

Stratification of acidity in the shallow soil surface - experiences in the cropping areas of southern and central NSW

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Abstract

We examined two long term experiments and two paddock surveys and identified large changes in soil pH_{Ca} within the surface 20 or 30 cm of soil. The 5-15 cm was the most acidic layer in most soils; this suggests that soil sampling in the 0-10 cm and 10-20 cm depths is inadequate to describe what the plant may experience. The sharp pH_{Ca} changes within the 0-10 cm layer were modified by surface application of some N fertilisers, which acidified the normally less acidic 0-5 cm soil. Liming in a no-till system increased the soil pH_{Ca} in the shallow surface and the decrease in soil pH from 0-5 cm to 5-10 cm was even greater than in an unlimed soil. Initially, soil pH testing in finer depth layers in some paddocks should be informative. A regular liming program, with strategic cultivation to incorporate lime more deeply and thoroughly, could be considered.

Keywords

Cropping, pastures, pH stratification, soil testing.

Introduction

Soil sampling for acidity has been based on 0-10 cm and 10-20 cm soil sampling. We now suggest that the stratification of soil pH in the profile is much finer than this and that bulking soil layers of sharply different pH may mask the severity of soil acidity.

Uptake by plants of excess cations leaves acid (H⁺) in the soil and alkali (OH⁻) in the plant (Paul et al. 2003; Tang et al. 2004). The addition of acid to the soil is probably proportional to root density. Alkaline plant litter and dung are returned to the soil surface. Therefore the root zone gets acidified, but the surface few centimetres of soil are "limed" by the return of plant material and dung. The net result is a stratified pH pattern with a higher pH in the surface 5 cm, an acidic throttle at 5-15 cm, and then increasing pH toward the subsoil (Paul et al. 2003). Following full soil disturbance, this pH_{Ca} pattern in the shallow surface soil can re-establish within one season (Paul et al. 2001).

Legumes, with a higher excess cation uptake than many commonly grown pasture and crop species, are likely to give the most pronounced stratification. N fertiliser modifies this pattern, varying with the form and placement of the fertiliser. With most N fertiliser commonly surface applied as urea, the downward leaching of nitrate formed in the soil surface will acidify the surface few cm of soil (Condon et al. 2004) and over several years might minimise stratification in the surface 10 cm. Each kg/ha of N applied to the soil surface as urea and lost through leaching as nitrate will acidify the soil surface by an amount equivalent to 3.6 kg/ha of lime (Fenton and Helyar 2000). N added as ammonium could acidify at twice this rate. The surface application of lime, with very shallow incorporation in no-till or zero till systems, would be anticipated to give greater stratification of pH within the 0-10 cm depth (Conyers et al. 2003a).

In this paper we review experiences in central and southern NSW for consistency with the above considerations and discuss possible implications and management. Data are drawn from two long term experiments and two paddock surveys.

Methods

Long term experiments

The experiment at Wagga, on a red kandosol soil, was commenced in 1979 and had treatments involving

cultivation and direct drill/no-till (DD/NT), stubble burning and retention and rotations of wheat/lupins (WL), wheat/subterranean clover (WC) and continuous wheat (WW) with added N. Nitrogen was added at 100 kg N/ha by surface application of urea in 3 equal applications (see Heenan et al. 1994). In 1992 the experimental plots were split for lime application at 1.5 t/ha (70% < 75 μm ; 98% CaCO_3) applied to half the plot and direct drill sowing (full soil disturbance) was changed to no-till (knife points: 5 - 20% soil disturbance). The experiment at Condobolin, on a red chromosol, commenced in 1978 with direct drill sowing and was continuous wheat with DAP at sowing (8 kg N/ha) with additional N as ammonium nitrate surface applied and incorporated by sowing (40 kg N/ha until 1988 then at 50 kg/ha; see Fettell and Gill 1995). Soil pH in fine segments was measured at Wagga (0–5 cm, 5–10 cm, 10–15 cm and 15–20 cm) after 22 years and Condobolin after 19 years (0–5 cm, 5–10 cm and 10–30 cm).

