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(RESEARCH ARTICLE)

Effect of NPK application dates on agronomic parameters of two Bambara groundnut varieties cultivated on ferric Lixisol in northern Sudanian Sector of Burkina Faso

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Abstract

Bambara groundnut is a neglected legume crop that contributes to improve global food and face food insecurity. In Burkina Faso, research on Bambara groundnut cropping system were essentially focused on mounding times. Less attention has been paid on the application of fertilizers. Experiments was carried out on the site of Tenkodogo University Centre (11°48'37''N, 0°22'19''W), Burkina Faso to study the response of two Bambara groundnut varieties to different NPK application periods. The experiments consisted of a factorial combination of two factors, including the varieties (KVS 235 and KVS 246) and the different NPK application dates (At basal, 7, 15 and 21 days after sowing) in completely randomised blocks with three replications. Characters were collected, including plant height and spread, total biomass at flowering, stalks weight, yield-components and yield. The results indicated that most of characters not varied significantly for both varieties whatever NPK application period except for stalks weight (P = 0.013). The interactions between varieties and NPK application dates had significant effects for only total biomass at flowering (P = 0.048). In addition, pod length has significant effect (P = 0.032) between varieties. The significant effect on the characters mentioned above in both varieties implies that application of NPK fertilizer have influenced the characteristics differently, depending on the period of bringing. NPK application at basal lead to best performance of the results regarding pod and seed dimension and 100-seeds weight and yield. In general, KVS235 outperformed than KVS 246.

Keywords: Bambara Groundnut; Burkina Faso; Fertilizer; NPK; Varieties; Yields

1. Introduction

Bambara groundnut (*Vigna subterranea* [L.] Verdc.) is a legume native to Africa and is grown throughout the semi-arid region of Sub-saharan Africa [1]. Although a neglected crop, Bambara groundnut can play a role in addressing food

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insecurity and malnutrition at the household [2]. It has high protein value, thus, can be used by poorer people in Africa to replace expensive animal protein [3]. In Sub-saharan Africa, Bambara groundnut is cultivated principally by farmers as a famine culture crop. It has outstanding agronomic potential and the ability to produce in soils considered insufficiently fertile. In these soils, Bambara groundnut can improve the characteristics of soil as a good source of nitrogen for the plant [4]. Thus, it has the potential to support sustainable land care in Sub-saharan Africa with more 40% of soils exhibit nutrient depletion [5, 6]. Sanchez [7] reported average annual nutrient depletion rates of 22 kg N ha^{-1}; 2.5 kg P ha^{-1}; 15 kg K ha^{-1} in 37 Africa countries. Studies have also shown negative balance of nitrogen, phosphorus and potassium in most Sub-saharan African countries [8, 9]. Similarly, annual nutrient losses were estimated to 7.9 Mt of NPK in Africa, six times the annual fertilizer consumption [10], strongly underscore the gravity of the problem.

Since Bambara groundnut is a minor crop, relatively less attention has been paid on the application of chemical fertilizer [11] in most of the farms, and this made its production to be marginal. Hence, it needs a minimum of NPK mineral to better express its agronomic potential. Studies have shown the effectiveness of NPK mineral fertilization on Bambara groundnut yields. In fact, application of nitrogen and phosphorus fertilizer increases the growth and yield of Bambara groundnut [12]. In Malaysia, Hasan et al. [13] showed that application of N30 + P60 kg/ha highly increased number of pods per plant, 100-seeds weight and number of seeds per pod. In Nigeria, experiment indicated that 10 g of NPK improved growth, number of leaves and fresh and dry Biomass compared to 10 g of Cow Dung fertilization [14]. Moreover, Jakusko and Dakato [15] has reported a significant effect on the number of pods/plant, the seed weight and 100-seeds weight of Bambara groundnut with NPK fertilizer. Although these results are conclusive, the judicious use of NPK fertilizer and the good time of his application to maintain soil fertility and improve Bambara groundnut yields have been rarely examined by research. In addition, Akombo and Asema [16] reported that Bambara groundnut need fertilizer for high seed yield, the use of mineral fertilizer for the production of this crop has rarely been practiced. Hence, it is necessary to determine the date of application of mineral fertilizer NPK for optimal production of Bambara groundnut.

2. Material and methods

2.1. Site description and soil characteristics

This study was carried out at the experimental field of Tenkodogo University Centre (11°48'37''N, 0°22'19''W) in the East-centre region, Burkina Faso. Climate of this region is Sudano-sahelian type characterized by annual rainfalls between 600 and 900 mm. Insolation is 7 - 8 h day^{-1} with low humidity. In 2021, rainfalls recorded were 787.7 mm with 52.2 mm on May against 249.5 mm on August. Temperature was ranged from 26 °C (August) to 31 °C (May).

