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Effects of Phosphorous and Potassium on the Growth and Nodulation of *Centrosema* spp.

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Summary

The effect of phosphorous (80kg P ha^{-1}; P_{80}) or potassium (70 Kg K ha^{-1}; K_{70}) alone or in combination (P_{80} K_{70}) on growth, nitrogen (N) status and nodulation of *Centrosema macrocarpum* and *Centrosema . acutifolium* were investigated in a pot experiment. Species wise *C. macrocarpum* as compared to *C.acutifolium* not only gave higher shoot, root and total plant dry matter (DM) yield, but also had a DM yield response to fertilizer applications consistently. Although the former compared to the latter species was lower in plant N concentration due to a dilution effect as a result of higher dry matter yield, the total plant N yield was also higher. N status of *C. macrocarpum* also improved more than that of *C.acutifolium* in response to fertilizer applications. With all fertilizer levels, *C. macrocarpum* had higher nodule numbers with significantly higher overall harvest mean. Comparing the different fertilizer effects, P_{80} was clearly and consistently superior to K_{70} in all parameters tested except in N concentration which was diluted due to the higher dry matter yield with P_{80}. Comparing between P_{80} and $P_{80}K_{70}$, the latter was higher only in total DM yield while P_{80} was superior in total plant N concentration and nodule numbers indicating the significance of P over K. It can be concluded that *C. macrocarpum* was the better species and considering the economic aspects as well, P_{80} seems to be the best fertilizer.

1 Introduction

Tropical soils are generally low in productivity as characterized by low cation exchange capacity, pH, organic matter, available soil nutrients, etc. These soils are becoming more degraded due to shifting and subsistence agriculture with minimum or no inputs. Traditional livestock production is also extensive and the level of production is low, especially due to scarcity of good quality forages, especially during the long dry spells. In such a situation, legume rhizobium symbiosis not only provides high quality forage, but also improves soil nitrogen fertility and therefore the sustainability of the system.

Within genus Centrosema, *C. pubescens* is the only species widely used both as a cover crop in plantation agriculture and as a forage plant (TEITZEL and BURT, 1976). However, species such as *C. macrocarpum* (SCHULTZE-KRAFT, 1986) and *C.acutifolium* (SCHULTZE-KRAFT *et al.* 1987) are described as better adapted to

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tropical acid soils under low fertilizer inputs. Nodulation and nitrogen fixation activity of legumes grown in tropical soils are low as compared with temperate legumes due to several reasons. Mineral deficiencies or toxicities could be considered as two key factors (COCHRANE *et al.* 1985). Phosphorus is often the most limiting nutrient for pasture establishment in tropical soils due to high fixation capacity (LEMARE, 1982). Potassium is also identified as a limiting nutrient due to high plant extraction rates and K leaching or fixation by clay minerals (SANZ-SCOVINO and ROWELL, 1988). It is therefore important to assess nutrient requirements to improve nodulation, especially under low input subsistence agriculture. Thus, the objectives of this study were to test the performance of introduced accessions of *Centrosema acutifolium* and *Centrosema macrocarpum* under local conditions, and to observe the effects of Phosphorus and Potassium when added individually and in combination on growth and nodulation of these plant species.

2 Materials and Methods

Two centrosema spp (*C. acutifolium* and *C. macrocarpum*) and the following 4 fertilizer levels were tested using a completely randomized design with 6 replicates.

P_0K_0	- No fertilizers	
P_{80}	- 80kg P ha^{-1}	= 400 mg of 45% Triple super phosphate/pot
K_{70}	- 70kg K ha^{-1}	= 350 mg of 60% Muriate of potash/pot
$P_{80}K_{70}$	- 80kg P ha^{-1} +70kg K ha^{-1}	= 400 mg of 45% Triple super phosphate/pot and 350 mg of 60% Muriate of potash/pot.

