FACTORS AFFECTING THE GROWTH OF WHEAT ROOTS IN THE SUBSOILS OF UPPER EYRE PENINSULA, SOUTH AUSTRALIA

A thesis submitted
by
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To - K.G. Wetherby
for believing that it was possible

CONTENTS

SUMMARY

The Upper Eyre Peninsula of South Australia constitutes about 20% of the State's wheat growing area and is characterised by alkaline, calcareous soils, a Mediterranean climate and low annual rainfall (<350 mm). Wheat yields are often much lower than would be expected from the growing season rainfall. This may be due, in part, to the inability of wheat to utilise subsoil water since roots are rarely seen to proliferate below 0.5 m, even in the presence of apparently available water. Excessive soil strength and soil chemical factors such as high extractable boron and high salinity were thought to be implicated and experiments were conducted to examine the effects of these factors on the growth of wheat. The boron and salt characteristics of some of the agronomically important land units of Upper Eyre Peninsula were studied in a survey in which samples were taken from five locations.

A field experiment was conducted to test the hypothesis that wheat roots would not grow into the subsoil in the presence of available water at the beginning of the season. Before sowing the wheat, irrigation was used to bring the water content of the soil close to field capacity in some plots, while other plots received rainfall only.

At sowing, the irrigated soil was weaker than the control soil. The soil at anthesis was too strong to permit penetrometer resistance to be measured below 0.18 m in both treatments. Water loss from the soil to anthesis was significantly greater from the irrigated soil than from the control soil. For the 0.7-1.1 m depth interval, the irrigated soil (EC_e 1.9 dS m^{-1}) was less saline than the control soil (5.9 dS m^{-1}). Soil boron increased with depth and was not significantly different between the two treatments. $CaCl_2$ extractable boron exceeded 15 mg kg^{-1} soil below 0.5 m.

There were significantly more roots in the irrigated than the control soil. Maximum rooting depth in the irrigated soil was 1.15 m and in the control soil 0.70 m ($P \leq 0.05$). Grain yields were not different between treatments. It is hypothesised that the rapid early growth and withdrawal of water from the irrigated soil led to a critical water deficit in the wheat between anthesis and maturity. Mean boron concentration in the grain from irrigated plots (10.3 mg kg^{-1}) was significantly higher than that from control plots (5.8 mg kg^{-1}). The data indicate a greater uptake of boron from the irrigated soil coincident with higher water use and deeper rooting. While roots were able to penetrate the subsoil in the presence of available water, the application of irrigation water modified the subsoil by leaching a large amount of salt.

A survey was conducted with the principal objectives of studying the extent of the potential hazard to cereals presented by boron and salt and the variability of their distribution in some of the agronomically important land units of Upper Eyre Peninsula . Samples were taken from five localities. Two of these, Nunjikompita and Cungena, represented a single mapping unit because of its size. The other localities were Minnipa-Wudinna, Penong, and Buckleboo. A hierarchical sampling design was adopted, with each land unit represented by two randomly located 10 km x 10 km areas, each containing two 1 km x 1 km areas. Samples were taken from each of 32 pits in each 1 km x 1 km area, the closest of which were 5 m apart.

It was concluded that the mapping unit comprising Cungena and Nunjikompita contained quantities of boron likely to present a low hazard to wheat production. Conversely, the Minnipa-Wudinna and Buckleboo units contained consistently high concentrations varying from the nutritionally adequate to >100 mg kg^{-1}. The Penong unit was very variable with respect to the distribution of boron. Salt was more variable than boron, and only the Buckleboo unit contained uniformly saline subsoils. Otherwise, saline and non-saline subsoils occurred to some extent in all units, with some very high EC_e s (>10 dS m^{-1}) recorded at Nunjikompita, Minnipa-Wudinna and Penong. Estimates of variance components from the survey data from each land unit are used to show how more precise estimates of mean boron and salt values may be obtained by modified survey designs, with greater survey effort concentrated at the sampling level where the highest proportions of the total variance occurred.

