0.5 cm mesh to remove any plant or grass fragment. Four hundred grams of the prepared soil samples in quadruplicates were placed in brown paper bags, tightly sealed and submitted to KALRO's National Agricultural Research Laboratories in Nairobi for soil chemical analysis using the methods described below.

2.2.1 Determination of Soil pH

Soil pH was determined using the $CaCl_2$ method (Thomas, 1996). To a soil sample weighing 10 g, 25 ml of 0.01M $CaCl_2$ solution was added. The mixture was shaken for 30 minutes. Prior to taking the pH reading from a pH meter, the electrode was thoroughly rinsed to free it of buffer solution. The suspension was stirred up and the electrode immersed into the suspension making sure it did not touch the base of the beaker. When the pH reading was stable, the displayed value was recorded (McNeal, 1982).

2.2.2 Determination of Soil Organic Carbon

A modified Walkley-Black dry combustion method was used to determine the percentage of organic carbon in the soil samples (Anderson and Ingram, 1983). About 15 g sucrose was dried at 105 ^{o}C for 2 hr and 11.87 g of this were dissolved in water. The solution was made up to 100 ml in a volumetric flask, to make a 50 mg C ml^{-1} solution. Two and half to 25 ml of the solution were pipetted into labelled 100 ml volumetric flasks, at 7.5 ml intervals, and made to the mark with deionized water. Two milliliters of each of these working standards were pipetted into labelled 150 ml conical flask and dried at 105 ^{o}C in an oven. One gram of air-dried soil sample was weighed into a 150 ml flask to which 10 ml of 1N $K_2Cr_2O_7$ was added and the contents were gently swirled until the sample was completely wet. This was followed by the addition of 20 ml of concentrated H_2SO_4 with further swirling to ensure through mixing of the solution in a fume cupboard. After cooling the solution, 50 ml of 0.4 % $BaCl_2$ was added. The solution was left to stand over-night and the absorbance of the samples and the standards were read at 600 nm on UV visible spectrophotometer (Spectronic-20-Bausch and Lamb).

2.2.3 Determination of Exchangeable Cations

Total exchangeable cations were determined following extraction using 1M acidified ammonium acetate (Lindsay and Norvell, 1978). Air-dried soil samples weighing 10 g were put in 150 ml plastic containers to which 40 ml of ammonium acetate were added. The containers were tightly closed and put on a reciprocating shaker (Stuart Flask model) for 1 hr. The solution was then filtered through a Whatman number 125 filter paper into 250 ml flasks. The remaining soil was washed using ammonium acetate making the volume in the collecting flask to about 90 ml. Fresh ammonium acetate was used to raise the mark to 100 ml. After leaching the bases, potassium (K) and sodium (Na) emission were read on a flame spectrophotometer with the filter set on either K or Na while magnesium (Mg), manganese (Mn) and calcium (Ca) absorption were read on an atomic absorption spectrophotometer (AAS) model SpectrAA50 using the respective lamps (Thomas, 1982). The resultant values were converted into percentage milli- eqivalents (meq %) per 10g using a conversion table.

2.3.4 Determination of Available Phosphorus

Soil available P was measured using the Olsen method (Olsen *et al*., 1954). An air-dried soil sample weighing 2.5 g was placed into a 250 ml polythene shaking bottle followed by addition of Olsen's extracting solution (0.5 M $NaHCO_3$ at pH 8.5). The mixture was put on a shaker for 30 minutes and the suspension filtered through Whatman No. 42. Five mililiters of 0.8 M boric acid and 10 ml of ascorbic acid reagent were added and allowed to stand for 1 hr. The P content was determined colorimetrically from a phosphorus molybdate complex formed by addition of acidified ammonium molybdate (Okalebo *et al*., 2002).

