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Original Research Article

EFFECTS OF DIFFERENT APPLICATION RATES OF SINGLE SUPER PHOSPHATE ON THE PERFORMANCE, NUTRIENT UPTAKE AND NODULATION OF PIGEON PEA IN DEGRADED ULTISOL.

Abstract

Phosphorus is one of the major critical plant nutrients and it is most essential for legumes as it play an importance role in nitrogen fixation. Two years experiments was conducted at the Teaching and Research Farm of Ambrose Alli University, Ekpoma, Nigeria to investigate the effects of seven rates of single super phosphate fertilizer on the growth, yield, nodulation and nutrient uptake of pigeon pea. The experimental design was a randomized complete block design with seven treatments and three replicates. The treatments included 0 kg (control), 25 kg / ha, 50 kg / ha, 75 kg / ha, 100 kg / ha, 125 kg / ha and 150 kg / ha of SSP fertilizer. Data on plant growth, yield, nutrient uptake and soil properties were collected and analysed using ANOVA at $p = 0.05$. The pre planting soil analysis showed that the soil was low of essential nutrients, however, there was significant increased in soil nutrient status after the first experiment. In both experiments, there was no significant difference in height and girth of pigeon pea but the application of 75 kg / ha significantly ($p < 0.05$) increased its number of leaves and nodulation. The application of 25 and 125 kg / ha of single super phosphate increased the grain yield of pigeon pea than the other rates of application in the first cropping season. On the other hand, the control and 25 kg / ha had the gain yield of 1,493.3 kg / ha and 1498.0 kg / ha which were significantly higher compared to other treatments during the residual experiment. The growth, nodulation, nutrient uptake and yield were significantly higher when single super phosphate was applied at rate of 25 – 75 kg / ha but the application of 25 kg / ha was more suitable.

Keywords: pigeon pea, nutrient uptake, nodulation, single super phosphate, degraded ultisol.

Introduction

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Pigeon pea is a leguminous food grain shrub rich in protein and containing good quality carbohydrate, crude fibre and lipids. It is also a source of dietary minerals and vitamins (Thiamine, Riboflavin and Niacin). The intercrop of Pigeon pea as a cover crop with maize, increase the yield of maize significantly (Egbe and Adeyemo, 2006). In addition to its food uses, pigeon pea has outstanding soil amelioration and conservation properties. The growth habit facilitates soil protection as the canopy are harvested. Pigeon pea produces more nitrogen from plant biomass per unit area of land than many other legumes and it also fix atmospheric nitrogen. Pigeon pea when used as green manure provides the benefits of improving longer term soil quality and fertility. Pigeon pea is drought resistant due to its deep rooting system and osmotic adjustment in the leaves; it also help to mitigate the impacts of climate change (Naylor *et al.*, 2004; Subbarao *et al.,* 2006). The yield increase of pigeon pea has been attributed to an improvement in nitrogen economy of the soils. The application of essential plant nutrients, particularly macro and micronutrients in optimum quantity and right proportion through correct method and time of application is the key to increased and sustained crop production. The deficiency of nutrient adversely affects the performance of crops. This is particularly important in tropical savanna agro ecosystems in which soil nutrient stocks are inherently low. Farm manure is low in phosphorus, it tends to have too little available P to plants. Therefore, the use of inorganic fertilizer with the right content and amount of nutrient to meet the needs of your plants is necessary. Phosphorus is an essential macronutrient in plants as it is part of Adenosine Triphosphate (ATP), DNA, RNA and plays a major role in energy storage and transfer. Due to its importance in biological activities in plants, phosphorus therefore plays a major role in the growth and yield of pigeon pea. Phosphorus fertilizer promotes root growth, flowering, fruiting and seed formation. Phosphorus deficiency is a problem on highly weathered, red tropical soil low in pH and high in acidity. Phosphorus is required by all plants but it is limited in soils. In many areas,

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phosphorus must be added to soil for the extensive plant growth that is desired for crop production. Phosphorus is the second most critical plant nutrient, but for legumes it is very essential. The soil of Ekpoma are generally low to medium in available P content and therefore, application of small quantity of single super phosphate will significantly improved seed yield, nodulation and nitrogenase activity in pea (Ahlawat and Ali, 1993; Chauhan and Singh, 1981). It is therefore necessary to investigate the rate of single super phosphate application that will best suit pigeon pea production in this area.

