Soil water characteristics of a red chromosol and brown vertosol and pasture growth

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ABSTRACT

Soil water characteristics of two major soil types used for native pasture production on the North-West Slopes of NSW were compared using laboratory and field techniques to highlight limitations to their production. A pressure chamber apparatus was used to calculate plant available water (mm) defined as being between field capacity (drained upper limit or –10 kPa) and wilting point (lower limit or -1500 kPa) for a brown vertosol and red chromosol. Plant available water content (mm) and soil water deficit were calculated from soil water content estimates obtained each month with a neutron moisture probe. Pasture growth was more rapid and growth rates higher on the red chromosol following rain.

KEYWORDS

Soil types, soil water, pasture growth, grazing.

Introduction

Sustainable land use and management implies an understanding of the edaphic resource upon which it is based. Capability and suitability of various soil types can limit land use. Successful grazing management relies on an understanding of the dynamics of pasture response to rainfall on different soil types. The Sustainable Grazing Systems (SGS) Key Program initiated experiments within the temperate rainfall zone aimed at improving productivity and sustainability of grazing industries (2). Experimental sites were established on the North-West Slopes of NSW to study the relationship between grazing management, surface runoff, ground cover, soil water content and evapotranspiration.

High pasture production requires the effective capture of rainfall, storage of water in the soil profile and its transpiration through pasture growth. Pasture production on the North-West Slopes is limited by water losses through high runoff (4) and soil evaporation (3) on low ground cover pastures. These losses make it essential to understand the water characteristics of the soil types that support these pastures and recognise any limitations to production that they may impose.

This paper compared laboratory and field techniques for estimating plant available water (PAW) in soil profiles and examined limitations of each approach. Soil porosity was determined from bulk density data and was compared with maximum soil water content recorded in the field. Growth of pastures on the two soils was recorded in relation to rainfall and soil water deficit (SWD). Accurate determination of plant available water has implications for production and biophysical modelling.

METHODS

An experimental site was established as part of the SGS National Experiment (2) to study the effect of grazing management on native grass pastures at 'Eloura' (30?49'S, 150?42'E, 475 m a.s.l.), 11 km south west of Manilla on the North-West Slopes of NSW. Five treatments were applied in three replicates in a randomised design across two soil types. The site was equally dominated by brown vertosol and red chromosols (1). Soil water retention characteristic, soil water content and pasture production data were collected to explore the growth of pastures in response to rainfall on these soils.

An automatic weather station (Tain Electronics, Melbourne) was installed to record meteorological information including rainfall, temperature, relative humidity, solar radiation and wind speed at 30 min intervals.

Bulk density was determined from soil cores extracted during installation of neutron probe access tubes (7) and soil porosity (Φ) was calculated assuming a soil particle density of 2.65 Mg/m3 (9). Plant available soil water content (PAW) was calculated for the root zone (0 to 1 m depth, G.M. Lodge unpublished data) for the two soils using laboratory and field techniques. The laboratory estimate of PAW (mm) was calculated for each depth using the difference between soil water content (θ_{vol}) at field capacity (drained upper limit or -10kPa) and wilting point (lower limit or -1500kPa) determined from soil cores (45 mm diameter by 20 mm depth) with ceramic plates and pressure chamber apparatus. The field estimate of PAW was calculated as the difference between soil water content (mm) of the wettest profile (field capacity) and the driest profile (wilting point) for each soil type. Soil water deficit (0 to 1 m depth) was calculated as the difference between soil water content (mm) and field capacity (mm) (8).

A neutron moisture meter (503DR Hydroprobe) was calibrated (7) for each soil type and used to estimate θ_{vol} % each month at 20 cm intervals to a depth of 1 m. Water content data were averaged for each depth across 26 access tubes in the brown vertosol and 23 tubes in the red chromosol and SWD (mm) was calculated and plotted over time for each soil type.

Pasture growth rate was measured using a cage technique, harvesting paired matching quadrats at intervals of 4 weeks (6). Harvested quadrats were sorted into green and dead material to estimate the growth rate of green material.