2.2.5 Determination of Total Nitrogen

Total soil N was determined using the semi-Kjeldhal method (Anderson and Ingram, 1983). Soil samples were digested using a digestion solution made up of selenium powder (being the catalysts), lithium sulphate and concentrated sulphuric acid. An air-dried soil sample weighing 0.5 g (0.1 g for ground plant material) was weighed into a digestion tube followed by addition of 4.4 ml of the digested samples. The resultant mixture was placed on a digester at 360°C for 2 hr. Three reagent blanks were included to each batch of the samples. The solution was allowed to cool and 25 ml of distilled water added. A further 75 ml of distilled water was added and the solution was allowed to settle. Standards were prepared by oven drying 7 g of ammonium sulphate [$(NH_4)_2SO_4$] at 105°C for 2 hrs. About 4.714 g of dry ammonium sulphate was dissolved in 1000 ml of deionized water (1000 mg N/litre) and 50 ml of the solution was pipetted into a 500 ml volumetric flask. Two and a half milliliters of the digested blank was added to each flask before marking it, to the mark with distilled water. To 0.1 ml of the sample or standard solution, 5 ml of reagent N1 (34 g sodium salicylate, 25 g sodium citrate and 0.12 g sodium nitroprusside dissolved 1000 ml de-ionized water) was added. After 15 minutes, 5 ml of reagent N_2 (30 g NaOH, 750 ml water and 10 ml sodium hypochlorite in 240 ml de-ionized water) was added. The solution was mixed well and left for colour development. Total N in the sample was determined calorimetrically from the clear solution against a set of standards at an absorbance of 655 nm.

2.3 *Screen-house Experiments*

The soil samples were used to evaluate agronomic performance of soybean and bambara groundnut cultivars through a screen-house experiment. Plastic pots (20 cm diameter and 25 cm height) were filled with soil samples and watered until adequately wet. Four seeds of each cultivar were planted on each pot but were later thinned to two. The set-up was arranged in Randomized Complete Block Design (RCBD) with four soil types, two soybean varieties or two bambara groundnut landraces each replicated four times. Watering was done twice a day in the morning and evening. The data collected were; Emergence days after sowing (EDAS), days to first flowering (DFF), days after sowing (DAS), leaf number (LNo 14, 54 and 70DAS), number of nodules per plant (NodP 21 and 54DAS), plant height (PHT, cm, 14, 54 and 70DAS), days to maturity (DTM), number of seeds per pod (SPD), number of pods per plant (NoPd) and weight of 100 seeds (WHS, g).

3.0 RESULTS

3.1 Soil Analysis

Differences in chemical properties of soil samples from the four study sites were as shown in Table 2. Soil samples from Kendu bay and Port Victoria were near neutral with pH ranging from 6.26 – 6.30, unlike Karungu and Kisumu which had acidic soils of pH ranging from 4.10 - 4.11. There was no major difference in the total soil N with the values ranging between 0.14 to 0.17 % for all the four sites. Available P levels varied with soils from Kendu bay and Port Victoria having high values ranging between 19.5 – 23.00 ppm while soils from Kisumu and Karungu had lower values ranging from 5 to 10 ppm. Other soil chemical factors varied as follows: Mg (7.60 – 7.85 meq % for Kendu bay and Port Victoria and 2.52 – 2.76 meq % for Kisumu and Karungu); K (0.19 – 0.20 meq % for Kisumu and Karungu and 0.56 – 0.62 meq % for Kendu bay and Port Victoria); Ca (3.50 – 3.95 meq % for Kendu bay and Port Victoria and 1.37 – 2.48 meq % for Kisumu and Karungu) and Na (0.7 meq % for Kendu bay and Karungu and 0.2 - 0.26 meq % for Kisumu and Karungu).

Table 2. Chemical composition of soils from the four study sites

Site	pH	N (%)	Org. C (%)	P̃ (ppm)	K (meq%)	Ca (meq%)	Mg (meq%)	Mn (meq%)	Cu (ppm)	Fe (ppm)	Zn (ppm)	Na (meq%)
Kendu Bay	6.26	0.17	1.66	23.00	0.62	3.50	7.60	0.84	1.19	14.50	6.23	0.26
Port Victoria	6.30	0.15	1.51	19.50	0.56	3.95	7.85	0.61	1.04	15.98	8.46	0.25
Kisumu	4.10	0.15	1.44	10.00	0.20	2.48	2.52	0.59	1.09	14.80	8.91	0.07
Karungu	4.11	0.14	1.29	5.00	0.19	1.37	2.76	0.67	1.06	18.07	6.00	0.07

NOTE: Each value is the mean of a quadraplicate soil analysis per site. P̃ - Available P

