Soil acidity in the high rainfall wheat belt of southern NSW.

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Abstract

Soils from 270 paddocks in Harden-Murrumburrah area of southern NSW were sampled and their acidity status was determined. Although lime had been applied at least once on 191 sites, acidity problems were still present at 74% of sites, based on at least one depth having aluminium saturation of the ECEC of ≥ 5%. Surface soil acidity (0–10 cm) was apparent in 33% of the sites, while 41% were non-acidic in the soil surface but were acidic below that depth in at least one soil layer. The application of lime increased soil pH_{Ca} in the surface by 0.31 pH_{Ca} units per t lime/ha. The mean pH_{Ca} of the limed soil was estimated to be 5.1 one year after liming and subsequently the soil pH_{Ca} declined by 0.058 pH_{Ca} units per year. Liming had no significant effect below 10 cm. All effects induced by lime were consistent with previously published research data. Our results reinforce the need to measure soil acidity parameters in the 10–20 cm layer to diagnose soil acidity problems, and support the use of acid tolerant species in combination with lime use to manage soil acidity in the present situation

KEY WORDS

Buffering, lime, residual lime, subsurface acidity.

Introduction

On the central and southern slopes of New South Wales in both 1979 and 1980, a general yellowing in crops was reported and this was subsequently associated with soil acidity (1,2). The "crop yellowing" problem also extended into north eastern Victoria, where again soil acidity was identified in some surveys as being one factor associated with the symptoms (3). Subsequent research, has demonstrated substantial yield increases following lime application in both cereals (1, 4, 6, 7, 8) and pastures (5, 9, 10, 11) and has resulted in increased usage of agricultural lime. It was estimated that approximately 30,000 t/annum was used in 1980 in central and southern NSW (mainly in stock feeds), rising to 100,000 t/annum in 1990 and to 420,000 by 1999 (WS and K. Helyar pers comm.). This increased lime use has been regarded as a major success, with little interest in sustaining research or focussed advisory effort in the area as “we know the answer to acidic soil is lime.”

The present study was conducted in the high rainfall cropping area in Harden-Murrumburrah region of southern NSW (about 600 mm average annual rainfall). Soils were sampled from paddocks at three depths and their acidity status was assessed. The data provides the first substantial assessment of progress in the management the acid soil problem in the area.

Materials and methods

Soils samples were taken in 270 paddocks at three depths (0-10 cm, 10-20 cm and 20-30 cm) in April 1999, on 48 farms located within a 40km radius of Harden. The samples were collected from an area of 3 m by 1.5 m per paddock taking 4 cores of 5cm diameter/site. The soil pH was measured in 0.01

M $CaCl_2$ (pH_{Ca}), while exchangeable cations (Al, Ca, Mg, K and Na) were measured by the method of Gillman and Sumpter (12). Aluminium (Al) was expressed as a percentage of the sum of exchangeable cations (percent of effective cation exchange capacity, ECEC). Soil texture was assessed in the surface soil sample. If a paddock had been limed, the year and the amount of lime applied were also recorded.

Farmers within the local Landcare group were invited to participate in the study. Site selection was made in two different ways. Farmers chose a set of paddocks based on their own requirements. A second set were selected on the basis that they cover a range of paddock histories and/or perceived productivity. These two selections are referred to as farmer chosen and “other” chosen sites.

Results

Farmers selected 113 sites and 92 of these had been previously limed; only 99 of 157 were limed in the other group (i.e. 81% selected by farmers were limed compared to 63% otherwise). However, the farmer chosen sites were not different in mean pH_{Ca} to the other selected sites within the limed and unlimed groups.

The mean soil pH_{Ca} across all sites and sampling depths was 4.63. At the 0-10 cm depth, the mean pH_{Ca} was 4.80, at the 10-20 cm depth it was 4.46 and at the 20-30 cm depth, 4.63. The soils with a clay loam texture in the surface were less acidic ($P \leq 0.05$) at all depths (0-10 cm, 10-20 cm and 20-30 cm; pH_{Ca} 4.93, 4.59 and 4.80 respectively), compared to the loam soils (4.64, 4.28 and 4.54) and sandy loam soils (4.71, 4.41 and 4.52), which were not significantly different. The most acidic soil layers were deeper than 10 cm, below the impact of lime application, with the 10-20 cm layer being the most acidic.

