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Soil characterization and potentiality to improve two Bambara groundnut varieties cropping under rock phosphate fertilization at sudano-sahelian climate of Burkina Faso

Koulibi Fidèle Zongo[1], Hervé Nandkangre[1], Daouda Guebre[2], Abdramane Sanon[3], Diane Judicaëlle Kambou[4], Paligwendé Kabore[1], Adjima Ouoba[2], Edmond Hien[4], and Mahama Ouedraogo[5]

[1]Centre Universitaire de Tenkodogo, Université Thomas SANKARA, 12 BP 417, Ouagadougou, Burkina Faso

[2]Centre Universitaire de Ziniaré, Université Joseph KI-ZERBO, 03 BP 7021, Ouagadougou, Burkina Faso

[3]Laboratoire d'Etude et de Recherche sur la Fertilité des Sols, Institut de Développement Rural, Université Nazi Boni, BP 1091, Bobo-Dioulasso, Burkina Faso

[4]Unité de formation et de recherche en sciences de la vie et de la terre, Université Joseph KI-ZERBO, 03 BP 7021 Ouagadougou, Burkina Faso

[5]Département Productions Végétales, Institut de l'Environnement et de Recherches Agricoles (INERA), 04 BP 8645 Ouagadougou, Burkina Faso

ABSTRACT: Bambara groundnut is a food seed legume with enormous agronomic and nutritional potential. However, it remains a neglected crop. In order to improve its productivity in relation to soil and climatic conditions, the present study was conducted in Tenkodogo from July to October 2021. Soil characterization was carried out according to FAO guidelines directives before the setting up of experimental device. Experimental design consisted of the trial following a completely randomized block design with four replications. The effects of applying of 0 (BP0), 30 (BP30), 60 (BP60), 90 (BP90) and 120 (BP120) kg ha^{-1} of Burkina phosphate (BP) on two varieties KVS246 and KVS 235 of Bambara groundnut were compared. Crop management consisted of a flat plowing, direct application of BP, sowing distances of 0.40 m x 0.20 m and ridging on the 49th day after sowing. Results showed that the soil of experimental site are an iron and manganese sesquioxide's soils class, specifically to shallow leached ferruginous tropical soil and should corresponding an endo petroplinthic lixisol. This acidic soil is characterized by a sandy surface texture and clay at depth, well drained, with low mineral content. In reference to the research results, the soil and climatic conditions of experimental site are potentially suitable for Bambara groundnut cropping. Treatments not significantly improved Bambara groundnut yields by verities. On this soil, the variety KVS 246 would better interact with applying of 60 and 90 kg ha^{-1} of BP and the variety KVS 235 with 120 kg ha^{-1} of BP to improve Bambara groundnut yield parameters compared to the control. Further research is needed over several years to better understand the effects of rock phosphate on Bambara groundnut crop and residual soil fertility.

KEYWORDS: Soil characterization, potentiality, Burkina phosphate, Bambara groundnut, yields, Burkina Faso.

1 INTRODUCTION

Agriculture in Sub-Saharan Africa remains highly dependent on natural resources, including soil fertility, which severely constrains crop yields. Declining soil fertility is a serious problem across Sub-saharan Africa, and a persistent constraint to agricultural production especially in low potential areas, thus posing a main threat to food security and rural livelihoods ([1], [2]). Reports that more 40% of soils in Sub-Saharan Africa exhibit nutrient depletion ([3], [2]). Sanchez ([4]), reports that average annual nutrient depletion rates in 37 Africa countries of 22 kg N ha^{-1}; 2.5 kg P ha^{-1}; and 15 kg K ha^{-1}. This agriculture is dominated by the production of cereals such as maize, rice, sorghum and millet for staple food. To this must be added the legume crops dominated by cowpeas, groundnuts and Bamabara groundnut.