Three fertilizer levels were selected considering the results of previous pot experiments (Seresinhe 1994). Round cement pots (24 cm diameter) were filled with 1:1 mixture of red yellow podsolic (pH 5.2) containing 16% clay, 21.3% silt and 61.2% sand and river sand. The soil had 0.145% N, 35.5 ppm P and 37.0 ppm K. Applied fertilizers were mixed well with the soil before planting the seedlings.

Twenty- four, sixteen day old, *C. macrocarpum* and *C. acutifolium* uninoculated seedlings were planted in pots at the rate of 4 seedlings / pot and, watered daily, and supported with bamboo sticks.

There were 4 harvests. The first partial (destructive) harvest was done four weeks after planting and, three harvests were done at weekly intervals. Thereafter at each harvest the following yield parameters were determined. The dry weights of shoots (all above ground parts), roots and nodules, nodule number and colour and the nitrogen concentration of total plant tissues (all above ground parts, roots and nodules). Dry matter and nitrogen contents were determined after drying at 80°C and Kjeldhal method, respectively.

The experimental data were analyzed using the SAS program package.

3 Results and Discussion

3.1 Shoot, root and total dry weights

Results are presented in Tables 1, 2 and 3. Data for individual harvests on shoot and root dry weights are also included in order to examine the growth as a function of time in general. Considering the overall harvest means of shoot and root dry weights, there was no interaction between the species and fertilizer effects, indicating that each species responded in a similar manner to each fertilizer treatment (Tables 1 and 2). As such, only the overall species and fertilizer treatments were statistically separated.

Without exception, each species with each fertilizer treatment gave increasing shoot and root dry weights with increasing time at each individual harvest. Irrespective of the species and the harvest, application of fertilizers (P,K or P and K) generally resulted in higher shoot, root and total dry weights compared to the zero control (Tables 1, 2 and 3). Similar response by different legumes to P and K fertilizers were observed elsewhere by several authors (GATES and WILSON, 1974, ISRAEL, 1987). Species wise, *C macrocarpum* had significantly higher shoot, root and total dry weights compared to *C. acutifolium*. The marked yield difference between the two species in this study could be related to the genetic differences between the two species (SCHULTZE-KRAFT and KELLER-GREIN, 1985). It was also reported that the accessions of *C. acutifolium* were the least demanding of P as compared with the accessions of *C. pubescens* and *C. brazilianum* (COSTA and PAULINO, 1990).

While P alone or P and K significantly increased the shoot dry weight, K alone had no effect compared to the zero control (Table 1). Only P plus K significantly increased the root dry weight compared to the zero control, although P alone compared to K alone tended to be superior again (Table 2). Total dry matter kept on increasing from zero control through K, P and P plus K; each being significantly different from other; clearly indicating and confirming the superiority of P over K on overall plant growth as expected from the results on the shoot and root dry weights as well.

Table 1. The effects of application of P and K seperately and in combination on shoot dry weight (g/plant) of *C. acutifolium* and *C. macrocarpum*.

Treat-ment	Harvest 1		Harvest 2		Harvest 3		Harvest 4		Harvest ($\bar{x}$)		Treatment
	C.a	C.m	C.a	C.m	C.a	C.m	C.a	C.m	C.a	C.m	$\bar{x}$
P_0K_0	0.117	0.236	0.162	0.364	0.314	0.692	0.721	0.421	0.329^{c}	0.678^{c}	0.523^{c}
P_{80}	0.228	0.503	0.456	0.845	0.957	2.079	2.130	0.409	0.942^{a}	1.709^{ba}	1.326^{ba}
K_{70}	0.200	0.329	0.331	0.693	0.675	1.093	1.558	2.730	0.691^{c}	1.211^{cb}	0.951^{cb}
$P_{80}K_{70}$	0.210	0.517	0.609	1.098	1.280	2.204	2.252	4.799	1.008^{a}	2.155^{a}	1.621^{a}
Var. $\bar{x}$									0.762^{b}	1.438^{a}	

Means bearing different superscripts are significantly different at P<0.05.