3.2 Effect of Soil Type on Agronomic Performance of the two Legumes Bambara Groundnuts

Significant ($p<0.05$) differences were observed between landraces BUSB and KAKC in the agronomic characters analyzed in screen-house pot experiments using the four soil types as shown on Table 3. The results showed that Port Victoria and Kendu bay soils were more suitable for cultivation of bambara groundnuts than Kisumu and Karungu. The fastest duration to seedling emergence was observed in Port Victoria and Kendu bay soils by both landrace KAKC and BUSB which took an average of 7 and 8 days respectively ($p<0.05$). Landrace BUSB took significantly longer duration of 11.56 and 11.92 days to seedling emergence in Kisumu and Karungu soils respectively ($p<0.05$). Plants grown in Port Victoria soils took the shortest days to form the first flower with landrace KAKC taking 44.22 days, followed by the same landrace in Kendu bay soils taking 51.37 days and landrace BUSB which lasted 51.67 days to form the first flowers in Port Victoria soils ($p<0.05$). The longest duration to form the first flower occurred in landrace

BUSB which lasted 67.74 days in Kisumu soils while landrace KAKC took 63.67 days in the same soils ($p<0.05$). Average values of 8 cm in plant height 14 DAS were observed in both landrace KAKC and BUSB in soils of Port Victoria, significantly differing from the plant height of 4 cm observed in Kisumu soils ($p<0.05$). Landrace KAKC had the greatest plant height 54 DAS of 18.41 cm occurring in Port Victoria soils, followed by the same landrace in Kisumu soils which were slightly below 18 cm in height ($p<0.05$). Kendu bay and Port Victoria soils had above 26 cm high plants for landrace KAKC *70 DAS* which was much higher than the 22 cm observed in Kisumu soils.

The lowest mean number of leaves per plant 14 DAS occurred in Kisumu soils with both landraces having an average of 4 leaves/plant, while the greatest number of leaves (8 per plant) were observed in landrace KAKC planted in Port Victoria soils ($p<0.05$). When mean leaf number per plant was obtained 54 DAS, landrace KAKC outperformed BUSB in all the soils which obtained the highest number of 33.17 leaves/plant in Port Victoria soils compared to 28.84 for landrace BUSB in the same soil while the least mean number of leaves 54DAS were obtained from Kisumu soils which gave 19.59 leaves per plant ($p<0.05$).

Very few nodules were recovered from plants of both landraces at 21DAS with a maximum of 3 nodules obtained from landrace KAKC grown in Kendu bay soils, but this increased to a maximum of 12 nodules 54DAS from landrace BUSB. In all the soils, landrace BUSB produced an average of less than 2 nodule per plant 21DAS since several pots did not form any nodules. Variation was observed in duration to maturity with the fastest days attained by landrace KAKC lasting 137 days in Port Victoria and Kendu bay soils different from landrace BUSB which gave the slowest response of 160 days ($p<0.05$).

3.3 Effect of Soil Type on Agronomic Performance of the **Soybeans**

Results of agronomic performance of two soybean varieties SB19 and 'Safari' on soils from four sites in Lake Victoria basin are listed on Table 4. The effect of soil type on duration of seedling emergence varied significantly ($p<0.05$) between the two varieties although there was no significant ($p>0.001$) var×site interaction for this variable. The shortest duration to seedling emergence of 3.48 days was observed on Variety SB19 on Port Victoria soils, followed by the same variety on Kendu bay soils at 3.69 days. Variety 'Safari' took longer duration for seedling emergence in Kisumu and Karungu soils at averages of 5 and 6 days respectively ($p<0.05$). A significant ($p<0.05$) var×site interaction effect was observed on plant height 14 DAS with values of 8.37, 9.34, 9.63 and 10.78 cm for Variety 'Safari' in Kisumu, Port Victoria, Kendu bay and Karungu soils respectively which differed significantly with 11.65, 12.14, 13.11 and 12.93 cm for Variety SB19 ($p<0.05$).

Variety 'Safari' had the greatest plant height of 28.86 cm at 35DAS in Port Victoria soils significantly ($p<0.05$) although it was overtaken by SB19 which attained the greatest plant height of 49.53 cm at 54DAS in Port Victoria soils; no significant ($p>0.001$) var×site interactions were observed for this variable. The greatest number of leaves per plant 14DAS, 35DAS and 54DAS of 14.47, 24.65 and 28.46 respectively occurred in Variety SB19 grown in Port Victoria soils ($p<0.05$) while the least number of 7.36, 14.12, and 18.87 cm were found on Variety 'Safari' grown in Kendu bay and Karungu soils respectively. There occurred a highly significant ($p<0.001$) interaction between variety and site of soil sampling for all the plant height factors evaluated. The number of nodules at 21DAS on each plant was quite low, with SB19 giving the highest value of 2 in Port Victoria soils ($p<0.05$) compared to 1.67 from both Kisumu and Kendu bay soils.