Bambara groundnut (*Vigna subterrana* [L] Verdc.) represents the third most important food legume in Sub-saharan after cowpea (*Vigna unguiculata* [L.] *Walp*.) and groundnut (*Arachis hypogeae* L.) ([5], [6], [7]). It contains about 55.5 – 70.0% carbohydrate; 4–12% lipids, 3–5% ash, 362–414 kcal 100 g^{-1} metabolizable energy; 17–24% protein 3–12% fiber; 4.9-48 mg 100^{-1} g iron (Fe); 11.44-19.35 mg 100 g^{-1} potassium (K); 2.9-12.0 mg 100 g^{-1} sodium (Na); 95.8-99.0 mg100 g^{-1} calcium (Ca) ([8], [9]) hence its importance in food and nutritional needs. Bambara groundnut is underutilized compared with major cash crops and has often been associated with small-scale, subsistence farming, with women being the major producers and processors ([10]). In addition to these qualities, it has an ability to resist pest and diseases and can thrive in poor soils ([11]). Bambara groundnut is also a legume crop that fixes atmospheric nitrogen for its growth. It fixes 20 – 100 kg N ha^{-1} ([12]) and improves soil nutrient status, especially nitrogen status, as a result of its nodulation process which traps nitrogen from atmosphere. Bambara groundnut can contribute to improve soil fertility through several mechanisms and processes, which would correlatively increase the yields of the crops *in situ* and subsequent. In the degraded and low fertility soil, Bambara groundnut can get better in the characteristics of soil and also a good source of N, P and K for the plant ([13]). It could be used to promote sustainable agriculture in a context of climate change, marked by poor soils and insufficient rainfall, and farmer's resilience. Despite their importance, legume yields on smallholder farms remain far below their potential, largely because the crops are grown on poor soils without adding fertilizer ([14]). Declining soil fertility, erosion, drought and a low rate of use of chemical fertilizers allowing only low harvests.

Bambara groundnut such as other legumes has a high P requirement (20 – 60 kg P2O5 ha^{-1}) which is essential due to higher ATP requirements for nitrogenase activity, nodule development, and function ([15]) and its deficiency limits the performance of the crop ([16]). In fact, legumes are highly sensitive to P deficient due to its role in nodulation, biological N_2 fixation and energy reactions ([17], [18], [19]). However, Phosphorus (P) is one of the most essential elements for crop production in many tropical soils. Many tropical soils are inherently deficient in P that can be so acute in some soils of the Savanna zone of Western Africa resulting in cessation of plant growth as soon as the P stored in the seed is exhausted ([20]). Low P is due to reduced native P, nutrient depletion due to mining and the increasing P-adsorption capacity of almuninium (Al), Manganese (Mn) and iron (Fe) oxides in the soils ([21]).

In Burkina Faso, national production of Bambara groundnut was increased from 2007 to 2020 (22]). The lowest production was recorded at 37605 t in 2007 and the highest at 74647 t in 2020. A lack of technology support limits the productivity of Bambara groundnut in the smallholders farming with mean of yields of 941 kg ha^{-1} ([23]). Theses yields remain lower than the estimated potential of more than 3000 kg per hectare ([8]). Lowest yields of Bambara groundnut are due to phosphorus deficiency especially in acidic soils ([24]). This research was conducted in this way to characterize the soil and determine their specific performance under rock phosphate fertilization for Bambara groundnut cropping.

2 MATERIAL AND METHODS

2.1 EXPERIMENTAL SITE

This study was carried out an experimental field of Tenkodogo University Center (11°48'37"N; 0°22'19"W) located in East-center region of Burkina Faso. Climate is Sudano-sahelian characterized by annual rainfall between 600 - 900 mm. Average minimum temperature is around 33 °C and maximum temperature can reach 41 °C (Figure 1). Insolation is 7 – 8 h day^{-1} with low humidity. In 2021, 52.2 mm of rainfall (May) was recorded against 249.5 mm (August); Temperature was ranged from 26°C (August) to 31°C (May) (Figure 1). A strong annual rainfall was observed in June, July and August.

