EFFECTS OF PHOSPHORUS FERTILIZER AND VARIETAL DIFFERENCE ON COWPEA (*VIGNA UNGUICULATA* (L.) WALP.) GROWTH, NUTRIENT UPTAKE, AND SOIL CHEMICAL PROPERTIES OLUFADE,

A. O. AND *ATERE, C. T.

Department of Soil Science and Land Resources Management, Obafemi Awolowo University, Ile-Ife, Nigeria.
**Corresponding author: cornelatere@oauife.edu.ng, +2348030720067*

ABSTRACT

The study evaluated the influence of varietal difference and phosphorus (P) fertilizer rates on cowpea growth, nutrient uptake and soil chemical properties. Three kilogramme of an Ultisol was sampled from 0–15 cm depth at the Teaching and Research Farm of the Obafemi Awolowo University, Ile-Ife, and amended with single super phosphate at the rates of 0 (SP0), 20 (SP1), 40 (SP2) and 60 (SP3) kg P ha^{-1}, respectively. The soil was maintained at two seedlings of cowpea per pot for two consecutive 8-week planting periods. After each cropping, agronomic parameters (plant heights (PLHT), number of branches (NOB), number of leaves per plant (NOLF), dry matter yield (DMY), plant tissue nutrients (N, P, K, Ca, Mg), and soil chemical properties (pH, soil organic matter, available P, exchangeable cations) were determined. Results showed that soil exchangeable cations were statistically similar among phosphorus rates. produced similar effects on Increases in agronomic parameters such as PLHT, NOB and NOLF were obtained with SP1, SP2 and SP3 over the control. While the tissue contents of N, Ca, and K were similar among the fertilizer treatments, the tissue contents of P and Mg were significantly increased by SP2 at the second planting. The DMY and shoot uptake of N, P, Mg and Ca were increased ($p<0.05$) by the variety TVX 113 and fertilizer treatment SP2. Considering the superior performances of cowpea variety TVX 113 and phosphorus application rate of 40 kg P ha^{-1} on most measured plant agronomic traits and soil properties, they are recommended for enhanced cowpea production.

Keywords: ***Cowpea, nutrient uptake, phosphorus fertilizer, cowpea growth***

INTRODUCTION

Several millions of people in West and Central Africa depend on farming systems that include cowpeas (*Vigna unguiculata* (L.) Walp) cultivation. Given that it is a less expensive source of protein and rich in nutrients, cowpea grain benefits both rural and urban consumers (Anyango *et al*., 2011; Carneiro da Silva, 2019). Cowpeas come in a number of edible forms, including young, delicate leaves, green seeds, and immature green pods. Dried seeds are used in more than 50 distinct culinary traditions (Quaye *et al*., 2009; Boukar *et al*., 2011). Cowpea in addition to being nutritious, complements the cereal protein. Cowpeas are farmed on over 14.5 million hectares of land globally with grain production of more than 6.5 million metric tons (Quaye *et al*., 2009; Boukar *et al*., 2011). Despite being the largest producer of cowpea in the world, Africa's average cowpea yield per hectare remains very low due to poor soil nutrient status (Anago *et al*., 2021).

Among the nutrients in high requirement by plants is phosphorus (P). It is one of the most crucial soil elements for the development of plants, particularly legumes, and it is only second to nitrogen in crop performance (Halder and Panda, 2014). According to several studies, P has been reported to promote the growth of lateral, fibrous, and adventitious roots, which are crucial for N_2 fixation, and nutrient and water uptake (Niu *et al*., 2012; Mohammed *et al*., 2020). Because it promotes growth, kick-starts nodulation, and affects the effectiveness of the rhizobium-legume symbiosis, P is essential in increasing cowpea biomass and crop yield (Haruna and Usman, 2013). Hence, low P availability to legumes that depend on symbiotic nitrogen fixation may result in nitrogen deficit due to ineffective N_2 fixation (Tairo and Ndakidemi, 2013). According to Kamara *et al*. (2008), the most common nutrient stress for the growth and development of grain legumes is P deficit.