Results

Total pore space (0 to 1 m depth) of the brown vertosol was higher than red chromosol indicating that it could potentially hold more soil water (Table 1). Wettest soil water values (0 to 1 m depth) were recorded on 15 September 1998 with the red chromosol (451 mm) being lower than the brown vertosol (460 mm, Table 1). Soils were driest on 19 March 1998 (red chromosol, 262 mm) and 19 January 1999 (brown vertosol, 283 mm) (Table 1). PAW calculated from the laboratory data was 123 mm for brown vertosol and 227 mm for red chromosol. In contrast, the PAW values calculated from the field estimates were 177 mm and 189 mm respectively for the brown and red soils.

Table 1. Soil water characteristic data (0 to 1 m depth) for brown vertosol and red chromosol, soil porosity (Φ, mm), field capacity (FC, mm, field measurement), wilting point (WP, mm, field measurement), plant available water - laboratory (PAW_l, mm), plant available water - field (PAW_f, mm).

Depth (cm)	Brown Vertosol					Red Chromosol				
	Φ	FC	WP	PAW_l	PAW_f	Φ	FC	WP	PAW_l	PAW_f
0-30	141.5	139.3	63.9	45	75.4	137.5	105.6	33.6	63	72
30-50	105.9	92.2	51.5	20	40.7	83.6	82.7	50.7	40	32
50-70	98.3	86.5	54.3	22	32.2	84.8	87.9	57.9	42	30
70-90	87.9	75.3	55.5	12	19.8	77.8	86.8	59.8	42	27
90-110	77.9	66.4	57.5	24	8.9	72.4	87.8	60.3	40	28

Total	511.5	459.7	282.7	123	177	456.1	450.8	262.3	227	189

SWD was lowest in spring 1998, which coincided with high rainfall, but rapidly increased through summer 1998-99 (Fig. 1). SWD variation was highly dynamic with the brown vertosol changing from wettest to driest within a period of four months.

Pastures responded more rapidly after rainfall and growth rates were generally higher on the red soil, while responses were slower and less on the brown soil (Fig. 2). Highest growth rates were in spring 1998 (45 kg DM/ha/day, brown chromosol; 43 kg DM/ha/day, red chromosol) when SWDs were least on both soils. Variations in growth rate (Fig. 2) showed the intermittent nature of pasture growth of native pastures on these soil types in this environment.

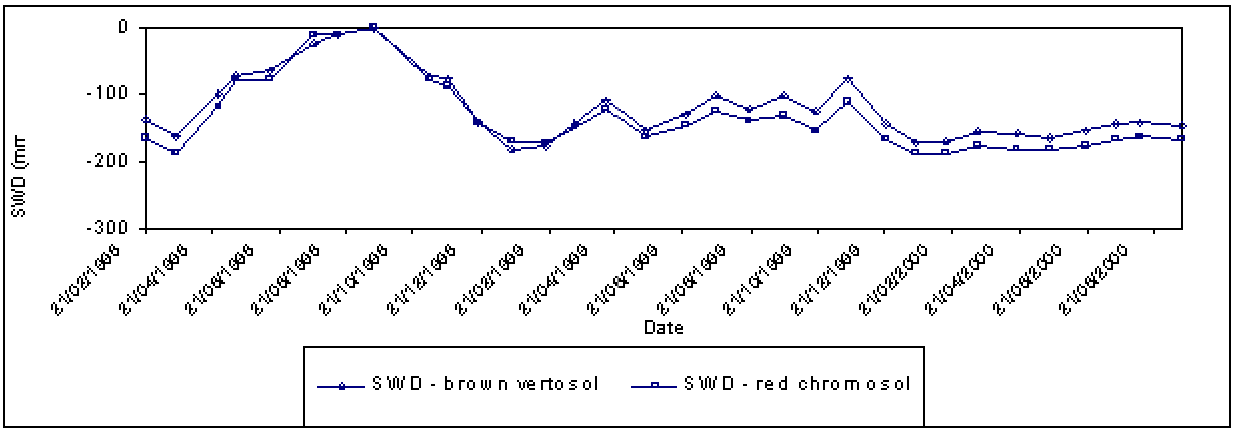

Figure 1. Soil water deficit (mm) of the brown vertosol and red chromosol profiles, 0 to 1 m depth.

