

Land clearing in the central western wheatbelt of NSW affects soil acidity

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ABSTRACT

Soil pH in the semi-arid region of central western New South Wales is highly variable and influences growth of annual medic pastures. A site 70 km north west of Condobolin was soil sampled to investigate the effect of windrow burning of felled timber on soil acidity. The site was cleared about 20 years previously and the windrow burns were still apparent on airphotos and by close inspection on the ground. Soil was sampled on a transect across the windrow. In the unburnt zones the surface soil pH_{Ca} was 5.4 to 5.5 in the surface 10 cm and in the burnt zone at this depth pH_{Ca} was increased to 7.4 to 7.6. The soil pH_{Ca} in the surface was related to pH_{Ca} at depths of 10 - 20 cm and 20 - 30 cm (r values 0.88 and 0.50 respectively). Exchangeable and soluble calcium was higher in the 0–10 cm depth in the burn zone (burnt, 10.5 cmol(+)/kg; unburnt, 4.04 cmol(+)/kg) and this was also higher to the 20cm depth. The ECEC expanded with rising pH_{Ca} and the additional exchange sites were occupied by Ca. These results suggested that alkalinity and Ca originally stored in the prior vegetation were concentrated in the zone of burning. The ongoing effect in the paddock is a narrow strip of enhanced Ca and pH_{Ca} contributing to variability of soil acidity across a paddock.

Keywords

Soil acidity, trees, land clearing, nutrients, ash alkalinity.

Introduction

Patchy growth of barrel medic (*Medicago truncatula*) has been observed in the Red Kandosols of central western NSW (12, 14). Soil pH_{Ca} is highly variable in these soils (a range of 2 pH units) and the areas of poor medic growth have been associated with areas of low soil pH (8, 12). Barrel medic has a low tolerance of acidic soils and its growth is inhibited (11). Root-nodule bacteria (*Rhizobium meliloti*) are reduced in number in low pH soils and nodulation can be poor (1). At higher soil pH, Howieson and Ewing (5) observed higher incidences of nodulation on a range of medic spp., resulting in increased growth in comparison to the same plants at lower pH. Scott (unpub.) suggested that the patches of increased plant growth in paddocks might be the result of prior tree locations or where timber was burnt when clearing.

Alkalinity may be stored in trees and redistributed as a result of land clearing practices. Noble and Randall (10) have suggested the storage of alkalinity in tree components. When timber with stored alkalinity is burnt, nutrient cations (e.g. Ca, K, Mg and K) form oxides in the burn and soil pH rises (7). Calcium oxide will form calcite, which can persist in the post-fire environment (13), and maintain a potentially higher soil pH in the burn zone.

In this study, a 20 year old windrow burn was identified and soil was sampled in a transect across the burn to determine the effect of the timber burn on soil acidity. Our aim was to determine whether land clearing may contribute to the variability of soil acidity in this low rainfall wheatbelt environment. This would in turn contribute to variable medic growth.

Materials and Methods

Apparent windrow burns were identified in a paddock at the Warra Warra property, 70 km NW of Condobolin, from an air photo taken in 1996. The Red Kandosol (6) at the site had been cleared in the late 1970s and had been cropped 3 - 4 times since. Prior vegetation was a bumble box (*Eucalyptus populnea*) – needle wood (*Hakea tephrosperma*) association in which the bumble box was the dominant

species. On the ground in spring 1999, the windrow burn zone could be identified by the presence of charcoal and indian hedge mustard (*Sisymbrium orientale*). The soil samples were assessed for colour (9) and slight differences confirmed the burnt area. The size of charcoal pieces observed in the surface soil indicated a timber burn, likely to be woody shrubs and trees. A windrow was chosen based on the increased growth of the indian hedge mustard and between two trees for ease of location. The transect was 38m long and was positioned at a 90° angle across the windrow (GPS coordinates: 461089.2E, 6364178.3N GDA94). The soil samples were taken in 10 cm sections to 30 cm at two metre intervals along the transect. At each sample position three soil cores were taken approximately 15 cm from the central point and bulked. The samples were air dried at 40°C and sieved to 2 mm particle size. Soil pH_{Ca} was measured in a 1:5, soil:0.01M CaCl₂ solution.

Soils from the extreme of the transect (unburnt zone; 0, 2, 36 and 38 m samples) and the zone of burn (22 to 26 m) were analysed for exchangeable cations (3). Effective cation exchange capacity (ECEC) was estimated as the sum of the exchangeable cations (Al, Ca, Mg, Na and K). The data analysed for burn effect, depth and their interaction by analysis of variance and *t*-test comparisons between burnt and unburnt zones are presented in Table 1.