Variety 'Safari' did not form any nodules in all the soils except Kisumu soils where some protuberances occurred in the roots and were recorded as nodules although the number was negligible. A similar trend occurred on nodule number per plant 54DAS in which 15.86, 11.09, and 9.74 nodules obtained from Kisumu, Karungu, Port Victoria and Kendu bay soils respectively for SB19. Highly significant ($p<0.001$) var×site interactions were observed for nodules 21DAS and 54DAS. There was a significant difference in the number of seeds per pod in which a range of 2.43 – 2.79 seeds from SB19 were obtained in all the soils while a range of 1.8 – 2.74 occurred for 'Safari' in all the soils.

Table 3: Agronomic performance of two bambara groundnut landraces grown in four soils of Lake Victoria basin

Site	EDAS		DFF		LNo14DAS		LNo54DAS		Ph14DAS (cm)		Ph54DAS (cm)	
	KAKC	**BUSB**	**KAKC**	**BUSB**	**KAKC**	**BUSB**	**KAKC**	**BUSB**	**KAKC**	**BUSB**	**KAKC**	**BUSB**
P. Victoria	7.36^{b}	7.32^{c}	44.22^{d}	51.62^{c}	8.40^{a}	7.68^{a}	33.17^{a}	28.84^{a}	6.37^{a}	6.21^{a}	18.41^{a}	17.27^{a}
Karungu	9.32^{a}	11.56^{a}	57.23^{a}	61.72^{a}	6.51^{c}	5.75^{b}	26.17^{c}	24.74^{c}	5.54^{b}	5.73^{b}	15.56^{c}	14.59^{c}
Kisumu	9.38^{a}	11.92^{a}	63.67^{a}	67.74^{a}	4.40^{d}	3.86^{c}	21.41^{d}	19.59^{c}	5.27^{c}	5.29^{b}	15.17^{c}	14.50^{c}
K. bay	8.57^{b}	8.28^{b}	51.37^{c}	54.76^{b}	8.22^{b}	7.58^{a}	28.51^{b}	27.34^{b}	5.45^{b}	4.08^{c}	17.62^{b}	16.72^{b}
Mean	**8.66**	**9.77**	**54.12**	**58.96**	**6.88**	**6.22**	**27.32**	**25.13**	**5.66**	**5.23**	**16.69**	**15.77**
LSD$_{5\%}$	0.522*		0.750*		0.099*		0.434*		0.078*		0.0925*	
CV%	11.7		2.8		3.2		3.5		2.1		1.2	

Site	Ph70DAS (cm)		Nod21DAS		Nod54DAS		DTM (g)		S/Pd		WHS (g)	
	KAKC	**BUSB**	**KAKC**	**BUSB**	**KAKC**	**BUSB**	**KAKC**	**BUSB**	**KAKC**	**BUSB**	**KAKC**	**BUSB**
P. Victoria	26.43^{a}	25.54^{a}	2.00^{b}	0.67^{a}	6.89^{bc}	4.02^{d}	135.22^{d}	144.56^{c}	1.44^{a}	1.02^{b}	41.22^{a}	38.57^{a}
Karungu	23.72^{c}	22.83^{c}	0.56^{d}	0.11^{b}	5.90^{c}	8.86^{c}	142.44^{b}	149.56^{b}	1.00^{b}	1.11^{b}	36.23^{c}	34.58^{c}
Kisumu	22.41^{d}	20.43^{d}	1.56^{c}	0.22^{b}	5.51^{d}	10.61^{b}	145.44^{a}	159.22^{a}	1.10^{b}	1.11^{b}	31.92^{d}	30.80^{d}
K. bay	25.73^{b}	24.54^{b}	3.44^{a}	0.67^{a}	8.10^{a}	12.31^{a}	137.44^{c}	144.56^{c}	1.39^{a}	1.22^{a}	37.82^{b}	37.87^{b}
Mean	**24.57**	**23.34**	**1.89**	**0.42**	**6.60**	**8.95**	**140.14**	**149.48**	**1.23**	**1.12**	**36.80**	**35.46**
LSD$_{5\%}$	0.188*		0.468*		1.158*		0.878*		0.164*		0.434*	
CV%	1.7		8.6		6.5		1.3		2.9		2.6	

