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RESEARCH ARTICLE

Initial and residual responses of Verano Stylo [*Stylosanthes hamata* (L.)] and Centro [*Centrosema pascuorum* (Benth.)] to phosphorus in ungrazed swards

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ABSTRACT

A field study was carried out to investigate the responses of *Stylosanthes hamata* and *Centrosema pascuorum*. (Benth.) to the initial and residual effects of phosphorus (P) application in 1989 and 1990 at Kurmin Biri and Kontagora in the guinea savanna zone of Nigeria. Five levels of P: 0, 20, 40, 60, and 80 kg ha^{-1}, were applied to each legume. The experiment was carried out over two years, without further P additions, to determine P's residual effects on the test crops. The responses to applied P depended on forage species and location. The P increased dry matter (DM) yield significantly in both legumes and years except *C. pascuorum* in which P application did not influence substantially the DM in the second year of establishment. Apart from the *C. pascuorum* grown at Kontagora (second year), yield increases over the first-year trials were observed in the levels of DM produced in the second year. The application of P significantly improved seed production from forages. Judging from the low P values of 4.50 mg kg^{-1} and 5.35 mg kg^{-1} of the soils, a very high response to applied P was expected. The applied P at 80 kg ha^{-1} to *C. pascuorum* at Kumin Biri gave the highest seed yield (1564.00 kg ha^{-1}) while unfertilized *S. hamata* at Katongora had the least (403.00 kg ha^{-1}). The relatively low but significant response of forage species to P was attributed to the high level of P fixation as well as the abundance of inactive P forms in these soils.

Keywords: Residual, Response, Centrosema, Phosphorus, Dry matter yield, Legumes, Establishment

INTRODUCTION

Assessment of mineral status for grazing animals involves sampling of forage consumed by them and the soil upon which the forages grow (Mtimium *et al.*, 1990). Low organic matter, phosphorus and nitrogen in most soils of northern Nigeria gave the avenue for the adoption of a low input approach for the improvement in soil fertility by growing legumes and keeping the land fallow (Bedoussac et al., 2015). The restorative techniques of maintaining soil fertility through fallow is no longer feasible because of pressure on arable lands for residential and industrial buildings, soil N fixed by legumes contribute much towards the yield improvements of subsequent cereal crops particularly, pearl millet (Omoregie et al. 2021). In an earlier study, Omoregie & Aken' Ova (2001) reported widespread deficiencies of both micro- and macro-nutrients (N, P, K, Ca, Mg, Fe, Mn, Cu) in northern Nigeria soils. Of these nutrients, phosphorus deficiency was fund to be common in all the soils studied.

Phosphorus is an important element in both plant and animal systems (Nwajei et al., 2018). Feed is critically in short supply in northern Nigeria, where the majority of ruminant livestock are found. The establishment of suitable pastures to meet animal feed requirement is limited by soil fertility particularly phosphorus (Omoregie, 1995; Omokanye et al., 1996; Omoregie, 1999). Reviewing the residues of fertilizers on succeeding crops, Isitekhale & Osemwota (2010) and Wafula et al. (2016) reported that past fertilizers application leaves residues of phosphorus in soil that benefit succeeding crops. They further explained that the application of inorganic fertilizers usually last only for a season. Still, the residual effects of phosphorus and potassium may continue for another season under favorable soil pH.

Meena et al. (2015) further reviewed that P application had continued over a period of several years, a large pool of undissolved rock phosphate could accumulate. However, residues of fertilizers left in the soil often raise yields that are difficult to imitate with fresh fertilizer dressings. Sometimes, responses to fresh dressings are unaffected by residues of previous dressings, but usually residues lessen the amount of the fresh dressing required or needed (Kumar et al., 2012).

This study was carried out to determine the response of P of two legumes, *S. hamata* and *C. pascuorum*, grown on soils derived from a basement complex in northern Nigeria. Findings from the current work will, therefore, be useful in determining the fertilizer requirements of forage legumes in the ecological zone under study.

MATERIALS AND METHODS

Experimental Location

Field studies were carried out in 1988 and 1989 at two locations earlier identified as deficient in P, namely: Kurmin Biri (Latitude 10º 10¹N, 7º 55¹E) and Kontagora (10º 17¹N, 0.02¹E), both in the sub-humid ecological zone of Nigeria. The areas consist of undulating plains with savanna type vegetative. The soils are ferruginous (Kowal & Knabe, 1972) and are formed on pre- to upper- Cambrian basement complex (Bannett et al., 1979). The physical and chemical composition of the soils are presented in Table 1.

