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RELATIONSHIPS BETWEEN ENZYME ACTIVITIES AND SOIL PROPERTIES IN PUMICE AND RECENT SOILS

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Introduction

Recent and Pumice Soils are relatively young, typically only one to three thousand years old. Recent Soils are weakly developed, although they have a distinct topsoil layer. Despite this, they are usually fertile with good water storage capacity and facilitate deep rooting. Pumice Soils, derived from volcanic eruptions, have low soil strength, but like Recent Soils they have good water storage and deep rooting facility. Pumice soils have low fertility because of low levels of some major nutrients and trace elements. However, all soils in this project were fertilised pastures. The two soil orders share many properties, including their susceptibility to soil hydrophobicity, a potential problem for the loss of fertiliser with runoff. We hypothesised that at least some of these common properties may be related to the soils' biological activity rather than to the soil order.

Method

Recent Soil was collected from three farms (sheep or mixed sheep and beef) east of Waipukurau in the foothills of the Ruahine Ranges. Pumice Soil was collected from three farms (mixed sheep and beef) northeast of Napier. Six samples were taken from a single paddock on each farm, maintaining a similar geographic aspect for each farm, but attempting to take samples with varying hydrophobicity.

Soils were stratified into 0-2 and 2-4 cm depths and sieved to 2 mm. Physicochemical properties measured by standard methods were pH, total carbon and nitrogen, mineral nitrogen, hot and cold water extractable carbon (H/CWC), phosphate, gravimetric water content (GWC) and the actual and potential persistence of water repellency. Repellency persistence results were grouped into three groups according to length of persistence: low (< 30 seconds), mid (31 to 240 s) and high (> 240 s). Enzyme activities measured were general dehydrogenase using iodotetrazolium chloride substrate (Shaw and Burns, 2006); glucosidase, galactosidase, cellobiohydratase, xylase, N-acetylglucosaminidase, arylsulphurtase and monophosphatase using methylumbelliferyl substrates (Giacometti et al., 2014); and tyrosinase and peroxidase using L-DOPA substrate (Bach et al., 2013). Results were analysed by statistical methods using GenStat (17th edition).

Results and Discussion

Some correlations between enzyme activities and physicochemical properties were evident, such as increasing HWC (high in polymeric carbohydrates) resulted in increasing carbohydrate polymer degrading enzyme activity (Figure 1a). Data graphed in Figure 1a was for the top 2 cm of the soil samples, a similar relationship existed for the 2 to 4 cm depth, although enzyme activities in all cases were lower than in the upper 2 cm. Since HWC includes complex carbohydrates, this suggests that the soil biota are responsive to available carbon sources. Increasing phosphate concentrations resulted in decreasing monophosphatase (phosphate releasing) activity, while a representative polymer degrading activity remained unchanged (Figure 1b). The decrease in monophosphatase activity similarly reflects adaptation to environmental conditions: more phosphate in the environment means less need to free it from organic forms. However, in no case were these trends statistically significant.