Despite the importance of P to legume production, P is often low in many tropical soils due to its fixation by Al and Fe in highly weathered tropical soils (Brenner *et al*., 2018; Hanyabui *et al*., 2020) or its existence in an unavailable form as phosphate minerals which constitutes most of the P in soils (Marschner, 2012). Hence, despite cowpeas being able to supply most of their nitrogen needs through fixation, there is the need for external input of appropriate rates of P capable of ensuring effective cowpea growth and yield (Nkaa *et al*., 2014) while also improving and preserving the soil properties. In the current study, we hypothesized that P fertilization would enhance cowpea growth and soil chemical properties. The objectives of the study were to determine the (i) appropriate rate(s) of P fertilization that would enhance growth and nutrient uptake of two cowpea varieties, and (ii) effect of P fertilization on soil chemical properties.

MATERIALS AND METHODS

Soil sampling and location Top soil (0–15 cm) samples of an Ultisol (Iwo soil series) with the following physical and chemical properties were obtained from an unfertilized plot at the Obafemi Awolowo University Teaching and Research Farm (OAUTR&F) (Latitude 7 30'–7 35' N and Longitude 4 30'–4 35' E): particle size analysis -700, 110 and 190 g kg^{-1} sand, silt and clay, respectively (sandy loam texture); pH - 6.4; organic C (OC) - 8.50 g kg^{-1}, total nitrogen (N) - 1.90 g kg^{-1}, available P - 10.90 mg kg^{-1}, exchangeable Ca, Mg, K and Na - 2.10, 0.80, 1.32 and 0.02 cmol kg^{-1}, respectively. The soil samples were bulked, air-dried, and passed through either a 2 mm sieve (for the laboratory analyses) or a 4 mm sieve (for the screenhouse study).

Cowpea seeds and phosphorus fertilizer

Seeds of cowpea (var. TVX 113 and TVX 3236) and single superphosphate (SSP) fertilizer were obtained from the Departments of Crop Production and Protection and the Soil Science and Land Resources Management, respectively, of the Obafemi Awolowo University Ile-Ife.

Analytical techniques

The physical and chemical properties of the soil were determined, following standard methods: soil particle size analysis determined using the hydrometer method (Bouyoucos, 1962); soil pH determined potentiometrically in a soil–solution ratio of 1:2 in 0.01 M calcium chloride ($CaCl_2$) using a glass electrode pH meter (pHS-3C); organic carbon (OC) analyzed using the Walkley–Black dichromate method (Nelson and Sommers, 1996); total N contents using micro-Kjeldahl digestion, distillation, and titration processes (Bremner, 1996); available

P extracted using the Bray-1 method and colorimetrically determined at 660 nm wavelength (Bray and Kurtz, 1945); exchangeable potassium (K), calcium (Ca), magnesium (Mg), and sodium (Na) extracted with 1 N ammonium acetate (Helmke and Sparks, 1996) while Na and K concentrations were determined using a flame photometer, and Ca and Mg determined using Atomic Absorption Spectrophotometer.

Treatment preparation and screenhouse study

Three kilograms (3 kg) each of soil was amended with 0, 20, 40 and 60 kg P ha^{-1} as SSP to give the following treatments: Soil only (Control) (SP0); Soil + 20 kg P ha^{-1} (SP1); Soil + 40 kg P ha^{-1} (SP2); Soil + 60 kg P ha^{-1} (SP3); where S = soil, and P1, P2, and P3 = 20, 40, and 60 kg P ha^{-1}, respectively. The amended soil was then transferred to plastic pots with perforations in the bottom and cotton wool plugs to allow free air exchange and drainage of excess water. The pots were arranged in a completely randomized design with three replicates. Three cowpea seeds were planted in each pot and the plants were thinned to two stands per pot at two weeks after planting. The experiment was terminated at around eight (8) weeks after planting (50% bloom) and the plant's growth parameters (heights, number of branches, number of leaves, dry matter yield, and nutrient uptake) were evaluated while the soil was analyzed for post-harvest chemical properties (pH, exchangeable Ca, K, Mg and Na; total N, OC and available P). Moreover, during termination, plant shoots were cut at 2 cm above the soil surface, and the roots were carefully harvested while their fresh weights were taken, and then ovendried at 65ºC for the determination of dry matter yield. A repeated cropping for eight (8) weeks, was done but without phosphorus fertilizer addition to assess any residual effect(s).