Materials and methods

Two years field experiment was carried out at the Teaching and Research Farm, Ambrose Alli University, Ekpoma, Nigeria in 2010 and the residual experiment was conducted in 2011. Ekpoma lies between Latitude 6° 45' 34" North and longitude 6° 8' 27" East with average annual rainfall of about 1500mm. Top soils (0-15 cm) were collected from the site prior to each planting season, the soils were air dried, sieved and the samples were analysed for both chemical and physical properties. Particle size analysis was carried out using hydrometer method (Bouyoucous, 1962). The pH was determined in water (ratio1:1, soil : water). Organic carbon was determined by wet dichoromate method (Nelson and Sommer, 1975) and Available phosphorus by Bray extraction method (Anderson and Ingram, 1993). Total nitrogen was determined by Kjeldahl method. Exchangeable cations (potassium, calcium and magnesium) were extracted with ammonium acetate, potassium was determined by flame photometer while calcium and magnesium by atomic absorption spectrophotometer. Micronutrients such as copper, zinc, iron and manganese were also determined. The experimental design was a randomized complete block design with seven treatments and three replicates. The treatments included 0 kg (control), 25 kg / ha, 50 kg / ha, 75 kg / ha, 100 kg / ha, 125 kg / ha and 150 kg / ha of SSP fertilizer. The plot measured 4.0 m x 3.0 m. The varieties of pigeon pea used was IAR&T50. The land was tilled, pigeon pea were planted at the rate of 3 - 4 seeds and later thinned to one plant per stand. Growth and yield parameters of pigeon pea measured were height, stem girth, number of leaves, the dry matter of shoot and grain yield at both cropping season while nodules count and index were determined only in the first cropping season. The nutrient uptake nitrogen, phosphorus and potassium in pigeon pea were also evaluated by multiplying nutrient concentration in the plant tissue by the dry matter weight, that is:

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nutrient uptake = concentration x dry matter yield.

Nodules index = Dry weight of nodules / Dry weight of shoot x 100 (Hughes and Heridges 1989).

Data collected were analysed using Anova and Duncan's multiple range test was used to separate means.

Results

Soil Analysis:

The initial soil used for cropping in the first season before the application of SSP was analysed and it was found to be deficient of organic matter and other essential nutrients mostly nitrogen, phosphorus, potassium, magnesium. The soil was slightly acidic with sandy loam texture (Table 1). During the residual experiment, when there was no application of fertilizer. The soil was moderately acidic with sandy loam texture. The organic carbon was higher in the control (21.5 g/kg) and lower in 50 kg/ha and 125 kg/ha application of single super phosphate to pigeon pea. The phosphorus content due to the application of single super phosphate ranges from 10.0 mg/g in 100kg/ha to 12.5 mg/g in the control. Calcium and Magnesium was higher in 50 kg/ha of the application of singe super phosphate. Potassium and Sodium content were higher in 150 kg/ha and 50 kg/ha application of single super phosphate. The ECEC was higher in 125 kg/ha application of single super phosphate to pigeon pea. The iron content ranges from 39.42 mg/g in 150 kg/ha to 77.63 mg/g at the application of 25 kg/ha of single super phosphate. Copper and zinc were higher in 50 kg/ha and 150 kg/ha of single super phosphate and values were 7.07 mg/g and 13.6 mg/g respectively (Table 4).

Growth parameters of pigeon pea.

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Pigeon pea showed no significant difference in height throughout the growth season. The stem girth was significantly ($p \leq 0.05$) higher at ten weeks after fertilizer application with rate of 75 kg / ha compared to other rates of applications. It was observed that the application of 75 kg / ha significantly ($p \leq 0.05$) increased the number of leaves of pigeon pea compared to other treatments throughout the growth season (Table 2). During the residual experiment, there is no significant difference in pigeon pea's height and stem girth. At twelve week after planting, 25kg/ha of single super phosphate had the highest number of leaves with the value 390.3 and the least was recorded at 100kg/ha application of single super phosphate with the value 167.0. At sixteen and twenty weeks after planting, the application of 25 kg/ha, 75 kg ha of single super phosphate and the control significantly ($p \leq 0.05$) increased the number of leaves of pigeon pea compared to other treatments (Table 5).

