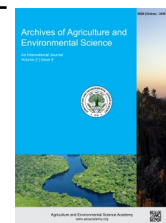


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ORIGINAL RESEARCH ARTICLE



Effect of different phosphorus levels on four cowpea (*Vigna unguiculata* Walp L.) varieties for grain and fodder yield in Upper East Region of Ghana

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ABSTRACT

A field experiment was conducted to examine the effect of cowpea varieties and different phosphorus levels on grain and fodder yield. Four cowpea varieties i.e. Asetenapa, Asomdwe, Hewale and Videza with four different phosphorus levels of single superphosphate (SSP) were used in the experiment. The experimental design was 4 × 4 factorial experiment laid in randomized complete block with four replicates. The results showed that cowpea varieties and phosphorus levels significantly influenced number of nodules per plant, pod length, number of pods per plant, fodder yield and grain yield. Phosphorus levels had no significant effect on stem girth, plant height and 100 seed weight. Asomdwe recorded the highest grain yield of 1229kg^{ha}⁻¹ while Videza and Asetenapa produced the highest fodder yield of 957kg^{ha}⁻¹. Interactive effect between Videza and 30kg^{ha}⁻¹ of SSP produced the highest fodder yield while Asomdwe and 60kg^{ha}⁻¹ of SSP was the treatment combination that produced the highest grain yield. Cowpea varieties and different phosphorus levels had effect on grain and fodder yield. Asomdwe would be recommended for commercial grain production because of the high grain yielding potential as observed in the study Asetenapa and Videza for fodder production to feed livestock.

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INTRODUCTION

Cowpea (*Vigna unguiculata* Walp (L.)) is an essential component of the cropping systems in the drier regions of the tropics and of vital importance to the livelihood of millions of people in West and Central Africa. It provides nutritious grain and an inexpensive source of protein for both rural and urban consumers (Anyango *et al.*, 2011). Cowpea is consumed in many forms with young fresh leaves, immature green pods and green seeds used as vegetables; dry seeds used in various food preparations including over 50 different dishes known (Quaye *et al.*, 2009); Boukar *et al.* (2011). The beans are nutritious and provide complementary proteins to cereals. The seeds of cowpea comprise (20 - 24%) protein, 63.3% carbohydrates and 1.9% fat (Davis *et al.*, 1991). Globally, it is grown on about 14.5 million hectares producing over 6.5 million metric tons of grain (Fatokun *et al.*, 2012). Africa alone accounts for about 83% of

the world production, with Nigeria being the world's largest producer (45.76%), followed by Niger (15%) (Fatokun *et al.*, 2012). Fodder from cowpea is also highly valued for livestock. It can be grown as a relay inter-crop with cereals or other crops in mid, if maturing varieties were used (Elawad, 2000).

Farmers in legume production usually receive little mineral phosphorus fertilizer from the natural available soil phosphorus and other nutrients for nitrogen fixation and growth, and this result to low yields (Singh *et al.*, 2011 and Nkaa *et al.*, 2014). Inadequate supply of phosphorus may result in nitrogen deficiency when legumes depend on symbiotic nitrogen (Tairo and Ndakidemi, 2013) as a result of poor N₂ fixation. Phosphorus (P) deficiency is the most frequent nutrient stress for growth and development of grain legumes including cowpea (Kamara *et al.*, 2008). Soil phosphorus is in the form of poorly soluble mineral phosphates which is not readily available to plants (Marschner, 2012).

Phosphorus has been reported to enhance the formation of lateral, fibrous and adventitious roots, which play an important role in N₂ fixation, nutrient and water uptake (Rahman *et al.*, 2008; Niu *et al.*, 2012). It is one of the most important soil major nutrients for crop production especially legumes, it is rated the second to nitrogen in terms of its importance to crop performance (Halder and Panda, 2014). Phosphorus (P) is very significant element to enhance the cowpea biomass and crop yield because it stimulates growth, initiate nodulation as well as influence the efficiency of rhizobium-Legume symbiosis (Haruna and Usman, 2013). Therefore the requirement of P for cowpea is quite higher than nitrogen in the form of single super phosphate or SUPA (Nkaa *et al.*, 2014). The objective of the study was to determine the effect of different Phosphorus fertilizer level on grain and fodder yield of four cowpea varieties and effect of the four cowpea varieties on grain and fodder yield.