NOTE: *Means followed by the same letter in a column are not significantly different* (* - Significant at $p \leq 0.05$)
EDAS – Emergence days after sowing; DFF – Days to first flower; LNo14DAS – Leaf number 14 days after sowing; LNo54DAS - Leaf number 54 days after sowing; Ph14DAS – Plant height 14 days after sowing; Ph54DAS – Plant height 54 days after sowing; PH70DS – Plant height 70 days after sowing; Nod21DAS – Nodule number 21 days after sowing; Nod54DAS – Nodule number 54 days after sowing; DTM – Days to maturity; S/Pd – Seeds per pod; WHS –Weight of 100 seeds, KAKC – Kakamega Cream landrace; BUSB – Busia Brown landrace.

Table 4. Agronomic performance of two soybean varieties grown in four soils of Lake Victoria basin

EDAS			**Ph14DAS (cm)**		**Ph35DAS (cm)**		**Ph54DAS (cm)**		**LNo14DAP**		**LNo35DAS**	
Site	**SAF**	**SB19**	**SAF**	**SB19**	**SAF**	**SB19**	**SAF**	**SB19**	**SAF**	**SB19**	**SAF**	**SB19**
Kisumu	5.19^{b}	4.46^{a}	8.37^{c}	11.65^{d}	26.84^{b}	27.61^{b}	36.33^{b}	39.73^{b}	10.32^{b}	12.95^{b}	19.24^{b}	22.57^{b}
P. Victoria	4.01^{c}	3.48^{c}	9.34^{b}	12.41^{c}	28.86^{a}	32.36^{a}	45.66^{a}	49.53^{a}	12.09^{a}	14.47^{a}	21.41^{a}	24.65^{a}
K. bay	4.15^{c}	3.69^{b}	9.63^{b}	13.11^{a}	23.82^{d}	26.44^{c}	32.60^{d}	34.76^{d}	8.01^{c}	10.12^{d}	14.12^{d}	17.99^{d}
Karungu	5.5^{a}	3.80^{b}	10.78^{a}	12.93^{bc}	24.42^{c}	26.87^{c}	33.71^{c}	35.87^{c}	7.36^{d}	10.62^{c}	15.61^{c}	19.02^{c}
Mean	**4.46**	**3.86**	**9.53**	**12.53**	**25.99**	**28.32**	**37.07**	**39.97**	**9.51**	**12.04**	**17.59**	**21.06**
$LSD_{5\%}$	**0.165***		**0.555***		**0.539***		**0.464***		**0.412***		**0.553***	
CV%	**6.0**		**7.6**		**3.0**		**3.3**		**5.7**		**4.3**	

LNo54DAS			**DFF**		**Nod21DAS**		**Nod54DAS**		**S/Pd**	
Site	**SAF**	**SB19**	**SAF**	**SB19**	**SAF**	**SB19**	**SAF**	**SB19**	**SAF**	**SB19**
Kisumu	22.41^{c}	24.79^{c}	42.54^{c}	39.07^{c}	0.67^{a}	1.67^{a}	0.67^{a}	15.86^{a}	1.80^{b}	2.70^{c}
P. Victoria	26.48^{a}	28.46^{b}	38.81^{d}	36.71^{d}	0.00^{a}	2.00^{a}	0.00^{a}	9.74^{b}	2.74^{a}	2.91^{a}
K. bay	18.87^{d}	21.40^{d}	46.73^{b}	43.91^{b}	0.00^{a}	1.78^{a}	0.00^{a}	9.74^{b}	1.61^{c}	2.43^{d}
Karungu	25.82^{ab}	30.00^{a}	52.21^{a}	54.67^{a}	0.00^{a}	1.67^{a}	0.00^{a}	11.09^{b}	2.60^{a}	2.77^{bc}
Mean	**23.39**	**26.16**	**45.07**	**43.59**	**0.17**	**1.78**	**0.17**	**11.61**	**2.18**	**2.7**
$LSD_{5\%}$	**0.721***		**0.750***		**0.708***		**1.129***		**0.142***	
CV%	**4.4**		**2.5**		**10.8**		**5.4**		**8.7**	

NOTE: *Means followed by the same letter in a column are not significantly different* (* - Significant at $p \leq 0.05$)

EDAS – Emergence days after sowing; DFF – Days to first flower; LNo14DAS – Leaf number 14 days after sowing; LNo54DAS - Leaf number 54 days after sowing; PH14DAS – Plant height 14 days after sowing; PH35DAS – Plant height 35 days after sowing; PH54DAS – Plant height 54 days after sowing; PH70DAS – Plant height 70 days after sowing; Nod21DAS – Nodule number 21 days after sowing; Nod54DAS – Nodule number 54 days after sowing; S/Pd – Seeds per pod; KAKC – Kakamega Cream landrace; BUSB – Busia Brown landrace.

