A COMPARISON OF TWO PHOSPHORUS SOIL TESTS AS INPUTS TO A PASTURE GROWTH MODEL

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ABSTRACT

Glasshouse and field studies were carried out to investigate relationships between plant growth and extractable soil phosphorus and between fertilizer phosphorus and extractable soil phosphorus respectively. The purpose of the studies was to provide information with which to quantify the parameters of a simple model designed to predict relative pasture yield as a function of soil and fertilizer phosphorus.

The relationship between yield and water-extractable soil P differed markedly between two soils of different P retention properties in glasshouse studies using both intact cores and conventional pots. To illustrate this difference, the levels of water-extractable P (0-8 cm depth) in intact cores required for 90% of maximum yield were 12.7 and 2.6 μg/g soil in the soils of lower and higher P retention respectively. In contrast, the relationship between yield and Olsen (bicarbonate-extractable) P was much less soil type dependent. The corresponding levels of Olsen P in intact soil cores required for 90% of maximum yield were 17.7 and 17.8 μg/g soil respectively. For modelling purposes, the Olsen procedure was therefore considered to provide a more suitable index of plant available soil P from which to predict pasture production on soils differing in P retention.

The proportion of yield variation accounted for by differences in extractable soil P was 25% or less in initial harvests from the intact cores, 50-75% in later harvests from the intact cores and 89-97% in the pot experiments. The results of the intact core experiments, however, were considered to be more directly applicable to the field situation than were the results of the pot experiments.

Seasonal changes in extractable soil P in Tokomaru silt loam included an increase during the dry season to reach a peak in late autumn followed by a decline in winter. The magnitude of these changes with respect to Olsen P was approximately 2.5 and 5 μg/g soil in the 0-8 cm and 0-4 cm depths respectively. A subsequent decline in extractable soil P during the spring and second summer was attributed largely to plant uptake of soil P and its loss in discarded clippings.

The application of superphosphate increased extractable soil P in proportion to the rate applied. The increases per unit of applied fertilizer P, in both absolute terms and relative to an initial (time-zero) increase, were greater in a soil of low P retention (Tokomaru) than in a

soil of high P retention (Ramiha). Water-extractable P (0-8 cm depth) was increased on average by 2.3 and 0.2 μg/g in the Tokomaru and Ramiha soils respectively six months after the application of 40 kg P/ha as superphosphate. The corresponding average increases in Olsen P (2.7 and 1.1 μg/g) were greater, and differed less between the soils, than the increases in water-extractable P. Thus, neither soil P extraction procedure was independent of soil type in terms of the effects of applied fertilizer P. For modelling purposes the effects of applied fertilizer would need to be assessed in a wider range of soils.

The level of water-extractable P in stored, air-dry soils was found to undergo short-term fluctuations, apparently due to changes in the conditions of extraction such as variations in the pH of distilled water. Longer-term increases of 25-100% in the level of water-extractable P of stored soils also occurred. No reason for the latter changes was apparent.

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CHAPTER 1

INTRODUCTION

The use of fertilizer, particularly phosphate fertilizer, has played a vital role in the productivity of New Zealand agriculture. The total amount of fertilizer used has steadily increased over the years, surpassing one million tonnes per annum in the mid-1950's and two million tonnes per annum in the mid-1960's. During the last fifteen years, between 1.7 m and 2.5 m tonnes per annum have been applied to New Zealand soils (Ministry of Agriculture and Fisheries, 1978). Variation between years, sometimes considerable, has reflected the overriding influence of the financial state of the farming industry on fertilizer use.

Most fertilizer used on New Zealand farms is manufactured from imported raw materials, the balance being imported in manufactured form. The total value of imported fertilizer materials is currently of the order of \$100 m per annum, of which about 65% is for raw rock phosphate and other phosphatic fertilizers (Ministry of Agriculture and Fisheries, 1978). Phosphate fertilizer is therefore not only a very important resource in New Zealand agriculture, but is also a very expensive one. Despite this, phosphate fertilizer applied to grazed pastures in recent years appears to have exceeded the maintenance requirements of New Zealand's livestock population (Karlovsky, 1975). Syers (1974) similarly concluded that fertilizer usage may be excessive, at least on certain soils, and in view of the inevitable increases in the price of phosphate fertilizer, considered there was a need for further research on the efficiency of fertilizer use on many soils.

Technically, efficient fertilizer use requires that wastage of fertilizer through the application of excessively high rates is avoided. Optimum fertilizer rates can be determined in specific situations by conducting field trials to measure the response of pasture to various rates of application. Such trials are often used to calibrate soil tests which are then used to assess the nutrient status of soils in areas where there is no information available from field trials.

A largely untested method, particularly in New Zealand, of evaluating fertilizer use in relation to optimum rates, times and frequencies of application, is systems modelling or more specifically the mathematical simulation of soil-plant relationships. Systems modelling has been defined as an activity involving the construction of a mathematical model of a system, generally but not necessarily followed by manipulation or experimentation with the model (Wright, 1976). A recent example of systems modelling in New Zealand is the development of a simulation model of an intensive pastoral beef grazing system, including soil, pasture, animal and management components, by Wright et al (1976). In the pasture component of this model, the potential growth rate of ryegrass-white clover pasture on any given day is determined by time of year and accumulated level of dry matter. The estimated potential growth rate is then modified by a temperature factor and a soil moisture factor to give actual growth rate.

A deficiency of the pasture growth model, however, is the absence of any soil nutrient component. To enable evaluation of the effects of alternative phosphate fertilizer policies on simulated pasture production, an attempt was made to develop a simple phosphorus (P) submodel (Smith et al, 1977). The overall pasture model would then integrate the separate effects of soil moisture supply, temperature and phosphate supply on plant growth.

The P submodel is based on two basic assumptions. The first is that relative pasture yield can be predicted from the level of plant available soil P if the relationship between these two variables is known. Extractable soil P is used as an index of plant available soil P because of problems associated with the definition and rapid measurement of the latter fraction. The relationship between relative yield (RY) and the level of extractable soil P (x) is represented in the P submodel by an exponential equation of the form:

$$RY = 1 - \frac{Be^{-cx}}{A}$$

where A is maximum attainable yield, B is the difference between maximum yield and actual yield when x = 0, and c is the curvature coefficient. If yield is zero when x = 0, then the equation simplifies to:

$$RY = 1 - e^{-cx}$$

Ideally, the soil P extraction procedure should be independent of soil type so that the magnitude of the c coefficient does not vary between different soils.

The second assumption made in the P submodel is that the level of extractable soil P at any given time can be predicted if it is known how the level changes over time and in response to applied fertilizer P. The relationship between the amount of fertilizer P applied (F) and the level of extractable soil P is represented in the P submodel by a linear equation of the form:

$$x_2 = x_1 + bF$$

where x_1 and x_2 are levels of extractable soil P before and after fertilizer application and b is the unit change in x per unit of applied F. The magnitude of the b coefficient can be expected to decrease with time as the extractability of the applied P declines.

Before the P submodel can be used to evaluate alternative fertilizer policies, it is necessary to know what values should be assigned to the coefficients in the equations representing the relative yield-soil P and fertilizer-soil P relationships. Unfortunately, there is a distinct lack of this type of information in relation to phosphate fertilizer use on New Zealand pasture soils. The aim of this study was to quantitatively investigate the above relationships.