MATERIALS AND METHODS

About the experimental sites

The study was established on 15th July, 2017 in Bonia in the Kessena – Nankana Municipality in the Upper East Region of Ghana, located on latitude 10.87° N and longitude 1.13° west at 194 m above sea level. The climate is warm, semi-arid with mono-modal with the average annual rainfall amount of about 1000 mm which falls mostly between May and September. This is then followed by seven months of dry season, which is characterized by the dry harmattan winds with high risk of uncontrolled bushfires resulting in the loss of vegetative cover of the vertisol soil.

Experimental design and treatment

The experimental sites were ploughed and ridged and sprayed with herbicides (roundup and stomp) having active ingredients glyphosate and pendimethalin respectively. The experimental was laid out in factorial design arranged in randomized complete block design with four replications. The replicates were made up of 16 plots each measuring 4m × 2.4m with 4 rows per plot, each row had a length of 4m, plot width of 2.4m, one meter between plots, 60 cm spacing between rows and 20 cm within rows with one meter between plots. The treatments used for the experiment were four single superphosphate fertilizer levels in kg ha⁻¹; 0, 30, 60, 90 and four cowpea varieties; Asetenapa, Asomdwe, Hewale and Videza. Three seeds were sown per hill and later thinned to two plants per hill two weeks after sowing; refilling was done two weeks after planting and weeding done by hoeing and hand pulling three weeks and five weeks after planting. Single Superphosphate (SSP) fertilizer at the rates indicated in the treatment was uniformly applied on the plots three days before planting. Composite soil samples at a depth of 0 – 15 cm were taken diagonally across the field before planting and soil sample analyzed for pH, organic matter, Organic carbon, total N, available P and exchangeable K. Harvesting was done on the two middle rows of each plot and

data collected included growth parameters, yield and yield components.

Growth parameters and yield measurements

Plant height

Five plants in the two middle rows of each plot were randomly selected, identified with a tag and plant height taken at harvest of each experiment. Height measurement was done from the ground level to the last terminal leaf. The average of five plants was then calculated for the plant height.

Stem girth

Were also measured from five cowpea plants from each plot of each treatment using electronic venire calipers. The stem girth of each of the five cowpea plants were placed in the external jaws of the calipers and the reading that was displaced on the LCD display recorded, the average was taken as the stem girth for plot.

Number of nodules per plant and nodules dry weight

The number of nodules per plant was taken from the five selected and tagged plants within the two middle rows. The roots of the plant were thoroughly washed to expose the nodules and a sharp blade was used to cut through the nodules. Viable nodules were counted, that is nodules with pinkish coloration and had the ability to fix nitrogen were counted and the average taken as the number of nodules per plant.

Pod length

The pod length of five cowpea pod were taken from each plot and measured using a ruler and the average length of the five pods taken as pod length.

Number of pods and grain yield

Pod harvest from five cowpea plants were counted and the average taken as the number of pods per plant. The pods in the two middle rows of each treatment were harvested and thrashed the seeds weighed for grain yield of each treatment.

100 seed weight

100 seeds from cowpea plants in the middle rows of each plot of each treatment from respective net plots were weighed for 100 seeds weight.

Fodder yield

The fodder from each of the five plants from each treatment was sun dried from each net plot, bulked and weighed then extrapolated as the fodder yield for treatment.

Statistical analysis

The data collected were subjected to statistical analysis using Genstat discovery edition 12 (2012). The means of the various treatments were separated using the least significant difference (LSD) at 5 % probability level.

RESULTS AND DISCUSSION

Characteristics of the experimental soil

The soils were slightly acidic, loamy sand with low available P, total N, exchangeable potassium and very low organic matter (Table 1).

