HIGH CONCENTRATIONS OF SOIL SOLUTION PHOSPHORUS IN WIMMERA SOILS

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Summary. Saturated extracts from various depths of three Ug alkaline soils from the western Wimmera region of Victoria were analysed for phosphorus content. This was always greater than 1 ppm and often exceeded 5 ppm. These figures are unusually high, and mass flow to plant roots would be a significant mechanism at these concentrations in overall phosphorus uptake by plants. The phosphorus in the extracts did not react with molybdate, and was measured using ICP technology. The form and plant availability of this phosphorus is not known, but it may be the reason why these soils show lower responses to P than others, and why no soil test has been found which can predict P response on these soils.

INTRODUCTION

In a review of the soil solution composition for various soils it was found that P concentrations ranged from <.03 ppm to 32 ppm, most commonly being in the range .03 to .3 ppm (1). Concentrations of phosphorus measured in expressed soil solutions and lysimeter percolates ranged from 0.2 to 7.2 ppm (2). In a more comprehensive study, the phosphorus concentrations in saturation extracts of 135 north central United States soils ranged from 0 to 0.24 ppm with a modal value of 0.05 ppm (3). In that paper, it was calculated that 3 kg P /ha would be directly contacted by roots of a maize crop, and a further .3 kg P/ha would be supplied by mass flow of water to the roots, amounting to less than 20% of the crop's uptake. The conclusion reached was that mass flow is not an important mechanism in the uptake of soil phosphorus by plant roots, and that diffusion is the dominant mechanism. In a paper explored the mathematics of phosphorus movement by diffusion (4), soil solution P concentrations for two soils of .34 and .16 ppm were reported.

Soil solution P concentrations ranged from 1.35 ppm in the top 30 cm to .05 ppm at depth in a study on nutrient uptake by wheat (5), and it was calculated that only 5% of the P taken up was supplied by mass flow.

Although there are some quite high values in some reviews (1,2) , subsequent work (6,7) has concentrated on the more commonly reported low figures, and in particular the values for 135 soils (3), so that there has been general agreement that mass flow is relatively unimportant as a mechanism of P movement to plant roots.

This paper reports unusually high concentrations of phosphorus in saturated extracts of three calcarious, alkaline soils soils in the Wimmera region of Victoria, a region characterised by low crop response to P fertilisation.

MATERIALS AND METHODS

Three sites were sampled in the western Wimmera region of Victoria as follows:-

1. Lillimur and Miram sites

In autumn 1990, 64 soil cores each 140 cm in depth and 5 cm diameter were taken at each of two sites (Lillimur and Miram). The soil was bulked for each site in 20 cm increments, dried at 40oC and ground to pass a 2mm sieve. Both soils were in the Ug category, however the Lillimur site was a dark coloured, cracking, self-mulching type, whereas the Miram site was locally termed a "red soil" although the colour difference was marginal. It was less friable and hard setting when cultivated. Detailed chemical analysis was carried out on these samples by the State Chemistry Laboratories.

In December 1990, 128 cores per site were sampled to 140 cm depth and bulked into four blocks per site and into 20 cm depth increments. Samples were dried at 40oC and ground to pass a 2 mm seive. Saturation extracts were prepared by adding distilled water with stirring until the saturation point was reached, allowing this to stand for two hours and then centrifuging (10,000 rpm, 10 min) to extract the soil solution. Electrical conductivities were measured on these, and they were then analysed by CSIRO, Adelaide using ICP methodology for a range of elements including phosphorus.

2. Hick's

A 20 ha "red soil" area in the Western Wimmera was sampled in April 1991 by taking 36 cores each 5 cm in diameter to a depth of 2 m, separating them into 25 cm depth increments and bulking them. These were dried at 40oC, ground to pass a 2 mm seive and a subsample was analysed by the State Chemistry Laboratories. Saturated extracts were prepared and analysed as above.

3. Form of Phosphate A bulk sample of the saturated extracts was prepared and various attempts made to analyse this using colorimetric techniques.