Paddock surveys

Survey 1 was undertaken in 1995 in southern NSW between Temora and Albury and to the west of a line joining those two centres. Soils were sampled (0–5 cm, 5–10 cm, 10–15 cm and 15–20 cm) from 19 paddocks, using 20 cores per composite sample. Paddock histories for the previous 6–12 years were recorded. A second survey of 32 paddocks was conducted in the Winchendon Vale area, about 30 km north-west of Junee, in 2006 (Anon undated; FAJ Harris unpub; MKC unpub). Soil cores were collected from 10–15 locations in a representative part of each paddock. Cores were segmented as for Survey 1. Detailed paddock histories were recorded.

Results

Long term experiments

Soil pH_{Ca} profiles for Wagga and Condobolin are presented in Figure 1.

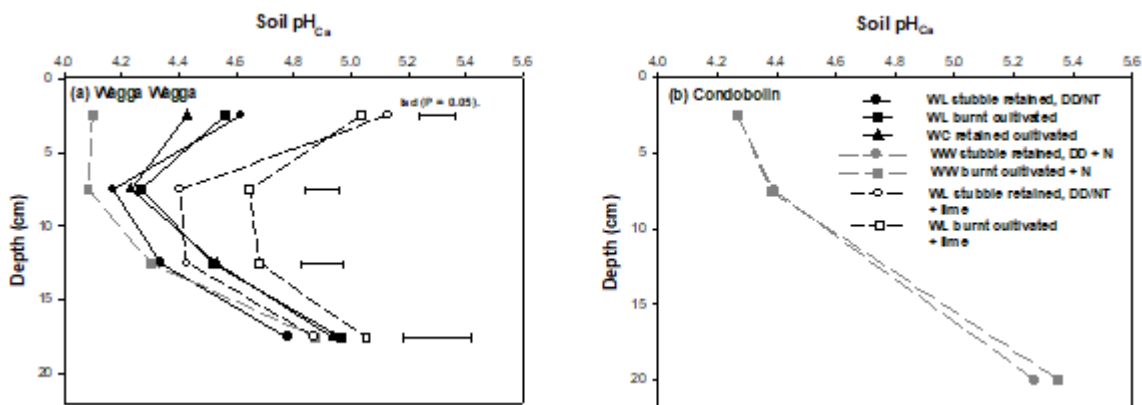


Figure 1. The pH_{Ca} in the shallow soil surface in two long term experiments at (a) Wagga Wagga after 22 years and (b) Condobolin after 19 years. Rotations with legumes are solid black symbols and lines; continuous wheat with added N are dark grey symbols and broken lines and limed rotations are open symbols and broken lines.

When legumes were the major source of N input (lupins or clover) soil pH_{Ca} clearly stratified (Figure 1a). When continuous wheat was fertilised with surface applied N as urea (Figure 1a) or ammonium nitrate (Figure 1b) the surface soil (0–5 cm) acidified making a near uniform pH_{Ca} in the 0–10 cm layer. Also, differences between cultivation and no-till (or direct drill), and stubble management had little effect on pH_{Ca} stratification. The application of lime, 8 years prior, in a no-till system has exaggerated the stratification of soil pH_{Ca} in the shallow surface soil with pH_{Ca} declining from the 0–5 cm to the 5–10 cm layer by 0.47 with nil lime and 0.75 with liming (Figure 1a). The incorporation of lime gave a deeper increase in soil pH_{Ca} .

Finally, the soil profile taken from near fence lines (12 cores per fence line to give a composite sample; fence lines N, S, E and W) from around the Condobolin long term experiment also gave stratification in the surface soil (Table 1). This profile was likely to approximate the effect of a long term pasture.

Table 1. The mean pH_{Ca} of the shallow soil profile near the boundary fences at the Condobolin experiment.

