SEEDLING GROWTH OF MEDICAGO TRUNCATULA AND ORNITHOPUS SATIVUS ON A MANAWATU FINE SANDY LOAM AS AFFECTED BY pH, N, P, K AND RHIZOBIAL INOCULATION

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ABSTRACT

Seedling growth of **Medicago truncatula** and **Ornithopus sativus** in small pots was sharply increased by additions of phospate to a soil considered, on the basis of soil tests, to be marginally P deficient for good pasture growth. **M. truncatula** showed a greater growth response than **O. sativus** to high levels of added phospate, but not to lower levels of P. Substantial lime additions depressed growth of both species, presumably through an effect on phosphate availability. No response to added potassium was found, although soil tests indicated low soil K levels. This soil was known, however, to have high levels of bound (poorly extractable) potassium. Young seedlings did not become nitrogen deficient rapidly enough in this soil to demonstrate substantial responses to nodulation or nitrogen application.

INTRODUCTION

Small plot trials with annual cool season legumes of the genera **Medicago** and **Ornithopus** were planted on several sites at Palmerston North during autumn 1976. Substantial differences were later recorded in growth and nodulation between sites and between species at different sites. Poorest medic growth occurred on a Manawatu fine sandy loam previously used for maize cropping. On this site, growth of **M. truncatula** cv. Cyprus and **M. littoralis** cv. Harbinger was very slow with plants showing purple foliar colouration and poor nodulation, while **O. sativus** grew and nodulated more effectively.

A number of reasons for this generally poor but differential growth of these species seemed possible. Multiplication of the nodule forming **Rhizobium meliloti (Medicago** species) is recorded by Robson (1969) to be more sensitive to low pH than that of **Rhizobium lupini (Ornithopus** species). Medic nodulation is also sensitive to low calcium at moderately low soil pHs (Andrew, 1976), while medic plants themselves are sensitive to several mineral toxicities at low pHs on some Australian soils (Robson, 1969). Alternatively, low potassium and/or low phosphorus levels on the site could have been responsible for the poor medic growth and indirectly for their poor nodulation. Solution culture work has demonstrated a high potassium (Asher and Ozanne, 1967) and high phosphorus (Asher and Loneragan, 1967) requirement for maximal growth of **M. truncatula**, while **Ornithopus** had a lower potassium requirement.

To test these possibilities, two pot trials were run with rhizobial inoculum levels varied and additions of lime, P, K and N made to the soil. A controlled environment growth room was used to simulate the temperature conditions in the period following planting and soil from the site was used as the growing medium.

EXPERIMENTAL

Materials

Single plants of **Medicago truncatula** cv. Cyprus (barrel medic) and **Ornithopus sativus** W48 (serradella) were grown from seed in 5 cm diameter pots containing 200g of air dry Manawatu fine sandy loam. This soil was taken from the top 10 cm of the site showing worst medic growth and gave the following analysis by M.A.F. Quick Test: pH 5.5; Ca 10; K3; P (Olsen) 15; Mg22. Levels of K $\geqslant$ 8 and P $\geqslant$ 18 would be considered satisfactory for good ryegrass, white clover growth.

Rhizobal strains previously demonstrated to be effective on these legumes were used, namely NZP 4008 for **M. truncatula** and NZP 2076 for **O. sativus.**

Methods

Plants were grown in the P.P.D. Climate Laboratory under controlled environment conditions approximating those of Palmerston North during the normal planting period for these forage crops (April). Temperatures were 16.5/9°C (day/night) with an 8 hr changeover period; photoperiod was 12 hr at a light intensity of 82 $w.m.^{-2}$ (visible). Relative humidity was maintained close to 90% during both day and night. Pots were hand watered daily to maintain the soil close to pot capacity.

Soil nutrients considered as possible limitations to growth were thoroughly mixed with soil at field rates calculated on a pot surface area basis. Two separate experiments were run. In the first, four field application rates of 0, 20, 60 and 180 kg/ha of elemental N, P and K separately and 20 P plus 20 K, 60 P plus 60 K, and 180 P plus 180 K jointly were tested. Nutrients were supplied as NH_4NO_3, NaH_2PO_4 and KC1 respectively. Non-sterilized soil was used and two levels of inoculation (0 and 10^8 rhizobia/plant) tested at each nutrient level. Each treatment was replicated 4 times.

In a second experiment, lime supplied as finely ground $CaCO_3$ was tested at field rates equivalent to 0, 2, 4 and 6 t/ha. Sterilized soil was used and rhizobia supplied at 0, 10^2, 10^3, 10^5 and 10^8/plant for each level of lime in a factorial design. Rhizobia were supplied in water to recently germinated seedlings. Each treatment was replicated 4 times.

Six weeks after sowing plants were harvested at ground level, dried and weighed, while roots were washed clean and their degree of nodulation recorded.

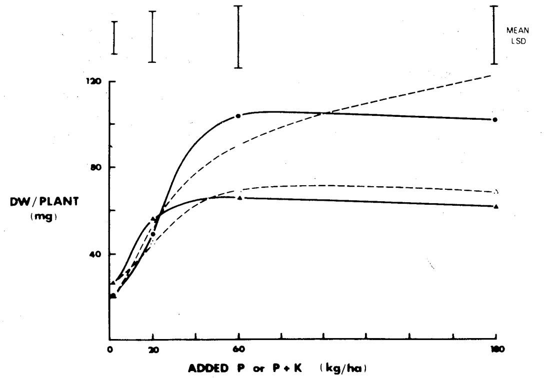

FIG 1. Effects of phosphate (——) and equivalent amounts of phosphate plus potassium (----) on seedling growth of **Medicago truncatula** cv. Cyprus (●) and **Ornithopus sativus** (▲). Mean LSD's for each nutrient rate are shown.