Results

In the surface soil to a depth of 10 cm across the transect, soil pH_{Ca} values varied between 5.1 to 7.7 (Fig. 1). Between 22 and 26m, the soil pH rose to a maximum between 7.4 and 7.6 and appeared to indicate the zone where timber burning was most intense, a burn zone. In the unburnt zones, to either side of the sample sites with higher pH_{Ca} values, there was a lower soil pH range between 5.1 to 6.4 at 0-20 m and 28-38 m. A similar effect on soil pH was found in the 10 – 20 cm depth, whereas in the 20 – 30 cm depth the effect dissipated.

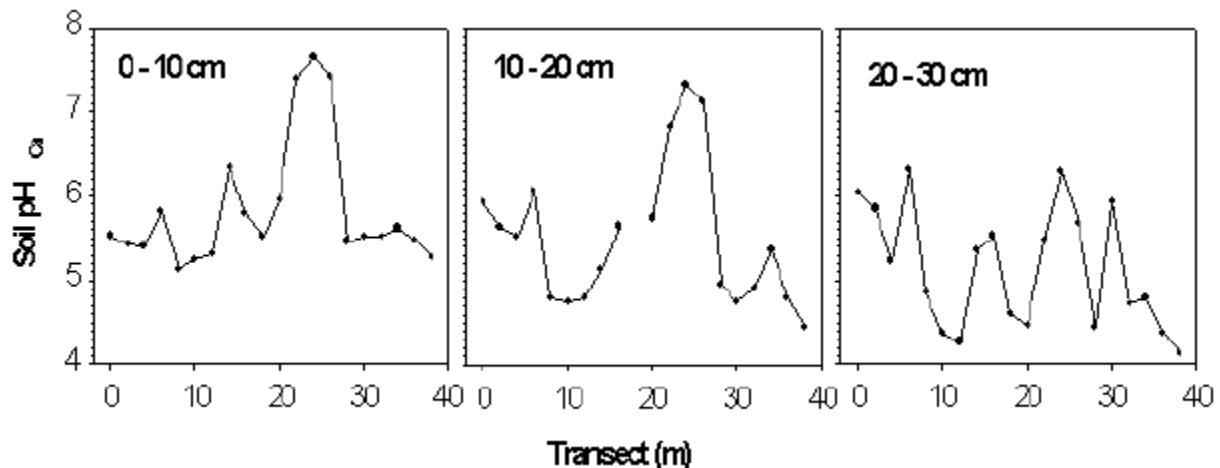


Figure 1. Soil pH_{Ca} at the 0 – 10, 10 – 20 and 20 – 30 cm soil depths in a transect across a windrow burn of cleared timber at Warra Warra property.

The soil pH_{Ca} in the surface 10 cm was related to pH_{Ca} at depths of 10 to 20 cm and 20 to 30 cm ($r = 0.88$ and 0.50 respectively). This was evidence that a burn effect persisted to a depth of 20 cm for twenty years after the burn.

The analysis of variance of the exchangeable cations and soil pH_{Ca} data indicated some significant burn effects and burn-depth interactions. Calcium, ECEC and soil pH_{Ca} were increased in the zone of the burn in the surface 10 cm and significant differences persisted in the 10 – 20 cm depth. Below 20 cm from the surface there are no significant differences between the burnt and unburnt zones for exchangeable cations and soil pH_{Ca}.

Calcium increased from 4.04 cmol (+)kg⁻¹ to 10.5 cmol (+)kg⁻¹ ($p \leq 0.001$, t -test comparison) in the surface 10 cm and ECEC values rose from 6.29 cmol (+)kg⁻¹ to 13.1 cmol (+)kg⁻¹ ($p \leq 0.001$) in the same depth (Table 1). Similar significant effects were found in the 10 to 20 cm depth where Ca rose from 4.32 cmol (+)kg⁻¹ to 8.68 cmol (+)kg⁻¹ and ECEC values changed from 6.91 to 11.2 cmol (+)kg⁻¹. Soil pH also increased from 5.43 to 7.49 units (surface 10 cm) and 5.21 to 7.09 units (10 – 20 cm).

There were no significant effects in Al, K, Mg and Na. Aluminium decreased as soil pH_{Ca} increased, although no significant effects were detected in the analysis of variance. Exchangeable K tended to be higher in the burnt zone compared to the unburnt zone in the surface two layers ($p = 0.06$).

Table 1. Exchangeable cations, ECEC and soil pH_{Ca} at three soil depths in the burnt and unburnt zones 20 years after burning.