4.0 DISCUSSION

4.1 Agronomic Performance of Bambara Groundnuts on Four Soil Types

The soil type used in cultivation of the two bambara groundnut landraces (KAKC and BUSB) and the plant genotype had a significant effect ($p<0.05$) on their agronomic performance under screen house conditions. The sandy loam soils from Port Victoria and Kendu bay were more suitable for cultivation of bambara groundnuts than the clay loam soils of Kisumu and Karungu. Port Victoria and Kendu bay resulted in faster seedling emergence, shorter days to first flower, more leaves per plant and higher shoot and root dry weights. Good growth in sandy loam soil may be attributed to adequate aeration, water drainage high water holding capacity that ensure suitable soil pH (Mojid *et al.,* 2009). Port Victoria and Kendu bay soils were moderately acidic with pH 6.1-6.3 compared to the clay loam Kisumu and Karungu soils which were more acidic (pH 4.10 – 4.11). Higher soil pH increases mineralizable of C and N by breaking the bond organic between constituents and clays making N available for plant (Curtin and Jalil, 1998). Soil pH that range from 6 to 8 strongly affects fertilizers' N nitrification rates (Kyveryga *et al.,* 2004). Other than Soil pH effect on soil nutrition, it affects microbial ecophysical indices such as rhizobia (Blagodatskaya and Anderson, 1998). Soil acidity hinders availability of bases such as Ca and Mg and other nutrients such as Mo and P which may secondarily influence growth and yield of legumes (Swanevelder, 1998; Miller, 2016; Neina, 2019). Where soil is acidic, liming has been recommended to improve production of bambara groundnuts (Crops For the Future Research Centre, 2012; Wijanarko and Taufiq, 2016). Findings corroborate those of Linnemann, (1990), Swanevelder (1998), Berchie *et al*. (2010) that bambara groundnut plants prefer less acidic soils of approximately pH 6.0.

Kisumu and Karungu soils had lower available P values (5-10 ppm) compared to Port Victoria and Karungu soils (21- 23 ppm), which may have resulted in better growth and development in the latter soil. Soil amendments were not done in this work and thus, low available P status of the Kisumu and Karungu soils must have had a negative impact on the overall growth performance. Hence, mechanisms for improving available P levels in the soil is necessary, although P-based fertilizers are expensive and inaccessible to most rural farmers in the region (Ojiem *et al*., 2006). On the other hand, some studies have alluded to challenges of direct application of P-based inorganic fertilizers to the soil since not all of it is usually available to the plants (Okalebo *et al*., 2002). This offers the alternative of soil amendments with the cheaper and more accessible rock phosphate. Rock phosphate has an added advantage of dissolving slowly increasing plant uptake and utilization (Waigwa *et al*., 2003).

Soil exchangeable cations showed high variability with Kisumu and Karungu soils having lower values of K, Ca, Mg, Mn and Na than Port Victoria and Kendu bay soils. In particular, high Na concentrations have been shown to influence soil salinity. Studies by Ambede *et al*., (2012) on two bambara groundnut landraces under glass house conditions found very high sensitivity to NaCl salinity, in which high concentrations significantly decreased percentage germination and subsequent growth factors. In this study, higher Na concentrations of Port Victoria and Kendu bay soils (0.26 – 0.23 meq %) had a positive effect on plant growth, indicating the tolerance of the landraces to this range of Na concentrations. Landrace KAKC performed better than landrace BUSB in most of the growth factors evaluated. This may be attributed to inherent genetic differences between the landraces. These findings confirmed a preliminary survey conducted amongst bambara growing farmers during seed sourcing, that landrace KAKC is arguably better in terms of yield enhancing traits. In addition, growth variations attributable to inherent genetic effects correspond to previous studies. Similar genetic effects on bambara plant growth were observed in number of pods per plant (Ntundu *et. al*., 2006; Adeniji *et al*., 2008), duration to first flower and plant height (Ouedraogo *et al*., 2008), duration to maturity (Berchei *et al*., 2010), number of nodules per plant and dry matter yield (Adeniji *et al*., 2008; Mohale *et al*., 2013). Landrace BUSB took longer days to seedling emergence compared to landrace KAKC. This resulted in a longer vegetative period linked to lower growth factors observed. Landrace BUSB has a brown and thick seed coat compared to KAKC which has a thin and cream seed coat and this may have affected seedling emergence and consequently plant development. Further investigations on the effect of genetic variations on agro-morphological factors of bambara groundnuts in Lake Victoria soils is necessary. This may provide useful information to extension officers and breeding programmes for higher quality genotypes to farmers in the Lake Victoria basin.

