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Thesis

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Nutrient Availability and Wheat Growth as Affected by Plant Residues and Inorganic Fertilizers in Saline Soils

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IN THE NAME OF GOD

GRACIOUS AND MERCIFUL

DEDICATION

The thesis is dedicated to my father, who has been a great source of motivation and inspiration. It is also dedicated to my mother, who gave love and support.

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Declaration

This thesis contains no material, which has been accepted for the reward of any other degree or diploma in any other university, and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where references have been made in the text.

I give contest to copy of thesis, when deposited in the University Library, being available for loan and photocopying.

Ahmed ELGHARABLY

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Abstract

Over 10% of the world's land is salt affected. Salt accumulation is a major soil constraint for agricultural sustainability in arable or newly cultivated soils. As a result of salinity, soil chemical, physical and biological properties deteriorate, plant uptake of water and nutrients, particularly P, decreases and plant growth declines. Application of plant residues can enhance the activity of soil microorganisms, the availability of nutrients, including P and the plant uptake of P and growth. Such a practice can also be economically viable as it can reduce the use of P from inorganic sources, maintaining the world's reserve of P rocks and reducing the price of fertilizers and the environmental pollution often associated with the excessive application of inorganic N and P fertilizers. Little is known about how P, with N in proper form, added from inorganic and/or residue sources can affect wheat growth in the salt affected soils with no confounding pH or sodium adsorption ratio (SAR). Increasing microbial activity, N and P availability and wheat uptake of P by application of N and P from organic and inorganic sources may improve wheat growth and hence productivity under saline conditions. The overall aim of this study was to determine ways for enhancing the activity of microorganisms and increasing the availability of N and P, the uptake of nutrients, particularly P and the growth of wheat by management of fertilization from inorganic and organic sources in saline soils. This study therefore was conducted with the following aims: 1) to investigate the relationship between salinity and P availability; 2) to assess wheat response to combined application of N and P fertilizers under saline conditions; 3) to evaluate the effect of plant residue addition on N and P availability and microbial activity in salt affected soils; 4) to determine microbial response to addition of inorganic N rate and form, and how this will affect N and P availability in a saline soil, and 5) to determine the effect of P added from inorganic fertilizer and plant residue, compared to inorganic P fertilization, on microbial biomass and wheat nutrient composition and growth in a saline soil.

In saline soils, P availability can be affected by the salt type and concentration and soil texture. Three experiments were conducted to study the relationship between P availability, soil texture and salinity. The results of the first experiment in which soil was shaken with different concentrations of NaCl or $CaCl_2$ or Na_2SO_4, indicated that P solubility decreased with increasing concentration of Ca^{2+}, but was not affected by Na^+ salts. In the second experiment, P availability (after 24h shaking) decreased with

increasing salt concentration up to $EC_{1:5}$ 3.1 dS m^{-1}, increased with increasing P addition (0, 100, 200, 400, 600, 1200, 2500 and 5000 µg P g^{-1} soil), and was generally higher in sandy soil than in sandy loam soil. In the third experiment (15 days incubation), it was found that P availability significantly decreased one day after P addition which was followed by a further decrease to day 5, but then remained unchanged until day 15. It can be concluded that P availability is reduced in presence of clay, and decreases with increasing concentration of salts, particularly Ca^{2+}, and that the availability of P stabilizes in sandy and sandy loam soils within 2 weeks after addition of P from inorganic source.

Increasing N or P fertilization enhanced wheat growth in salt affected soils. Therefore combined application of N and P may enhance wheat growth in saline-non sodic soils with neutral pH. Three glasshouse experiments were carried out with the aim to determine the salinity range to be used in the subsequent experiments and to test the hypothesis that combined addition of N and P fertilizers can enhance wheat growth in a sandy loam soil with low SAR and neutral pH. The first two experiments were conducted in a sandy loam salinized to $EC_{1:5}$ of 0.18, 1.36, 2.00 and 2.67 dS m^{-1} using NaCl and $CaCl_2$. The wheat varieties Janz and Krichauff died in all soils to which salt was added showing that these EC levels were too high. The third experiment was conducted with Krichauff in the sandy loam soil with $EC_{1:5}$ 0.19, 0.32, 0.49, 0.67 and 0.86 dS m^{-1}, equivalent to EC_e 2.2, 4.4, 6.7, 9.2 and 11.8 dS m^{-1}, respectively, and with 0, 30 and 60 mg P kg^{-1} soil and 50, 100 and 200 mg N kg^{-1} soil. Salinity reduced plant dry matter at all N and P application rates. Increasing N application rates decreased growth at low and high salinity, whereas increasing P addition improved growth at all salinity levels. The highest shoot and root dry weights were obtained with 50 mg N and 60 mg P kg^{-1} soil. Nitrogen and P fertilization did not increase wheat growth in soil with greater than $EC_{1:5}$ 0.67 dS m^{-1}, equivalent to EC_e 9.2 dS m^{-1}.