	Soil Depth (cm)					
	Unburnt			Burnt		
	0-10cm	10-20cm	20-30cm	0-10cm	10-20cm	20-30cm
Al cmol (+)kg ⁻¹	0.05	0.31	0.73	0	0.01	0.03
Ca cmol (+)kg ⁻¹	4.04	4.32	4.44	10.5 ^{***A}	8.68 ^{**}	5.49
Mg cmol (+)kg ⁻¹	1.06	1.17	1.34	1.04	1.23	1.37
Na cmol (+)kg ⁻¹	0.07	0.06	0.07	0.06	0.07	0.07
K cmol (+)kg ⁻¹	1.08	1.04	1.02	1.49	1.16	0.84
ECEC	6.29	6.91	7.60	13.1 ^{***}	11.2 ^{**}	7.80
soil pH	5.43	5.21	5.10	7.49 ^{***}	7.09 ^{**}	5.40

^ASignificantly different (t test) from the unburnt zone at that depth; **, $p \leq 0.01$; ***, $p \leq 0.001$

Discussion

The movement of timber during land clearing at this site has led to a redistribution of alkalinity across the site. Alkalinity has been concentrated in the windrow and has been released into the soil upon burning. The increase of 2 pH units between the soil under the tree burn and the soil in the unburnt zones which

we observed was consistent with the observations of soil pH variability for the region commented on by Little *et al.* (8) and Young *et al.* (14).

The increases in soil pH_{Ca}, Ca and ECEC following burning at this site are similar to the results found in other studies. Khanna *et al.* (7) has described soil pH differences of two pH units in a comparison of burnt and unburnt zones in a eucalypt forest. The accumulation and storage of alkalinity in trees is the most likely explanation for this increase in soil pH after burning. The alkaline component in trees is a response to excess cation uptake from the soil and the concurrent production of organic anions by the tree. This leads to a store of alkalinity distributed in the bark, branches and leaves of the tree (4, 10). When the trees are burnt organic anions are oxidised; nutrient elements such as Ca, K, and Mg are released to form oxides initially. These then form hydroxides and carbonates if not immediately leached from the ash (2). At this site trees burnt in the windrow have supplied a significant input of stored Ca in particular and perhaps some K to the soil under the burn when compared to the unburnt zone. This has resulted in the increase in soil pH_{Ca} in the burn zone and a decrease in the likely effects of soil acidity on plant growth.

In the present study the effect of timber burns on the soil parameters we measured was confined to the surface 20 cm of soil and was clearest in the 0 – 10 cm depth. In our experiment both Ca and K were not elevated and Al was not different in the 20 – 30 cm depth under the burn than in the unburnt soil at this depth. Ulery *et al.* (13) also recorded higher pH values to a depth of 15 cm and a similar increase in calcium, they suggested that calcium in the form of calcite had induced the increases in soil pH. In eucalypt forest, Khanna *et al.* (7) stated that in the post-burn soil environment the major nutrients, Ca, K, Mg, NH₄, increased and exchangeable Al decreased in the surface to a soil depth of 5 cm.

In the 0 – 10 cm soil in the burn zone of our transect there is a possibility that calcite remained in the soil 20 years after the burn. The soil pH_{Ca} is at or near 7.6 (equilibrium pH_{Ca} for calcite dissolution) and the ECEC of the soil, driven by increasing Ca, is greater than we anticipated for this soil. The implication is that calcite is present and dissolved in the exchangeable cation measurement. The exchangeable Ca reported here may be in effect the exchangeable plus soluble Ca and the ECEC may be inflated as a result. Any remaining calcite would presumably be in concentrated pockets or protected in some way, perhaps within the charcoal particles.

After 20 years the effects of a windrow burn of cleared timber are still present by observation and soil chemical analysis. At this windrow site it has been found that it is Ca that remains in the surface soil in the burn zone 20 cm. Ulery *et al.* (13) found that calcite, and K carbonate, can persist in the soil for three years after high temperature burns; during this study they also observed a persistent difference of two pH units between burned and unburned soil sites. Eventually the effect of the burn may dissipate, Khanna *et al.* (7) estimated that cation composition under the ashbed soils may persist for up to 50 years after a burn, with Ca decreasing and Al increasing.

Changes in soil pH and Ca that cause a reduction in soil acidity favour the healthy growth of barrel medic, particularly with low Al at soil pH > 4.6 (8) and the symbiotic relationship with the bacteria, *R. meliloti*. On the burn zone soil pH conditions rise above 7.0, which is conducive to population growth of *R. meliloti* (1) and the subsequent vigour of medic plants.

Conclusion

In this study, the windrow burn has a mean soil pH_{Ca} of 7.5, and the ground to either side of the burn has a mean soil pH_{Ca} of 5.5, a difference of two pH units. The windrow burn zone represents a significant effect on the surface soil (0 – 20 cm) at this site and is likely to contribute to a patchiness effect in plant growth that is related to changed and more fertile soil conditions than found over the majority of the surface soil.

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