RESULTS

1. Lillimur and Miram sites

The soil types at Lillimur and Miram were Ug 5.24 and Ug 5.34 respectively, and were of light clay texture at the 0-20 cm depth increasing in texture to medium clay at depth. Both soils were alkaline, increasingly so with depth, conductivities of 1:5 extracts ranged from .23 dS/m at the surface to 1.27 at depth, with total soluble salts showing similar increases with depth (Table 1). Exchangeable sodium exceeded 6 below 20 cm depth. Overall there were only minor differences shown by the analyses of the ground samples between the two soils, despite their distinctly different behaviour from a production viewpoint, the Miram soil being regarded as much inferior to the Lillimur soil. Analysis of the saturated extracts revealed that the Miram soil has much higher conductivity values, but these were still less than 6.0 dS/m above which growth is affected. The conductivity of the 1:5 extracts was similar for both soils, while that of the saturated extracts differed. A possible explanation might be the presence of gypsum (or a similar sparingly soluble compound) in the Lillimur soil which would result in higher conductivity of the 1:5 extracts. This would also accord well with the better behaviour of this soil observed in the field. The phosphorus concentrations of the saturated extracts ranged from 2.2 ppm in the surface 20 cm and generally increased to above 5 ppm at depth.

2. Hick's

The soil type was Ug 5.34, but was of slightly lighter texture overall than the two above, and had lower levels of exchangeable calcium, particularly in the surface, than the other soils. Cation exchange capacity was lower, and exchangeable sodium percentage higher than the Lillimur and Miram soils. As for the Miram soil, there was quite good agreement between the EC of the 1:5 extract and that of the saturated extract, indicating that there was little effect of sparingly soluble compounds such as gypsum. (Table 1). This soil type is also regarded as difficult by farmers to manage. The phosphorus concentration of the saturated extracts ranged from 2 to 7.7 ppm.

Table 1 pH, electrical conductivity (EC), total soluble salts (TSS), cation exchange capacity (CEC), exchangeable sodium percentage (ESP) of 1:5 extracts, and electrical conductivity (EC) and phosphorus concentration of saturated extracts of soil from Lillimur, Miram and Hick's

3. Form of Phosphate

The saturated extracts were analysed using ICP methodology, and attemps were made to analyse the phosphorus contents of these samples using the Molybdate method. No phosphorus could be detected by this method even after pretreatment of samples with acid. Phosphorus standards made up with saturated extracts reacted normally indicating that there was no interference from the salts in the extracts, but that the phosphorus is present in a form other than orthophosphate.

DISCUSSION

Maximum efficiency of grain (wheat) production per unit of transpiration is 20 kg/ ha/ mm (8). French (pers. com.) suggests that wheat requires 3.2 g P uptake for every kg grain if maximum yields are to be achieved. This then calculates to 64 g P/ ha /mm transpiration, or requires a concentration of 6.4 ppm P in the transpiration stream if the crop's P requirement is to completely met by mass flow. It should be noted that this figure represents the maximum efficiency of grain production for wheat, and that rates of half this would be common, implying a figure of 3.2 ppm P required in the transpiration stream for less efficient crops. Given the amount likely to be encountered by direct root/ soil contact, this estimate could be reduced by a further 10 to 20%. The conclusion which emerges is that mass flow would account for a significant part of phosphorus uptake by crops in the soils studied here, where P concentrations in the saturated extracts ranged from 2 to 8 ppm. This finding is in contrast to the more common finding that mass flow is relatively unimportant, and that diffusion is the dominant mechanism by which P reaches plant roots.

High levels of P at depth have been reported in calcareous soils of the United States (9), and the authors pointed to the paucity of studies on phosphorus distribution with depth. The methods these authors used to extract phosphorus was different to the saturation extract method used here, so no direct comparisons are possible beyond noting that high P levels have also been measured.

This paper does not identify the form of P present, other than suggesting it does not react to form the phosphomolybdate complex so is therefore not orthophosphate. Little insight into possible organic forms was gleaned from the review of organic phosphorus (10) as there are no studies of soluble P forms at the concentrations reported here or at these depths. Electrical conductivity and sodium absorbtion ratio have been shown to affect the concentration of phosphate in soil column leachates (11), but this P was in a form which would react with molybdate, unlike the material reported here. It is possible that under the conditions of the soils studied here (high pH, high concentrations of sulphate and calcium) that some kind of complex ion forms which is stable (12) or it may be that some type of polyphosphate forms under these conditions. Further studies are needed to characterise the P present, and to determine if it available to plants.

It is noteworthy that wheat responses to phosphorus fertiliser in the Wimmera region are low in comparison to other areas of the state (13,14), and that soil tests (all of which were based on measurement of P by the molybdate method) have proved ineffectual in predicting P response (15,16).

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