Nodulation and yield of pigeon pea

The application of 125 kg/ ha single super phosphate significantly ($p < 0.05$) increased the number of nodules of pigeon pea compared to other rate of application of SSP fertilizer (Table 3). The nodules weight and index were significantly ($p \leq 0.05$) higher in 75 kg / ha SSP fertilizer application compared to other treatments. The dry matter weight of shoot was significantly ($p < 0.05$) lower at the application of 100 kg / ha compared to other rate of SSP fertilizer application with the value of 3,167.0 kg / ha. The dry weight of leaves was significantly ($p < 0.05$) higher at the application of 75 kg / ha and 150 kg / ha with the values of 2000.0 kg/ ha and 1833.0 kg / ha respectively compared to other treatments. The grain yield of pigeon pea was significantly ($p < 0.05$) increased when SSP at the rate of 25, 50, 75 and 125 kg / ha were applied and significantly lower at 0 (control) kg /ha.

Nutrient uptake (tonnes/ha)

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Result in table 6 shows that the nitrogen uptake of pigeon pea was significantly ($p \leq 0.05$) lower in 125kg/ha and 150kg/ha of single super phosphate application. The phosphorus uptake in 50kg/ha application of SSP was 10.9% which was significantly higher compared to other treatments. The potassium uptake was significantly ($p \leq 0.05$) higher in the control with the value of 40.47 tonnes / ha compared to other treatments.

Dry matter weight (tonnnes/ha)

From the result in table 6, the dry matter yield of pigeon pea was higher in the application of 50kg/ha application of SSP with the value 3.2 tonnes/ha and the least dry matter weight was recorded was 150kg/ha with the value 2.13tonnes/ha. The grain yield of pigeon pea were significantly higher in control, 25, 50 and 75 kg /ha application of single super phosphate while the grain yield were lower at the application rate of 100, 125 and 150 kg / ha (Table 6).

Discussion

The soil analysis indicated that cultivation of pigeon pea and the addition of small quantity of single super phosphate on the field increased the essential nutrient elements (nitrogen, phosphorus, potassium, magnesium) above critical values (Enwenzor, *et al*., 1987). The cultivation of pigeon pea increased the soil organic matter due to its litter fall and this confirmed the earlier work done by Hayat *et al*. (2008). He reported that pigeon pea is high in protein and therefore it is nitrogen rich; because the crop residues contain much carbon than nitrogen and bacteria in the soil need both the nitrogen supplied by pigeon pea to facilitate the decomposition of crop residues in the soil and their conversion to soil building organic matter thereby increasing soil organic matter. The soil cultivated with pigeon pea had higher phosphorus content and this shows that pigeon pea can utilized and mined phosphorus because of its deep rooting system which was in agreement with the work done by Ishikawa *et al*.(2002) and Vesterager *et al*. (2006). The ability of pigeon pea to fix nitrogen is a peculiar characteristic of leguminous crop due to symbiotic rhizobia living in the roots. The nutrient (nitrogen, phosphorus and potassium) uptake in pigeon pea was significantly higher