Regression analysis of the relationship between pH_{Ca} and log (Al saturation %) showed that the relationship was significantly different between the soil layers. There was some variation in the regression coefficient within layers that may indicate that the relationship varied with different soils within the district. The soil texture classes were not significantly different in the pH_{Ca}/log (Al saturation %) relationships for clay loam, loam and sandy loam soils at the 0-10 cm and 20-30 cm depths. In the 10-20 data there was a slight but significant difference between the clay loam and loam relationships. The loam soils had higher Al saturation below pH_{Ca} about 4.3. With all soil depths and texture classes a pH_{Ca} of about 4.5 to 4.6 was associated with an exchangeable Al saturation ECEC of about 5%. For the purposes of this paper we describe a soil as acid if its Al % saturation was ≥ 5%.

On this basis only 71 sites had no acidity problem at any depth (26% of all sites; Table 1). Acidity problems were present at 74% of sites. Surface soil acidity (0–10 cm) was apparent in 33% of the total number of sites. At these sites it was likely that the 10-20 cm layer was also acid (65 of 88 sites; 74%). The largest group of soils (111 sites; 41% of sites) were non-acid in the soil surface but were acid below that depth at either or both of the 10-20 cm or 20-30 cm layers. Of these 111 sites, 98 had been limed at some time. Sixty-three of the 111 sites were acidic at both 10-20 cm depth and 20-30 cm depth.

Table 1. Acidity categories of 270 agricultural sites in the Harden- Murrumburrah area of NSW in 1999.

Acidity category	Proportion of sites (%)
Sites with no acidity problem (Al < 5% at all depths)	71/270 (26%)
Sites that are acidic to 10 cm (Al ≥ 5%)	88/270 (33%)
Sites that are non-acidic in the 0–10 cm but acidic in either the 10–20 cm or 20–30 cm layer	111/270 (41%)

ECEC increased with increasing soil pH_{Ca}. The relationship between ECEC and pH_{Ca} (± *se*) in the 0-10 cm depth using all 270 sites was: ECEC = -8.65 (± *0.85*) + 3.09 (± *0.18*) x pH_{Ca} (R^2 = 0.54). Soils with a clay loam texture had higher ECEC than the loam soils at the 0-10 and 10-20 cm depths, while the sandy loam soils and loams soils were not different. The intercepts and slopes for the 0-10 cm soil for the clay loam were –8.42 (± 1.24) and 3.29(± 0.25), while for the loam they were –7.15 (± 2.53) and 2.56 (± 0.53), and for the sandy loam soils were –6.53(± 1.62) and 2.47(± 0.33), respectively.

Lime had been applied at least once on 191of the 270 sites, and a second lime application had occurred on 35 of the sites. The majority of sites were limed at 2000 to 2500kg/ha, but eleven sites had been limed at < 1500kg/ha or >3000kg/ha and were excluded from further analysis. The remaining 180 sites that had been limed (31 had been relimed) were considered the limed sites. The 180 limed sites were then grouped by time since last lime application and the results presented in table 2. The longest time since last lime application was 12 years (2 sites).

The surface soil pH_{Ca} was increased by lime application, and decreased with years since liming (Table 2). A linear relationship between years since lime application and soil pH_{Ca} in the 0–10 cm depth estimated a pH_{Ca} immediately after liming of 5.17 ± 0.082 (intercept ± se) and a pH_{Ca} decline of 0.058 ± 0.0174 pH_{Ca} units per year. Intercepts and slopes for the 10–20 cm and 20-30 cm depths were 4.49 ± 0.0725 and – 0.012 ± 0.015 and 4.67 ± 0.07 and –0.014 ± 0.015 respectively. While the soil pH_{Ca} at these deeper layers decreased slightly with years after lime application, there was no significant relationship between years after liming and pH_{Ca} i.e. the slope of the fitted line in both cases was not significantly different from zero. The relationships were not significantly different between soil texture classes.

Table 2. Mean soil pH_{Ca} for site profiles in unlimed and limed categories in the Harden-Murrumburrah area of NSW in 1999.

		Time since last lime application			
Soil depth (cm)	Unlimed	≤ 2 years	3 to 5 years	6 to 8 years	≥ 9 years
0 – 10	4.41	5.12	4.95	4.74	4.51
10 – 20	4.50	4.48	4.46	4.37	4.37
20 – 30	4.66	4.63	4.66	4.60	4.44
Number of sites	79	68	78	16	18

The surface soil pH_{Ca} one year after lime application was estimated from the linear regression to be 5.107. The estimated increase in soil pH_{Ca} one year after lime application was 0.694 pH_{Ca} units (5.107 - 4.413) and indicated a pH_{Ca} increase of 0.31 pH units per t lime/ha, as the average lime application rate over the 180 sites was 2.25 t/ha. There is no significant change in soil pH_{Ca} at the 10–20 cm and 20-30 cm depths following lime application (Table 2).