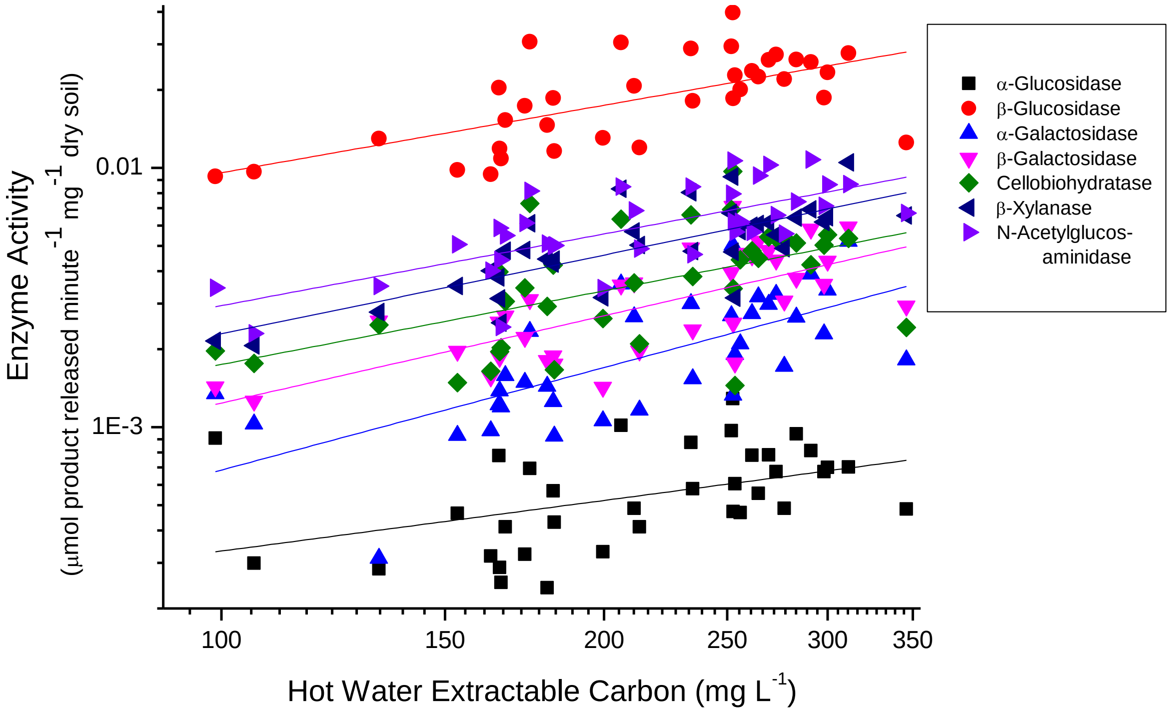


Figure 1a. Relationship between Hot Water Extractable Carbon concentrations and enzyme activities of α-glucosidase, β-glucosidase, α-galactosidase, β-galactosidase, cellobiohydratase, xylanase and N-acetylglucosaminidase. These results are for all the samples, looking only at the top 2 cm of the soil.

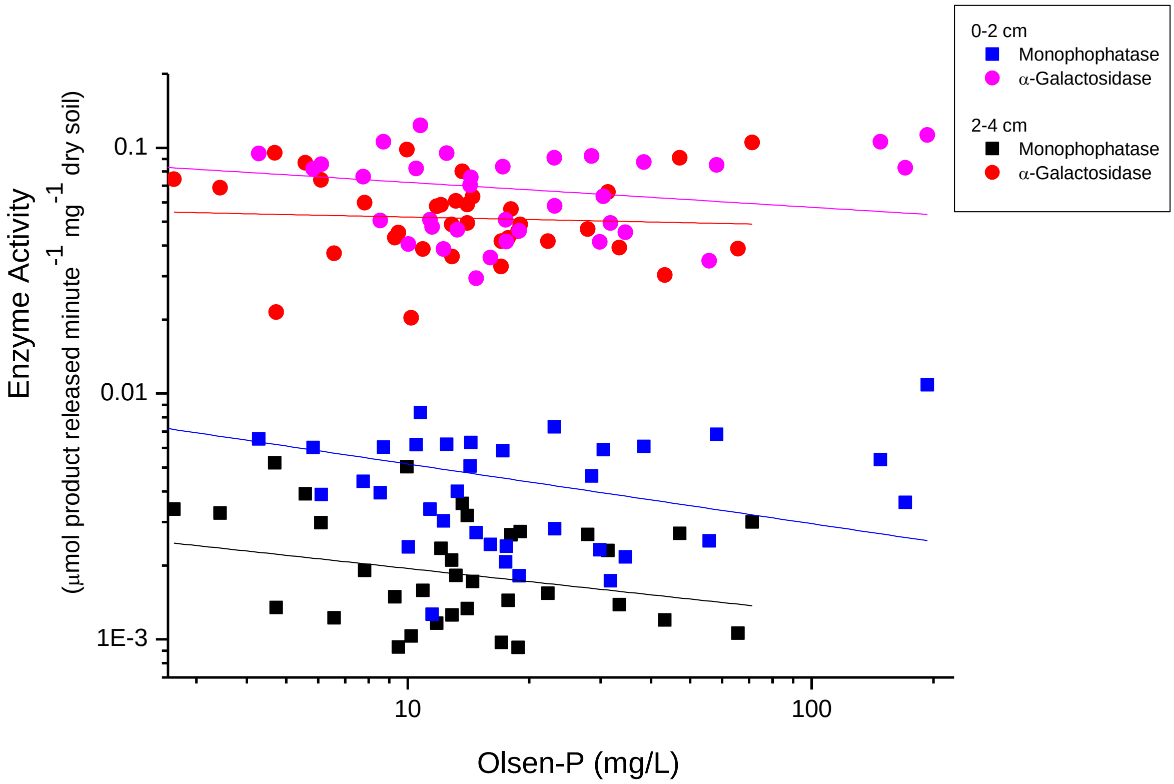


Figure 1b Relationship between Olsen-P phosphate concentrations and enzyme activities of monophosphatase and α-galactosidase.

A principal component analysis was used to analyse any underlying interactions between the samples and physicochemical properties (Figure 2). Three quarters of the variation was accounted for in the first two dimensions of the analysis, with the third dimension accounting for about 8% of the total. There was no distinct separation of sample groupings, although the two soil orders and two depths were not completely intermingled. For soil depth, most enzyme activities were greater closer to the soil surface, as were HWC, mineral nitrogen and Olsen-P levels. The correlation between the enzyme activities and the soil chemical properties have previously been discussed. Pumice Soils had higher CWC, ammonia and Olsen-P levels than Recent Soils. These differences were subtle and underlined the similarity of the soil of these different Orders. Possibly the mineral differences of the two orders have been concealed by the similar farming regimes that were similar for all the farms surveyed.