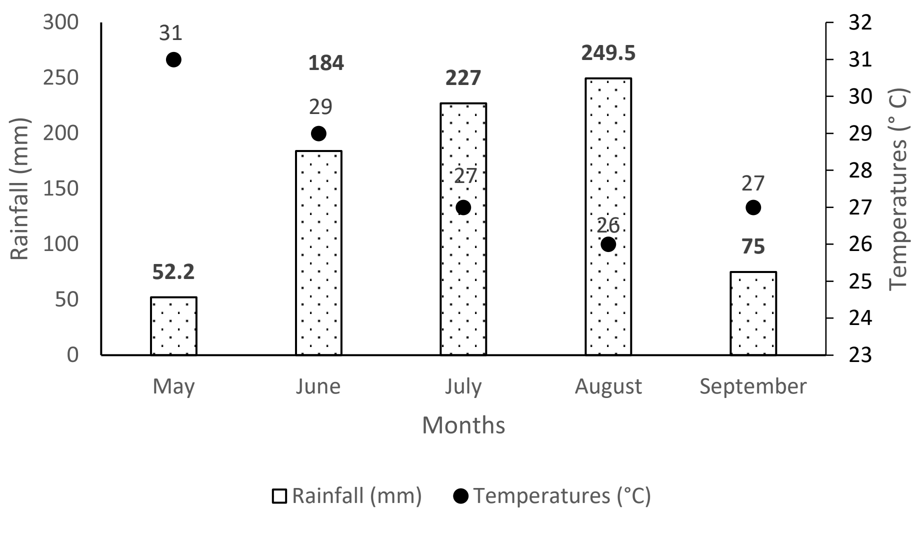

Fig. 1. Average rainfall and temperature of experimental site

Data source: Centre-Est meteorological station in 2021

2.2 PLANT MATERIAL AND FERTILIZER

Plant material of our study consisted of two Bambara groundnut varieties KVS235 and KVS246, respectively a cream-colored line variety and a cream-colored population variety with black markings selected in Institute of Environment and Agricultural Research of Burkina Faso (INERA). The cycle of both varieties is 90 days. The fertilizer used is a natural rock phosphate finely grinded (Burkina Phosphate "BP"). According to Mining society of the Phosphates of Burkina Faso, the characteristics of BP was in %: 28.35 (P_2O_5); 42.79 (CaO, Lime); 18.52 (SiO_2); 1.75 (Fe_2O_3); 3.09 (Al_2O_3); 0.31 (MgO); 0.03 (MnO); 0.48 (K_2O); 0.22 (Na_2O); 0.27 (TiO); 5.40 (loss on fire); 0.03 (water solubility).

2.3 EXPERIMENTAL DESIGN AND TREATMENTS

Experimental design used for the study was a completely randomized block design with four replications. It consisted of four blocks arranged along the length of the slope of the land. The dimensions of the design were 15.8 m long and 13.2 m large. In total, there were ten elementary plots of 1.2 m wide and 2 m long each. Interval between elementary plot was 0.8 m and blocks were separated by 1 m alley. Two factors were applied to each block: variety and Burkina Phosphate (BP). The treatments were composed of a combination of two varieties of Bambara groundnut (KVS 235, KVS 246), and five level of fertilization consisting of 0 (BP0), 30 (BP30), 60 (BP60), 90 (BP90) and 120 (BP120) kg ha^{-1} of Burkina Phosphate.

2.4 PHYSICAL AND CHEMICAL CHARACTERIZATION OF THE SOIL

The soil of experimental site has consisted to digging of a pedological pit. Soil and their environment were described according to the FAO soil description guidelines ([25]) and classified according to the French classification ([26]). A correlation with the World Reference Base ([27]) was also proposed. Soil samples were collected by layers, air-dried and sieved to 2 mm for analysis. Soil layers particles sizes was measured by Pipette Robinson method at 3 fractions. pH was determined by AFNOR method ([28]). Total carbon content is determined by the Walkley and Black ([29]) method. The determination of the total carbon permits to calculate total organic matter rate. Total nitrogen, phosphorus and potassium by KJELDAHL method ([30]).

2.5 FIELD MANAGEMENT

Seedbed preparation consisted of a plane tillage with a disc harrow connected to a tractor. Doses of Burkina phosphate (BP) were applied as a basic manure at Sowing (spreading and burying method). Sowing was carried out on July 7, 2021 and was done at one seed per hole. Spacing of sowing was 40 cm between the line and 20 cm between hole at same line. Two manual weeding were carried out respectively on the 15th and 30th day after sowing (DAS) to reduce the competition between crop and weeds for soil resource. A mounding was carried out manually on the 49th DAS in all elementary plots. The aim was to favor the burying of young pods in formation and their development. Phytosanitary treatment was not applied.

2.6 DATA COLLECTION

Data were collected according to two treatments (BP fertilization and varieties). Data was considered about yield-related traits of Bambara groundnut. The emergence rate at 21 DAS (EMG21) of the percentage of Bambara groundnut plants that emerged per plot (treatment and variety). Plant height (PlH) and spread width (PlS) in cm consisted of measuring the crown heights and widths of 5 plants per treatment at 70 DAS. Assessment of nodule numbers (NN) and nodules dry weight (NDW) in mg and Plant dry weight at flowering stage (PDWf) in g consisted of careful digging of 3 Bambara groundnut plants per unit plot at the stage when 50% of the plants had emitted their first flower. The nodules were detached, counted and dried in filter papers and plant biomass at flowering (shoot and root biomass) was sun-dried. At maturity, plant biomass (shoot and root biomass) and pods per unit plot were harvested, sun-dried for three (03) weeks and weighed. The harvest yields in t ha^{-1} of plant dry weight (PDWh), pods (PY) and seeds (SY) of Bambara groundnut were evaluated. Pod length (PLen) and width (PWid) in mm of 10 randomly selected were measured with a caliper. The length (SLen and width (SWid) in mm of the 10 seeds corresponding to these pods were also measured. All dry measurements were done by ensuring that each sample had a constant weight.

