INVESTIGATING AND MODELLING THE DEPENDENCY OF PASTURE GROWTH ON SOIL SULPHUR AND PHOSPHORUS AVAILABILITY

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ABSTRACT

A study was conducted in the lower North Island of New Zealand to evaluate new soil testing methods for diagnosis of sulphur (S) deficiency against pasture growth responses to applied S fertiliser, in the presence and absence of phosphorus (P) and nitrogen (N).

Field trials were conducted on eight sites at the AgResearch Hill Country Research Station at Ballantrae. The amounts of total soil S, P, and N at each site varied widely, caused by different superphosphate (SSP) fertiliser histories (low fertiliser input [LF] to high fertiliser input [HF]) and differences in grazing animal excreta return. Pasture growth on all of the eight plot trial sites chosen to represent a range of fertility levels, did not increase significantly to applications of S fertiliser alone (+S) (3 x 50kg S/ha as gypsum) over two years. Three LF sites did show significant increases in yields to application of S together with P (+SP, equivalent to SSP) (2 x 50kg P/ha as MCP). The +SP treatment was the most effective at promoting legume growth.

A suite of soil tests were designed and tested for their ability to extract sulphate S and labile organic S from soils. The amount of S extracted by a mixture of 4%H_2O_2 and 0.5M KCl [4%H_2O_2/$KCl_{(16hr)}$] (ranged from 50.7 - 105.3mg S/kg at a LF to a HF site) was found to be as good as the Olsen P test (ranged from 14.4 - 39.2mg P/kg soil) at predicting actual yields on unfertilised control plots (R^2 > 63% using several mathematical expressions). The 4%H_2O_2/$KCl_{(16hr)}$ and the Olsen P tests were also strongly correlated (R^2 = 77%). However, the 4%H_2O_2/$KCl_{(16hr)}$ was found to be better than the Olsen P test at predicting relative yield (RY) due to the application of a +SP treatment (R^2 = 60% and 19% respectively) probably because it has the ability to predict any S deficiencies that applied P would have induced. Only after basal S fertiliser was applied to the control did the Olsen P explain a similar percentage of the variation in RY (R^2 = 58%). As pasture growth was not singularly responsive to S, the ability of the 4%H_2O_2/$KCl_{(16hr)}$ test to predict S deficiency without P could not be tested.

The $4\%H_2O_2/KCl_{(16hr)}$ test was examined on a series of short-term trials established at nine locations in the lower North Island on different soil types and different climatic conditions. The fertiliser treatments on these trials included an S treatment (50kg S/ha as gypsum) with and without N (50kg N/ha as urea). A basal application of P at a rate of 40kg P/ha as MCP was also applied. Similar to Ballantrae, application of S on top of P (+SP) was the most effective at promoting legume growth (17 - 400%). Application of N caused detrimental effect on legume growth but did increase total pasture yield at all sites (14 - 83%).

Although the amounts of S extracted ranged from 59 to 156mg S/kg soil, this variation did not explain the variations in RY response to S at these sites, neither did the more traditional phosphate extractable S test (ranged from 4.1 - 10.5mg S/kg soil). The large range in RY suggest that basal P induced S deficiency on the control plots subsequent to soil sampling. For evaluation of the soil S test, an unfertilised control plot should have been included in the trial design. Failing to incorporate the interaction of S and P into the design of field experiments appear to be the main weakness in using RY as the pasture yield parameter for regression against soil test values. While efforts into improving soil tests for S are still required, it was concluded that the RY device is inadequate to normalise yields across sites because i) differences in yield potential caused by the interactions of soil fertility with climate could not be eliminated, and ii) estimates of yield potential vary with experimental designs.

To overcome these problems with RY, a mechanistic pasture growth model was developed to incorporate the effects of actual evapotranspiration (ET_a) on the relationships between pasture yields and soil fertility. It is assumed that climate can adequately be represented by rainfall, average temperature, and sunshine hours. A soil water balance model developed at Ballantrae, predicted daily soil water contents, drainage, and ET_a. Pasture growth dependency on ET_a and existing harvestable pasture mass were then modelled on a daily basis.

The model was developed from pasture yields derived from 2 and 4 weekly harvesting regimes throughout 1993. The ceiling yield ($Y_{ceiling}$) and ceiling growth rate ($g_{ceiling}$) values for each site that were estimated from these data, ranged from 662 - 2526 kg/ha and 7.1 - 30.3 kg/ha/mm respectively from LF to HF sites. Soil fertility as indicated by the Olsen P test explained much of the variation in $Y_{ceiling}$ (R^2 = 69%) and $g_{ceiling}$ (R^2 = 77%). The estimated maximum yield (Y_{max}) and maximum growth rate (g_{max}) values unconstrained by soil fertility were 3125kg DM/ha (R^2 = 69%) and 38.4 kg/ha/mm (R^2 = 77%). These values were considered too low because the 2 and 4 weekly data did not represent the full range of pasture growth normally represented in sigmoid curves. Nevertheless, the structural strength of the model was shown by both $Y_{ceiling}$ and $g_{ceiling}$ approaching Y_{max} and g_{max} at the same rate, controlled by $f_{1/2}$, the fertility level at which 50% of Y_{max} ($f_{1/2}$ = 23.0 mg P/kg soil, Olsen P) and 50% of g_{max} ($f_{1/2}$ = 22.5 mg P/kg soil, Olsen P) are obtained.

A better estimate of Y_{max} (8923 kg/ha) was obtained when yields harvested after a 9 week summer growth period was used to represent the ceiling yields at each site. As the dependency on soil fertility was the same, a g_{max} of 70 kg/ha/mm was estimated. These estimates were used to simulate pasture growth over variable harvest intervals from autumn 1990 to autumn 1992. The same parameter values were transferred to simulate pasture growth on sites in the east coast of the North Island. The seasonal variations in predicted harvested yields, closely resembled the patterns of yields measured through time. However, the actual yields predicted were generally lower than measured. The model therefore has structural strength but need extensive data for better estimates of initial parameter values.

This new approach, although require further development, emerges as a far better basis for understanding the relationship between pasture yields and nutrient supplies than regressions of soil tests against RY.

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