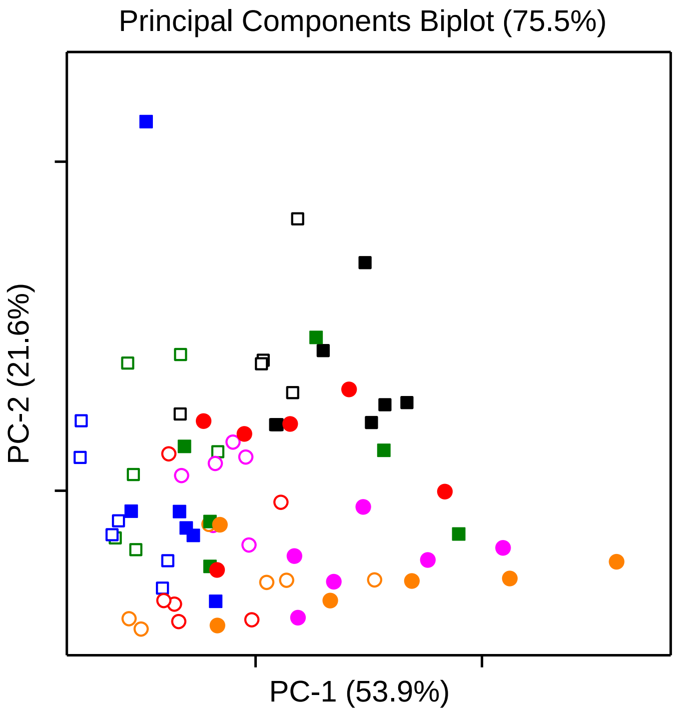
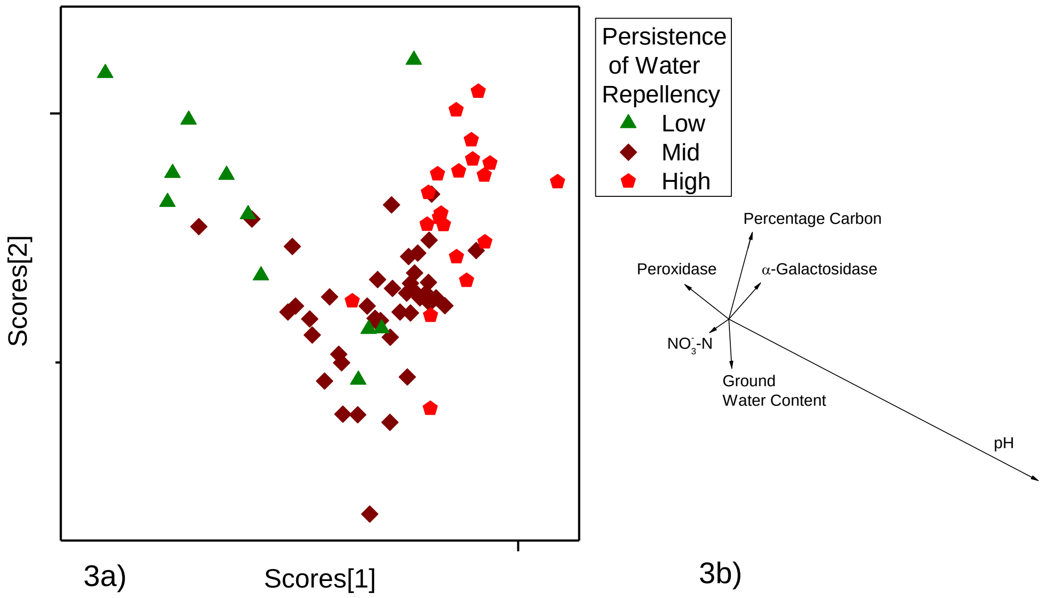


Figure 2 Principal Component Analysis of enzyme activities and physicochemical properties. First two dimensions, representing approximately three quarters of the sample variation, are plotted here. Square symbols denote Recent Soils, circles denote Pumice Soils; full symbols denote 0-2 cm soil layer, hollow denote 2-4 cm soil layer. An individual colour represents each farm.

Stepwise discriminant analysis was used to differentiate soil samples according to levels of persistence of water repellency and determine properties most likely to differentiate levels of hydrophobicity (Figure 3). Soils were grouped according to the time it took a water droplet to fully soak into the soil; for low persistence, this took less than thirty seconds, for the mid group between 30 and 240 seconds, and the high persistence soils this took more than four minutes, up to three hours. The analysis correctly assigned 90% of the samples into the correct group, with none of the high persistence samples in the low persistence group or *vice versa*. There was no linear progression from low through mid to high persistence, suggesting complex processes are generating hydrophobicity. For instance, water content played a significant role: lowering GWC is involved in moving from mid to high persistence, yet in the transition from low to mid persistence the GWC generally increased.



3a) 3b)

Figure 3a Stepwise Discriminant Analysis of Actual Hydrophobicity. Samples were divided into three groups of low, mid and high persistence of water repellency. The least number of soil properties to distinguish the three groups were calculated. The underlying separation vector for the Stepwise Analysis is given in figure 3b.

Conclusion

While there were correlations between single physicochemical properties and enzyme activities, these were not statistically significant. More complex statistical analyses showed that the two soils were very similar and it is likely that similar mechanisms were involved in the development of hydrophobicity in both soils. Further sampling at new sites and at different time points will be needed to confirm that the observed differences are truly significant.

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