2.7 STATISTICAL ANALYSIS

Statistical analysis of data including analysis of variance (ANOVA) and comparison of means was performed using XLSTAT 2021 4.1 (ADDINSOFT, 2021). ANOVA was used to detect varieties, treatments, and their interactions effects while Tukey's test was used to compare means at 5% significance threshold. Principal component analysis (PCA) was performed to show the relationship of Bambara groundnut yields parameters and interactive between varieties and treatments with Pearson correlation.

3 Results And Discussion

3.1 Results

3.1.1 Physico-Chemical Characteristics Of Experimental Site Soil

The characterization of environment of experimental site soil showed that it belongs to a savanna park with *Azadirachta indica, Eucalyptus camendulensis, Lanea microcarpa, Vitellaria paradoxa, Diospyros mespiliformis*. The herbaceous carpet is mainly composed of *Senna obtusifolia, Hibiscus Esculantus*. The environment is highly anthropized with a low slope (< 1%) and a quasi-flat topography.

The physical properties of the soil in the trial showed that it consists of 2 layers supported on a ferruginous shell (plinthite) of layer 3 (Figure 2). The surface layer (layer 1) is 0 - 16 cm depth. The soil texture at the experimental site was sandy, with sand, silt and clay contents of 86.5 and 10% by volume (Table 1). Its dry color of pink (5YR7/4) and moist of strong brown (7.5YR5/8). The structure is particle and friable. This layer has very numerous and small pores, very small and very many roots. Biological activity is well developed with excessive to perfect drainage. The succession with layer 2 is irregular. Layer 2 was 16-36 cm depth. The texture was sandy-clay, by sand, silt and clay contents of 50, 10 and 40% by volume (Table 1) with a dry color of yellowish red (5YR5/6) and moist of strong brown (7.5YR5/6). The structure of this layer is few massive, polyhedral sub-structure with the presence of about 30% of ferruginous nodules. This layer has a low hardness. We note the presence of many medium and large pores with numerous roots. Drainage is perfect and limited by the plinthite of layer 3 (Figure 2).

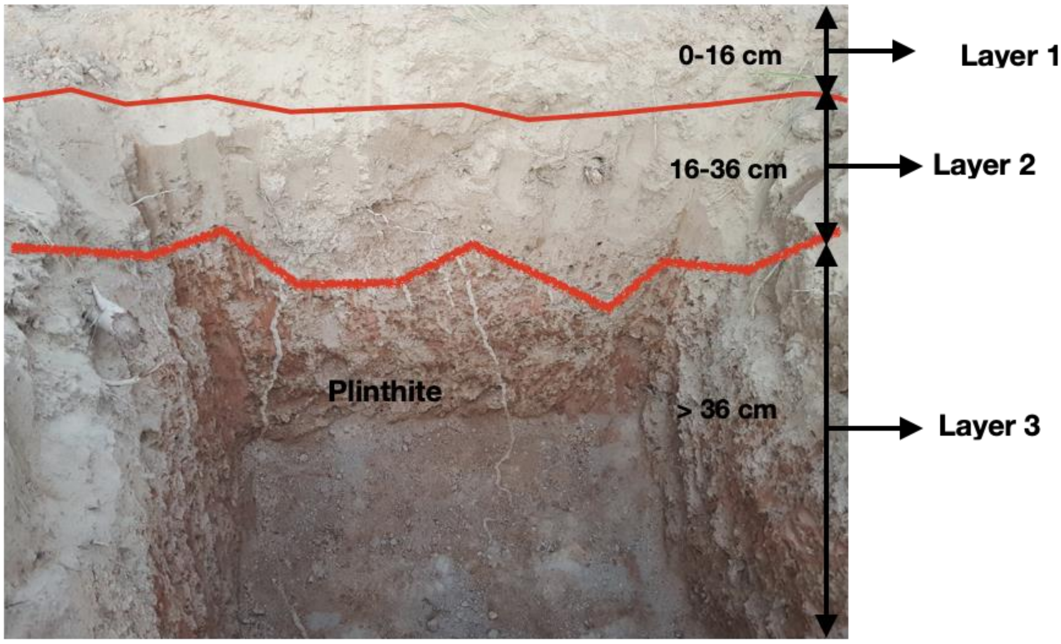

Fig. 2. Profile of experimental site soil

The particle size, texture, contents of totals organic matter, carbon, nitrogen, phosphorus, pH (H_20) and KCl of experimental site soil are recorded in Table 1. Total organic matter, carbon, nitrogen and phosphorus of 2 layers was slightly different. The soils at the experimental site are acidic with a slight accentuation in the 10-30 cm depth layer compared to the 0 - 10 cm depth layer. The potassium content is about 2 times higher in the lower layer (10 - 36 cm depth) compared to the upper layer (10 - 36 cm depth).