Within individual land units, some easily recognised subsoil features such as the presence of Blanchetown Clay at Buckleboo or the reddish phase of the Wiabuna Formation could be useful in indicating where high concentrations of boron are likely to occur within a profile. In the Buckleboo, Minnipa - Wudinna and Penong land units, high boron may be associated with elevated portions of the landscape.

The effects of salt and boron in the subsoil at high concentrations typical of the subsoils of a large area of Upper Eyre Peninsula were examined in a glasshouse experiment. Wheat was grown in deep pots of solonised brown soil comprising 0.2 m sandy loam topsoil above 0.6 m treated calcareous sandy loam subsoil and a base layer of light clay 0.26 m thick. The subsoil was treated with mixed salt (0, 13, 39, 75 $mmol_c$ kg^{-1}) and boron (0, 20, 38, and 73 mg kg^{-1}) in factorial combination. The basic hypothesis of this experiment was that the added salt and boron would not affect the root growth, water use efficiency, dry matter production or grain yield of the wheat. The soil was initially watered to field capacity and water use was determined by regularly weighing the pots. The soil was allowed to dry gradually during the season, but the weights of the pots were not permitted to fall below that corresponding to 17% of the available water holding capacity of the soil.

Tillering, dry weight of shoots and grain, and root length density were determined. Water-use efficiency was calculated with respect to total dry weight and grain production.

Salt decreased tillering, dry matter production, grain yield, root length and water-use efficiency (total dry weight): it increased sodium and decreased boron concentrations in the plants. Boron decreased dry matter production (but not tillering), grain yield, root length and water-use efficiency (total dry weight and grain yield): it increased the concentrations of boron and decreased the concentration of sodium in the plants. At the concentrations of salt and boron used, boron had more deleterious effects on wheat than did salt. Yield was depressed by salt at concentrations of sodium in the tissue commonly found in field-grown plants.

A penetrometer study was conducted to test the hypothesis that mechanised agriculture could be implicated in increasing soil compaction on agricultural soils typical of Upper Eyre Peninsula. Penetrometer resistance measured on virgin soil was increased by wheel traffic and agricultural operations in all cases. The increase in soil strength was significant down to 0.30 m, which is considerably greater than the normal depth of tillage in the area (0.05 m). Reduction in the coefficient of variation of penetrometer strengths after the passage of wheels was taken as evidence for associated losses of soil structure. Virgin soils provide important reference states for assessing the impact of agriculture in an area.

A study of the amounts and types of field traffic was done with the objective of quantifying some of the factors causing soil compaction. Fields are cropped typically in only 50% of years with the other 50% of years being self-sown pastures involving negligible field traffic. In a cropping year, the total area of wheel tracks of farm vehicles is equal to 165% of the area of the field,but only 47.5% of the actual area is covered by wheels. The total amount of traffic is 62.6 t km ha^{-1}. The mechanisms which are important in maintaining a good soil structure in humid, temperate regions of the northern hemisphere are either absent or of negligible effect in the semi-arid, Mediterranean-type climatic region considered. Therefore, in spite of the relatively low levels of field traffic, there is a perpetual, insidious increase in soil compaction and associated problems.

Experiments were carried out to evaluate the efects of tillage in ameliorating a perceived soil compaction problem at two sites (Minnipa and Cungena). The experiments were done in 1987 and 1988 which unfortunately were both drought years. The experimental hypothesis was that deeper than conventional tillage would reduce soil strength, improve the root growth of wheat and alter the soil water regime in the root zone in comparison with conventionally tilled soil, resulting in yield increases.

Tillage deeper than the conventional depth (0.05 m) with a chisel plough at Minnipa had no measurable effect on water use or root growth in the period of measurement, or on grain yield. Soil strength was reduced by tillage to 0.30 m, but tillage to 0.15 m did not remove a hard pan below normal tillage depth. The loosening effect of deeper tillage was not measurable in dry soils by anthesis.

At Cungena, tillage to 0.3 m resulted in some enhancement of root growth and soil water extraction. Grain yields were increased by tillage to 0.3 m in both seasons. Soil strength was considerably reduced by deeper than normal tillage.

