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SOIL WATER CONTENT AFFECTS THE AVAILABILITY OF PHOSPHATE

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Abstract

Reduction in water content of a soil increased the concentration of ammonium and nitrate in solution, but had no effect on the concentration of phosphate. The corresponding reduction in the quantity of phosphate in solution caused an equivalent reduction in the response of ryegrass to applied phosphate.

Keywords: soil solution, soil water content, phosphate, ryegrass, nutrition.

INTRODUCTION

Soil water has a two-fold role in the nutrition of pasture plants. Besides the obvious physiological need for water by the plant, water is also the medium within the soil from which plants absorb their inorganic nutrients.

The total quantity of soil water can vary greatly between the extremes of field capacity and wilting point (Rickard 1957), and although variation within this range in the surface soil may not be critical from the need for water per se, it can affect the supply of nutrients to the plant. The effect of soil water on mineral nutrition can be exerted in a number of ways. Thus, it is well established that when plant growth is limited by soil water supply, nitrogen tends to accumulate within the plant (Richards & Wadleigh 1952), but Mitchell (1957) found that, under drying conditions, the initial check to grass growth may have occurred when adequate water was still available from lower layers of the soil and may have resulted from the lessening availability of nitrogen as the surface soil dried. Sherrell & Saunders (1974) showed that both dry matter yield and plant phosphate content were increased with an increase in soil water.

In general, drying of the soil should increase the concentration of a nutrient in solution as a result of reduction of solution volume. In a simple solution, the concentration of an ion in solution should be increased proportionately to the reduction in solution volume, and the quantity of dissolved nutrient should remain constant. However, the concentration of nutrients in soil solution is buffered to a greater or less extent by adsorption of these ions by the solid phase of the soil, particularly for phosphate, for which strong adsorption or “fixation” controls the concentration in solution over a wide range of volume change (Holford 1979). This buffering will reduce the quantity of available phosphate in solution as the volume of soil water decreases. A reduction in water volume would also reduce the rate at which the solution-phosphate is replenished through desorption (Sharpley 1983), diffusion (Porter et al. 1960) and mass solution flow (Gardner & Mayhugh 1958). The effect of reduced phosphate supply could act on the plant independently of its need for water. To examine this effect, phosphate concentrations in soil solution at different soil water contents, and the effect of soil water content on the response of ‘Grassland Ruanui’ perennial ryegrass (*Lolium perenne* L.) to applied phosphate, were measured.

METHODS

To each of 48 Petri dishes containing 25 g Ramiha silt loam (Cowie 1976), 16 ml of solution containing 480 μMol P as $Ca(H_2PO_4)_2$ was added. This saturated the water-holding capacity of the soil. The soils were then kept in darkness at 25°C for two weeks, during which time they were weighed twice daily and allowed to dry to prescribed water contents and held at the required content by additions of water by weight. The water contents at which they were held were 64, 60, 56, 52, 48, 44, 40, 36, 32 and 28% water/soil by weight. There were 4 replicates. A further 8 dishes were held at 28% for 12 days and then raised to, and held at, 64% for 2 days before analysis. Soil solution was extracted by the method of Whelan & Barrow (1980) using carbon tetrachloride as the displacent and analysed for phosphate (Murphy & Riley 1962), ammonium (Brown 1973) and nitrate (Henzell et al. 1968) concentrations.

The effect of different soil water content on the response of ryegrass to phosphate was studied in a factorial pot trial in a glasshouse. Ten phosphate treatments (0 to 14.4 g $Ca(H_2PO_4)_2$ per pot containing 3824 g air-dry Ramiha soil) were mixed through the soil prior to sowing. Two water levels (1100 and 1370 ml water per pot) were imposed, and maintained within 8%, by regularly watering to weight. Adequate N, K, Mg and S were applied and the pots were sown with ryegrass (4 plants per pot) on 5 April and harvested 53 days later when the dry matter yield of tops was measured.

