SOIL PH CHANGE OVER TIME IN RELATION TO ROTATION, N FERTILISER, STUBBLE MANAGEMENT AND TILLAGE

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Abstract

Trends in soil pH (0-10 cm, $CaCl_2$) in a long-term rotation, tillage and stubble management field trial commenced in 1979 at Wagga Wagga on a red earth are presented and discussed. Soil pH commenced at 4.9 in 1979 and declined in all treatments until 1987-88 though at different rates. Thereafter, pH of each treatment either remained stable, slowly acidified or increased. The most acidifying treatment was N fertilised wheat-wheat followed by subclover-wheat and lupin-wheat. Unfertilized wheat-wheat has increased pH by 0.2 units since 1990. The major trends and differences in pH were mainly related to inputs of nitrogen. There has been little change in pH with tillage treatment in the 0-10 cm layer. Similarly, there was no difference between stubble options until 1988. Thereafter, burning has maintained a marginally but consistently higher pH than retention. The alkaline residue remaining after burning was the most likely explanation for the pH difference.

Key words: Soil pH, rotation, tillage, stubble, acidification.

Soil acidification is a major cause of lost farm production from over 14 M hectares in southern Australia; areas receiving 500 mm rainfall or more are at particular risk (1). Natural ecosystems may acidify slowly, but by changing the system and altering such processes as inputs or losses of organic matter and nitrogen (N) and product removal, change in direction and rate of pH movement may be promoted. Pasture legumes, N fertiliser and more recently, grain legumes can produce high wheat yields but have also been shown to promote acidification (9, 2). Long-term field trials incorporating appropriate agronomic treatments are most suitable for ?following and understanding these trends in soil pH. Such a long-term trial was established at WaggaWagga in 1979 and includes rotations of wheat with subclover, lupin and wheat with and without added N fertiliser, stubble burning versus retention and tillage treatments. Early results (1979 - 90) on soil pH change were reported by Heenan and Taylor (5). This paper reports further data from this trial up to 1997.

Material and methods

Details on the site, treatments, management and measurements are reported elsewhere (4, 5). The soil was a red earth (Gn 2.12, 8) and average annual rainfall at WaggaWagga is 550 mm . N fertiliser as urea was applied to wheat - wheat (WW) at 100 kg N/ha as a 3-way split at sowing, mid-tillering and flowering. In 1991-92, all plots were split for lime application, but this paper presents results from unlimed plots only. Soil cores (0-0.1m) for pH (0.01 M $CaCl_2$) determinations were taken prior to cultivation and sowing in autumn. Stubble was burnt in early autumn when fire bans were lifted. The subclover pastures were grazed with an average intensity of 10 lambs/ha. There were three replicates and all phases were represented each year.

