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Phosphorus influence on the response of pasture plants to salinity

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PHOSPHORUS INFLUENCE ON THE RESPONSE OF PASTURE PLANTS TO SALINITY

A thesis submitted in fulfilment of the requirements for the award of the degree

DOCTOR OF PHILOSPHY

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BY

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CERTIFICATION

I, Kanjanarat Cho-Ruk, certify that this thesis is my own work and has not been submitted for acquiring qualifications at any other institutions. I also declare that the contents of this thesis are from my personal studies unless otherwise indicated or acknowledged. This thesis is submitted in fulfillment of the requirements for the award of Doctor of Philosophy, in Environmental Science Unit, University of Wollongong, Australia.

Kanjanarat Cho-Ruk

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ABSTRACT

Soil salinity is a growing global problem, as the presence of salts in soils is known to impact on the growth of various plants. One feasible means suggested for limiting the impacts of salinity is the use of nutrient fertilisers. This project was initiated to access whether the use of phosphate fertiliser would benefit the growth of pasture plant species. The interaction of P and salinity in relation to the growth of pasture plants was studied using a series of experiments. The investigations included pot experiments, using sand cultures with salinity impositions, and natural saline soils in the greenhouse, plant nutrient uptake in saline conditions, by assessing tissue mineral contents. Soil P adsorption under saline conditions was also determined to assist in explaining the results of the pot experiments.

P adsorption isotherms were measured for 3 NSW soils in various concentrations of NaCl. Different methods of salt addition (direct addition of salt solution, salt incubated soils, and different periods of time of soil in contact with salt solution) were applied to the studied soils. Salt addition increased P adsorption significantly in all 3 soils. However, there was no significant difference in P adsorption when varying the concentrations of salt (0.003-0.12mol/L NaCl). Salinity increased P adsorption in soils but further increases in NaCl concentration did not increase P adsorption. Extended contact time between soils and NaCl solution appeared to reduce the overall P adsorption capacity in soils.

Plants from 5 pasture species were grown in pots with suboptimum, optimum, and high P levels in saline cultures to compare yields. Salinity affected plant seed germination in all species by reducing the numbers of sown seeds germinated and slowing the germination rate. At the highest salinity level used (12 dS/m), all seeds failed to germinate. Considering the germination rate, the salt tolerance ranked from ryegrass, birdsfoot trefoil, orchard grass = red clover and white clover. Under normal experimental conditions in sand culture, 25 ppm P as NaH(subscript2)PO(subscript4) solution was determined as the optimum P level for all pasture species. Insufficient and excessive levels of P caused injury in plants and affected yields and plant tissue mineral contents.

Ryegrass with various salinity treatments (0, 2, 4, 8 and 12 dS/m) showed that salinity reduced ryegrass yields significantly as the degree of salinity was increased despite the optimum P additions (25 ppm). Salinity impacts varied during the plant growth development. When plants grew older, their salt tolerance improved, and the plants showed more tolerance to salinity as they reached maturity. Salinity also reduced P uptake by ryegrass plants.

Plants responded positively up to certain limits to P additions (17 and 25 ppm) in non-saline treatments. In saline treatments, plants responded differently over the whole range of added P. Positive results were obtained when P was added up to 17 and 25 ppm. Further increases in added P did not increase plant yields; indeed, negative results or no change were obtained. Therefore, over a wide range of studied P, plants showed both positive and negative effects as well as no effect of P in saline conditions. Increasing added P increased P content in plant tissues. In all treatments where salinity was imposed, salinity increased Na and Cl contents in plant tissues. However, the effects of salinity on other mineral constituents were highly crop specific.

In a natural saline soil culture, there was no mass response of red clover and ryegrass yields to P additions. Increased P level in the treatments did not show any plant capacity to overcome the effect of salinity. Plants still showed symptoms of salinity injury, such as yellowing and leaf burn. Salinity therefore was the main retarding factor. Increasing P fertilisation in a natural saline soil increased P content in plant tissues.

This current study indicates that the interactive effects between salinity and P depended on P range and salinity level. Plants responded differently over a wide range of P at low and medium levels of salinity. However, P additions at any concentration were not able to assist plants overcome the effects of salinity at extremely high saline conditions, as poor soil structure and plant physiological disorders limited plant responses to added P. Limiting the development of soil salinity is the major way to reduce its impact on crop production.

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LIST OF SPECIAL NAMES OR ABBREVIATIONS

P = Phosphorus

EC = Electrical Conductivity

EC_{se} = EC_e = Electrical Conductivity of soil extract

dS/m = decisiemens/meter

ads = adsorption

ESP = Exchangeable Sodium Percentage

SAR = Sodium Adsorption Ratio

CEC = Cation Exchange Capacity

Mha = million hectares

ha = hectare

mL = millilitre

L = Litre

g = gram

mM = millimol

mm = millimetre

ppm = part per million

µm = micrometre

nm = nanometre

rpm = revolutions per minute

µS/cm = microsiemens/centimetre