PARTITIONING OF PHOSPHORUS IN WHITE CLOVER POPULATIONS WITH DIFFERENT NODULATION PATTERNS

J.R. Crush
AgResearch, Ruakura Research Centre, Private Bag 3123, Hamilton, New Zealand

ABSTRACT
The objective of this study was to see if a white clover (*Trifolium repens L.*) population selected for development of relatively few, but large nodules, differed in the way it used absorbed phosphorus, compared to a white clover population selected for many small nodules. Plants of both populations were grown in minus-nitrogen sand culture and the dry weights and phosphorus contents of shoots, roots and nodules were measured. There were no differences in growth or partitioning of dry matter or phosphorus between the clover lines.

KEYWORDS
White clover, nodules, phosphorus, growth

INTRODUCTION
Nodules of white clover have an apical meristem, usually contain relatively high concentrations of phosphorus (P), and act as a sink for P at all stages of their development (Hoshino, 1974). Recently populations of white clover have been developed from within the cultivar 'Grasslands Huia', that differ in distribution of nodule size classes (Crush and Caradus, 1996). In minus-nitrogen sand culture the population with fewer but larger nodules fixed more nitrogen (N) and grew faster than the population with more, but smaller nodules. Nutman (1967) concluded that *T. subterraneum* plants with few nodules are more efficient than those with many, because abundantly nodulated plants divert a disproportionate amount of resources into the meristems and cortical regions of their nodules. In mixed pasture white clover suffers from competition for P from grasses (Jackman and Mouat, 1970) and a nodulation pattern that used P inefficiently to fix N, would exacerbate the effect of competition for P. This report describes an experiment to see if the different nodulation types varied in their partitioning of P between roots, shoots and nodules.

METHODS
White clover seed from a selection for high nodule numbers (Margot Forde Germplasm Centre (NZ) No. C15832), and a selection for low nodule numbers (No. C15818), (Crush and Caradus, 1996) was scarified, surface sterilised and germinated in aerated sterile water. When the radicles were 5-8 mm long, 50 seeds of each line were transferred to sterile sand culture (Crush 1994) and inoculated with Rhizobium leguminosarum bv trifolii strain ICMP 2153. The sand cultures were irrigated 3 times/week with minus-N nutrient solution (Hewitt, 1966) while the plants were growing for 69 days during summer in a glasshouse. At harvest the plants were floated out of the sand, washed, dried at 80 oC, and weighed. Seventeen plants that expressed the ìfew but large nodulesî characteristic strongly, and 13 plants that had many small nodules were selected for detailed study. The nodules were rubbed off the roots and retrieved using a binocular microscope so that small nodules could be identified accurately. After weighing in bulk, the nodules from each plant were counted and their individual outline areas measured using a PC-based image analysis system and Video-ProR software.Using this data, 10 plants of each nodulation type were selected and analysed for shoot, root and nodule P content. All the data was analysed using Minitab.

RESULTS AND DISCUSSION
There was no difference in total plant dry matter (DM) accumulation or DM partitioning between the clover lines varying in nodulation pattern (Table 1). This was unexpected because previous research with these clover selections has shown that white clover with fewer but larger nodules fixes more N and grows faster than clover with many small nodules (Crush and Caradus 1966). The earlier experiment had supportetd Nutmanís (1967) conclusion (for T. subterraneum) that plants with few nodules are more efficient than those with many, because abundantly nodulated plants divert a disproportionate amount of resources into the meristems and cortical regions of their many nodules. The same culture system was used in both our experiments, but in the experiment described here, the average plant size was only about 60% of that recorded in the earlier experiment. Differences in growth between the nodulation selections may have developed if the experiment had run for longer although the data came from plants with clear differences in the number and size of their nodules. The nodule measurements were made on dried, shrunken nodules so the nodule sizes in Table 2 are not comparable with turgid nodules. We have assumed similar shrinkage in nodules from different sources.

Tissue P concentrations fell in the normal range for white clover - averages of 0.31 % P in shoots, 0.24 % P in roots and 0.68 % P in nodules.There were no differences between the two clover populations in the way P was partitioned among shoots, roots and nodules (Table 2). This probably reflects the lack of any differences in plant growth rate. The two clover lines did not vary in growth per unit nodule P. The results for these young plants do not provide any evidence that changing nodulation patterns will improve the growth per unit P absorbed, of white clover. Further work will be required to see if the differences in nodulation pattern persist in older clover plants with new root systems forming from stolon nodes, and if the nodulation pattern is persistent, whether it influences P partitioning.

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Table 1
Plant growth and nodule characteristics for white clover seedlings selected for few, large nodules or many, small nodules.

Nodule type	mg total DM	Root/shoot ratio	mg nodule DM	Nodules/plant	Mean nodule area (mm2)
Few, large	260	0.59	9.3	27.8	1.4
Many, small	283	0.65	7.7	43.1	0.6
Significance	ns	ns	ns	$P< 0.01$	$P< 0.001$

Table 2
Phosphorus content of shoots, roots and nodules of white clover seedlings selected for few, large or many,small nodules.

Nodule type	µg shoot P	µg root P	µg nodule P
Few, large	466	238	63
Many, small	505	229	51
Significance	ns	ns	ns