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above the critical value according to Kumar Rao and Dart, (1987). The result shows that the growth of pigeon pea was significantly influenced with the application of single super phosphate and also heavy application of SSP does not improved the growth and yield of pigeon pea. This was also the observation made by Minchin *et al*, (1981) and Tsvetkova and Georgier, (2003) that oversupply of P caused decrease in plant growth, nodulation and acetylene reduction in soybean. Also legumes supplied with inorganic fertilizer application during vegetative period improves their growth. The nitrogen uptake was significantly higher when single super phosphate was applied at the rate of 25kg/ha-75kg/ha and these were not significantly different from the result obtained in the control. The significantly lower nitrogen uptake obtained in 125kg/ha and 150kg/ha application of single super phosphate showed that application of higher quantity SSP to pigeon pea will not significantly influence the uptake of Nitrogen. The significantly higher P uptake at the application of 50kg/ha of single super phosphate showed that pigeon pea requires small amount of single super phosphate to enhance its nutrient uptake. This confirmed the earlier work done by Uzoma *et al*. (2006). The application of SSP at the rate of 25 kg / ha – 75 kg / ha. The significant increase in growth, yield and nodulation of pigeon pea at the rate of 25 – 75 kg / ha showed that this range was suitable for the nutrient uptake of pigeon pea and this was agreement with the work of Pramanik et al. (2009) and Yakubu et al. (2010) that legumes such as pigeon pea response to small quantity of P depending upon P status of soil. However, the residual experiment does not showed significant difference in growth and yield of pigeon pea compared to the control. It is therefore evidence that SSP has little or no residual effects on the growth and yield of pigeon pea.

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Table 1: Pre planting physico-chemical properties

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of the soil used for the investigation.

Parameters	Results
pH (1:1) H_2O	5.4
pH (1:1) Kcl	4.7
N (g/kg)	0.36
OC (g/kg)	14.9
P (mg/g)	8.04
Exchangeable bases (cmol/kg)	
Ca	0.57
Mg	0.36
K	0.08
Na	0.10
Acidity (H and Al)	0.60
ECEC	1.71
Mn	69.34
Fe	41.82
Cu	7.83
Zn	2.63
Particle Size Analysis	g / kg
Sand	876
Silt	104
Clay	20
Textural Class	Sandy Loam

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Table 2: Effect of different levels of single super phosphate on pigeon pea height, stem girth and number of leaves

	Weeks after single super phosphate Application (kg/ha)								
	← Height (cm) →			← Stem girth (cm^2) →			← Number of leaves →		
Treatments	2	6	10	2	6	10	2	6	10
0	47.100a	84.47a	144.20a	3.03a	3.87a	4.30b	76.33b	262.7c	1265.3b
25	42.667a	86.87a	148.14a	2.97a	3.80a	4.48b	69.00b	295.7c	987.7c
50	45.900a	98.67a	161.67a	2.97a	4.00a	4.82b	74.67b	355.0b	1438.0b
75	52.100a	97.80a	161.33a	3.13a	4.50a	5.86a	112.33a	562.0a	1883.3a
100	45.900a	80.13a	135.97a	2.83a	3.70a	4.98b	70.00b	274.3c	892.3c
125	44.900a	92.47a	156.43a	2.93a	3.93a	4.18b	81.67b	393.7b	1398.7b
150	46.233a	86.67a	151.57a	2.83a	3.87a	4.65b	73.00b	375.7b	1137.7b
	NS	NS	NS	NS	NS				

Mean values followed by the same letters under the same vertical column are not significantly different according to Duncan's multiple range test. ($p \leq 0.05$)

Table 3: Effect of different levels of superphosphate fertilizer on number nodules, dry weight of nodules, nodules index, dry matter weight of shoots, dry matter weight of leaves and grain yield.

Treatments	Number of Nodules (kg/ha)	Weight of Nodules (kg/ha)	Nodules Index	Dry matter wt. of shoots (kg/ha)	Dry matter wt. of leaves (kg/ha)	Grain Yield (kg/ha)
0	576.70c	8.00c	0.24c	3333.00a	1333.00b	495.00c
25	666.70c	9.000c	0.27c	3333.00a	1333.00b	1071.00a
50	620.00c	8.00c	0.22c	3667.00a	1500.00b	969.70a
75	1223.30b	17.67a	0.44a	3833.00a	2000.00a	990.30a
100	673.30c	11.00b	0.35b	3167.00b	1500.00b	711.70b
125	1506.70a	13.33b	0.38b	3500.00a	1500.00b	1084.30a
150	876.70c	10.33b	0.28c	3667.00a	1833.00a	857.30b

Mean values followed by the same letters under the same vertical column are not significantly different according to Duncan's multiple range test. ($p \leq 0.05$).

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Table 4: Physico-chemical properties of soil used for the residual experiment.

