Understanding Subsoil Water-Use on Southern Mallee Soils: I. Spatial Characteristics of Subsoil Constraints

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Abstract

A field survey was conducted to assess the relationship between subsoil conditions and the growth and water-use of wheat (*Triticum aestivum* cv. Frame) in the Birchip region. This was conducted to address the issue of poor water-use efficiency of cereals in the Southern Mallee, Victoria. Classifications of 150 soil profiles revealed large spatial differences on both an inter-site basis, (EC: 0.2-4.2 dS m^{-1}, ESP: 10.2-41.0 % & B: 3.9-48.0 mg kg^{-1} @ 60-100 cm) and an intra-site level, (EC: 1.2-3.4 dS m^{-1}, ESP: 16.3-41.0 % & B: 6.3-48.0 mg kg^{-1} @ 60-100 cm). This large variation in the spatial distribution of soil properties corresponded to marked differences in crop growth and water-use. The degree of soil variability at several sites is defined.

Key words

Subsoil, water-use, cereal, sodicity, boron, salinity.

INTRODUCTION

Yields of dryland crops in south-east Australia are governed largely by availability of soil moisture. Water use efficiency (WUE) can be used to estimate crop yield potential ie., wheat 20 kg $ha^{-1}mm^{-1}$ [1]. However, crops rarely reach their potential yield, even when nutrition is optimised and the effects of disease and other environmental factors are considered [2]. This suggests that other biological, chemical and physical properties of the soil may be limiting plant growth. In particular, subsoil properties such as high sodicity, salinity and boron have the potential to limit crop growth. Soils with an exchangeable sodium percentage >6% are considered sodic. Above these levels, structural degradation restricts plant growth [3]. Excessive soil salinity also restricts crop growth by reducing the osmotic potential and adsorption of water at the rhizophere. The threshold electrical conductivity for wheat is 6.0 dS m^{-1} $_{(sat)}$ [4]. Limited data estimates the threshold soluble boron for cereals to be 15 mg kg^{-1} [5]. Within the alkaline soils of the Southern Mallee, these factors are likely to restrict root growth, utilisation of subsoil water and crop WUE. This research was conducted to define the spatial characteristics of major subsoil properties in the Birchip region and define how these properties limit the WUE of cereals in the Birchip region of Victoria. Principal component analysis is used to define the order of importance of pH, salinity, sodicity and soluble boron on the growth of cereals. The variation in soil properties at intra- and inter- paddock level is considered. Two sites, sites C and I, from the survey, are used in this report. The crop response on these soils is considered in a second paper [6].

MATERIALS AND METHODS

A field survey was conducted to assess the relationship between subsoil conditions and the growth and water-use of wheat, (*Triticum aestivum* cv. Frame). The survey was carried out on 14 sites within 20 km of Birchip, Victoria, with 10 observations per site. Sampling depths were 0-10, 10-20, 20-40, 40-60 and 60-100 cm. One site was also located at Dooen Victoria, on grey cracking clay, to provide a comparison in land system. Classifications of 150 soil profiles were completed for pH, electrical conductivity (EC), exchangeable sodium percentage (ESP) and soluble boron (B). Soil pH was measured in a 1:5 soil/water & $CaCl_2$ suspension and EC was measured in 1:5 soil/water suspension. ESP was determined using 1M NH_4Cl at pH 7.0 for 30 minutes [7]. With this method soluble salts were removed by prewashing with 60% alcohol [8]. B was extracted using 0.01M hot $CaCl_2$ for 10 minutes [7].