Results and discussion

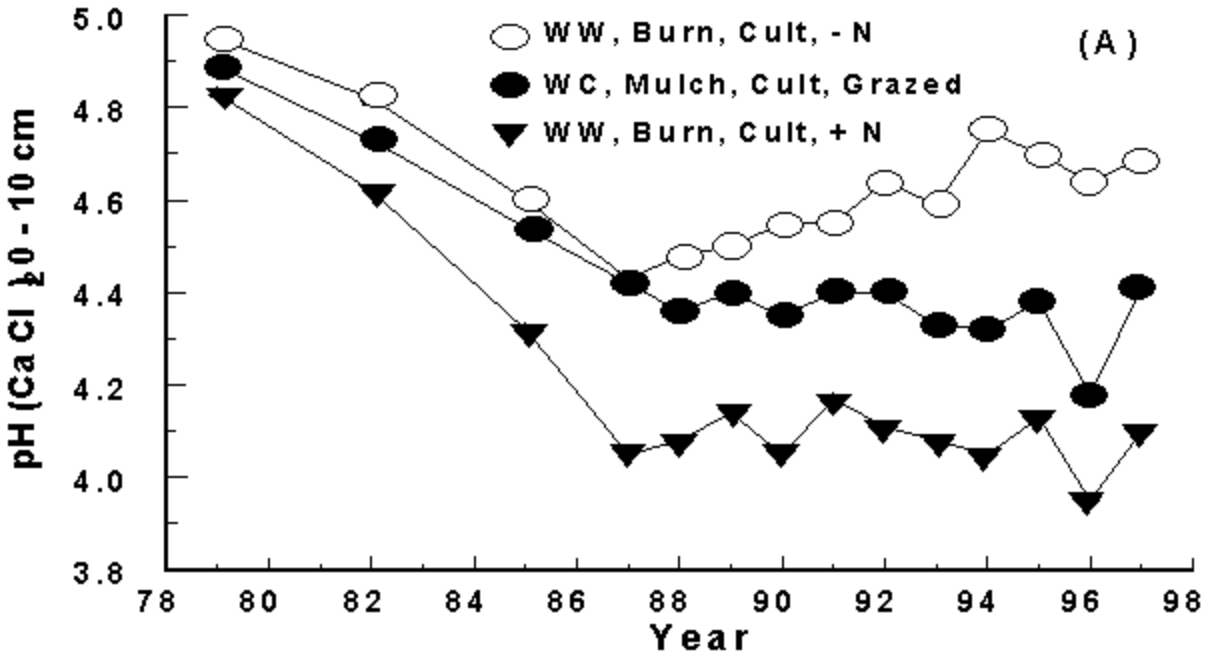

Figure 1

As reported by Heenan and Taylor (5) all treatments from 1979 to 1987-88 declined in pH with annual rates varying from 0.06 to 0.09 units (Fig. 1). Acidification is mainly the result of acids produced in the carbon (C) and N cycles in these agricultural systems (7). The initial high acidification rate of all treatments until 1987-88 was probably related to the long period of legume based pasture prior to the beginning of the trial in 1979. The high soil N supply produced from this long term pasture prevented a yield response to N fertilisation of wheat - wheat before 1983 (4) suggesting high rates of mineralisation and subsequent nitrification with potential acidification. As well, the different cropping systems imposed after 1979 most likely had separate effects on acid addition through varied N inputs and organic matter removal. The finding that the maximum acidification rate was when N fertiliser was applied to wheat - wheat strongly suggests that N was implicated in at least this treatment. However, by 1987-88 the pool of soil N in the surface 0.1 m had diminished in most treatments (6). Therefore, the impact of the history prior to 1979 would have subsided and any pH change after 1987-88 was more likely to be characteristic of the cropping system alone.