Soil depth	Time since commencement of experiment	
	15 years	22 years
0 – 2.5 cm	5.36	5.47
2.5 – 5 cm	4.86	5.05
5 – 10 cm	4.56	4.74

Paddock surveys

The mean soil pH in both surveys demonstrated the change in soil pH_{Ca} within the 0-10 cm layer, and that soil pH_{Ca} was at a minimum in the 5-15 cm soil depth (Figure 2a). Using these mean soil pHs as an example, it is clear that sampling in the layers 0-10 and 10-20 cm depth would mask the pH changes in the shallow soil. In Survey 1 the estimated soil pH_{Ca} for the 0-10 and 10-20 cm layers would be 4.74 and 4.83, while in Survey 2 these values would be 5.10 and 5.07, respectively, suggesting uniform pH_{Ca} profiles.

The soil pH_{Ca} was generally lower in the 5-10 cm layer compared with the 0-5 cm soil; the mean declines were 0.49 pH_{Ca} units in Survey 1 and 0.67 pH_{Ca} unit in Survey 2 (Figure 2b). Most soils showed some decline, with few soils increasing in pH_{Ca} in the 5-10 cm soil (Figure 2b).

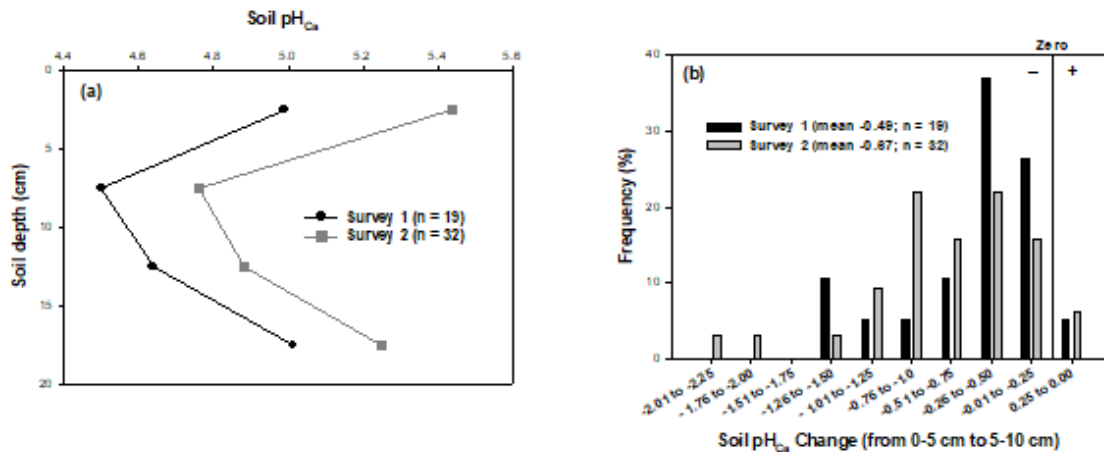


Figure 2 (a). Mean soil pH_{Ca} in the shallow soil surface in farmers' paddocks in two surveys conducted in 1995 (Survey 1) and 2006 (Survey 2; from Anon undated) and (b) the variation of change in soil pH_{Ca} from the 0 - 5 cm to the 5 - 10 cm soil depth (pH_{Ca} 5-10 cm minus pH_{Ca} 0-5 cm) in two surveys of farmers' paddocks.

Surveys 1 and 2 were grouped into those paddocks that were never limed, those limed > 5 years before, and those limed within the last 5 years, the effect of recent lime application on the surface 0-5 cm layer becomes apparent (Figure 3).