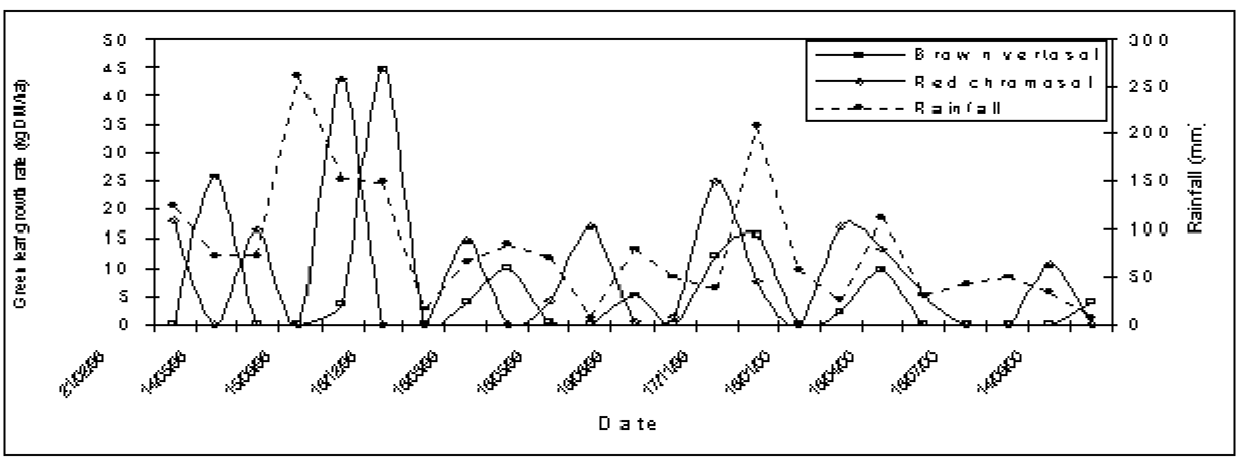

Figure 2. Rainfall and green growth rate (kg DM/ha/day) for the brown vertosol and red chromosols, 25 February 1998 to 14 September 2000. Cumulative rainfall for each growth rate period is presented for comparative purposes.

DISCUSSION

Both the laboratory and field techniques indicated that the red chromosol had potentially more PAW for pasture growth compared with the brown vertosol. Laboratory estimates of PAW were lower than field estimates for brown vertosol. This may have occurred as a result of the expansive clay types or the small size of soil cores used in the laboratory and the fact that the wettest and driest field profiles may not be representative of actual field capacity (-10kPa) and wilting point (-1500kPa). The field technique could provide elevated PAW estimates for the surface layer (0-30 cm) where minor waterlogging has occurred in that layer. Conversely, PAW may be underestimated at depth where the water content does not change markedly.

In contrast, SWD values indicated that the brown vertosol had a smaller deficit than the red chromosol. However, SWD was calculated using total soil water content and so may not accurately reflect pasture growth rate, which should be more strongly related to PAW. Except for the wet winter – spring period of 1998, SWD for both soils generally ranged from –125 to –175 mm. This indicates that substantial rainfall would be needed to achieve zero deficit and that for long periods of time the soil water content is well below the level defined by White et al. (8) as field capacity.

Comparison of soil porosity (511.5 mm) and the wettest soil water content for brown vertosol (459.7 mm) highlighted that it was slow to wet and despite 561.2 mm of rainfall in winter spring 1998, it did not completely wet up. In contrast, soil porosity (456.1 mm) and wet profile data for the red chromosol (450.8 mm) was in reasonably good agreement. Total storage achieved in the field also did not accurately reflect total porosity values calculated from bulk density data.

The small volume of plant available soil water further highlights that for adequate pasture growth in this environment loss from runoff (4) and evaporation (3) need to be minimised so that water content in the profile can be maximised.

The different response of pasture growth of the two soil types has implications for timing and intensity of grazing following rainfall. It also supports anecdotal evidence from local producers that pastures on these soils are difficult to manage when matching forage availability and animal production.

Biophysical models, such as the SGS Pasture Model (5), simulate pasture and animal growth, which is driven by nutrient and water dynamics. Soil water characterisation is required for modelling of the movement of water within the soil profile, but some care may be required in interpreting both laboratory and field derived data.

Conclusion

Both laboratory and field soil water characteristics calculated in this study may have limitations for estimating PAW. SWD values were high for both soil types, except in the wet winter-spring of 1998. This was reflected in low pasture growth rates. Pasture growth on the brown chromosol took longer to respond following rain and its growth rates were lowest. Graziers would need to carefully manage pastures on these soils to achieve sustainable production.

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