Table 2. The effects of application of P and K seperately and in combination on the root dry weight (g/plant) of *C. acutifolium* and *C. macrocarpum.*

Treat-ment	Harvest 1 C.a	Harvest 1 C.m	Harvest 2 C.a	Harvest 2 C.m	Harvest 3 C.a	Harvest 3 C.m	Harvest 4 C.a	Harvest 4 C.m	Harvest ($\bar{x}$) C.a	Harvest ($\bar{x}$) C.m	Treatment $\bar{x}$
P_0K_0	0.058	0.086	0.071	0.115	0.107	0.217	0.178	0.285	0.104^{c}	0.176^{c}	0.139^{b}
P_{80}	0.060	0.115	0.110	0.191	0.192	0.408	0.337	0.627	0.166^{ba}	0.335^{b}	0.251^{ba}
K_{70}	0.077	0.079	0.106	0.171	0.118	0.246	0.303	0.556	0.158^{b}	0.263^{bc}	0.211^{ba}
$P_{80}K_{70}$	0.079	0.106	0.139	0.280	0.203	0.378	0.443	0.994	0.216^{a}	0.439^{a}	0.328^{a}
Var. $\bar{x}$									0.161^{b}	0.303^{a}	

Means bearing different superscripts are significantly different at $P<0.05$.

3.2 Concentration and total nitrogen in plant tissues.

Since there was no interaction between the species and the fertilizer treatments, only the overall species and fertilizer means were statistically separated (Table 3).

The highest nitrogen concentration of both species was observed with P alone while K alone or even K in combination with P resulted in lower nitrogen concentrations. The increase in legume N concentration at higher P levels agrees with the earlier observations of ANDREW and ROBINS (1989) where they found that N concentration in the plant tops was increased by P supply. In fact, the combination of P and K resulted in lower nitrogen concentration compared to the zero control. In contrast, the highest nitrogen yield was with the combination of P and K while all fertilizer applications resulted in higher nitrogen yields compared to the zero control. Nitrogen yield of *C. macrocarpum* was superior to that of *C. acutifolium* in spite of its lower nitrogen concentration (Table 3).

Table 3. The effects of application of P and K seperately and in combination on the nitrogen concentration (%) of plant tissues, nitrogen yield (g/plant) and total dry matter yield (g/plant) of *C. acutifolium* and *C.macrocarpum.*

Treatment	mean nitrogen concentration (%)			nitrogen yield (mg/plant)			total dry matter yield (g/plant)		
	C.a	C.m	Treatm. ($\bar{x}$)	C.a	C.m	Treatm ($\bar{x}$)	C.a	C.m	Treatm. ($\bar{x}$)
P_0K_0	2.86	2.44	2.65^{ab}	13	23	18^{b}	0.464	0.865	0.664^{d}
P_{80}	2.97	2.47	2.72^{a}	36	49	43^{a}	1.242	1.981	1.640^{b}
K_{70}	2.73	2.42	2.58^{b}	26	50	38^{a}	0.992	1.488	1.240^{c}
$P_{80}K_{70}$	2.59	2.26	2.43^{c}	38	58	48^{a}	1.478	2.756	2.110^{a}
Var. $\bar{x}$	2.78^{a}	2.34^{b}		28^{b}	45^{a}		1.040^{b}	2.020^{a}	

Means bearing different superscripts are significantly different at $P<0.05$.

Thus, nitrogen concentrations of species and also in response to fertilizer applications have been inversely related to the dry matter yield indicating a dilution effect of nitrogen concentration due to high dry matter accumulation.