RESULTS AND DISCUSSION

Soil characteristics

Site C, 20 km N of Birchip, is situated on a light dune system (Fig. 1). Cores 1-6 run along the ridge of the dune at 50 m intervals, while cores 7-8 and 9-10 run down into the swales either side of the dune ridge. Soil pH trends at this site are alkaline, with topsoil pH ranging from 5.0 to 7.5. The higher values occur within the swale regions, and rapidly increase with depth i.e. >8.0 at 60-100 cm (Fig. 2). Salinity levels rarely exceed 0.8 dS m^{-1}. This is due to course textured nature of this site and free drainage characteristics. Correspondingly, levels of boron, which tends to accumulate in poorly drained soils, are also low at this site. Threshold levels of B for cereals (>15 mg kg^{-1}), [5] are not exceeded within the subsoil (60-100 cm). The ESP of these soils indicate that sodicity (ESP>6%) occurs as shallow as 50 cm, however, these levels are only moderately sodic down to 100 cm thus are unlikely to effect cereal growth [3]. Intra-site variability at this site is low.

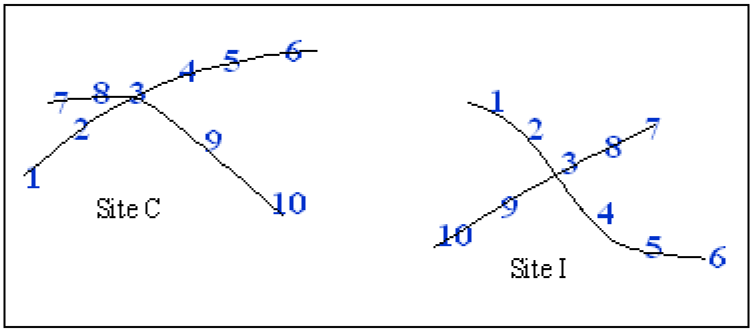

Figure 1. Spatial position of profile points at sites C and I. Points are at 50 metre intervals.

By comparison, site I, 15 km SW of Birchip, is situated on a red rise-swale system (Fig. 1), and displays large intra-site variability. Profiles 1-6 run a traverse from the top of a red rise down into the swale, and profiles 7-10 follow a contour half way up the rise. Similar to site C, pH trends are alkaline across the landscape, irrespective of relief (Fig. 2). Salinity and sodicity are highly correlated with profile and depth at this site. For all profiles other than 5 and 6, salinity and sodicity are unlikely to restrict crop growth until 20-40 cm (EC>0.8 dS m^{-1} & ESP>6%). At profiles 5 and 6 the topsoil in saline/sodic and would be likely to limit crop growth. Significant within paddock variation was evident (EC: 1.2-3.4 dS m^{-1} & ESP: 16.3-41.0 % at 60-100 cm). Soil boron does not follow the same spatial pattern. Elevated subsoil B is restricted to points running along the contour at mid slope. Here, B becomes phytotoxic (B> 15 mg kg^{-1}) at 20-40 cm, whereas at lower and higher points in the landscape, soil B abundance show similarities, with depth, to site C i.e. non-toxic down to 100 cm.