Plants are known to respond differently to N form. A glasshouse experiment was carried out to assess the effect of N form (NH_4^+, NO_3^- or NH_4NO_3) added at 50, 100 and 200 mg kg^{-1} soil, in addition to the control (no N), on nutrient composition and growth of Krichauff in a sandy loam soil with $EC_{1:5}$ 0.21, 0.48 and 0.86 dS m^{-1}, equivalent to EC_e 2.8, 6.6 and 11.8 dS m^{-1}. Increasing soil salinity decreased shoot and root dry weights and shoot macro- and micronutrient concentrations with all forms of N. At every N addition rate and with increasing N addition from N50 to N200, compared to NH_4^+, the salinity of soil solution was far higher with NO_3^- and lowest with NH_4NO_3. Shoot and root dry weights were highest with addition of 50 mg NO_3-N or 100 mg NH_4-N or as NH_4NO_3 at all salinity treatments. Concentrations of shoot P, Fe, Mn and Zn concentrations were greater with NH_4^+ and NH_4NO_3 compared to NO_3^-, but concentrations of shoot K and Ca were higher with NO_3^- than with NH_4^+ nutrition at all salinity treatments. At a given N rate, shoot and root dry weights were greatest with NH_4NO_3 in the saline sandy loam soil with up to $EC_{1:5}$ 0.67 dS m^{-1}.

Two experiments were conducted to evaluate the effect of plant residue addition on microbial activity and biomass, and N and P availability in salt affected soils. Although the same amounts of Na^+ and Ca^{2+} salts, $EC_{1:5}$ differed between tested soils due to differences between soils in clay content and water holding capacity. The first experiment aimed to assess the salinity range for microbial activity over 2 weeks in saline soils with different texture amended with glucose/nitrate (C/N ratio 16:1). The $EC_{1:5}$ were 0.2, 1.26, 1.83, 2.28 and 2.99 dS m^{-1} in the silty loam, 0.16, 1.10, 1.98, 2.33 and 3.18 dS m^{-1} in the sand and 0.19, 0.82, 1.75, 2.03 and 2.79 dS m^{-1} in the sandy loam. Soil respiration significantly decreased with increasing salinity in the glucose/nitrate amended soils, but was not completely inhibited even at highest salinity treatment. Cumulative CO_2-C increased over 2 weeks and was highest in the silty loam soil and decreased in the following order: silty loam soil < sandy loam soil < sandy soil. The second experiment was conducted to determine the effect of three different plant residues added at 2% (w/w) on microbial biomass and N and P availability over time (70 days) in saline sandy and sandy loam soils with low SAR and neutral pH. The $EC_{1:5}$ was 0.21, 1.08, 1.90, 2.63 and 2.89 dS m^{-1} in the sand and 0.19, 0.87, 1.63, 2.32 and 2.49 dS m^{-1} in the sandy loam. Microbial biomass C, N and P decreased with increasing soil salinity and were highest on day 10. With residue addition, microbial biomass C and P were significantly higher in the sandy than in the sandy loam soil, whereas no significant differences were found between soils for microbial biomass P at all salinity treatments. Under all salinity treatments, compared to other residues, highest biomass N was found in canola-amended sandy loam and in lupin-amended sandy soils. With increasing soil salinity, highest microbial P was found in the sandy soil amended with lupin residue. Nitrogen availability was generally higher in the sandy soil than in the sandy loam soil, whereas the opposite was found for P availability. Compared to canola and lucerne, N and P availability were highest in lupin amended sandy and sandy loam soil.

