CHARACTERIZING THE PLANT AND SOIL INTERACTIONS THAT AFFECT THE GROWTH AND NUTRITION OF COTTON (*GOSSYPIUM HIRSUTUM* L.) IN SODIC VERTOSOLS

By

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Statement of Originality

The work presented in this thesis is, to the best of my knowledge and belief, original except as acknowledged in the text. I hereby declare that I have not submitted this material either in whole or in part, for a degree at this or any other institution.

[redacted]

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Abstract

Soil maps and surveys of Australian soils suggest that the surface and/or the subsoil in a majority of cotton growing regions in Australia are sodic. Sodicity has the potential to reduce the productivity of cotton crops by affecting their growth and nutrient acquisition. Cotton growers are however uncertain about the implications of sodicity for the productivity of their crops. Additionally, it is unclear to what extent the effects of sodicity on cotton growth and nutrient accumulation are due to soil physical or chemical factors, which creates difficulties in applying appropriate management strategies to problem sodic fields. Soil physical factors with the potential to limit cotton growth and nutrient accumulation include high soil strength and poor aeration. Soil chemical factors with the potential to limit cotton growth and nutrient accumulation included high soil solution sodium concentrations and elevated soil pH values.

The main objectives of this project were;

- To better quantify the effects of soils with a range of exchangeable sodium percentage (ESP) values on cotton growth and nutrition.
- To determine the relative importance of various physical and chemical properties of sodic soils on the growth and nutrition of cotton.

An experiment was established in order to measure the relationships between sodicity and the growth and nutrition of a cotton crop in a commercial field production situation. Increasing soil sodicity was correlated with reductions in cotton dry matter accumulation and lint yield. Additionally, increasing soil sodicity tended to produce cotton plants with reduced phosphorus (P) and potassium (K) concentrations and increased sodium (Na) concentrations. The results of this field experiment were used to inform the design of subsequent glasshouse experiments, which determined the dominant soil physical and chemical processes behind the effects of sodicity on cotton growth and nutrition.

A nutrient culture experiment was used to determine the direct effects of the Na:Ca ratios found in the soil solutions of Grey Vertosols with sodicity levels ranging from 2 to 25%, on the accumulation of nutrients by cotton plants. These nutrient solution Na:Ca ratios affected the accumulation of Na and Ca by seedling cotton but had little effect on the other nutrients.

A method was developed to create soils with a range of sodicity levels from one original non-sodic Grey Vertosol. Large cultures of these soils were amended with the synthetic soil conditioner polyacrylamide (PAM), in order to determine the relative importance of various physical and chemical properties of sodic soils on the growth and nutrition of cotton. Soil physical factors limited cotton yield at ESP levels up to 20% and reduced cotton K concentrations across the range of ESP levels. In highly sodic soils (24% ESP), soil chemical factors, including high Na concentrations and micronutrient deficiencies were as significant in limiting cotton yield as physical factors. There was no affect of sodicity on cotton P concentrations in this experiment.

In a separate experiment the artificially sodified soils were inundated for a period of 7 days and then labelled with ^{32}P, in order to determine the effects of waterlogging on cotton growth and nutrition across a range of sodicity levels and to determine the effects of sodicity on the recovery of cotton root activity after a waterlogging event. Both sodicity and waterlogging reduced cotton root activity. Waterlogging also limited cotton K concentrations in the moderately sodic soils and P nutrition across the range of sodicity levels. Increases in cotton Na concentrations following the waterlogging event were exacerbated by increasing soil sodicity.

Nutrient solutions treated with agar to induce anaerobic conditions were used to determine the interactions between the effects of high soil solution Na concentrations and waterlogging on cotton nutrition. The nutrient solutions were labelled with ^{32}P to indicate the recovery of cotton root activity following the waterlogging event. Increases in cotton Na concentrations and decreases in cotton K and P concentrations and root activity following the waterlogging event were not exacerbated by elevated nutrient solution Na concentrations.

Together the results of the field and glasshouse experiments described in this thesis demonstrate that sodicity limits cotton growth in soils of low to moderate sodicity, due largely to soil physical factors, such as high soil strength and poor soil aeration. Further reductions in cotton growth in highly sodic soils are more likely to be caused by soil chemical factors, such as Na toxicity and micronutrient deficiencies. The relationship between waterlogging, sodicity and increased Na uptake by cotton is of particular significance to cotton producers, as increased levels of plant tissue Na following waterlogging events may lower the threshold soil ESP at which cotton lint yield is reduced.

It is probable that excess accumulation of Na contributes to cotton yield reductions at YML Na concentrations of 0.09% – 0.18% between squaring and harvest. At low to moderate sodicity levels (ESP values less than approximately 20%), high soil strength and poor soil aeration is likely to be more limiting to cotton production than accumulation of excess quantities of Na. In highly sodic soils however, Na toxicity has the potential to reduce the yield of cotton crops

Contrary to long held belief, sodic soil solution chemistry plays little or no role in the symptoms associated with premature senescence (K and P deficiency) of cotton in the field. This thesis has determined that the adverse physical condition of sodic soils have the potential to induce K deficiency in cotton, which, in turn, may limit crop productivity at low to moderate ESP levels. Similarly, the poor aeration of sodic soils has the potential to limit the P nutrition of cotton. The declining P fertility of soils with increasing soil sodicity is however also a significant factor in determining the P status of cotton crops.

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