Statistical analysis

Data generated were analyzed using one-way analysis of variance technique. Means were separated using the Duncan's New Multiple Range Test (DNMRT) at 5% level of probability with SAS 9.0 Software Package.

RESULTS

Response of soil pH, organic carbon, total nitrogen, and available P to phosphorus fertilizer at the end of each of two consecutive 8-week cropping of cowpea in the screenhouse

At the end of the first planting, varietal differences in the cowpea had no significant impact on OC, available P, total N, or soil pH (Table 1). At both plantings, the soil pH was mostly similar among the treatments and the control, except that SP3 had its pH reduced ($p<0.05$) compared with the control in the second planting. The OC content was similar among the treatments and the control. While the total N in SP1 was higher ($p<0.05$) than that in SP3, it was comparable to that in SP2 and SP0. In SP1 and SP2 treated soil, the available P content was significantly higher than in SP0. During the second planting, the pH in SP3 was substantially lower than that in the control. Even though the OC was similar among all treatments and the control ($p<0.05$), the SP1 treatment significantly increased the total N over SP2 and SP3 treatments but did not differ from that in the control. On the other hand, all of the treatments significantly increased the available P over the control (SP0).

The means in a column with the same letter(s) are not significantly different ($p<0.05$)

according to Duncan's Multiple Range Test. Where a = first planting, b = second planting, SP0 = control, SP1 = 20 kg P ha^{-1}, SP2 = 40 kg P ha^{-1}, and SP3 = 60 kg P ha^{-1}, respectively, TVX 113 and TVX 3236 are cowpea varieties.

TABLE 1: Results of soil reaction (pH), organic carbon, and available P and total N contents at the end of the first (a) and second (b) eight weeks of cropping of two cowpea varieties (V*igna unguiculata* (L.) Walp) in the screenhouse

Treatments	pH (0.01 M $CaCl_2$)		OC (g kg^{-1})		N (g kg^{-1})		P (mg kg^{-1})	
	a	b	a	b	a	b	a	b
SPO	7.69a	7.66a	7.69a	7.31a	1.82ab	2.14ab	25.99b	11.95c
SP1	7.58a	7.585ab	8.01a	8.01a	1.88a	2.29a	39.02a	31.89b
SP2	7.59a	7.59ab	7.75a	7.05a	1.82ab	1.69b	38.95a	39.69a
SP3	7.62a	7.53b	7.87a	7.15a	1.69b	1.71b	34.49ab	36.63ab
Varieties								
TVX 113	7.59a	7.55a	7.94a	7.90a	1.84a	1.69b	32.23a	29.27a
TVX 3236	7.65a	7.63a	7.72a	6.62b	1.77a	2.23a	36.99a	30.81a

The means in a column with the same letter(s) are not significantly different ($p<0.05$) according to Duncan's Multiple Range Test. Where a = first planting, b = second planting, SP0 = control, SP1 = 20 kg P ha^{-1}, SP2 = 40 kg P ha^{-1}, and SP3 = 60 kg P ha^{-1}, respectively, TVX 113 and TVX 3236 are cowpea varieties.