Table 1. Physical and chemical properties of the soil of experimental site

Property	Value obtained	
Soil layer (cm)	0-10	10-36
Sand (%)	86	50
Silt (%)	5	10
Clay (%)	10	40
Soil textural class	Sand	Sandy-Clay
Total Organic Matter (%)	0.38	0.42
Total Carbon (%)	0.22	0.24
Total Nitrogen (%)	0,02	0.02
C/N	11	14
Total Phosphorus (mg Kg^{-1})	218.40	273,00
Total potassium (mg Kg^{-1})	544.11	1165,96
pH (H_20) (W/V: 1/2.5)	5.81	5.53
pH (KCl) (W/V: 1/2.5)	5.39	5.30

3.1.2 Effects Of Treatments On The Yield-Related Traits Of Bambara Groundnut

Overall effects of treatments

In table 2, mean values of emergence rate at 21 days after sowing (EMG21), plant height (PlH) and Plant spread (PlS); pod length (PLen) and width (PWid); and seed length (SLen) and width (SWid); number (NN) and dry weight (NDW) of nodules; Plant weight at flowering stage (PWf); Plant weight (PDWh), pods (PY) and seed yields (SY) at harvest stage were not significantly affected by all treatments. BP120 and BP60 performed better the PWid by 13% compared to control BP0 (Table 3). BP120, BP90, BP60 improved PDWf by 7, 9 and 8% respectively compared to the control. An increase of 10% of PDWh was recorded under BP30 compared to the control. Except BP90 that increased NN by 8%, all other BP treatments negatively affected NN compared to the control. All BP treatments induced a depressive effect on NDW, PY and SY of Bambara groundnut compared to the control. PlS, PLen, PWid, SLen, SWid was increased under all BP treatments compared to control.

Effects of treatments per varieties

The yield-related traits of Bambara groundnut by variety were not significantly different under treatments (Table 2). The results showed that compared to the control BP0, the highest performance for the KVS246 variety at 27% of PWid under BP60; 38% of NN and 37% of NDW under BP90; 14% of PDWf under BP90; 32% of PDWf under BP30; 5% of SY under BP120 was obtained. PLen, SLen, PDWf and PDWf was increased by all BP treatments compared to control under KVS246. Better performance for KVS 235 was increasing of 12% of EMG21 and 18% of PWid; 26% of NN under BP120; 9% of PDWf under BP60 and BP90 respectively; 5% of PY and 4% of SY under BP30 compared to BP0. PlS was increased by all BP treatments compared to the control under KVS235.

Interactive effects between treatments and varieties

Mean values of yields-related traits of Bambara groundnut did not significantly affect by interactions between varieties and treatments (Table 2). Comparing the effects of the same treatment following to the 2 varieties, KVS246 was better performed by increasing 13% of EMG21; 11% of PlH; 43% of NN; 48 of NDW; 16% of PY; 15 % of SY under BP90; 9% of PlS under BP 0; 27% of PWid under BP 60; 4% of SLen and SWid under BP120 compared to KVS235. BP90 had positive effect on all yields-related traits with KVS246 variety compared to KVS235.PlH, PlS, PDWf of KVS246 variety was increased under all treatments compared to KVS235. The variety KVS235 performed better than KVS246 by increasing 8 % of EMG21; 18% of PWid; 133% of NN; 45% of NDW under BP120; 15% of PY; 20% of SY under BP30; 48% of NDW; 51% of PDWh under BP0.

Table 2. Effects of treatments and their interaction between varieties on the yield-related traits of Bambara groundnut