4.2 Agronomic Performance of Soybeans on Four Soil Types

Agronomic performance of soybean varieties 'Safari' and SB19 differed remarkably on the four soil types. Variety SB19 exhibited faster growth and early maturing tendencies in all the four soil types tested. Variety SB19 is a fast maturing soybean line which was recommended to farmers in Lake Victoria basin following an up-scaling study by KALRO (Mahasi *et al*., 2011). As was observed in bambara groundnuts, variations in soil type had a significant influence on growth performance of the two varieties; with Port Victoria and Kendu bay soils having better yield compared to Kisumu and Karungu soils. This may be attributed to differences in soil pH, available P and exchangeable cations (similar to bambara groundnut tests) and may have resulted due to growth differences in the soybean varieties. Soil pH has been associated with plant intake of molybdenum which has a direct influence in legume nodulation (Somesegaran and Hoben, 1985). Molybdenum concentration was not analysed in the soil samples used in this study but a report by Motsara and Roy, (2008) indicates that plants grown at pH values above 6.4 access the mineral more easily than plants grown in highly acidic soils (below pH 5.5). Molybdenum is also critical for nodule formation and nitrogen fixation (Somesegaran and Hoben, 1985). It is therefore plausible to infer that the more acidic Kisumu and Karungu soils inhibited intake of this mineral element resulting in the low number of nodules observed and may have had a negative effect in overall plant growth.

Differences in agronomic performance between Variety SB19 and 'Safari' may be attributed to chemical of soils on which they were cultivated. However, growth variation due to genetic/varietal differences was evidenced by better growth of Variety SB19. It showed early maturing tendencies resulting in better seedling emergence, faster duration to flower formation, earlier pod setting and faster maturity. Variety SB19 was previously reported to be an early maturing variety by Waswa *et al*., (2013) and Mahasi *et al*. (2011). It was recommended as a suitable soybean line for cultivation in Lake Victoria basin since the region experiences erratic rainfall which may insufficient for slow growing varieties. Variety SB19 had high mean nodule numbers in nearly all the soils, most of which were effective. This was unlike Variety 'Safari' which produced two nodules in Kisumu soils. Being specific, the variety may have secluded many rhizobial groups, which led to low nodulation that may have slowed its growth. Soil chemical analysis revealed low levels of N in all soils (0.14-0.17%) as was shown by the soil analysis. Effectively nodulated legume plants use both N-fixed due to symbiosis and soil N for its growth and metabolism (Unkovich *et al*., 2008). At the same time, since symbiotic N-fixation is directly dependent on translocation of carbohydrates from the leaves, the rate of fixation is fully synchronized with the rate of plant growth (Sessitch *et al*., 2002). However, non- nodulated/ineffectively nodulated plants are completely dependent on soil N for its growth (Giller, 2001) and this may explain the slow growth observed in Variety 'Safari'.

CONCLUSIONS

Agronomic performance of bambara groundnuts and soybeans was influenced by the soil type with Port Victoria and Kendu bay soils resulting in better growth compared to Kisumu and Karungu soils. Soil chemical properties and inherent varietal differences between the legumes significantly influenced plant growth and distribution of rhizobial isolates obtained from each site. Although sensitive to low P and pH, bambara groundnuts and soybeans are likely to perform well in the region with proper soil amendments.

RECOMMENDATIONS

Soybeans and bambara groundnuts require soils of high P and near neutral pH for optimum agronomic performance. Guidelines on soil amendments through liming and use of rock phosphate as a P-source may lead to improved production of the two legumes in Lake Victoria basin. Landrace KAKC and SB19 were found to have better agronomic performers and are recommended to farmers and seed companies for certified seed production.

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