Effects of phosphorus fertilizer on soil exchangeable cations at the end of each of two consecutive 8-week croppings of cowpea (Vigna unguiculata (l.) Walp) in the screenhouse

The effects of the P fertilizer on the exchangeable cations in the soil after two consecutive 8 weeks of planting are shown in Table 2. The two cowpea varieties have different effects on the exchangeable cations; in the first planting, variety TVX 3236 recorded greater K and Mg than TVX 113. The parameters, however, were the same for both treatments in the second planting. The exchangeable cations (K, Mg, and Ca), except Na (the least in SP3) were comparable across all treatments in the first planting. Except for Ca, where SP3 had the least value, there was no significant difference among the treatments for the soil exchangeable cations (K, Mg, and Na) in the second planting.

Effects of phosphorus fertilizer on cowpea agronomic parameters at the end of each of two consecutive 8-week croppings in the screenhouse

Plant height (PLHT) data were significantly ($p< 0.05$) affected by Variety TVX 113 in the first and second cropping, out-performing Variety TVX 3236 (Table 3). Both SP2 and SP3 produced significantly ($p<0.05$) taller plants than the control across the weeks.

The number of branches (NOB) was similar among the two cowpea varieties during the first and second plantings (Table 4). In the first planting, while the number of branches was only increased ($p<0.05$) by SP3 at 3 and 4 wap, it was increased by all the phosphorus fertilizer treatments from 5 to 8 wap. In the second planting, however, both cowpea varieties were similar while all phosphorus fertilizer treatments were mostly comparable to the control, in terms of the number of branches.

significantly increased the number of leaves), all treatments produced

TABLE 2: **Exchangeable cation contents at the end of each of two 8 consecutive weeks of cowpea (V*igna unguiculata* (L.) Walp) cropping in the screenhouse**

Treatments	K		Mg (cmol kg^{-1})		Ca		Na	
	a	b	a	b	a	b	a	b
SP0	0.16a	0.15a	0.40a	0.19a	12.56a	8.63a	0.06ab	0.08a
SP1	0.16a	0.11a	0.39a	0.21a	12.81a	8.00ab	0.06ab	0.08a
SP2	0.16a	0.09a	0.40a	0.19a	13.21a	7.26ab	0.07a	0.08a
SP3	0.15a	0.11a	0.39a	0.12a	12.45a	5.66b	0.06ab	0.08a
Varieties								
TVX 113	0.12b	0.12a	0.38b	0.21a	12.65a	7.35a	0.07a	0.08a
TVX 3236	0.19a	0.11a	0.42a	0.15a	12.86a	7.43a	0.06a	0.08a

The number of leaves (NOLF) was similar among the two cowpea varieties during the first and second plantings, except for the third week of the second planting, when variety TVX 3236 had significantly more leaves than variety TVX 113 (Table 5). With the exception of weeks 3 and 4 (when only SP3 significantly ($p<0.05$) greater number of leaves than the control during the first planting. During the second planting, only SP1 and SP3 significantly ($p< 0.05$) increased the number of leaves compared to SP0 at 3 and 4 wap.

According to Duncan's Multiple Range Test, the means in a column with the same letter(s) are not significantly different ($p<0.05$), where a = first planting, b = second planting, SP0 = control, SP1 = 20 kg P ha^{-1}, SP2 = 40 kg P ha $^{-1}$, and SP3 = 60 kg P ha $^{-1}$, respectively, TVX 113 and TVX 3236 are cowpea varieties.

TABLE 3: Cowpea (*Vigna unguiculata* (L.) Walp) plant height during the first (a) and second (b) 8 weeks of growth in the screenhouse

Treatments	3 wap	4wap	5 wap	6 wap	7 wap	8 wap
(a)			cm			
SP0	12.67b	15.17c	17.67c	21.50b	31.33c	45.33b
SP1	14.17ab	18.33b	20.83bc	31.50b	49.83b	60.83a
SP2	15.33a	22.17a	24.50ab	42.33a	58.83ab	67.00a
SP3	15.67a	21.67a	26.67a	51.17a	67.33a	75.50a
Varieties TVX						
113	16.83a	20.08a	24.17a	41.33a	57.67a	69.00a
TVX 3236	12.08b	18.58a	20.67b	31.92b	46.00a	55.33b
(b)						
SP0	23.83a	39.50a	56.00a	62.00ab	66.50b	78.33a