At Cungena, a further series of (recompaction) experiments was conducted in which tilled soil was recompacted by four passes of a large (11,800 kg) tractor before sowing. It was hypothesised that soil tilled below normal tillage depth would, after relatively few passes of a tractor, assume a soil strength equal to or greater than soil tilled to normal depth. As a result, root growth, soil strength, soil water contents and grain yields would not differ between treatments. Changes in soil water content at anthesis similar to those produced by deeper tillage in the tillage experiment at Cungena occurred in the recompaction experiment in 1987. Otherwise, differences evident in the tillage experiments (e.g.in rooting density and grain yields) were not reproduced in the recompaction experiments. Deeper tilled soil appeared to be more susceptible to the effects of recompaction (in terms of increasing soil strength) than control soil. The effect of four passes of wheels of a large (11,800 kg) tractor was to remove in both years the yield benefits induced by tillage to 0.3 m. The effects of deeper tillage in this environment are not likely to be lasting under the current tillage systems operating.

The amount and intensity of wheel traffic on Eyre Peninsula is much lower than in Europe, but there is evidence that cultivated soils in the area are more compact than comparable virgin soils. Compaction is more likely to be due to the absence of mechanisms which undo compaction than to high values of traffic intensity. While deeper tillage had some beneficial effects at one site, other less expensive and more cost effective methods of enhancing root growth in these strong soils need to be investigated.

It was concluded that the presence of high concentrations of salt and boron and a steadily increasing soil compaction problem present serious impediments to the growth and penetration of the roots and ultimately the yield of wheat over much of Upper Eyre Peninsula.

STATEMENT

This thesis contains no material that has been accepted for the award of any other degree or diploma in any University, and, to the best of my knowledge and belief, it contains no material previously published or written by another person, except when due reference is made in the text.

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SOUTH AUSTRALIAN DEPARTMENT OF AGRICULTURE
CLEVE RESEARCH LABORATORIES

MAP LEGEND

Soil units

1 - Highly calcareous loamy sands and sandy loams.

2 - Jumbled calcareous sand ridges with calcareous sandy loam soils over calcrete (class II and IIIC) in the inter-ridge flats.

3 - Jumbled siliceous sands (sands up to 2 m deep) over clays and tertiary sediments.

4 - Parallel sand ridges with shallow loamy soils in the swales.

5 - Parallel siliceous sand ridges with sandy loams over class II or IIIC calcrete in the flats.

6 - Shallow sandy loam and loamy soils over class II calcrete..

7a - Loamy soils grading to clay loams and clays with bedrock (granite, schists, etc.) or alluvium.

7b - Sandy loam soils over weak (class III) calcrete in alluvial/aeolian material.

8a - Calcareous sandy loams to light sandy clay over weak calcrete (class III A/B).

8b - Highly calcareous sandy loams to light sandy clay loams over weak calcrete (class III A/B).

9 - Calcareous light sandy clay loams and loams over weak calcrete (class III A/B) in gently undulating topography.

10 - Slightly calcareous sandy loam and loam soils over weak calcrete (class III A/B).

11 - Light sandy clay loams and loams grading to clay loams over weak calcrete (class III A/B) with clay at depth.

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13 - Jumbled siliceous sandhills superimposed over a dissected topography with soils varying from shallow sandy loams to loams over bedrock or clay.

14 - Jumbled siliceous sandhills superimposed over a rolling topography which has shallow sandy loam to loam soils grading to clay over bedrock.

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17 - Sandy loam to loam soils grading to clay loams and clays with weak calcrete (class III A/B) over bedrock or alluvium.

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Compiled by: K.G. Wetherby from data of Crocker (1946a), Davies (1975), Elliot (1965), Firman (1978), French (1958), King and Alston (1975), Northcote (1961), Smith (1960) Stephens (1943), Wetherby (1980, 1984, 1985a,b,c,) Wetherby and Hughes (1990), Wetherby and Kew (1990), Wetherby *et al.* (1982, 1983) Wood (1974), Wood and Davies (1975) and Wright (1985).

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