INVESTIGATIONS INTO THE INFLUENCE OF FERTILISER HISTORY AND CLIMATE REGIME ON THE SOIL FERTILITY, SOIL QUALITY AND PASTURE PRODUCTION OF WAIRARAPA HILL SOILS

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TO WHOM IT MAY CONCERN

This is to state the research carried out for my PhD thesis entitled "Investigations into the influence of fertiliser history and climate regime on the soil fertility, soil quality and pasture production of Wairarapa hill soils" in the Institute of Natural Resources, Massey University, Turitea Campus, New Zealand is all my own work.

This is also to certify that the thesis material has not been used for any other degree.

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Supervisor: M. J. Hedley

Date: 27/9/2000

ABSTRACT

The effects of long-term application of single superphosphate (SSP) on soil plant-available nutrient supply and indicators of soil biological quality was investigated on Wairarapa hill soils ranging widely in previous fertiliser history (from 0 to 250 kg SSP ha^{-1} yr^{-1}) and climate regime (annual and seasonal rainfall distribution). At 12 field sites spring pasture response to strategic N fertiliser application was measured, while the plant-available nutrient (P, N and S) supplying capacity of the soils was assessed in glasshouse studies. Based on the pasture growth patterns in field and glasshouse studies, a new climate-driven, soil fertility dependent pasture growth model was developed and tested. In addition, the suitability of the Biolog™ GN microtitre plating system was assessed as an indicator of soil 'quality', using these Wairarapa hill country soils.

Results of soil analyses indicated that small increases in mineralisable N, in the order of 280 kg mineralisable Nha^{-1}, with increased rates of fertiliser (P and S) may represent inefficient use of P and S fertiliser. Soil mineralisable N increased by approximately 8.6 kg mineralisable Nha^{-1} for every 1 unit increase in Olsen P. The ratio of accumulated plant-available N:P:S of these soils, resulting from long-term SSP applications, is approximately 17:2:1. Olsen P status was shown to be strongly correlated with measures of plant-available N and S.

Pasture growth response in the field to strategic N fertiliser (30 $kgNha^{-1}$) applied in spring was highly variable across sites, and within the range of 0:1 to 31:1 kgDM kgN^{-1}. Simple single factors representing soil fertility indices, or climatic regime, could not explain the variation in site-to-site pasture growth response to applied N. Factors constraining N response are discussed.

In glasshouse studies, on samples of the same soils, ryegrass and white clover showed large yield differences (clover, 0.27-2.29 gDM pot^{-1}; ryegrass, 0.22-2.25 gDM pot^{-1}) on low P status and high P status soils respectively. Glasshouse DM yields did not correlate with those measured in the field, confirming that at field sites yield responses to nutrient availability are strongly modified by (site-specific) climate. The relationship between Olsen P and clover yield in the glasshouse (curvilinear, R^2 = 0.80) was similar to that

previously seen in (spring) field conditions. The S:P and N:P ratios of clover in the glasshouse trials confirm that P availability in these soils is the major growth-limiting factor, probably followed by S or N, which becomes limiting when P availability is adequate to high.

A modified Stanford and DeMent bioassay technique was used to estimate the amount of plant available N, P and S in each soil. Using an exhaustive cropping regime, these soils exhibited a large variation (range) in ryegrass yields when soils were the sole source of P and N. Yields for each soil were strongly correlated with various soil tests for N, S and P availability. S availability to plants was less variable across soils, but the smaller variation in S limited yield was still strongly correlated with the variation in a newly developed soil hydrogen peroxide-extractable S test. Results from both glasshouse experiments provide strong evidence that the Olsen P soil test is a valuable soil fertility indicator of plant-available P, N and S on legume-based pasture soils with a history of superphosphate use. The amount of dry matter production, when considered with the quantity of soil used for each treatment (-N, 100g; -P, 50g; -S, 25g), suggest that these soils have large pools of plant-available or mineralisable P and S, and, relative to plant demand, small pools of soil mineralisable N. A four-fold increase in field DM production resulted from a 3-fold increase in soil mineralisable N at these sites. This suggests that the rate of N cycling probably also increases with yield increase, and that the size of the soil mineralisable N pool is not directly related to pasture N supply.

A new climate-driven, soil fertility dependent pasture production model has been developed and tested using actual DM yields from the field trial sites. The model assumes that pasture growth is proportional to evapotranspiration, and that the proportionality constant (k) depends on soil fertility*. Soil-limited evapotranspiration is calculated from a simple daily soil water balance model. Values for k varied from 11 to 19 kg DM ha^{-1} mm^{-1} of evaporation. With the exception of growth after severe drought conditions, the model shows potential to closely predict actual pasture yield. It is hoped that discrepancies between the modelled and measured production may lead to useful

* Pasture growth per mm of evapotranspiration was strongly related to soil available P status at these sites. From results of the glasshouse study, it was concluded that Olsen P was a strong indicator of 'general' (plant-available P, N and S) across these sites, and therefore suitable for use as the soil fertility proportionality constant in the pasture production model.

speculation and further research on the interacting effects of weather and fertility on pasture growth.

The Biolog™ GN microtitre plate system, for comparing substrate use patterns of 95 single C compounds was assessed as an indicator of soil microbial functional diversity across the 12 test hill soils. Preliminary studies showed that saline extracts of different fertility status pasture soils used for Biolog™ microtitre plate assay inoculation contain significant amounts of readily available C. It was concluded that in order to interpret the substrate use patterns correctly, this effect must be corrected for.

The Biolog™ microtitre plate system, for use as an indicator of soil quality and health, was shown to have limited application to this range of pasture soils with differing pasture histories. Adaptive factors, such as constitutive and inducible enzyme activities, were shown to complicate the interpretation of microbial growth on the C substrates. Substrate use patterns also changed when soils were rewetted and incubated. Possible 'indicator' substrates were identified, but it was concluded that these were low-energy decomposition products, and as such, are not useful as indicators of microbial functional diversity across these soils. Further research would be required to establish how stable the substrate use patterns are, or the relevance of these indicators to field soil processes. However, as a research tool, the Biolog™ assay showed potential to separate these soils on the basis of microbial functional diversity. The direction of future research, and limitations of current techniques used in this field are discussed.

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