Two experiments were conducted to assess whether N addition (rate and form) can affect the microbial activity in presence of residues in a saline sandy loam soil. The first experiment aimed to evaluate the effect of N rate (0, 25, 50 and 100 mg N kg^{-1} soil) added as NO_3^- on soil respiration over 2 weeks under non-saline conditions in presence of 2% lupin residues. The second was to determine the effect of N added at 50 mg N kg^{-1} soil as NH_4^+ or NO_3^- and lupin residue added at 2 and 4% (w/w) on microbial activity and biomass and N and P availability over 45 days in a sandy loam soil with $EC_{1:5}$ 0.21, 0.51 and 0.85 dS m^{-1}, equivalent to EC_e 2.8, 7.0 and 11.7 dS m^{-1}. Soil respiration and cumulative respiration were not significantly affected by N application rate over 2-week-incubation under non-saline conditions. Microbial biomass and N and P availability decreased with increasing salinity and were highest at 4% lupin residue. Soil respiration rate and cumulative CO_2-C and microbial biomass C, N and P were greater with addition of 50 mg N kg^{-1} soil as NO_3-N compared to NH_4-N at every addition rate of lupin residues under saline conditions. Soil microbial biomass C, N and P were highest on day 15 and decreased over time, whereas N and P availability were lowest on day 15 and increased over time.

Since addition of inorganic N and P fertilizers improved the growth of wheat (cv Krichauff) in the saline sandy loam soil at SAR 1 and neutral pH, two glasshouse experiments were conducted to determine the effects of plant residue addition on the nutrition of wheat. The first experiment was conducted under non-saline condition to determine the effect of lupin residue rate (2% and 4% w/w) on wheat growth. The second experiment was conducted under saline conditions to determine the effect of P added as lupin residue (2%) and/or KH_2PO_4 (0, 20 and 40 mg P kg^{-1} soil) with and without 50 mg N kg^{-1} soil added as $(NH_4)_2.SO_4$ on microbial biomass, N and P availability, plant growth and nutrient composition in the saline sandy loam soil. The $EC_{1:5}$ were 0.23, 0.35 and 0.51 dS m^{-1}, equivalent to EC_e 3.1, 4.8 and 7.0 dS m^{-1}, respectively. In the first experiment under non-saline conditions, shoot dry weight was lower with addition of 4% than with 2% lupin residue with and without inorganic N. In the second experiment under saline conditions, microbial biomass C and N increased with increasing application of inorganic P, but was not as much as in presence of lupin residues. In presence of lupin residue, wheat growth increased with increasing addition of inorganic P under saline conditions. Compared to the soil with P from inorganic fertilizer and residues, inorganic P increased shoot and root dry weights and shoot P, K, Mn and Zn concentrations, but not N concentration. Addition of 50 mg inorganic N in presence of lupin residues significantly increased N and P availability and microbial biomass, but had no significant effect on wheat growth in a saline sandy loam soil.

The results showed that optimal application of N and P organic and inorganic fertilizers can improve N and P availability, microbial activity and wheat growth in salt affected soils. Highest wheat dry weight was achieved by application of 60 mg P kg^{-1} soil in a sandy loam soil with $EC_{1:5}$ 0.67 dS m^{-1}, equivalent to EC_e 9.2 dS m^{-1}. Wheat growth was also improved with application of N-NH_4^+ or as NH_4NO_3 at 100 mg N kg^{-1} soil. These N and P fertilization rates can potentially enhance wheat growth in the sandy loam soil with up to $EC_{1:5}$ 0.67 dS m^{-1}, but with SAR 1 at neutral pH.

Plant residues increased microbial activity and N and P availability in the saline soils. In the soils used here, with residue addition wheat growth was P limited due to competition with microorganisms for available P. Therefore application of residues with inorganic P is necessary to satisfy wheat requirements of N and P in the saline sandy loam soil. In the saline sandy loam soil at SAR 1 and neutral pH, application of 2% lupin residues and 40 mg KH_2PO_4-P kg^{-1} soil achieved highest microbial biomass, nutrient availability and wheat growth. However, wheat growth with these rates is not as high as with inorganic P at similar rate due to micronutrient deficiency in the saline soil with lupin residues.