Parameters	Application of single super phosphate per hectare (kg/ha)						
	Okg/ha	25kg/ha	50kg/ha	75kg/ha	100kg/ha	125kg/ha	150kg/ha
pH (1:1) H_2O	5.64	5.60	5.65	5.85	5.73	5.92	5.71
OC (g/kg)	21.50	19.70	16.00	20.50	16.00	15.40	20.30
N (g/kg)	2.20	2.00	1.70	2.10	1.70	1.60	2.10
P (mg/g)	12.52	12.32	11.29	10.86	10.00	11.83	11.47
Ca (cmol/kg)	0.80	0.89	1.30	1.08	1.20	1.01	1.27
Mg (cmol/kg)	1.07	1.11	1.30	1.08	1.20	1.10	1.27
K (cmol/kg)	0.19	0.22	0.22	0.13	0.15	0.18	0.24
Na (cmol/kg)	0.43	0.43	0.76	0.38	0.41	0.41	0.71
H^+ (cmol/kg)	1.20	0.56	0.56	0.64	0.80	2.56	0.80
Al^{3+} (cmol/kg)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
ECEC	3.69	3.21	4.14	3.16	3.71	5.26	4.20
Mn (mg/kg)	57.81	63.54	61.93	72.57	78.19	72.91	71.93
Fe (mg/kg)	61.60	77.63	55.62	40.44	42.83	43.14	39.42
Cu (mg/kg)	0.70	0.66	1.07	0.53	0.68	0.69	0.60
Zn (mg/kg)	6.83	5.29	5.72	5.54	7.83	6.64	13.60
	Particle Size Analysis						
Sand (g/kg)	842	832	852	852	852	852	852
Silt (g/kg)	34	34	34	34	34	34	34
Clay (g/kg)	124	134	114	114	114	114	114
Textural Class	Sandy Loam						

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Table 5: Residual effect of different rates of single super phosphate fertilizer on pigeon pea height, stem girth and number of leaves.

	Weeks after single super phosphate Application (kg/ha)											
	← Height (cm) →				← Stem girth (cm^2) →				← Number of leaves →			
Treatments	8	12	16	20	8	12	16	20	8	12	16	20
0	83.57	172.47	245.33	386.67	3.08	8.97	25.18	30.92	71.67	349.00	1202.30a	1534.00a
25	93.60	171.50	269.83	370.00	4.84	9.67	22.15	27.15	91.67	390.30	1200.70a	1495.30a
50	90.83	189.43	295.00	382.69	3.40	10.25	22.15	27.25	94.67	256.30	834.30b	1145.30b
75	88.27	183.33	280.07	391.50	4.22	10.56	26.33	31.84	84.00	360.30	1362.70a	1592.70a
100	86.23	164.00	231.03	318.00	4.80	9.25	19.00	24.39	90.33	167.00	879.40b	1212.00b
125	80.90	156.17	230.00	314.00	2.87	7.85	17.18	25.11	76.67	206.70	709.00b	1198.70b
150	68.69	136.43	209.50	306.67	2.27	7.20	16.31	22.12	69.33	177.00	432.00c	1144.00b
	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		

Mean values followed by the same letters under the same vertical column are not significantly different according to Duncan's multiple range test ($p \leq 0.05$).

Table 6: Residual effect of different rates of single super phosphate fertilizer on nutrient uptake, dry matter and grain yield of pigeon pea (tonnes/ha)

	Application rate of single super phosphate						
Treatments	0	25	50	75	100	125	150
N	113.00a	95.77a	113.60a	117.8a	94.67a	39.7b	19.50b
P	8.37b	4.90b	10.93a	6.50c	5.23d	4.40d	3.17e
K	40.47a	32.5b	26.87c	25.50bc	21.83d	29.40bc	24.27d
Dry matter yield	3.11a	3.13a	3.20a	3.11a	26.6b	3.03a	2.13b
Grain yield	1.49a	1.50a	1.23a	1.10a	0.78b	0.55b	0.33b

Mean values followed by the same letters under the same horizontal column are significantly different according to Duncan's multiple range test. ($p \leq 0.05$)