SP1	28.33a	47.83a	58.17a	70.33a	79.67a	84.50a
SP2	24.17a	39.50a	46.33b	59.67b	65.17b	76.83a
SP3	27.83a	42.33a	58.00a	63.67ab	72.50ab	77.33a
Varieties TVX						
113	29.25a	49.92a	63.75a	71.92a	77.50a	89.00a
TVX 3236	22.83b	34.67b	45.50b	55.92b	64.42b	69.50b

The means in a column with the same letter(s) are not statistically different ($p<0.05$), according to Duncan's Multiple Range Test, where a = first planting, b = second planting, SP0 = control, SP1 = 20 kg P ha^{-1}, SP2 = 40 kg P ha^{-1}, and SP3 = 60 kg P ha^{-1}, respectively, TVX 113 and TVX 3236 are cowpea varieties.

TABLE 4: Cowpea (*Vigna unguiculata* (L.) Walp) number of branches during the first (a) and second (b) 8 weeks of growth in the screenhouse

Treatments (a)	3 wap	4wap	5 wap	6 wap	7 wap	8 wap
SP0	4.00b	5.17b	6.50b	9.50b	14.00b	19.83b
SP1	4.00b	6.67ab	10.33a	18.00a	25.33a	29.33a
SP2	4.67ab	7.00ab	11.00a	17.83a	25.33a	30.83a
SP3	5.33a	8.00a	13.00a	23.50a	28.00a	31.50a
Varieties TVX 113	4.50a	6.58a	9.17a	16.92a	22.50a	28.75a
TVX 3236	4.50a	6.83a	11.25a	17.50a	23.83a	27.00a
(b)						
SP0	4.50b	7.17ab	10.50a	12.67a	16.33a	15.17a
SP1	5.67a	10.33a	14.33a	15.67a	17.67a	19.33a
SP2	4.67b	6.67b	10.67a	13.67a	15.67a	16.00a
SP3	5.33ab	9.33ab	13.33a	12.83a	15.17a	20.50a
Varieties TVX 113	4.75a	7.50a	12.83a	14.33a	15.50a	17.33a
TVX 3236	5.33a	34.67b	11.58a	13.08a	16.92a	18.17a

The means in a column with the same letter(s) are not statistically different ($p<0.05$), according to Duncan's Multiple Range Test, where a = first planting, b = second planting, SP0 = control, SP1 = 20 kg P ha^{-1}, SP2 = 40 kg P ha^{-1}, and SP3 = 60 kg P ha^{-1}, respectively, TVX 113 and TVX 3236 are cowpea varieties.

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Table 5: Cowpea (*Vigna unguiculata* (L.) Walp) number of leaves after the first (a) and second (b) 8 weeks of growth in the screenhouse

Treatments (a)	3 wap	4wap	5 wap	6 wap	7 wap	8 wap
SP0	11.00b	15.50b	18.33b	28.50b	42.00b	59.50b
SP1	12.00b	19.67ab	31.00a	52.00a	71.00a	86.00a
SP2	14.00ab	20.00ab	33.00a	53.50a	76.00a	92.50a
SP3	16.00a	24.00a	39.00a	64.50a	80.00a	94.50a
Varieties TVX 113	13.50a	19.08a	27.25a	47.75a	67.50a	86.25a
TVX 3236	13.00a	20.50a	33.67a	51.50a	67.00a	80.00a
(b)						
SP0	13.50b	18.50c	31.50a	38.00a	48.50a	42.67a
SP1	17.00a	31.67a	43.00a	47.00a	54.00a	57.50a