Land preparation

At each location, the experimental site was cleared, stumped and the debris removed from the plot without burning. The site was manually prepared into a fine tilth using hoes. Forty plots each measuring 3m x 3m with an alleyway of 0.6m between adjacent plots were laid out.

Experimental design and layout

The experiment was arranged as a 2-factor factorial fitted in to a randomized complete block design using four replications. The two factors were: *S. hamata* and *C. pascuorum*, and five levels of Phosphoeus (0, 20, 40, 60 and 80 kg ha^{-1}) applied as single superphosphate (SSP). Potassium, S, Magnesium (Mg), Calcium (Ca) were applied as 85.6 kg KCl, 239.57 g $NaSO_4$, 56.25 MgCl, and 190.36 $CaCO_3$ per plot respectively. The fertilizers were applied by broadcasting evenly on the surface during land preparation. Basal applications were made only in the first year of the experiment.

Planting

Scarified seeds of *S. hamata* (Paton & Robbins, 1986) and *C. pascuorum* (by abrasive method) were sown by broadcasting at 10 kg ha^{-1} in June. Plots were kept weed free by hand weeding as required throughout the study period.

Data collection

The dry matter (DM) yield was estimated at 20 weeks after sowing (WAS), and the seed yield was recorded in December of the same year (24 WAS). DM and seed yields of the legumes were estimated from cuttings obtained from two randomly placed 0.3 x 0.3 m^2 quadrats in both years.

In April of the following year, the dry plant remains from the previous year's planting were cut at ground level, and the herbage was removed from the plots. DM yields were recorded in November of the second year and later compared with those of the previous year to assess the residual effects of the applied P.

At the end of each growing season, soil samples were obtained at 0 – 20 cm depth for routine soil analysis (Okalebo et al., 2002) and to determine the various forms of P in the soils using the methods of Jackson (1962); Saunders & Williams (1995); Change & Jackson (1957). The residual P was taken as the difference between total P on one hand and inorganic P and organic P on the other (Udo, 1981).

Data analysis

All data collected were analyzed using analysis of variance (ANOVA) at 5% level of probability and the means were separated using Duncan's Multiple Range Test (DMRT) when the F – ratio proved significant (Steel & Torie, 1980).

RESULTS AND DISCUSSION

Soil chemical properties

The Chemical properties of the experimental sites are presented in Table 1. The available P contents of the soils (4.50 and 5.34 mg kg^{-1}) were below the critical level of 15 $mgkg^{-1}$ recommended for plant growth in Nigeria by Adepetu et al. (1979).

Table 1. Some chemical properties of the experimental sites

Location	pH (H_2O)	Organic Carbon	Total N	Available P	Exchangeable Ca	Exchangeable Mg	Exchangeable K	Extractable Fe	Extractable Al
		%	%	mg kg^{-1}	cmol kg^{-1}	cmol kg^{-1}	cmol kg^{-1}	%	%
Kurmin Biri	5.8	0.67	0.06	4.50	1.85	1.42	0.56	0.74	0.12
Kontagora	5.6	0.41	0.05	5.34	1.00	3.67	0.12	0.44	0.26

Soil P Content

The forms of P were no significantly influenced by the phosphorus applied (Table 2). The inactive P forms (organic P and residual P) were predominant in the soils. The crops *S. hamate and C. pascuorum* were not significant with the forms of P in both locations. The highest organic P content was recorded in S. hamata in Kumin Biri after first year of cropping and Kotangora after second year of cropping. The residual and total P were higher at Kotangora after first year of cropping.

Table 2. Quantity of P forms pre- and post-application of SSP under two forage legumes in northern Nigeria

Growth Season	Organic P	Ca-P	Al-P	Fe-P	Residual P	Total P
	Mg kg^{-1}					
S hamate						
KB1	27.90ns	2.50ns	0.20ns	7.10ns	95.30ns	133.00ns
KB2	32.17	2.77	0.20	7.80	190.73	233.67
KB3	28.03	1.90	0.40	7.93	156.77	195.33
KG1	20.30	2.50	0.20	4.40	155.60	183.00
KG2	24.07	3.40	0.47	7.00	233.73	263.67
KG3	17.93	2.50	0.40	4.40	208.44	233.67
C. pascuorum						
KB1	27.90	2.50	0.20	7.10	95.60	133.00
KB2	28.87	2.27	0.13	7.93	199.80	239.00
KB3	31.10	2.93	0.30	8.90	175.65	215.67
KG1	20.30	2.50	0.20	4.40	155.60	183.00
KG2	20.89	3.63	0.40	5.97	227.07	257.33
KG3	23.60	2.43	0.30	4.47	202.20	233.00

SSP = Single Superphosphate; KB = Kurmin Biri; KG = Kontagora; 1 = Pre-application of SSP.
2 = After first year of cropping; 3 = After second year of cropping; ns= not significant.