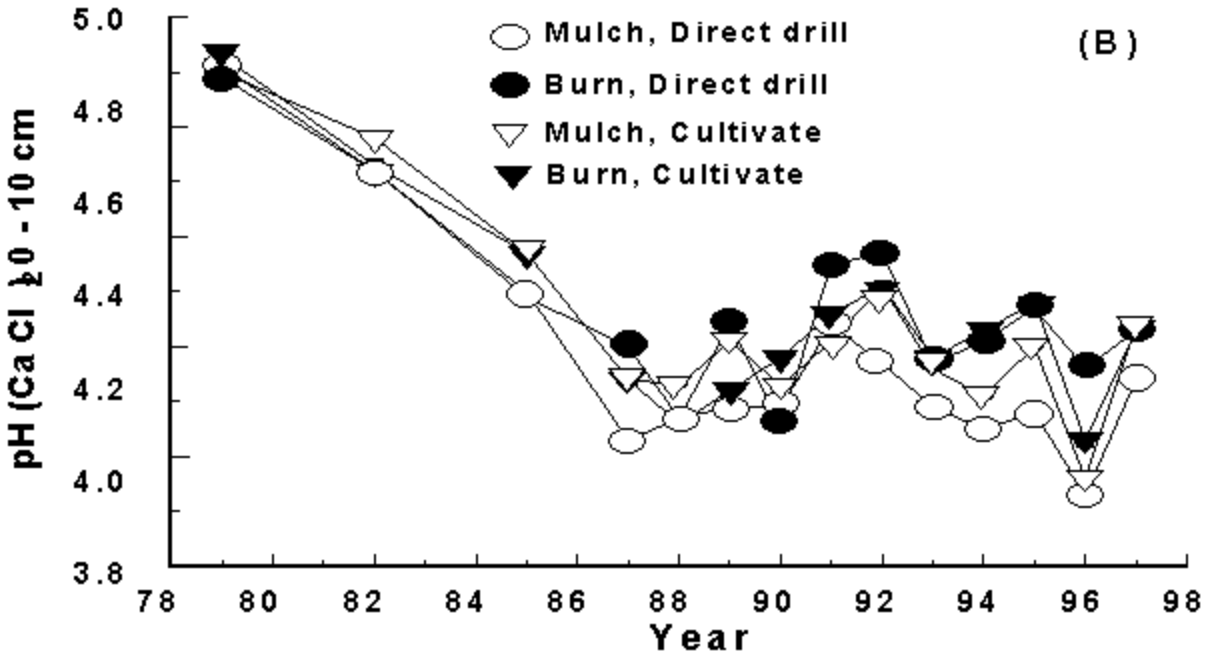

Figure 1a

Following the initial rapid decline in pH, the trends for all treatments changed dramatically. Regression analysis of data from 1987 indicate no significant change in the surface 0.1 m over the past 10 years for N fertilized WW (Fig. 1a). This is despite the continued potential acidification via nitrification and nitrate leaching and product removal in grain. Also, the marked appearance of aluminium toxicity symptoms in 1989 - 90 (4) have not been repeated in recent times though significant grain yield responses to lime were recorded in 1993 and 1995 (D. P. Heenan, unpublished data). The same wheat variety (Dollarbird), which is acid tolerant, has been used since 1988.

Since 1987, WW without added N fertiliser has slightly but significantly increased in pH at an average annual rate of 0.025 units. While alkaline ash accumulation in the surface, from burning stubble, may have contributed to a rise in pH, it is likely that organic C oxidation was the dominant cause. Soil organic C has declined markedly since 1979 at a rate of 400 kg C/ha/year and the associated decline in total soil N (53 kg N/ha/year) (6) and absence of any N input would have reduced the impact of N cycling on acidification.

Within lupin - wheat rotations there was no significant change from zero slope for any of the tillage or stubble treatments between 1987and 1997, although burnt stubble slopes were positive whereas retained stubble slopes were negative suggesting slight but non-significant acidification in the latter. On an annual basis stubble burning promoted significantly higher pH when direct drilled in 1987, '89, '92, '94, '95, '96, and '97. In a cultivated situation there was only one year of significant difference, being in 1994. The reason for the greater effect of stubble burning on surface pH when direct drilled may be related to greater vertical distribution of the alkaline ash which may have moved below 10 cm when incorporated.

There were no consistent differences between tillage treatments. Generally, direct drilling into retained stubble maintained lower pH than incorporated stubble, but the difference was significant in 1989 and 1997 only. Again, the reason for these differences are not clear but may be related to differences in vertical distribution of stubble and/or greater leaching of nitrates following nitrification with direct drilling. When stubble was burnt, direct drilling usually resulted in similar or higher pH than when cultivated though any difference was significant in 1996 only. Differences in vertical distribution of the alkaline ash could account for a slightly higher pH with direct drilling.

Despite the higher potential for acidification through greater nitrification in subclover - wheat compared to lupin - wheat (3), there was no significant difference between these two treatments. Differences in management between the two treatments include greater cultivation occurrences with the cropping rotation. As noted above, cultivation when stubble was retained, maintained similar or slightly higher surface pH. However, a higher level of soil organic C was maintained in the subclover - wheat rotations (6) and most likely provided a greater pH buffering capacity than under lupin - wheat.

Conclusion

The acidification of all management practices over the initial 8-9 years of this long term experiment emphasises the importance of paddock history prior to the experiment and period of time necessary for pH trends to become a characteristic of a particular management treatment imposed. In this experiment even after the 'turning point' was reached, some slow changes have been recorded. For continuous cereal production with no outside N input and low soil N supply, pH has risen since 1987. With annual applications of 100 kg N/ha as urea, a low pH of around 4.08 has been maintained and is indicative of the danger of relying on high rates of N fertiliser in non-legume rotations. On the other hand, alternating legume - wheat rotations have to date maintained a pH of around 4.4 which can allow high production of acid tolerant crops and pastures. Slightly higher acidification with a combination of direct drilling and stubble retention is unlikely to offset the advantages on other indices of soil quality (organic matter, total nitrogen, soil structure, biology, etc.) promoted by these practices.

Acknowledgments

We thank Messrs G Heath and G Poile for technical assistance and Grains Research and Development Corporation for financial support.

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