Plant height, stem girth and pod length

The effects of cowpea varieties and different phosphorus levels on plant height, stem girth and pod length have been shown in Table 2. The cowpea varieties and the different phosphorus levels had little or no influence on plant height and stem girth as observed in the study, however a significant varietal influence on pod length was observed with no effect of the different phosphorus levels on pod length. Asomdwe produced the highest plant height of 46.61 cm while Videza produced the lowest plant height of 45.44 cm. The little or lack of significant difference between the cowpea varieties for plant height and stem girth could be attributed to the lack of varietal effect between the

cowpea varieties for plant height. This observation in the study is contrary to Magani and Kuchinda (2009) who attributed differences in plant height to the genetic effect of individual varieties. Karikari *et al.* (2015), El Naim (2012) and Abduselam (2018) reported varietal differences among cowpea and sorghum (*Sorghum bicolor* L. Moench) for plant height.

60kg ha^{-1} of SSP produced the highest plant height of 46.14 cm even though it was not significantly different from 0kg ha^{-1} which recorded the lowest plant height of 45.16 cm. The lack of significant difference of phosphorus levels on plant height as witnessed in the study is contrary to Ayodele and Oso (2014) who reported significant increase of plant height of cowpea when P was applied with basal N+K. Halder and Panda (2014) also observed a significant effect of different phosphorus levels on plant height in a groundnut. Nkaa *et al.* (2014) also observed that plant height of cowpea and number of leaves per plant was significantly enhanced by phosphorus application. There was a lack of interactive effect between the cowpea varieties and the different phosphorus levels on plant height and stem girth.

Table 1. Soil characteristics of experimental site.

Soil parameter	Value
Texture class	loamy sand
pH	5.59
Organic matter (g/kg)	66
Organic carbon (g/kg)	3
Total N (g/kg)	114
Available P (mg/kg)	9.68
Exchangeable K (cmolc/kg)	0.14

Table 2. Effect of cowpea variety and different phosphorus levels on plant height, stem girth and pod length.

	Plant height (cm)	Stem girth (mm)	Pod length (cm)
Variety			
V ₁ = Asetenapa	46.46	39.31	8.91
V ₂ = Asomdwe	46.61	38.49	10.83
V ₃ = Hewale	46.14	38.46	9.64
V ₄ = Videza	45.44	39.88	11.29
LSD (0.05)	NS	NS	0.52
P levels (kg/ha)			
P ₁ = 0	45.16	38.52	10.39
P ₂ = 30	46.01	38.75	10.28
P ₃ = 60	46.14	40.35	10.11
P ₄ = 90	45.44	38.50	9.99
LSD (0.05)	NS	NS	NS
Variety × P levels			
V ₁ × P ₁	46.65	38.85	9.2
V ₂ × P ₁	43.95	40.05	10.95
V ₃ × P ₁	45.9	35.75	9.9
V ₄ × P ₁	44.13	39.45	11.53
V ₁ × P ₂	47.18	40.35	8.7
V ₂ × P ₂	44.9	39.60	10.4
V ₃ × P ₂	45.78	37.35	9.85
V ₄ × P ₂	46.2	37.70	11.78
V ₁ × P ₃	45.5	38.90	8.85
V ₂ × P ₃	47.75	36.05	10.98
V ₃ × P ₃	45.73	44.50	9.5
V ₄ × P ₃	44.75	41.95	11.13
V ₁ × P ₄	46.5	39.15	8.9
V ₂ × P ₄	49.83	38.25	11.0
V ₃ × P ₄	47.18	36.20	9.33
V ₄ × P ₄	46.7	40.40	10.73
LSD(0.05)	NS	5.64	1.04
C.V (%)	1.7	10.2	3.0

NS - not significant, LSD - Least Significant Difference, CV - coefficient of variation.

Table 3. Effects of cowpea varieties and different phosphorus levels on nodules per plant, nodules dry weight and pods per plant.