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

The physical properties of the soil showed that it consists of two layers (0 - 10 and 10 - 36 cm depth) supported by plinthithe characterized by ferric lixisol. Soil analysis of the experimental site showed details on the particle size, texture, contents of totals organic matter, carbon, nitrogen, phosphorus, pH (H_20) and KCl, in table 1 [17] suitable for Bambara groundnut cultivation. Total organic matter, carbon, nitrogen and phosphorus of 2 layers was slightly different. The soils of 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 two times higher in the lower layer (10 - 36 cm depth) compared to the upper layer (10 - 36 cm depth). The soil total carbon, nitrogen and phosphorus contents are low according to interpretation standards of Burkina Faso National Soil Office [18]. Otherwise, the sandy surface texture of this soil makes it well drained and favors pods penetration in the soil.

2.2. Treatments and agronomic practices

The experiments consisted of factorial combination of two factors with different levels. (i) The first factor consisted of two varieties, KVS235 and KVS246 developed by Institute of Environment, and Agricultural Research. The KVS235 variety has a white seed coat without eye, while KVS246 has a brown seed coat with an eye like a butterfly. KVS235 has been purified and is phenotypically homogeneous. On the other hand, KVS246 is a population variety that is not homogeneous. (ii) The second factor consisted of four different dates of NPK (14-23-14) application, viz. at basal, 7, 15 and 21 days after sowing (DAS). NPK was hand broadcasting at the rate of 75 kg ha^{-1}. Experiments were laid out in randomized complete blocks design with three replications. Each block was made up of eight elementary plots measured 2 m x 1.2 m. The spacing between rows were 0.8 m and 1 m between the replication. Soil preparation consisted of flat plowing with a tractor on 1st July, followed by hand striping. Sowing was done at one seed per hole on July 04, 2021, on 0.4 x 0.2 m spacing. Forty-four seeds of Bambara groundnut were sowed per plot. Plot management consisted of three manual weedings that were performed as needed. Mounding was carried out on the 49th day after sowing (DAS).

2.3. Data collection and analysis

Data collection was carried out according to the Bambara groundnut descriptor [19]. Eleven characters were recorded. The characters measured during the vegetative stage were plant height (cm), plant spread (cm) and total biomass at flowering (g). After harvest the pods and stalks were dried to constant weight before get into measurement. Post-harvest measurements were made on the pod length (mm) and width (mm), seed length (mm) and width (mm), 100-seeds weight (g), weight of seeds per plant (g), stalks weight (g), and the yield (kg ha^{-1}) was calculated. Statistical analyses were performed with mean values per plot and per block. Data collected were subjected to an analysis of variance using Genstat V12ed software to reveal differences between characters for different treatments. The significance of the effect of the treatments was determined using a F-test at P = 5%.

3. Results and discussion

3.1. Effect of NPK application dates on plant height, plant spread and total biomass at flowering

The results of the analysis of variance are shown in table 2. The characters plant height, plant spread and total biomass at flowering are not significantly influenced by different dates of application of NPK fertilizer (at basal, 7, 15, 21 DAS) and the varieties (KVS235 and KVS246) at 5% probability treshold (Table 2). The results of the study indicated that whatever the NPK application period, these characteristics remain the same for both varieties. The overall values of plant height (KVS235 = 17.45 cm ; KVS246 = 17.32 cm) and plant spread (KVS235 = 32.78 cm ; KVS246 = 31.53 cm) are very closed. The reason could be attribute to the fact that major nutrient which influenced the growth of Bambara groundnut is nitrogen. This result is not surprising because NPK fertilizer contains the essential nutrients Nitrogen, Phosphorus and Potassium, which are macro elements required for the growth of plants [20]. Since Bambara groundnut is able to fix atmospheric nitrogen for its nutrition, all the plants benefit from important amount of nitrogen for growth. Bambara groundnut can fix 20 to 100 kg N ha^{-1} [21] and improves soil nutrient status, especially nitrogen, through its nodulation process that traps nitrogen from the atmosphere. This nitrogen is relevant for the enhancement of vegetative growth as it provides the basic constituents of protein and nucleic acid [22]. The results are similar of those obtained by Diagara et al. [23] on the characterization of 30 Bambara groundnut accessions from Niger. The global mean values for both varieties showed that the best performance in total biomass at the flowering is obtained when NPK is applied at 7 DAS (15.61 g) followed by 15 DAS (15.17 g) ; whereas the lowest values are recorded when NPK is applied at 21 DAS (12.33 g) (Table 2). The results are different from those of Zongo et al. [17] who found higher values of plant height and plant spread with different doses of rock phosphate applied at basal with the same varieties. Interactions between varieties and NPK application dates had significant effects for only total biomass at flowering (P = 0.048).