Dry matter yield

At Kurmin Biri, the highest DM yield of *S. hamata* was produced at 80 kg P ha^{-1} a and the least when no P was applied (Table 3). Applying at 80 kg P ha^{-1} raised DM yield by 31.7%. At the same location, the highest DM yield by 1719 kg ha^{-1} or 47% over unfertilized plants.

In Kontagora, the highest DM yields were produced at 40kg P ha^{-1} and 80kg P ha^{-1} for *S. hamata* and *C. pascuorum*, respectively. As observed for Kurmin Biri, higher DM yield was also associated with higher P applied to *C. pascuorum*. Dry matter reduction was noted for *S. hamata* above 40kg P ha^{-1} in Kontagora. In s similar work, Mohamed-Saleem & Kaunfmann (1986) did not find any plant response to applied P by *S. hamata* in Kurmin Biri. The lack of response was attributed to the deficiency of some micro-nutrients like Cu (Akinola et al., 2010).

In the present study, the low response to P in these soils was attributed to the high sorption capacity (Omoregie & Ake'Ova, 1999) and high level of the inactive forms of P in the soil (Table 2). High responses would only be expected after the P fixation capacity of the soils had been satisfied, a major feature of tropical soils.

Table 3. Effect of initial and residual P and DM yield of *S. hamata* and *C. pascuorum* in the field at two locations in the sub-humid zone of Nigeria

Locations	P level kg ha^{-1}	*S. hamate* ←	Kg ha^{-1}DM	*C. pascuorum* →	
Kurmin Biri		First year	Second year	First year	Second year
	0	3863^{c}	4177^{b}	3630^{b}	5327^{a}
	20	3961^{bc}	4755^{ab}	4675^{a}	5861^{a}
	40	4316^{bc}	5274^{a}	4889^{a}	6701^{a}
	60	4617^{b}	5457^{a}	5058^{a}	6692^{a}
	80	5092^{a}	5274^{a}	5350^{a}	5790^{a}
Kontagora					
	0	3503^{d}	5564^{b}	3783^{b}	3483^{b}
	20	6405^{b}	8272^{ab}	4908^{ab}	4701^{a}
	40	8583^{a}	8230^{ab}	5333^{ab}	3958^{ab}
	60	8583^{a}	7617^{ab}	5408^{a}	3649^{ab}
	80	5911^{c}	8735^{a}	5683^{a}	4278^{ab}

Values in a column followed by same letter(s) for each location and year are not significantly different at 5% level of probability using DMRT. DM = Dry matter

The response to applied P by the legumes varied with location and the forage species planted. From the study, 40 kg P ha^{-1} appeared to be the most effective P rate for producing the legumes at both locations. There was no significant difference in the DM produced by *C. pascuorum* at the two locations (Table 4) in the year of establishment.

Table 4. Effect of location and legume type on DM yields of *S. hamata* and *C. pascuorum* in Nigeria sub-humid zone in the establishment year

Locations	*S. hamate* ←	kg DM ha^{-1}	*C. pascuorum* →
Kurmin Biri	4369^{b}		4720^{b}
Kontagora	6495^{a}		5022^{b}

Values followed by same letter(s) are not significantly different at 5% level of probability using DMRT; DM = Dry matter