	Nodules per plant	Nodules dry weight	Pods per plant
Variety			
V ₁ = Asetenapa	67.16	36.45	66.4
V ₂ = Asomdwe	74.47	39.53	69.7
V ₃ = Hewale	76.59	35.85	52.3
V ₄ = Videza	76.93	40.81	60.0
LSD (0.05)	7.41	2.68	5.94
P levels (kg/ha)			
P ₁ = 0	76.89	36.7	54.64
P ₂ = 30	86.23	36.58	60.96
P ₃ = 60	75.71	39.23	65.61
P ₄ = 90	56.33	40.14	67.23
LSD (0.05)	7.41	2.68	5.94
Variety × P levels			
V ₁ × P ₁	72.5	36.65	54.3
V ₂ × P ₁	78.0	38.29	59.8
V ₃ × P ₁	66.4	33.98	50.3
V ₄ × P ₁	51.8	38.88	54.3
V ₁ × P ₂	78.5	37.3	66.1
V ₂ × P ₂	83.0	35.85	70.2
V ₃ × P ₂	79.6	32.55	50.2
V ₄ × P ₂	56.8	40.63	57.4
V ₁ × P ₃	79.4	36.35	72.4
V ₂ × P ₃	91.3	41.13	73.3
V ₃ × P ₃	79	37.8	54.1
V ₄ × P ₃	58.7	41.63	62.7
V ₁ × P ₄	77.2	36.5	73.0
V ₂ × P ₄	92.6	42.85	75.7
V ₃ × P ₄	79.8	39.08	54.5
V ₄ × P ₄	58.1	42.13	65.8
LSD (0.05)	14.82	5.36	11.87
C.V (%)	4.5	1.9	3.7

Videza was the cowpea variety that produced the longest pod length and was statistically different from Asetenapa, the variety with the shortest pod length. The varietal differences observed between the cowpea for pod length in the study could be attributed to genotypic variation between varieties used for the study. This observation is in agreement with (Belay *et al.*, 2017) who reported varietal difference for pod length in a study of agronomic performance evaluation of cowpea varieties. Also the lack or little effect of the different phosphorus levels on pod length as observed in the study is contrary to Karikari *et al.* (2015) who reported a significant effect of different phosphorus on the pod length of cowpea. Lakew (2019) also reported a positive influence of phosphorus levels on pod length in his study growth and yield of wheat (*Triticum aestivum* L.) cultivars as influenced by rates of phosphorus. A significant interactive effect between cowpea varieties and phosphorus levels were observed for pod length. This shows that with Videza and 30kg ha⁻¹ phosphorus interaction produced the highest pod length with a mean 11.77 while Asetenapa and 30kg ha⁻¹ phosphorus interaction produced least pod length with a mean of 8.7.

Nodules per plant, nodules dry weight and pods per plant

The effect of cowpea varieties and different phosphorus levels on number of nodules per plant, nodules dry weight and number of pods per plant are shown in Table 3. Varietal differences were observed in the number of nodules per plant, nodules dry weight

and number of pods per plant. Asomdwe produced the highest nodule per plant from the results with a mean 86.2 compared with Videza which produced the least nodules per plant with a mean of 56.3. The varietal difference observed between the cowpea varieties used in the study could be attributed to genetic difference in the varieties interacting with the native rhizobia in forming effective and viable nodules. This finding agrees with Ayodele and Oso (2014) and Karikari *et al.* (2015) who reported varietal difference in nodules per plant in cowpea. The effect of the phosphorus levels on number of nodules per plant was statistically significant between the different phosphorus levels for number of nodules per plant. 90 kg ha⁻¹ of phosphorus produced the highest nodules per plant with a mean of 76.93 while 0 kg ha⁻¹ produced the lowest nodules per plant with a mean of 67.16. The results of this study are in agreement with (Agboola and Obigbesan, 1977) who indicated the effect of phosphorus on the number of nodules per plant. The finding also is in support of Rahman *et al.* (2008) and Niu *et al.* (2012) that phosphorus enhances the formation of lateral, fibrous and adventitious roots, which play an important role in nodule formation, N₂ fixation, and nutrient and water uptake. A significant interactive effect between the varieties and the different phosphorus levels on nodules per plant as was observed from the studies. Interaction between Asomdwe and 90 kg ha⁻¹ phosphorus produced the highest nodules per plant (92.6) while Videza and 0 kg ha⁻¹ interaction produced the least nodules per plant (51.8).

Videza was the variety with the highest nodules dry weight with a mean of 40.81g while Asetenapa produced the lowest nodules dry weight (36.45g). Phosphorus levels also had significant influence on nodules dry weight. 90kg ha^{-1} phosphorus produced the highest nodules dry weight (40.14g) while 30kg ha^{-1} phosphorus produced the least nodule dry weight (36.58g). The finding of this study is in conformity with (Nkaa *et al.*, 2014) who reported that increasing phosphorus levels increase number and size of nodules.