A similar response with *Pueraital phaseoloides* and *S. macrocephala* was reported by CADISCH *et al.* (1989). SCHULTZE-KRAFT and KELLER-GREIN (1985) indicated that the lower leaf stem ratio of *C. macrocarpum* as compared to *C. acutifolium* accounts for the lower shoot nitrogen concentration, which was also evident in the preliminary stages of this study (results not shown). Thus the combination of P and K with the highest dry matter yield resulted in the lowest nitrogen concentration while *C. macrocarpum* with the higher dry matter yield, compared to *C. acutifolium* also had a lower nitrogen concentration. In contrast, high dry matter yields have more than compensated for the resulting low nitrogen concentrations giving the highest nitrogen yields with P and K combination as well as with *C. acutifolium*. The response to fertilizer application of *C. macrocarpum* compared with *C. acutifolium* was also superior considering the total plant nitrogen.

3.3 Nodulation

As with shoot and root dry weights, the number of nodules per plant increased with each subsequent harvest in both species with all fertilizer treatments, without exception. *C. macrocarpum* had a greater number of nodules / plant at all harvests with all fertilizer treatments, except with the zero control during the first two harvests, resulting in a significantly higher number for overall harvest mean compared to *C. acutifolium*. As seen with other parameters, there was no interaction between species and fertilizer treatment effects on nodulation since each species responded in similar manner to different fertilizer applications (Table 4). Therefore, only the overall species and fertilizer treatment means were statistically compared.

At the first harvest (4 weeks after transplanting) both species in all treatments were nodulated. According to the subjective observations, at 5 weeks more than a half of the nodules were pink to red in colour, and there was only a slight difference between the two species. Nevertheless, marked difference were observed in the number of nodules/plant (Table 4), number of nodules /g root and nodule dry weight / g root (Fig. 1 and 2 respectively) in different treatments as well as in the two species. With both species, up to the second harvest, P alone gave the highest response while *C. macrocarpum* continued to respond in a similar manner up to the last harvest, resulting in the highest overall fertilizer treatment mean with P alone (Table 4). In contrast, even compared to the zero control, K alone often failed to incite a better response at different harvests irrespective of the species, resulting in a significantly lower number of nodules/ plant when compared to P or P and K.

Although, the number of nodules per g root did not show a clear trend as a function of time, with both species and different fertilizer treatments, nodule dry weight/ g root generally increased with time irrespective of the above mentioned variables rested (Figures 1 and 2). Since the nodule number / plant increased with time (Table 4) while number / g root had no clear trend together with nodule dry weight / g root following a similar trend to the former indicates that, rather than the number of nodules, the weight or size of nodules tend to increase with time, in relation to root growth. The increase in the number of nodules and dry weights per root weight basis is an indication of the direct involvement of P on nodule development (CADISCH *et al.* 1993). It is evident that P deficiency may limit nitrogen fixation capacity by affecting the survival of rhizobia, root hair infection, nodule development and nodule function as well as by affecting host plant growth (ROBSON *et al.* 1981).

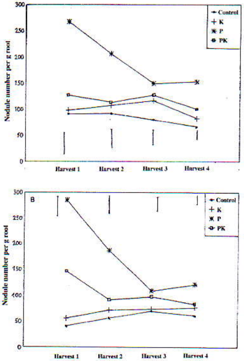


Figure 1:
Nodule number in relation to root weight of
(A) *Centrosema acutifolium*
(B) *Centrosema macrocarpum.*
Bars indicate Least Significant Difference (at $\alpha = 0.05$)

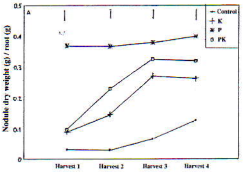
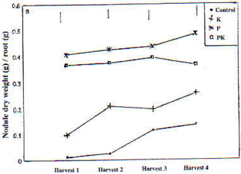


Figure 2: Nodule dry weight in relation to root weight of
(A) *Centrosema acutifolium*
(B) *Centrosema macrocarpum*
Bars indicate Least Significant Difference (at $\alpha=0.05$)



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