SP2	14.33ab	20.67bc	32.00a	41.00a	47.00a	48.00a
SP3	16.00ab	27.33ab	35.00a	38.50a	45.50a	61.50a
Varieties TVX 113	43.25b	24.33a	38.50a	43.00a	46.75a	50.33a
TVX 3236	16.17a	24.75a	32.25a	39.25a	50.75a	54.50a

The means in a column with the same letter(s) ***Effects of phosphorus fertilizer and varietal*** are not statistically different ($p<0.05$), ***differences on dry matter yield and shoot*** according to Duncan's Multiple Range Test, ***uptake of Ca, Mg, K, Na, N and P at the end*** where a = first planting, b = second planting, ***of each of two consecutive 8-week cropping*** SP0 = control, SP1 = 20 kg P ha^{-1}, SP2 = 40 ***of cowpea (*****Vigna unguiculata (L.) Walp*****)*** kg P ha^{-1}, and SP3 = 60 kg P ha^{-1}, ***in the screenhouse*** respectively, TVX 113 and TVX 3236 are When compared to TVX 3236, TVX 113 cowpea varieties. significantly enhanced the shoot and the total dry matter yields (11%, Table 7). The shoot

Tissue contents of total N, P, Ca, K, Mg and and the total dry matter yields were increased ***Na at the end of each of two consecutive 8-*** ($p<0.05$) by only SP2 during the first ***week cropping of cowpea (*****Vigna** planting. The dry matter yields were, **unguiculata (L.) Walp*****) in the screenhouse*** however, similar during the second planting. The TVX 3236 had significantly higher The TVX 113 in comparison with TVX 3236, tissue P and K in the first planting, and Ca was also higher ($p<0.05$) in the shoot uptake and K at the second planting, while TVX 113 of N (36), P (28), Mg (138), and Ca (165%) had higher N content at the second planting during the first planting, but the parameters

(Table 6). were similar during the second planting

The tissue contents of N, Ca, and K fertilizer (Table 8). With reference to phosphorus treatments did not differ significantly among fertilization, only SP2 increased ($p<0.05$) the the fertilizer treatments at the end of first and shoot uptake of N (78%), P (2748%), Mg second plantings. On the other hand, tissue (124%) and Ca (175%) when compared with contents of P and Mg were significantly the control. increased by SP2 compared to the control at the second planting.

TABLE 6: Cowpea (*Vigna unguiculata (L.) Walp)* tissue contents of N, P and cations after 8 weeks of cropping in the screenhouse

Treatments	N		P		K		Mg		Ca		Na	
					%							
	a	b	a	b	a	b	a	b	a	b	a	b
SP0	2.39a	1.05a	0.33a	0.12b	1.89a	1.49a	0.25a	0.25b	1.19a	1.00a	0.01a	0.04a
SP1	2.33a	1.19a	0.31a	0.19ab	1.63a	1.49a	0.21a	0.35b	1.11a	1.14a	0.09b	0.03a
SP2	2.32a	1.08a	0.32a	0.20a	1.56a	1.51a	0.24a	0.54a	1.27a	1.06a	0.01ab	0.04a
SP3	2.30a	1.13a	0.33a	0.16ab	1.89a	1.58a	0.24a	0.31b	1.37a	1.08a	0.01ab	0.03a
Varieties												

TVX 113	2.34a	1.28a	0.28b	0.18a	1.47b	1.33b	0.23a	0.33a	1.24a	0.91b	0.01a	0.04a
TVX 3236	2.33a	0.94b	0.36a	0.16a	2.01a	1.71a	0.24a	0.39a	1.23a	1.23a	0.01a	0.03a

The means in a column with the same letter(s) are not statistically different (p>0.05), according to Duncan's Multiple Range Test, where a = first planting, b = second planting, SP0 = control, SP1 = 20 kg P ha^{-1}, SP2 = 40 kg P ha^{-1}, and SP3 = 60 kg P ha^{-1}, respectively, TVX 113 and TVX 3236 are cowpea varieties.