Asomdwe produce the most number of pods per plant (69.7) while Hewale was the variety with least number of pods per plant (52.3). The difference in the number of pods per plant as observed between the varieties in the study may be as a result of genetic difference in partitioning photosynthesis into pods development. This finding agrees with Masenya (2016), who recorded significant varietal effect on number of pods per plant in evaluation of introduced cowpea lines. The finding is also collaborated by works of Shambharkar *et al.* (2006); Onat *et al.* (2016); Dapaah *et al.* (2014) and Sharma *et al.* (2013) who reported varietal effect for number of pods per plant in groundnut. A significant influence between 90kg ha^{-1} of phosphorus 30kg ha^{-1} and 0kg ha^{-1} were observed for number of pods per plant. 90kg ha^{-1} phosphorus levels produced the highest number of pods per plant (67.2) with 0kg ha^{-1} producing the lowest number of pods per plant (54.6). The significant difference in phosphorus levels on number of pods per plant as observed in the study is collaborated by Owolade *et al.* (2006) and Olaleye *et al.* (2011).

A significant interactive effect was also witnessed between the cowpea varieties and the different phosphorus levels for nodules dry weight and number of pods per plant. The interaction between Asomdwe and 90kg ha^{-1} phosphorus levels produced the largest number of pods per plant (75.68) while as the interaction of Hewale and 30kg ha^{-1} phosphorus levels produced smallest number of pods per plant (50.18).

100 seed weight, fodder yield and grain yield

The effects of varietal difference and different phosphorus levels on 100 seed weight, fodder and grain yield as presented in Table 4. A lack of significant different was observed between the cowpea varieties and the different phosphorus levels on 100 seed weight. Videza produced the highest 100 seed weight (59.42g) while Asomdwe produced the least 100 seed weight (58.24g). The absence of significant varietal and phosphorus levels differences in the study is contrary to (Henshaw, 2008) who observed significant varietal variations in 100 seed weights of cowpea cultivars. Shahid *et al.* (2009) reported significant influence of phosphorus levels and inoculation on 1000 seed weight of soybean which was contrary to what was observed in the study. Singh *et al.* (2011) also reported a significant effect of phosphorus levels on 100 seed weight of cowpea varieties in the Sudan Savanna of Nigeria.

There was a significant varietal variation between the cowpea varieties for fodder yield. Videza produced the highest fodder yield (957kg ha^{-1}) while Asomdwe produced the lowest fodder yield (737.6kg ha^{-1}). The difference in fodder yield between the

varieties as observed in the study could be attributed genetic difference between the varieties. This observation consent to (Singh and Tarawali, 1997) who reveals significant differences among cowpea varieties for both grain and fodder yields of promising medium-maturing cowpea varieties. Singh *et al.* (2002) also reported significant fodder yield between selected breeding lines under intercropping and sole cropping averaged over two crosses. Also, (Relwani *et al.*, 1970) reported significant difference between cowpea varieties for fodder yield in a study varietal trial on cowpea (*Vigna sinensis*) for fodder production.

A significant influence of phosphorus levels on fodder yield were observed in the study as shown in Table 4. There was an increase in the fodder yield as the phosphorus levels increase. 90kg ha^{-1} produced the highest fodder yield (915.4kg ha^{-1}) while 0 kg ha^{-1} produced the least fodder yield (784.5kg ha^{-1}). The finding in this study is collaborated by (Sandhu *et al.*, 1976) who in a study observed a significant increase in fodder quantity and quality when 25kg P₂O₅ were applied. Singh *et al.* (2011) also reported a significant cowpea stover yield when 60kg P₂O₅ were applied. A significant interactive effect between the cowpea varieties and phosphorus levels on fodder yield. Videza when applied with 30kg ha^{-1} and 60kg ha^{-1} of single superphosphate produced the highest fodder yield (1010.4kg ha^{-1}) while Asomdwe with 0kg ha^{-1} of SSP produced the least fodder yield of 638kg ha^{-1} .

