NITROGEN AND THE AVAILABILITY OF SOIL AND FERTLISER PHOSPHORUS TO PLANTS

by

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I. Introduction.

It is an interesting paradox that while phosphorus is one of the most important of the plant nutrient elements, phosphorus-deficiency is without doubt the most widespread and important mineral inadequacy affecting the crops of the world. Agricultural and forest crops over enormous areas in many countries (particularly Australia, South Africa and Great Britain) are limited by deficiencies in phosphorus supply.

This circumstance has had two results (i) the wide-scale and routine use of phosphorus-supplying fertilisers in affected areas, and (ii) the stimulation of soil chemists, agronomists and silviculturalists to enquire into the behaviour of phosphorus in the soil and factors which affect its availability to and uptake by the plant.

These enquiries have shown that the chemistry of soil phosphorus is extremely complex : the ability of the plant to take up phosphorus from the soil is governed by many interacting climatic, soil and plant factors.

Reported in the last issue of Forest Notes (Vol. 5, No. 1) by A.L. Clifton, was an example of one of these phosphorus interactions. Clifton reported C.S.I.R.O. findings that the use of a combination phosphorus and nitrogen fertiliser resulted in a significantly greater growth response of pines on low-fertility sites than if only phosphorus or nitrogen fertilisers alone were used. As there can be little doubt that West Australian foresters will be hearing more of this phenomenon in the future, perhaps it is an appropriate time to briefly discuss the behaviour of soil and fertiliser phosphorus in the soil and the effects of nitrogen additions on this behaviour.

II. The Behaviour of Phosphorus in the Soil.

According to Russell (1956) phosphorus has been found to exist in the soil in four different groups of compounds. In all of these phosphorus occurs as the phosphate, PO_4 . The groups are:

(a) Inorganic minerals containing phosphorus as an integral part of their structure - e.g. , apatite.

(b) Insoluble phosphate "reaction-products", formed when soluble phosphate fertilisers are added to the soil.

Some uncertainty as to the exact nature of these compounds still exists,

(c) Phosphates held on the surface of hydrated iron and aluminium oxides.

(d) Organic phosphates that exist in humus, soil organic matter and the living soil population.

According to Black (1957) only phosphates in a soluble form (the $H_2PO_4^-$ - ion) can be absorbed by the plants - phosphorus cannot be taken directly from the solid phase nor absorbed as an organic compound.

It would seem logical to assume, therefore, that deficiencies in soil phosphorus could be simply overcome by just adding a sufficient quantity of water-soluble phosphate to the soil. Unfortunately it is not as simple as this. Phosphate fertilisers differ from nitrogen, calcium and potassium fertilisers in that only a relatively small proportion of applied phosphate is taken up by the crop. This proportion varies according to the species, other factors which may limit plant growth (such as zinc deficiency), the pH of the soil and certain climatic factors. As a general rule, recovery of added phosphate is rarely in excess of 20% (Black, 1957). The other 80% forms insoluble phosphate reaction products and becomes locked, or "fixed" in the soil.

III. The Phosphorus-Nitrogen Interaction.

Since the early part of this century it has been well known that the addition of nitrogen generally increases uptake by plants of both soil and fertiliser phosphorus. Since then , a great deal of work has been done on this so-called "phosphorus-nitrogen interaction".

Broadly speaking, the effect of nitrogen on the uptake of phosphorus can be divided into two groups : (i) chemical effects and (ii) biological effects.

1. Chemical Effects. According to Grunes (1959), the addition of nitrogen can have two chemical effects on phosphorus availability to the plant: salt effects and pH effects.

Salt Effects. Work by several investigators, including Wild (1950) and Caldwell (1960) has indicated that different nitrogen carriers have different effects on the solubility of soil and fertiliser phosphorus. Their work has shown that :

(i) The uptake of phosphorus from phosphates of low water-solubility was not affected by the addition of nitrogen in either the ammonium or nitrate form.

(ii) Salts such as ammonium nitrate and ammonium sulphate markedly increased uptake of phosphorus from superphosphate.

(iii) Salts such as calcium nitrate and sodium nitrate have no effect on phosphorus uptake under any conditions.

The implication of these findings is that the effects of nitrogen salts on phosphorus availability appears to be principally an effect of the ammonium ion.

pH Effects Phosphorus availability is profoundly influenced by the pH of the soil. As a general rule, phosphorus availability is greatest in neutral and least in acid or alkaline soils (Russell, 1956). Consequently we would expect phosphate availability to increase in soils which are strongly acid or strongly alkaline when some other factor tends to adjust soil pH towards neutrality.

It has been shown that additions of nitrogen can increase phosphate availability in this way (Lorenz and Johnson, 1953; Rennie and Mitchell, 1954) Several workers have shown that increased phosphorus uptake will occur following (i) the addition of a residually-acid nitrogen fertiliser to an alkaline soil, or (ii) the addition of a residually-alkaline nitrogenous fertiliser to an acid soil.

pH effects such as these could only be expected in soils not highly buffered against pH change.

2. Biological Effects . Nitrogen is a fundamentally important plant nutrient in its own right, so it is reasonable to expect that some of the effect of nitrogen in causing an increased uptake of phosphorus is due indirectly to the effects of nitrogen itself on the growth rate and general thrift of the plant.

In a soil in which all other plant requirements are adequate the addition of nitrogen will stimulate both root and top growth of the plant. Nitrogen, in fact, is essential for the growth of roots and is an important fertiliser for root-crops grown on low-N soils. In view of this it may be submitted that additions of nitrogenous fertilisers to N-deficient soils increases the uptake of phosphorus through a stimulation of root growth and thus an increase in both the foraging capacity of the plant root system and the volume of soil explored.

IV. Literature Cited.

[References cited in the above article are available from the writer. They are excluded here to save space - Ed.]