TABLE 7: Effects of phosphorus fertilizer on shoot, root and total dry matter yield after two consecutive 8 weeks of cowpea (*Vigna unguiculata (L.) Walp*) growth in the screenhouse

Treatments	Shoot dry matter yield (g plant^{-1})		Root dry Matter (g plant^{-1})		Total Dry Matter (g plant^{-1})	
	a	b	a	b	a	b
SP0	4.78b	3.12a	1.87a	0.88a	6.65b	4.00a
SP1	6.87ab	3.38a	1.65a	0.95a	8.52ab	4.33a
SP2	10.48a	3.07a	2.43a	1.43a	12.92a	4.50a
SP3	7.07ab	3.87a	1.65a	1.00a	8.72ab	4.87a
Varieties						
TVX 113	10.44a	3.33a	2.05a	1.17a	12.49a	4.36a
TVX 3236	4.16b	3.39a	1.75a	0.97a	5.91b	4.49a

The means in a column with the same letter(s) are not statistically significantly different (p<0.05), according to Duncan's Multiple Range Test, where a = first planting, b = second planting, SP0 = control, SP1 = 20 kg P ha^{-1}, SP2 = 40 kg P ha^{-1}, and SP3 = 60 kg P ha^{-1}, respectively, TVX 113 and TVX 3236 are cowpea varieties.

TABLE 8: Effects of phosphorus fertilizer on shoot cations, shoot N and P uptake after two consecutive 8 weeks of cowpea (*Vigna unguiculata* (L.) Walp) growth in the screenhouse

Treatments Shoot Shoot Shoot Shoot Shoot Shoot (a) N P K Mg Ca Na

	g plant^{-1}					
SP0	11.96b	14.13b	86.47a	11.16b	50.21b	0.62a
SP1	19.60ab	20.56ab	102.29a	14.90ab	72.24ab	0.61a

SP2	21.29a	32.19a	146.80a	25.08a	138.21a	1.17a
SP3	16.40ab	23.19ab	134.94a	16.83ab	92.60ab	0.86a
TVX 113	23.87a	29.66a	151.18a	23.93a	128.25a	1.20a
TVX 3236	96.26b	15.38b	84.06b	10.06b	48.41b	0.43b
(b)						
SP0	35.27a	3.91a	43.17a	7.49a	28.24a	1.27a
SP1	43.59a	6.99a	51.27a	11.93a	38.95a	0.89a

Treatments Shoot Shoot Shoot Shoot Shoot Shoot (a) N P K Mg Ca Na

SP2	34.480a	5.72a	45.10a	18.42a	30.94a	1.21a	g
SP3	43.10a	6.34a	59.36a	15.28a	40.15a	1.34a	plant^{-1}
TVX 113	42.05a	5.64a	43.51a	12.38a	29.37a	1.25a	
TVX 3236	36.18a	5.84a	55.94a	14.19a	39.77a	1.11a	

Means in a column with the same letter(s) are not statistically different (p>0.05), according to Duncan's Multiple Range Test, where a = first planting, b = second planting, SP0 = control, SP1 = 20 kg P ha^{-1}, SP2 = 40 kg P ha^{1}, and SP3 = 60 kg P ha^{-1}, respectively, TVX 113 and TVX 3236 are cowpea varieties.

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DISCUSSION

The soil used for the current study was loamy sand which is favourable for good root growth and aeration in cowpea production (Omoigui *et al*., 2018). According to Adepetu (1990), the soil was slightly acidic (pH 6.4, in 0.01 M $CaCl_2$) and low in organic carbon (8.47 g kg^{-1}) and total N (0.20 g kg^{-1}). The measured available P (10.90 mg kg^{-1}) falls within the medium range of fertility (Anonymous, 2006). The exchangeable Ca and Mg of 2.10 and 0.80 cmol kg^{-1} were low and moderate, respectively. The exchangeable K and Na contents of 1.32 and 0.02 cmol kg^{-1} were low. The soil was, therefore, considered moderately fertile.