Table 2 Results of analysis of variance on the plant height, plant spread and total biomass at flowering

Source of variation		**Plant height (cm)**	**Plant spread (cm)**	**Biomass at flowering (g)**
Varieties	KVS235	17.45	32.78	14.69
	KVS246	17.32	31.58	13.75
	Probability	0.821	0.414	0.422
NPK application dates	At basal	17.17	31.57	13.78
	7 DAS	17.40	30.40	15.61
	15 DAS	17.57	33.03	15.17
	21 DAS	17.40	33.73	12.33
	Probability	0.969	0.383	0.216
Interaction NPK * Variety	Probability	0.611	0.769	0.048*

Legend : **DAS :** Day after sowing ; ***** : Significant difference at *P* < .05 level

Total biomass value at the flowering increase according to the period of NPK application and depending on the variety. KVS235 had the highest biomass at flowering with the values of 18.78 and 15.22 g respectively when NPK is applied at 15 DAS and 7 DAS compared to the other treatments (Table 3). As for the variety KVS246, it showed a better biomass performance at the flowering when NPK was applied at the 7th DAS and at basal, with respective values of 16 and 14.67 g. In view of these results, it would be advisable to apply NPK early (≤ 15 DAS) as order to allow the plants to benefit as much as possible from the major elements provided by NPK resulting in better growth. Iluga et al. [24] in their works for understanding the best period of application of NPK fertilizer with two corn varieties in Congo reached to the same findings.

Table 3 Results of the analysis of variance of the variety x treatment interaction on total biomass at flowering

Interaction Variety*Treatment	**At basal**	**7 DAS**	**15 DAS**	**21 DAS**	**Probability**
KVS235	12.89	15.22	18.78	11.89	-
KVS246	14.67	16.00	11.56	12.78	-
Mean	13.78	15.61	15.17	12.33	0.048*

Legend : **DAS :** Day after sowing ; ***** : Significant difference at *P* < .05 threshold

3.2. Effect of NPK application dates on the pod and seed related-traits

The effect of different dates of NPK application on the pod and seed dimensions for the both varieties are shown in table 4. Pod length was significantly affected (*P* = 0.032). On the other hand, pod width, seed length and seed width had not significantly affected between the varieties in the overall way for all the treatments. The significant effect on the trait mentioned above between both varieties implies that the date of NPK application have influenced the characteristics differently, depending on the period of fertilizer bringing. The variety KVS235 has longer pods (15.33 mm) than KVS246 (14.90 mm).

The overall effect of varieties shows no significant difference between the different fertilization dates for pod and seed dimensions. These traits did not respond significantly to the different dates of NPK application. This could be attributed to low amount of rainfall fell during the flowering and fruiting stage. Vurayai et al. [25] stated that Bambara groundnut is more sensitive to water stress during reproductive growth stage. Many studies showed that plant metabolism, growth and development are adversely affected by water deficits, including stomatal control [26], leaf and flower growth and root development [27]. Furthermore, the soil has a very sandy texture (86 %) at a depth of 0 - 10 cm and a low organic matter content (0.38 %), resulting in rapid infiltration of water ; which results a permanent need of water for plants. However, we can note an increase of the pod length (15.44 mm), pods width (12.36 mm), seeds length (10.24 mm) and seed width (8.85 mm) when NPK is applied at basal. When NPK is applied at 7 DAS or at 21 DAS, there is a dropping of the pod length (14.95 mm) and width (11.7 mm). NPK application at 7 DAS showed negative impact on pod dimensions.