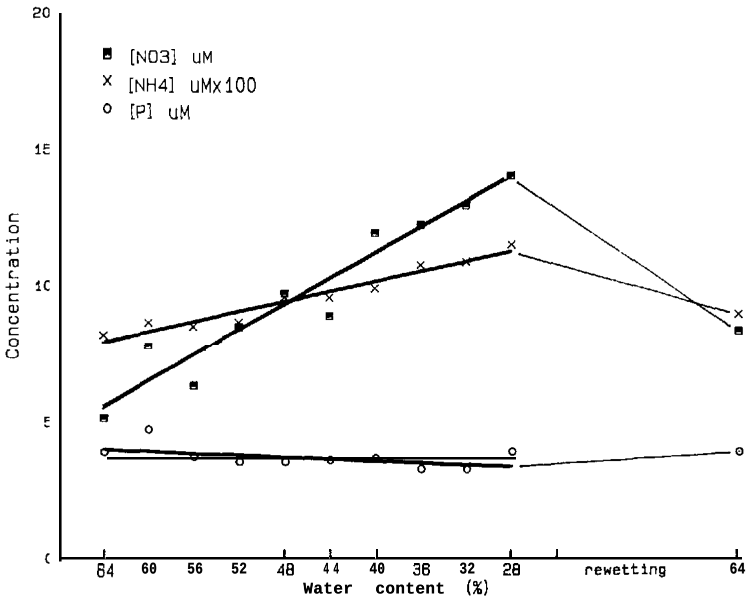

Figure 1: The effect of reduction of soil water (W%) on concentration of ammonium, nitrate and phosphate in soil solution

($[NH_4] = 1378 - 9.12W$, $r = -.818^{***}$

$[NO_3] = 20.5 - .234W$, $r = -.784^{***}$

$[H_2PO_4]$ no significant regression),

and the effect of rewetting on this concentration.

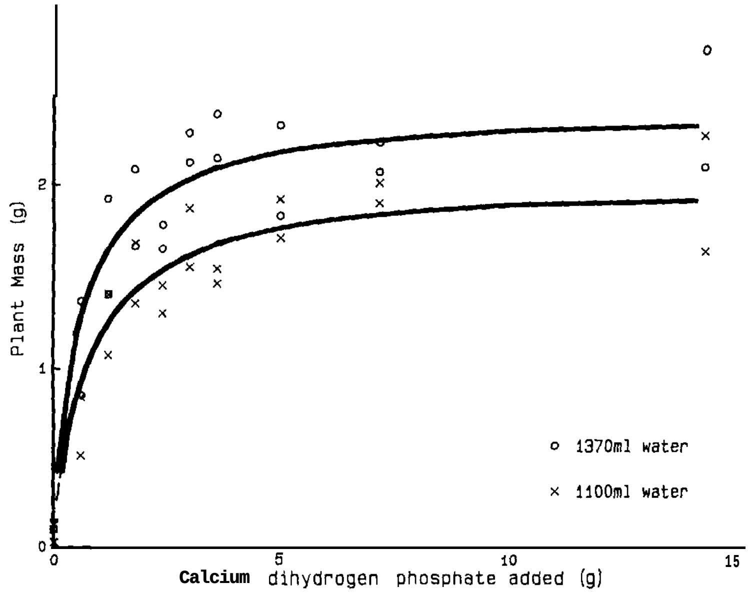

Figure 2: Response in dry matter yield of ryegrass to phosphate application at two soil water levels. The hyperbolic regression lines differ significantly,
*DM Yield (1370 ml) = .11 + 2.32P/(.626 + P), r = .980****
*DM Yield (1100 ml) = .05 + 1.97P/(.772 + P), r = .973****