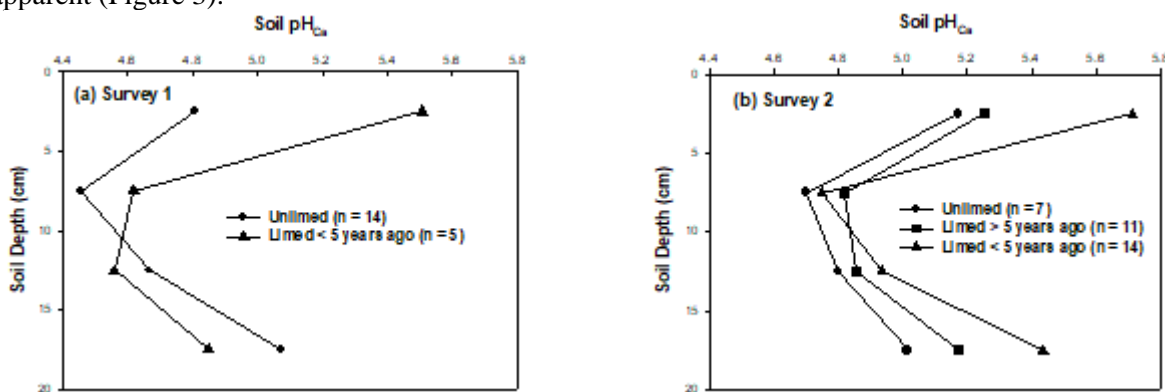


Figure 3. The stratification of soil pH_{Ca} with depth for (a) 19 paddocks in Survey 1 and (b) 32 paddocks in Survey 2, grouped as described in the figure.

The more acidic 5-15 cm depth was clear and the recently limed paddocks (< 5 years ago) accentuated the change in pH_{Ca} between the 0-5 and 5-10 cm depths due to an increase in pH_{Ca} in the 0-5 cm. Of the 14 limed paddocks in Survey 2 (2006), lime incorporation was by sowing alone in 4 paddocks, and 6 paddocks were incorporated by a single scarifying before sowing. Incorporation by sowing alone would be expected in no-till or direct drilled systems, but would be expected to give a shallow lime incorporation with poorer mixing. In Survey 1 (1995) it was more likely that the lime was incorporated by cultivation. However, it is clear that greatest increase in soil pH_{Ca} with lime application was at the 0-5 cm depth.

Discussion

In central and southern NSW the common occurrence of an acidic soil layer in the 5-15 cm depth, can underestimate the intensity of soil acidity in the profile when using the standard depths of soil sampling for

measuring soil acidity (0-10 cm and 10-20 cm). The acidic 5-15cm existed in the more acidic soils in the long term experiment at Wagga, the fence line at Condobolin, and the surveys of farmers' paddocks. The pattern was modified by the surface application of N fertilisers such as urea and ammonium nitrate. These fertilisers acidified the shallow surface (0-5 cm soil).

Liming in no till systems confines the lime effect to the shallow surface making 0-10 cm soil testing even less informative. In limed or unlimed soils, germinating seeds and young seedlings may experience more severe acidity than indicated by the standard soil test. Seed of all crops (except canola) would be placed into the more acidic soil and the seedling's early root growth would be in the most acidic soil in the profile. Erosion by wind or water results in a big loss of nutrients and alkali because these are concentrated in the surface few cm of soil, especially under zero till (< 5% soil disturbed).

As an initial step we suggest soil testing in finer depth layers on some paddocks to establish whether an acidic layer exists near the soil surface and its depth into the profile. Sandier soils are likely to acidify to greater depth than the mainly loam soils examined in this paper. Amending this acidic soil layer at 5-15 cm could be achieved by regular liming, to maintain surface soil $\text{pH}_{\text{Ca}} > 5.5$ (e.g. 2.5 t/ha every 6 to 10 years; Conyers et al. 2003b). This can result in a high pH at 0-5 cm but it stops the acidic throttle from forming because adequate alkali from the limestone leaches through the soil. If liming is less regular, say every 10-15 years and/or at lower lime rates, then it would be opportune to cultivate the lime into the soil and then return to conservation tillage. Limited data suggests that such occasional tillage does minimal harm to soil structure, and aggregate stability recovers after 2 to 5 years.

Conclusion

Examining the soil pH_{Ca} at finer depths is recommended to identify any masking of a more acidic layer in the soil. Occasional use of such finer depth sampling would monitor any efforts made to eradicate the acidic 5-15 cm soil. Maintaining adequate lime rates, applied at regular intervals, preferably with incorporation, should overcome the acidity at 5-15 cm given time.

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