Phosphorus is important to cowpea due to its role in nodulation, N_2 fixation, and overall growth and yield of the crop (Niu *et al*., 2012; Haruna and Usman, 2013; Mohammed *et al*., 2020). Phosphorus is, however, low in the highly weathered tropical soils due to fixation by Al and Fe or its existence in an unavailable form (Marschner, 2012, Mabagala and Mng'ong'o, 2022), necessitating its mineral application for optimum cowpea growth and yield. In the current study, phosphorus fertilization rarely affected the soil OC and total N; nevertheless, its application, as expected, increased soil available P when compared with the control due to P release by the fertilizer.

Plant height was significantly influenced both by cowpea variety and phosphorus fertilization. The variation in plant heights between the cowpea varieties could be attributed to the difference in their genetic diversity. Further, the observed increase in plant heights with P application was in line with earlier reports which indicated that 39 kg P ha^{-1} caused significantly higher plants heights when compared with the control (Nkaa *et al*., 2014; Namakka *et al*., 2017). This could be attributed to the contribution of P to shoot and root tips', high metabolic rates and rapid cell division, which cause the plant to grow higher (Kim and Li, 2016; Liu, 2021). Ayodele and Oso (2014) reported a significant increase in plant height and leaf area index after applying 20 kg P ha^{-1}. According to Feng *et al*. (2021), phosphorus application greatly increased plant height and leaf count.

The increase in the number of branches per plant due to the treatments, especially SP2 and SP3, could be due to the stimulatory effect of phosphorus on plant growth, cell division and development of plant's growing tip (Lines-Kelly, 1992; Namakka *et al*., 2017). Several lateral buds were produced, and these later developed into branches. This finding is similar to earlier reports that phosphorus application at 40 kg P ha^{-1} increased the overall number of branches per plant (Ayodele and Oso, 2014; Namakka *et al*., 2017).

There was increase in the number of leaves due to phosphorus application as supported by the earlier study which found a strong correlation between soil P levels and the number of leaves, with soil P levels of 60 kg ha^{-1} and 40 kg ha^{-1} consistently producing the maximum number of leaves (Thosago, 2015; Nkaa *et al*., 2014). In another study by Subbarao *et al*. (2014), the number of leaves per plant and the leaf area index increased when phosphorus was applied.

In plants, phosphorus is mobile and is concentrated in the plants' regions of active cell division and development, which has the beneficial impact of increasing plant heights, number of branches and number of leaves per plant, accounting for the results obtained in the current study.

The variety TVX 3236 had higher contents of most of the tissue nutrients determined, indicating a difference in the genetic characteristics of the two cowpea varieties. However, due to its higher dry matter yield, variety TVX 113 also performed better in the shoot uptake of N, P, K, Ca, Mg, and Na. The increase in tissue content of P and Mg, and the shoot uptake of N, P, Mg, and Ca in response to the application of 40 kg P ha^{-1} indicated the optimal level of the fertilizer rate for the plant's nutrient uptake. These results show that apart from growth conditions (environment), varietal difference influences dry matter accumulation in legumes. This result compares with the report by Addo-Quaye *et al*. (2011) that cowpea varieties have different capacities for dry matter production.

CONCLUSION

The cowpea variety TVX 113 outperformed TVX 3236 in plant height (20–43%), dry matter accumulation (111%), tissue content of N (36%) and uptake of N (303%), P (93%), K (80%), Ca (165%) and Mg (138%). While soil properties were largely unaffected, application of phosphorus fertilizer, especially at 40 kg and 60 kg P ha^{-1} enhanced most of the measured plant agronomic traits such as plant heights number of leaves, tissue contents of P and Mg, and N and P uptake. From the outcome of the current study, cowpea variety TVX 113 and fertilizer application rate of 40 kg P ha^{-1} are recommended for enhanced agronomic performance with cheaper economic implications.

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