Yield-related	EMG21	PlH	PlS	PLen	PWid	SLen	SWid	NN	NDW	PDWf	PDWh	PY	SY
traits	(%)	cm		mm					mg	g	t ha^{-1}		
Overall effects of treatments													
BP120	91	20,18	41.55	15.23	13.74	10.33	8.94	28.38	186.00	22.62	2.78	2.78	2.14
BP90	83	21.03	42.45	15.50	12.43	10.57	9.09	31.88	201.01	23.13	2.73	2.51	1.92
BP60	88	20.80	40.89	15.13	12.09	10.25	8.72	28.25	177.28	22.88	2.75	2.75	2.12
BP30	88	20.35	40.78	15.14	13.74	10.39	8.70	26.29	156.39	21.00	3.32	2.74	2.06
BP0	87	21.23	40.68	14.98	12.01	10.24	8.68	29.25	218.88	21.00	2.98	2.91	2.19
P	0.40	0.33	0.80	0.26	0.53	0.30	0.06	0.99	0.86	0.63	0.48	0.66	0,68
Significance	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Effect per varieties													
KVS 246													
BP120	88	20.75	42.00	15.64	12.62	10.57	9.13	18.75	160.63	23.25	2.92	2.94	2.23
BP90	88	22.25	43.50	15.78	12.73	10.69	9.08	42,00	281.90	24.67	2.81	2.70	2.08
BP60	92	21.00	42.67	15.48	16.62	10.60	8.65	26.75	170.20	23.00	2.73	2.73	2.05
BP30	85	21.25	41.50	15.22	12.16	10.39	8.68	27,00	158.98	22.00	3.51	2.65	1.97
BP0	88	22.00	41.75	15.05	12.16	10.26	8.63	26.25	176.65	21.25	2.37	2.94	2.13
P	0.62	0.71	0.92	0.14	0.22	0.52	0.09	0.63	0.61	0.83	0.38	0.92	0.93
Significance	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
KVS 235													
BP120	95	19.60	41.10	14.81	14.86	10.10	8.75	43.67	233.27	21.33	2.50	2.65	2.10
BP90	77	19.80	41.40	15.21	12.14	10.46	9.10	24,00	145.40	22.75	2.70	2.27	1.76
BP60	85	20.20	40.30	15.04	12.06	10.33	8.78	29.75	184.35	22.75	2.81	2.77	2.20
BP30	90	20.65	40.80	15.24	12.16	10.37	8.82	20.50	121.38	20.00	3.25	3.04	2.36
BP0	83	20.07	38.20	14.99	12.12	10.41	8.95	32.25	261.10	20.75	3.59	2.88	2.26
P	0.26	0.80	0.70	0.55	0.52	0.59	0,48	0.71	0.52	0.75	0.18	0.38	0.38
Significance	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interactive effect between treatments and varieties													
P	0.43	0.43	0.30	0.94	0.07	0.43	0.59	0.85	0.71	0.72	0.29	0.73	0.70
Significance	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

0 (BP0), 30 (BP30), 60 (BP60), 90 (BP90) and 120 (BP120) kg ha^{-1} of Burkina Phosphate. EMG21: emergence rate at 21 days after sowing; PlH: plant heights; PlS: plant spread; PLen: pod lengths; PWis: pod widths; SLen: seed lengths; SWid: seed widths; NDN: nodule number; NDW: nodule dry weight; PDWf: Plant dry weight at flowering stage; PDWh: yields of Plant dry weight at harvest; PY: pod yields; SY: seed yields. P = Probability according to ANOVA at 5% level of significance. P ⩾0.05: No significant (NS).

3.1.3 PCA Between Interactive Of Varieties And Treatments On The Yield-Related Traits Of Bambara Groundnut Yields

The results of principal component analysis (PCA) showed that the two dimensions (axis F1; axis F2) contribute to explain 56.36 % of data variance (Figure 2). Variables of EMG21, SLen, NN, NDW, PDWf, NN of Bambara groundnut are positively correlated of dim 1 with R^2 of 0.39; 0.65; 0.80; 0.51; 0.36; 0,80 respectively. Interactions between varieties and treatments KVS 246*BP60 (R^2 =0.76) and KVS 235*BP120 (R^2 = 0.55) were also highly and positively correlated to axis F1, but negatively to KVS 246*BP30 (R^2 = 0.75). Axis F2 was positively and highly correlated by PLen, PWid, SWid at respectively R^2 = 0.74; 0.76; 0.87 and KVS 246*BP90 ($R^{2=}$ 0.56) but negatively to KVS 235*BP0 (R^2 = 0.55).