Discussion

The Harden-Murrumburrah area appeared typical of much of the high rainfall wheat belt of southern and central NSW in that unlimed soils were very acid (Table 2) and lime use was an established practice. The soils of the area are red earths with some red and yellow podsolics; the major soils of the high rainfall wheat belt.

Site selection

On aggregate 71% of all sites were limed, although the farmer preference for choosing limed paddocks for this study may have distorted this figure. The true percentage of paddocks limed in the area may be closer to the 63% estimated from the “other” selection, but this still remains a substantial proportion of the sample. We suggest that farmers who limed may have obtained a soil test prior to the liming decision, but had not retested to evaluate the effects of lime. Our study provided an opportunity for them to do so.

Soil acidity status

Seventy four percent of sites sampled (199 of the 270) had a soil acidity problem (exchangeable Al saturation ≥5% of ECEC) at some depth in the soil profile. This is consistent with the estimates of Helyar *et al*. (13). In paddocks where the surface soil was acidic (33% of sites) there was a high chance (approx. 3/4) that the 10–20 cm depth was also acid, and 1/2 chance that the acidity extended to the 20–30 cm depth. The second group of soils was acidic below 10 cm but non-acidic in the soil surface. Most of sites with a non-acidic surface soil (98 of 111 sites) had been limed and lime incorporated into the plough layer (approx. 0–10 cm) depth and this liming had little if any effect on the soil below 10 cm. Of the acidic soils less than half would have been identified as being acidic from a surface soil (0–10 cm) analysis alone. These soils would require a soil pH_{Ca} assessment on the 10–20 cm layer before the current acidity problem could be identified. The need for pH measurement in this soil layer has been identified and recommended to farmers since 1984 (14).

The problem of manganese (Mn) toxicity in acidic soils has not been highlighted by this study as no measurement of soil Mn was made. We would suspect that Mn toxicity is a problem for sensitive species such as lucerne (*Medicago sativa*) and canola (*Brassica napus*) when grown in this area because Mn toxicity has been identified on similar soils in the Goulburn area to the east (15) and in Albury area to the south (16).

Effect of lime

The application of lime increased soil pH_{Ca} in the soil surface by about 0.31 pH_{Ca} units per t lime/ha. This increase is consistent with data from research which indicated a similar values (e.g 0.335 pH_{Ca} units per t lime/ha; 6). The Limeit model (17) was used to estimate soil pH buffering capacity using the data for the unlimed sites (pH_{Ca} 4.41, ECEC 5.50 cmol(+)/kg) and this estimated that 2.25 t/ha of lime would increase pH_{Ca} to 5.4 with a buffering capacity of 0.40 pH_{Ca} units per t lime/ha. The survey data has given a buffering estimate that is lower than that from either of the research studies. However the discrepancies are not large and all research had been conducted using lime of high quality (99.5% < 250 µm; 98% $CaCO_3$) while agricultural usage in the Harden area would include a range of less effective products.

There was no evidence that the application of lime to the 0–10 cm layer had any effect on the pH_{Ca} of the deeper soil layers. A previous study indicated the effect on soil pH_{Ca} in the 10-20 cm layer was small when the 0–10 cm layer was limed, but the effect on wheat yield was substantial (6). It is likely that in the present study any change in soil pH_{Ca} below 10 cm was small and errors in the measurement of pH_{Ca} across soils has made it impossible to identify with any certainty the downward movement of a pH_{Ca} effect.

On average the limed soil was pH_{Ca} 5.1 one year after liming and the pH_{Ca} declined by 0.058 pH_{Ca} units per year. This agreed closely with the value for a single site near Albury of 0.052 pH_{Ca} units per year after a pH_{Ca} of 5.1 was achieved one year after liming (6). The greater ECEC in the clay loam soils identified in the present study was not reflected in differences in apparent soil buffering capacity nor in the rate of reacidification after lime application, as would be anticipated from the Limeit model (17).

Conclusion

This survey has demonstrated that the soil acidity problem remains substantial in this high rainfall cropping area, despite over a decade of increasing lime usage. Greater lime input may be required to sustainably manage the acid soils in the area. We highlight the need to measure the soil pH_{Ca} below the 10 cm depth in identifying acid soil problems and suggest that the amendment of the soil below 10 cm by lime application to the surface layer (0–10 cm) will be a slow process likely to take decades. Research in other areas of the high rainfall wheat belt has shown that an acidic subsurface soil reduced grain yield of wheat and barley (6, 18) Where the subsurface soil was acidic, cereals tolerant of acidic soils gave higher grain yields than sensitive cereals even when the surface was limed (18). We recommend the application of lime combined with the selection of crop and pasture plants tolerant of soil acidity.

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