There was no significant effect in the two-way interactions between varieties and dates of NPK application for pod and seed related-traits

Table 4 Results of analysis of variance on the pod and seed dimensions

Source of variation		**Pod length (mm)**	**Pod width (mm)**	**Seed length (mm)**	**Seed width (mm)**
Varieties	KVS235	15.33	11.81	10.34	8.64
	KVS246	14.9	12.17	10.54	8.70
	Probability	0.032*	0.236	0.128	0.711
NPK application dates	At basal	15.44	12.36	10.24	8.85
	7 DAS	14.95	11.7	10.72	8.42
	15 DAS	15.07	11.95	10.4	8.67
	21 DAS	15.00	11.94	10.41	8.74
	Probability	0.249	0.447	0.093	0.203
Interaction NPK * Variety	Probability	0.101	0.385	0.071	0.084

Legend : **DAS :** Day after sowing ; ***** : Significant difference at *P* < .05 threshold

3.3. Effect of NPK application dates on the grain weight, stalks and grain yield

The results showed that different dates of NPK application had not affected significantly 100-seeds weight, seeds weight per plant, stalks weight and the yield (Table 5). Furthermore, the interactions between varieties and different dates of NPK application did not differ significantly. However, the results show significant effect between the varieties for the stalks weight (*P* = 0.013) for the global effect of treatments. The variety KVS235 has produced more stalks (765 g) than KVS246 (579 g). Although significant difference was not registered for grain yield between the varieties, there is an increase in yield for KVS235 compared with KVS246 by 13.36%. KVS235 is homogeneous variety developed on the basis of its interesting agronomic traits.

Table 5 Results of analysis of variance on the seeds weight, stalks and grain yield

Source of variation		**100-seeds weight (g)**	**Seeds weight per plant (g)**	**Stalks weight (g)**	**Grain Yield (kg.ha^{-1})**
Varieties	KVS235	53.67	20.33	765.00	2613.54
	KVS246	52.42	20.29	579.00	2305.56
	Probability	0.302	0.989	0.013*	0.086
NPK application dates	At basal	53.83	20.28	657	2635.42
	7 DAS	52.67	17.21	573	2340.97
	15 DAS	53.17	21.52	732	2426.39
	21 DAS	52.50	22.24	725	2435.42
	Probability	0.85	0.639	0.322	0.649
Interaction NPK * Variety	Probability	0.736	0.235	0.563	0.142

Legend : **DAS :** Day after sowing ; ***** : Significant difference at *P* < .05 threshold

This could be explained by the inherent characteristics of this variety and ability to uptake major nutrients in order to increase its yield. The overall effects of the different treatments gave satisfactory 100-seeds weight (KVS235 = 53.67 g) and yield (KVS235 = 2613.54 kg ha^{-1} and KVS246 = 2305.56 kg ha^{-1}) compared the results obtained by Massawe [28] on two varieties DodR1995 and LunT1995 (100-seeds weight = 30.80 g). In addition, Ouedraogo et al. [29] working on mounding time obtained low values of 100-seeds weight (KVS235 = 50.33 g) and yield (KVS235 = 1083.50 kg ha^{-1} and

KVS246 = 1244.80 kg ha^{-1}). Otherwise, KVS246 recorded a lowest value of 100-seeds weight (52.42 g) compared the findings of Ouedraogo et al. [29] (54.61 g). Research carried out by Wiggleswort [30] on six Bambara groundnut landraces from Botswana showed a low value of 100-seeds weight range to 30.7 - 49 g with a mean of 38.90 g and high mean value of weight of seeds per plant (102.10 g) with a range of 84.10 - 121.80 g. This high value of seeds weight per plant is due to the high number of pods produced, which has tremendous influenced on seeds weight per plant. As regards of the treatments, application of NPK at basal recorded the best performances for 100-seeds weight (53.83 g) and the yield (2635.42 kg ha^{-1}). Ilunga et al. [24] report that the application of NPK at sowing is very advantageous if it is not followed by a dry period.

Treatment effects showed that minimum weight of grains per plant (17.21 g) and low stalks weight (573 g) were observed with the fertilizer application at 7 DAS. NPK application at basal had the highest increased yield (2635.42 kg ha^{-1}) in comparison with the application at 7 DAS (2340.97 kg ha^{-1}), 15 DAS (2426.39 kg ha^{-1}) and 21 DAS (2435.42 kg ha^{-1}). Each NPK application date recorded satisfactory overall yield values compared to previous studies undertaken by Ouédraogo et al. [31] ; Nandkangre et al. [32] and Zongo et al. [17].

4. Conclusion

The current research was undertaken to evaluate the behavior of two Bambara groundnut varieties KVS235 and KVS246 under the effect of different dates of NPK application viz. at basal, 7, 15, 21 DAS. The results obtained showed that NPK application at basal lead to the best performance regarding the pod and seed dimension, the 100-seeds weight and the yield. Comparison of the two varieties shows that KVS235 performs better under the overall effect of the different treatments compared. Most of the interactions between the varieties and the fertilizers date of application had not affected significantly the traits considered in this study except for the total biomass at the flowering.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare that they have no conflicts of interest.

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