The DM yields at all levels of applied P were lower in the first-year trials at Kurmin Biri when compared with the second-year trials. Increase in DM yields in the second year over the first year was not consistent for *S. hamata* at Kontagora. Also, yield reduction was observed for *C. pascuorum* at the same location and year (Table 3). These results suggest that there were high responses to applied P in the succeeding year for *S. hamata*. As with the first-year trials in Kurmin Biri, *S. hamata* responded to residual P as the rate of applied P increased; though a slight decrease (183kg DM ha^{-1}) was observed at 80kg P ha^{-1}. The highest DM yield was obtained at 60kg P ha^{-1} for *C. pascuorum*. This is in agreement with earlier observation that the magnitude of residual response depends in part on the amount of superphosphate (SSP) applied initially; the greater the initial application, the greater the carry-over response in subsequent years. This result is line with the reports by Ezekiel & Gabriel (2006); Gilbert et al. (1987); Jones (1990) and Varma (2017) found that the response of verano stylo to applied P persisted in the second year of forage establishment. Saunders et al. (1963); (Shaw et al., 1994) and Malami et al. (2013) observed an initial pasture deficiency in respond to the application of superphosphates for several years of study. The soils of the experimental sites used for this study had low (Bray P-1) P concentration of 4.50 and 5.34 mg kg^{-1} respectively for Kurmin Biri and Kontagora. This perhaps explains the high response to residual P by the sown crops. The amount of P to be supplied to these forages in subsequent years depends to a large extent on the residual effectiveness of past applications. This aspect is of considerable importance in determining the long-term availability of sorbed P for plants grown on these soils (Akinolai et al., 2010), particularly, because these soils have high sorption capacities (Omoregie, 1995; Jayanta, 2018).

The relatively lower response of the legumes to applied P in the year of forage establishment could be related to the high fixation of P in the soil and the high level of the organic and residual forms (Table 2). The residual P is not available for plant's use (Shaw et al., 1994) while the organic form could be mineralized to yield available P for DM production. The responses show that with pure verano stylo and *C. pascuorum* swards, DM yields can be sustained in the short run after initial P application. However, as soon as yield decline is noticed, there is a need to top dress the sward pasture^{-1} with single superphosphate to stabilize forage yield.

Seed yield

Generally, seed yields increased with the rate of application from 0-80 kg P ha^{-1} (Table 5). However, the application of P had no significant effect on seed production of verano stylo at Kurmin Biri. Also, adding more than 60kg P ha^{-1} decreased seed yields by 5.7% in the year of forage establishment. The application of 80kg P ha^{-1}, significantly, increased yield over the unfertilized treatment by 52.2% for *C. pascuorum* at Kontagora. On the other hand, seed yields increased significantly to the applied P for *S. hamata* at Kontagora and *C. pascuorum* at Kurmin Biri with the highest obtained when *C. pascuorum* was treated at 80 kg P ha^{-1}. Except for *S. hamata* in Kurmin Biri, there was significant response to P application by both crops in both locations. This, however, suggests that P at the highest levels (60 and 80 kg P ha^{-1}) is important for seed production in these forage species. A similar trend was reported by Mohamed-Saleem & Von Kanufmann (1986) and Meena et al. (2015) in this zone for *S. hamata* grown under comparable soil and climatic conditions. The high seed production is essential in the self-regeneration of these forages and thus avoids the need for manual replanting.

Table 5. Effect of applied P on the seed yield (kg ha^{-1}) of *S. hamata* and *C. pascuorum* in the field at two locations in the sub-humid zone of Nigeria.

Locations	Crop variety	0	20	40	60	80
		←		P (kg ha^{-1})		→
Kurmin Biri	*S. hamata*	1033^{a}	1067^{a}	1128^{a}	1267^{a}	1194^{a}
	C. pascuorum	1444^{c}	1478^{bc}	1536^{ab}	1547^{ab}	1564^{a}
Kontagora	*S. hamata*	403^{b}	483^{ab}	503^{ab}	539^{a}	561^{a}
	C. pascuorum	956^{c}	1106^{bc}	1200^{ab}	1297^{ab}	1464^{a}

Values followed by same letter(s) are not significantly different at 5% level of probability using DMRT.

CONCLUSION

Arising from the low P values of 4.50 mg kg^{-1} and 5.35 mg kg^{-1} of the soils, the crops had higher response to the rates of applied P than the control. The relatively low but significant response of forage species to P applied and its residues was attributed to the high level of P fixation as well as the abundance of inactive P forms in these soils. The application of P in the form of superphosphate to *S. hamata* and *C. pascuorum* improved their dry matter and seed yields. However, the application of P at 60 and 80 kg ha^{-1} significantly improved seed production of forages than the control. High responses to residual P were also observed and these varied with forage species and locations. The high fixation capacity of P and the high levels of inactive P forms in these soils suggest the need for heavy P fertilization at 60 and 80 kg ha^{-1} to raise DM yields to economic levels.

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