CHARACTERISATION OF THE LEAST LIMITING WATER RANGE OF A TEXTURE-CONTRAST SOIL

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by

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This work is dedicated to my late son, KITO SEAN SEMETSA

TABLE OF CONTENTS

CHAPTER 3: ESTIMATION OF *LLWR* FROM SOIL PHYSICAL PROPERTIES **30**

ABSTRACT

This thesis addresses three main questions:

1. To what extent does the *Least Limiting Water Range*, ***LLWR***, of a texture-contrast soil change with depth? Most previous studies have been conducted on relatively uniform soils, where clay content does not vary significantly with depth in the root zone; the occurrence of clay at depth may provide increased water holding capacity for use by plants later in the growing season.
2. To what extent does the volumetric water content fall outside the ***LLWR*** during a typical mediterranean growing season, P_{out}? An inverse relationship between ***LLWR*** and P_{out} has previously been shown to exist in moderated climates, but little is known about this relationship where rainfall is strongly seasonal.
3. What impact do the ***LLWR*** and P_{out} have on field plant performance in a mediterranean climate? Plant performance is generally thought to improve when ***LLWR*** is large and P_{out} is small, but little work has been conducted using cropping patterns designed to maximise water use efficiency in mediterranean climates.

To calculate the ***LLWR*** of the soils used in the study, two functions were required: the water retention curves, ***WRC***, ($\theta = f(\Psi)$, where θ is the volumetric soil water content and Ψ is the matric potential) and the soil resistance curves, ***SRC*** (***SR*** $= f(\theta)$, where ***SR*** is the soil resistance to a cone penetrometer). Examples of these were i) taken from published pedotransfer functions and ii) developed from relevant soil and landscape properties collected from undisturbed cores, including landscape position, clay content, carbonate content, organic carbon content, bulk density (and of course

volumetric water content and soil resistance as functions of soil matric potential). The published pedotransfer functions included models along the following lines: for the ***WRC***, $\log \theta = \log a + b \log \psi$, and for the ***SRC***, $\log SR = \log c + d \log \theta + e \log \rho$, where ρ is the soil dry bulk density and ***a***, ***b***, ***c***, ***d*** and ***e*** are constants. The functions developed from soil and landscape properties included models of the following types: for the ***WRC***, $\theta_{ijkl} = C + P_i + D_j + \psi_k + \rho_l$, and for the ***SRC***, $\log SR_{ijkl} = C + + P_i + D_j + \theta_k + \rho_l$, where θ_{ijkl} and SR_{ijkl} are respectively the volumetric water content and soil resistance corresponding to the i^{th} position in the landscape, ***P***, the j^{th} depth in the soil profile, ***D***, the k^{th} matric potential, Ψ, and the l^{th} bulk density, ρ. Minor variations to the models for the ***WRC***s and ***SRC***s were necessary to take into account the presence or absence of carbonates in the soil, which seemed to correlate with differing trends.

To obtain the data necessary for the ***WRC*** and ***SRC***, undisturbed soil cores were collected from 6 different depths (between 0 and 80 cm) at 5 different locations down a topographic transect of a sodic hypercalcic chromosol at Roseworthy Agricultural College, South Australia. Across the landscape, clay contents ranged from 10 to 37%, organic carbon contents ranged from 0.1 to 10.3 g C kg^{-1} soil, calcium carbonate contents ranged from 0 to 441.2 g $CaCO_3$ kg^{-1} soil, and bulk densities ranged from 1.3 to 1.7 g cm^{-3}. The soil cores were equilibrated at 8 matric potentials ranging between –0.001 and –1.5 MPa, and volumetric water content and cone-penetration resistance were measured.

Calculation of ***LLWR*** showed that no aeration problems were experienced at the wet end, but that high soil strength severely limited the amount of available water at the dry end. Because of high soil strength, all values of ***LLWR*** were rather small (all <

0.12 cm^3 cm^{-3}; many < 0.07 cm^3 cm^{-3}) indicating minimal plant available water in this soil. There was a minor trend of increasing ***LLWR*** with depth, and this was attributed to an increase in clay content and a decrease in bulk density with depth, both of which coincided with an increase in the concentration of $CaCO_3$. Because of the coincident occurrence of these soil properties, no simple relationship could be established between the ***LLWR*** and inherent soil properties.

To address the second question (*viz.* $\boldsymbol{P_{out}}$ *vs.* ***LLWR*** during a typical mediterranean growing season), the volumetric water content was measured throughout the growing season as a function of depth for crops having different rooting patterns (and thus different patterns of water extraction). Cereal grains, which were shallow-rooting, were grown either alone ('mono-cropped') or else inter-seeded ('inter-cropped') with lucerne, which is deep-rooting; $\boldsymbol{P_{out}}$ was determined at various depths throughout the profile. Values of $\boldsymbol{P_{out}}$ were expected to be greater for smaller values of ***LLWR***, and this was borne out by the data in a strong curvilinear relationship, particularly later in the growing season when the soil began to dry out. Values of $\boldsymbol{P_{out}}$ > 0.70 were not uncommon in the top 30 cm, and both wheat and oats had the same effect on $\boldsymbol{P_{out}}$.

To address the third question (*viz.* impact of ***LLWR*** and $\boldsymbol{P_{out}}$ on crop performance), dry matter yields at tillering and anthesis were measured, and final grain mass, and grain protein were measured. Dry matter and grain yields were found to be significantly greater in the mono-cropped cereal treatments than in the inter-cropped treatments, and this was due to the higher average seasonal volumetric water content in the mono-cropped treatments. Obviously this was strongly related to the magnitude of $\boldsymbol{P_{out}}$ in the top 30 cm in as much as larger values of $\boldsymbol{P_{out}}$ coincided with reduced dry matter and grain yields.

The primary implications from this work are summarised as follows:

- Application of pedotransfer functions to determine the ***LLWR*** for texture-contrast (duplex) soils, or indeed any soil whose properties change significantly with depth, needs to be done with caution.
- It is possible in duplex soils for the ***LLWR*** to increase with depth, so that efforts to improve subsoil conditions may prove to be highly fruitful in terms of water use efficiency in such soils.
- Further work on calcareous duplex soils is required to determine whether the apparently confounding effect of $CaCO_3$ on ***LLWR*** is related in any way to other measurable soil properties such as clay content or bulk density.

STATEMENT

This work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

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

SIGNED: DATE:......19/7/2000.......

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LIST OF FIGURES

LIST OF TABLES