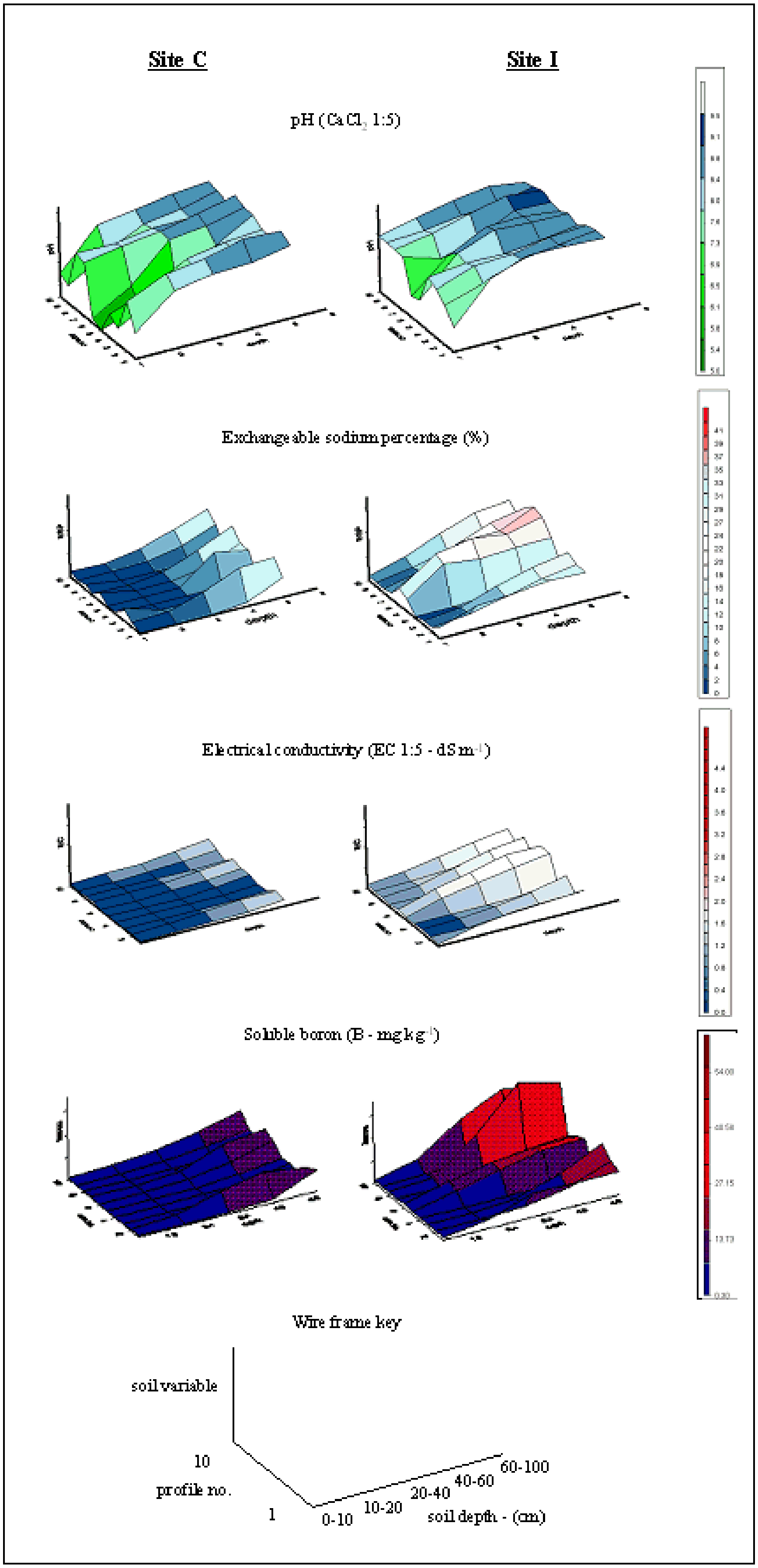
Site C
Site I
pH (CaCl$_2$ 1:5)
Exchangeable sodium percentage (%)
Electrical conductivity (EC 1:5 - dS m^{-1})
Soluble boron (B - mg kg^{-1})
Wire frame key
soil variable
10
profile no.
1
0-10
10-20
20-40
40-60
60-100
soil depth - (cm)

Figure 2. Intra-site variability in pH ($CaCl_2$), exchangeable sodium percentage (ESP), electrical conductivity (EC - dS m^{-1}) and soluble boron (B - mg kg^{-1}) at sites C and I at 10 profile points across the paddock and 5 depths (0-100 cm).

CONCLUSION

In summary, site C displays uniform characteristics across the landscape and shows similar trends down the profiles for all soil variables considered. Salinity, sodicity and boron appear low and non-limiting. In contrast, site I has high spatial variability. Moreover, high soil B and salinity/sodicity exist independently of one another. Almost certainly, the high subsoil levels of salinity, sodicity and boron at this site will induce yield penalties. These examples show that intra-paddock variability in soil properties can be greater than at an inter-paddock level. Crop response data for these sites in considered in a subsequent paper [6].

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