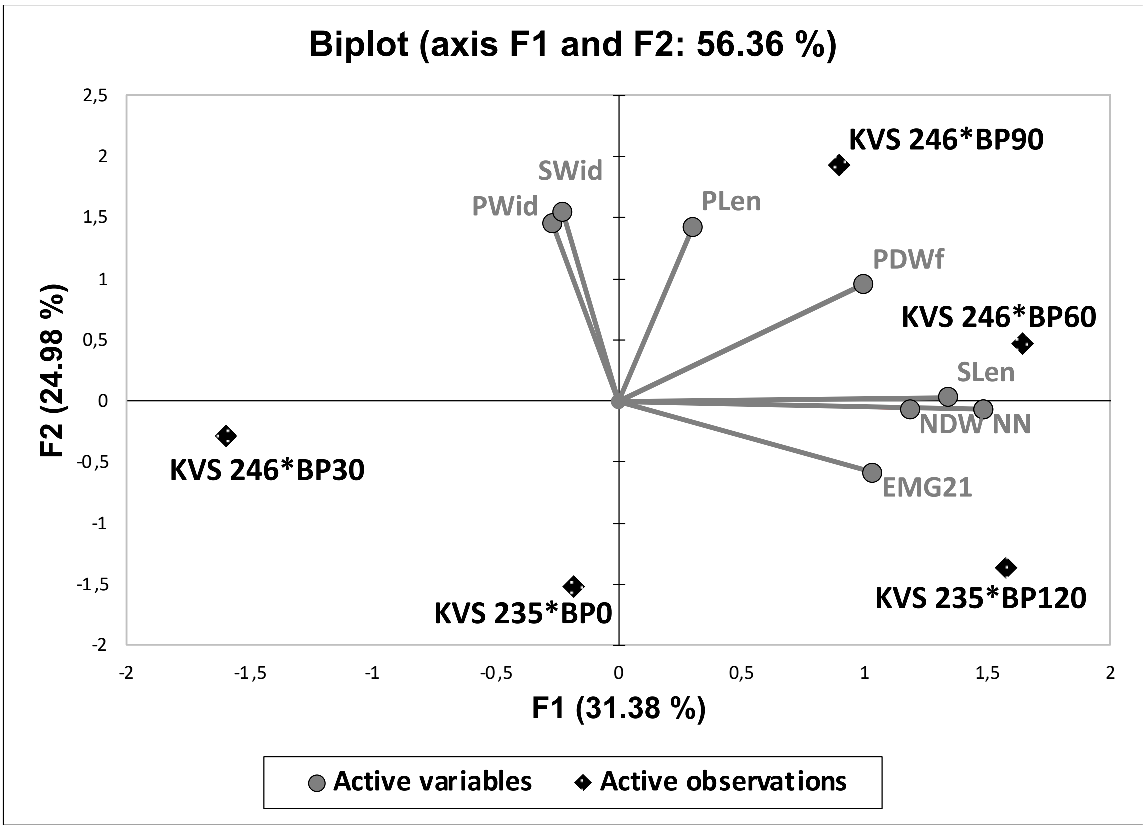

Fig. 3. Principal component analysis between the yield-related traits of Bambara groundnut and interactive of varieties and treatments

0 (BP0), 30 (BP30), 60 (BP60), 90 (BP90) and 120 (BP120) kg ha^{-1} of Burkina Phosphate. EMG21: emergence rate at 21 days after sowing; PlH: plant heights; PlS: plant spread; PLen: pod lengths; PWis: pod widths; SLen: seed lengths; SWid: seed widths; NDN: nodule number; NDW: nodule dry weight; PDWf: Plant dry weight at flowering stage; PDWh: yields of Plant dry weight at harvest; PY: pod yields; SY: seed yields.

4 DISCUSSION

This soil belongs to the iron and manganese sesquioxides soils class and specifically to shallow leached ferruginous tropical soil according to the French classification ([26]). Based on equipotentiality's, this soil would correspond to an endo petroplinthic lixisol according to World Reference base of soil classification ([27]). These ferruginous tropical soils are characterized by a sandy, low in organic matter and base exchange capacity ([31]). Soil of experimental site is acidic and their total carbon, nitrogen, phosphorus and potassium are low according to interpretation standards of Burkina Faso National Soil Office ([32]). The sandy to sandy-clay texture and the well-drained of this soil prevent clogging and promotes pod penetration soil. This texture makes it potentially suitable for Bambara groundnut cropping. Sandy soils with light textured are the best for the production of Bambara groundnut and the optimal depth of the soil recommended is between 50 and 100 cm ([33]). However, it can grow on sandy-to-sandy loam and well-drained soil ([34]) and which make it easier to harvest ([35]). The ideal soil pH range for cropping is 5.0 to 6.5 ([34], [8]) and should not be less than 4.3 or greater than 7 ([35]). Also, Bambara groundnut can meet its nitrogen requirement from N_2 fixation and soil mineral N, and there is no need for supplementary mineral N fertilizer. Nitrogen requirement is provided by natural N_2 fixation with nitrogen–fixing bacteria belonging to the genus *Rhizobium* ([36]). High nitrogen level mostly leads to few pods production ([37]). Also, acidification of the rhizospheric soil of legumes as a result of H_3O^+ proton excretion in response to its nitrogen-fixing activity ([38], [39]) results in an increase in the organic phosphorus pool that can lead to its phyto-availability. These soils under tropical and sub-tropical climates are often extremely P deficient with high P fixation as mostly acidic ([40], [41]). Phosphorus is deficient because soluble inorganic P is fixed by Al and Fe (Adnan *et al*., 2003 [42]). Phosphorus availability is maximized at pH 6.5 for mineral soils and pH 5.5 for organic soils ([43]). To reduce P fixation, it is necessary to apply large amounts of P fertilizer (rocks phosphate and Triple Superphosphate) and lime to saturate Al and Fe ions and increase the soil pH ([44]). In case of K, K^+ ions are entrapped by clay minerals is the fixation or immobilization that should be explained the high content of K under layer 2 with sandy-clay texture compared to layer 1 with sandy texture in experimental site soil. The availability of K depends upon the exchangeable K in soils and its release is facilitated by pH above 6.0, texture, and soil moisture ([45]). Soil K status is dynamic and determined by a number of factors such as soil texture, mineralogy, temperature, and pH ([46]). Moreover, the day temperature of 30 to 35 °C is considered as the optimum temperature for the growth of Bambara groundnut and also germination is being reduced at 15 °C below and 40 °C above ([8]). Under the full sun, 20 to 28 °C is the average day temperature and also 600 to 750 mm is the average annual rainfall is optimum condition for cultivating Bambara groundnut but higher rainfall than optimum level results better yield ([8]). In comparison, climate of experimental site with annual rainfall between 600 and 900 mm and temperature around 33 °C to 41 °C is adapted for Bambara groundnut cropping. The analysis and interpretation of physical and chemical properties of soil and climate of experimental site shows that it has pedo-climatic potentially for Bambara groundnut cropping after supply phosphorus.