A significant varietal variation on grain yield was observed between the cowpea varieties used in the study as shown in Table 4. Asomdwe was the cowpea variety from the study that partitioned most of its assimilates into grain production and produced the highest grain yield (1229kg ha^{-1}) while Videza produced the least grain yield (1083kg ha^{-1}). The varietal variation as observed in the study could be attributed to genotypic variation in phosphorus use efficiency among the cowpea varieties used in the study. This also shows that the different cowpea varieties inherently have different means of mobilizing phosphorus and other growth resources for grain production. This observation is in agreement with Singh and Tarawali (1997), Singh *et al.* (2002), Adjei-Nsiah *et al.* (2008) and Timko *et al.* (2007) who all reported significant varietal influence of grain yield.

A significant effect of the phosphorus levels on grain yield were also observed in the study. 90kg ha^{-1} produced the highest grain yield (1201kg ha^{-1}) while 0kg ha^{-1} produced the lowest grain yield of (1138kg ha^{-1}). The increase in grain yield by the 90kg ha^{-1} might be as a result of the overall improvement in growth and yield attributing traits such as number of pods per plant, which also showed an increasing trend as a result of P application. This finding is consistent with (Nkaa *et al.*, 2014), Haruna and Usman (2013) and Ayodele and Oso (2014) who all reported a positive influence of phosphorus application on grain yield. The interaction effect on grain yield between cowpea varieties and the phosphorus levels also witnessed a significant difference. Asetenapa and 60kg ha^{-1} interaction produced the highest grain yield with a mean of 1273kg ha^{-1} while Videza and 90kg ha^{-1} produced the least grain yield of 1069kg ha^{-1} .

Table 4. Effect of cowpea variety and different phosphorus levels on 100 seed weight, fodder and grain yield.

	100 seed weight (g)	Fodder yield (kg/ha)	Grain yield (kg/ha)
Variety			
V ₁ = Asetenapa	56.69	957	1222
V ₂ = Asomdwe	58.24	737.6	1229
V ₃ = Hewale	58.69	849.6	1144
V ₄ = Videza	59.42	957	1083
LSD (0.05)	NS	67.31	35.33
P levels (kg/ha)			
P ₁ = 0	58.78	784.5	1138
P ₂ = 30	58.52	885.4	1158
P ₃ = 60	60.15	888.7	1180
P ₄ = 90	55.6	915.4	1201
LSD (0.05)	NS	67.31	35.33
Variety × P levels			
V ₁ × P ₁	65.6	843.8	1180
V ₂ × P ₁	63.0	638.0	1209
V ₃ × P ₁	52.2	760.4	1090
V ₄ × P ₁	54.3	895.8	1091
V ₁ × P ₂	57.7	929.7	1210
V ₂ × P ₂	56.3	724.0	1194
V ₃ × P ₂	58.2	877.6	1136
V ₄ × P ₂	61.9	1010.4	1098
V ₁ × P ₃	62.1	979.2	1273
V ₂ × P ₃	56.7	773.4	1264
V ₃ × P ₃	68.2	878.4	1172
V ₄ × P ₃	53.6	1010.4	1093
V ₁ × P ₄	52.3	966.1	1224
V ₂ × P ₄	58.8	815.1	1250
V ₃ × P ₄	54.4	862.0	1177
V ₄ × P ₄	56.9	911.5	1069
LSD (0.05)	12.49	134.6	70.66
C.V (%)	4.6	1.0	1.2

NS – not significant, LSD – Least Significant Difference, CV – coefficient of variation.

Conclusion

The findings of this study showed that cowpea varieties positively influenced pod length, dry nodules, nodules per plant, pods per plant fodder and grain yield but no influence on stem girth, plant height and 100 seed weight. Asomdwe was the cowpea variety that produced the highest grain yield with Asetenapa and Videza producing the highest fodder yield. The different phosphorus levels had a significant influence on pod length, nodules per plant; nodules dry weight, pod per plant, fodder yield and grain yield. 90kg_{ha}⁻¹ of SSP produced the highest fodder and grain yield among the other phosphorus levels. The phosphorus levels had little or no significant influence on the stem girth, plant height and 100 seed weight. The interaction between Videza with 30kg_{ha}⁻¹ and 60kg_{ha}⁻¹ produced the highest fodder yield and Asomdwe with 60kg_{ha}⁻¹ produced the highest grain yield. It could therefore be recommended that for commercial production of fodder for livestock Videza and Asetenapa can be considered while Asomdwe could be considered for grain production.

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