RESULTS AND DISCUSSION

The effect of drying the soil on ion concentration in the displaced soil solutions is shown in Fig. 1. Phosphate concentration did not change with reduction in volume of soil water, but ammonium and nitrate increased in concentration. In part, this increase in concentration offset the reduction in the quantity of available nitrogen through the lessening of solution volume. A 50% reduction In water volume was accompanied by a 37% increase in nitrogen (ammonium and nitrate) concentration. On the other hand, the quantity of phosphate in solution available to the plant was reduced by an amount equal to the reduction in solution volume. Therefore, a reduction in the volume of soil water would be expected to produce an equivalent reduction in the available P supply to the plant, irrespective of the initial supply of available P. This was expressed in plant response to phosphate (Fig. 2). There was a highly significant overall reduction in dry matter yield with lowering of the soil water content, and there was a highly significant response in dry matter yield to phosphate application, but there was no interaction between water level and P application on yield. The lack of interaction suggests that the effect of water content on P availability was one of direct equivalence to the volume of water present. The direct response to water itself is obvious at the higher values of P input in Fig. 2., but this effect will diminish as P stress becomes apparent at lower P inputs, and this would be expected to show as a positive nutrient interaction on growth. However, the reduction in growth with lowered soil water content continued, even when the plants were under considerable stress through P shortage and obviously not limited

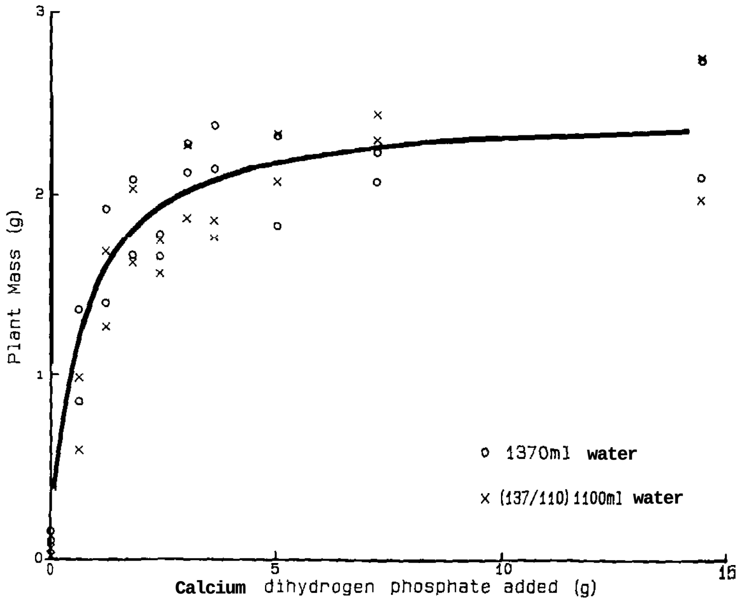

Figure 3: The yield of DM at the lower water treatment (1100 ml) "corrected" on a relative wafer volume basis (137/110), compared with the yield at the higher water treatment (1370 ml).

through any direct effect of water shortage. At these levels of P stress, the role of water as a sink for available P in solution is markedly affecting the response in plant growth to P application. This is supported by the similarity of the overall reduction in dry matter yield with lowered soil water content (21.6%) and the reduction of soil water volume (19.7%). This reduction was constant in effect over all P levels, as shown by the similarity between the response to Pat the 1370 ml water level and that calculated from the response at the 1100 ml level assuming a simple proportional relationship on a water volume'basis (Fig. 3).

Yield at 1370 ml = 1370/1100 (Yield at 1100 ml).

The two response curves do not then differ, nor do they differ from the overall regression illustrated in Fig. 3.

DM Yield (both) = .08 + 2.39P/(.698 + P), r = .976***.

This effect was to be expected since it has been seen that the quantity of phosphate available in solution is directly proportional to the volume of the solution in the soil.

Agronomic benefit could therefore be gained from keeping the soil water levels above that needed merely to satisfy the water requirements of the plants, when utilization of phosphate could be a factor limited plant growth. As a corollary, it may be stated that some of the benefits of added water to pasture could well accrue from increasing the availability of phosphate rather than from the physiological response of the plants to water itself.

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