The production of Bambara groundnut on this soil with a sandy surface texture and a sandy-clay depth shows that the Burkina phosphate treatments (BP30, BP90 and BP120) performed overall in increasing several yields-related traits compared to the control (BP0), although there is not significant effect between the different doses of BP applied. A glasshouse experiment using sandy clay loam soil and conducted in Malaysia showed that applying of 30 kg N ha^{-1} and P 60 kg P ha^{-1}) increased highly plant height (21.73 cm), leaves number (265.50) and leaf area (2802.9 cm^2) number of pod (41.75) and pod weight (49.68 g) of Bambara groundnut compare to control ([47]). Thus, these applications have increased the growth parameters, yield, nodulation, and nutritional composition of Bambara groundnut. Use of phosphate rocks, has been also reported to increase crop yields though their reaction is slow in releasing available P ([48], [49]). Except BP30 treatment, all treatments had a depressive effect on plant height compared to control BP0. It showed that phosphorus discriminated most traits of Bambara groundnut except plant height. Also, all Burkina phosphate treatments had a depressive effect on nodulation (nodule numbers and dry weight), pod and seed yields of Bambara groundnut compared to control, excepted BP90 that increase nodule numbers. This shows that phosphate applying did not have a positive effect on theses yields-related traits regardless of the varieties. According to a part of results, Bambara groundnut at 0 kg P ha^{-1} had a significantly higher number of nodules (1.50 ± 0.93) compared to the 0.23 ± 0.37 nodules recorded at 25 kg P_2O_5 ha^{-1} in Kenya ([50]). Bambara groundnut varieties yields-related traits were not significantly affected by any treatments. These varieties were not sensitive to the different doses of rock phosphorus applied but instead to the soil conditions of production. Interactions between phosphorus doses and varieties on yields-related traits also revealed no significant effect. These results are an accordance with those obtained by ([51]). They showed that yields of Bambara groundnut were not significantly affected by applying at sowing of P_2O_5 (0, 45, 60 and 75 kg ha^{-1}) on sandy loam soil texture in south eastern of Nigeria. Principal component analysis showed that KVS246 outperformed than KVS235 because it positively affected several the yield-related traits of Bambara groundnut. These results also showed that KVS246 would better interact with applying 60 kg ha^{-1} (BP60) and 90 kg ha^{-1} (BP90) and KVS246 under 120 kg $ha^{-1}$of Burkina Phosphate (BP 120) to improve Bambara groundnut yields compared to control. Furthermore, no-significant differences recorded following Burkina Phosphate supply could be explained by the low dissolution and mineralization capacity of Burkina Phosphate during the first year of application resulting in low phosphorus availability for good plant mineral nutrition. These results are similar to those of Somda ([52]) who showed that Burkina phosphate has a solubility that varies between 25 and 33% per year depending on rainfall and soil type, and did not have significant effects on maize and groundnut yields during first year application. Thus, the sandy texture of the soil, its particle structure and high porosity would have facilitated leaching of Burkina phosphate, making minerals few available for crops.

5 CONCLUSION

Climate and soil of experiment site are potentially suitable for Bambara groundnut cropping according to the result of study. On this acidic soil, poor in major mineral elements, with a sandy in surface texture and a sandy-clay in depth supported by plinthite, Bambara groundnut production was indifferent to the improvement yields under rock phosphate applying in one cropping year. However, Bambara groundnut variety KVS246 outperformed than KVS235 variety in increasing several Bambara groundnut yield parameters. Different doses of Burkina phosphate 90 and 60 kg ha^{-1} was improved several Bambara groundnut yield parameters with KVS246 contrary to 120 kg ha^{-1} for KVS235 variety. It is therefore important to lead investigations over several years to better understand the effects of these rock phosphate on both Bambara groundnut varieties and residual soil fertility.

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