RESULTS AND DISCUSSION

Effect of phosphate

The effect of added phosphate on seedling growth of **M. truncatula** and **O. sativus** is shown in Figure 1. Both species responded sharply to phosphate additions even though soil tests had indicated a reasonable P level as regards pasture growth. At higher phosphate additions, medic seedlings outgrew those of **Ornithopus**, while at low P levels **O. sativus** seedlings were larger although this was not statistically significant. When potassium was supplied at the same time as phosphate, there appeared to be a small additional positive response at the highest levels of application, but analysis of variance (Table 1) did not confirm its significance. Neither did added potassium on its own affect seedling growth (Table 1), even though soil tests indicated inadequate levels for pasture growth. The type of test used is likely to underestimate potassium status, however, because of the potassium "fixing" properties of this soil (During, 1972).

Effect of lime

The effect of added lime on soil pH and on seedling growth of **M. truncatula** and **O. sativus** is shown in Figure 2. Soil pH was sharply raised even by the lowest level (2 t/ha) of finely ground $CaCO_3$ and

TABLE 1: Analysis of variance of treatment effects based on mean dry weight per treatment.

Source of Variation	F	
Experiment 1		
Phosphate	314.61	***
P x species	46.54	***
Species	38.48	***
Inoculation	9.21	**
Nitrogen	4.75	**
N x species	5.10	**
Potassium	0.71	ns
K x species	1.97	ns
P x K interaction	0.74	ns
P + K x species	3.92	*
Experiment 2		
Lime	119.68	***
Species	35.53	***
Species x lime	6.80	**
Inoculation	2.73	ns
Species x inoculation	0.76	ns
Lime x inoculation	1.67	ns

seedling growth was sharply reduced. Because of the marked phosphate response noted on this soil, lime could be reducing growth through an effect on P availability. Phosphate in the soil can be made less available with increasing pH through formation of less soluble calcium triphosphates; binding commencing at pH 6 and reaching a maximum at pH 8 (Sauchelli, 1965). The larger and significant (Table 1) depressing effect of lime on serradella growth compared to medic growth is less easy to explain in terms of phosphate availability. Serradella is reported to be adapted to acidic conditions (Gladstones and Barrett-Lennard, 1964), however, while the medics generally do better under neutral to alkaline conditions (Robson, 1969), so some other effect of soil pH may be operating to produce a combined response. Lime depressions of growth in this pH region have been reported as species specific and often transitory (Munns and Fox, 1976).

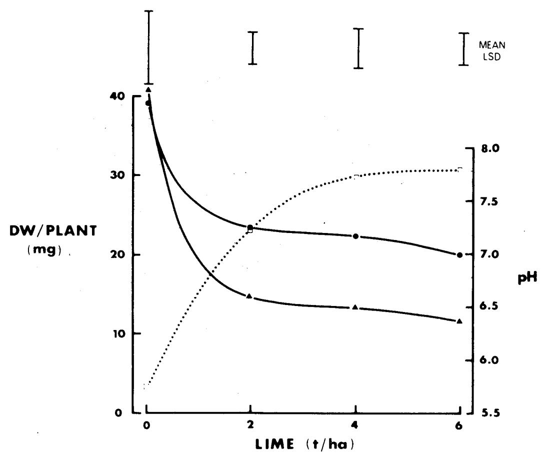

FIG. 2. Effect of lime (——) on seedling growth of **Medicago truncatula** cv. Cyprus (●) and **Ornithopus sativus** (▲). Resultant soil pH's are also shown (···□···). Mean LSD's for each rate of lime are shown.

Effect of inoculation and nitrogen

In the lime x inoculation level experiment, increasing levels of inoculum substantially increased the number of nodules on roots of both species. Increasing lime application progressively decreased the nodulation of serradella, but increased that of the medic at intermediate (2 to 4 t/ha) levels before decreasing it again at 6 t/ha. When no inoculum was added, no nodulation occurred in sterilized soil, but rather surprisingly this did not have a significant (Table 1) effect on growth of these small plants. It seemed likely that natural soil N levels increased by steam sterilization were sufficient to sustain plant growth for the short period of the experiment.

In the other experiment, addition of K and particularly of P substantially increased nodulation, but some nodules were formed with no added inoculum in non-sterilized soil. Statistical analysis (Table 1) demonstrated a small though significant effect of added inoculum on dry matter production and this may have become more pronounced had the plants been grown for a longer period. Added N also had a small positive effect on growth, as would be expected from the small positive nodulation effect. This response was more consistent with serradella than with the medic. Low soil P may have an overriding effect in restricting growth of the medic.

CONCLUSIONS

Poor legume seedling growth on the Manawatu fine sandy loam site is likely to have been caused by insufficient phosphate. Better growth of **O. sativus** than of **M. truncatula** may result from differing phosphate requirements of the two species. Any "low fertility" response of **Ornithopus** could be considered an advantage, but in intensive forage cropping systems using these legumes (Taylor and Hughes, 1976) high levels of production resulting from optimal fertilizer levels would probably be most profitable. In the region of maximum yield, Loneragan and Asher (1967) have shown that a number of annual winter growing grasses and legumes (including **M. truncatula**) have similar efficiencies in terms of P utilization, namely of 3 to 4 g DW/mg P.

In intensive forage cropping systems with no animal returns, maximum production from these cool season legumes, and particularly the medics, could require substantial inputs of phosphatic fertilizer.

On other sites in the Manawatu, some medic species have substantially outyielded **Ornithopus** in cool season production, but the reasons for this are still not clear.

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