Towards an understanding of variability in yield responses to liming

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Abstract

Acid soils and soil acidification is a major soil constraint impacting on the productivity and sustainability of agriculture across many regions of Australia. In Western Australia one-third of the soils are acid or at high risk from acidification (pH_{CaCl2}?≤?5). While the application of lime has been demonstrated to be an effective means of neutralising soil acidity in this environment, yield responses vary and are often not immediate, thus impacting on the cost effectiveness of treatment. We have carried out a preliminary analysis of data from lime trials conducted in the wheatbelt of WA to examine the main factors that drive the variability of the response to liming across seasons, environments and management. The analysis to date indicates the potential to move beyond the 'on-average' responses when talking about the response of crops to liming and provide a basis for more specific recommendations to farmers.

Key Words

Acidity, Lime, Wheat, Season, Yield

Introduction

Soil acidity is a major soil constraint impacting on the productivity and sustainability of Australian agriculture. In Western Australia one-third of the soils are acid or at high risk from acidification (pH_{CaCl2}?≤?5). Application of lime is an effective means of neutralising soil acidity and there is a large resource of liming materials available in WA. A ten-year, integrated research, development and extension project focussing on soil acidity and its amelioration ("Time to lime") was carried out, commencing in 1992. While lime use has increased significantly following this effort, it is still below that required to treat the existing problem, let alone on-going acidification (State of Environment Report 2006). Results of farmer surveys conducted at the end of this project suggested that high costs (especially transport), uncertainty of the effects of lime on nutrition and the variability in the response to lime application were major limitations to the adoption of liming practices (Miller 2002).

A preliminary analysis of published information from 72 trial-years of data from lime trials conducted in the wheatbelt of WA has found that the wheat yield response varies from -190 to 1200 kg/ha (-10 to 60 %) for lime applied at 2 to 2.5?t/ha (Davies et al 2006). The information that was used by Davies and his colleagues represents a subset of the available data from field trials and demonstrations that have been conducted throughout WA. These data are a fantastic resource to investigate the variability in liming responses further. The aim of this study was to compile individual plot data from a range of trials and demonstrations and to conduct a preliminary analysis to examine the main factors that drive the variability of the response to liming across seasons, environments and management. Specifically, we sought to examine the supposition that the main determinant of the yield response to lime is the time since lime application.

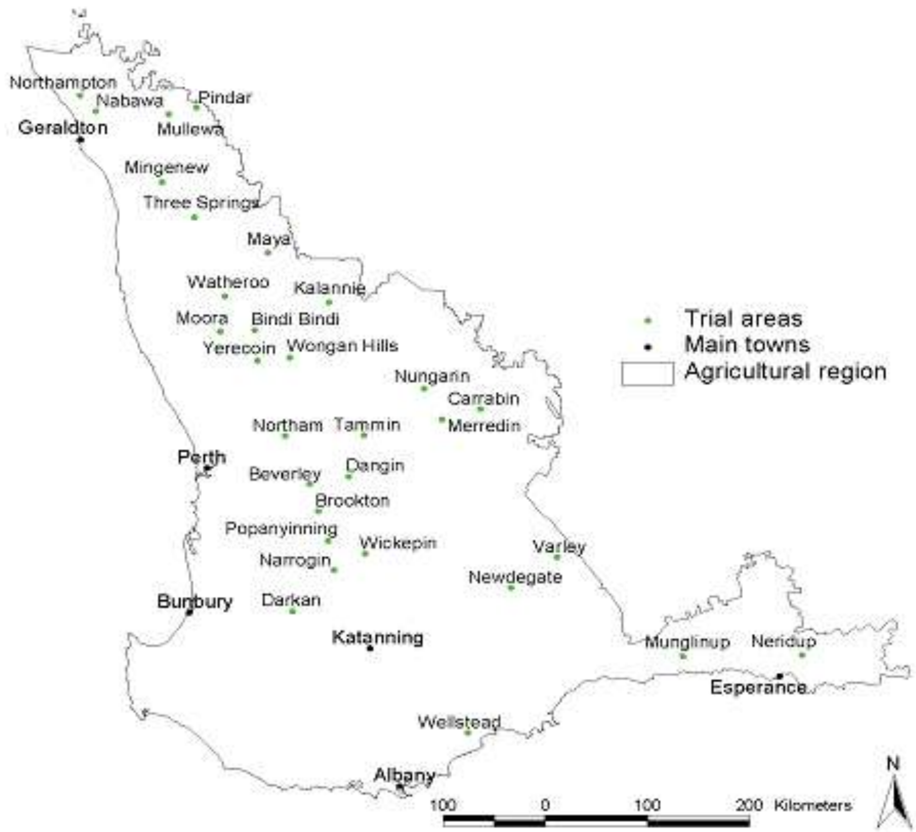
Methods

Data compilation

The data used in this paper came from field trials that were conducted in the agricultural area of WA. This region (between latitude 27?S and 35?S) has a Mediterranean-type climate with around 80% of the annual rain falling between April and October. Dryland agriculture based on winter-annual crops and grazing is currently the dominant industry.

Data were compiled from 61 liming trials conducted by staff of the Department of Agriculture and Food between 1990 and 2004. Results from many of these have previously been reported on an individual trial basis (Penny and Gazey 2002). The trials were located in the southern (20 trial-years), central (77 trial-years) and northern wheatbelt (65 trial-years) (Figure 1). These trials provided a total of 5064 observations after any missing values had been removed. The trials used included yield data for cereals (wheat 2293, barley 286, oats?9), legumes (lupin 2114, chickpea 12) and canola (350). Information for each trial included the rate of lime applied to each plot (0 to 4 t/ha), a soil description, year of lime application (1980, 1984, 1988, 1990-1998 and 2000) and, type and quality of lime applied.

Limesand was the lime used in the majority of the trials (4349 observations). The limesand had a typical analysis of 90% Neutralising Value (NV) with 99% fineness (F) (proportion passing through a 0.6 mm sieve). The range for limesand was 62-97% NV and 89-100% F; for limestone 68-95% NV and 58-87% F; for dolomite 50-97% NV and 42-60% F and for other limes including G-lime and chalk lime 77-102% NV and 35-76% F.



The soil in each trial was categorised into a standard soil group (Schoknecht 2002) based on the soil description, the location of the trial and local knowledge. This categorisation resulted in 17 soils; yellow sandy earth (2322), yellow deep sand (723), acid yellow deep sand (352), duplex sandy gravel (340), grey shallow sandy duplex (242), acid yellow sandy earth (220), pale deep sand (200), red shallow loam (190), loamy gravel (84), yellow/brown deep sandy duplex (81), grey deep sandy duplex (73), red shallow loamy duplex (66), gravelly pale deep sand (63), red sandy earth (45), reticulite deep sandy duplex (36), acid shallow duplex (18),yellow/brown shallow loamy duplex (9).

Visualisation and preliminary analysis

The data were visualised and analysed using the R statistical system (2005). Trellis displays were used to examine the response of crop yield to year of harvest, soil group, years since lime application, rate of lime application, number of applications of lime and lime neutralising value and fineness. Due to the large imbalances in the number of data points for the different crops, subsets of the data for barley, for lupin and for wheat (from control plots or those that

Figure 1. Map of the agricultural area of Western Australia showing the towns closest to the locations of the liming trials and demonstrations that were used in this analysis.

had received limesand) were used in analyses of variance and linear regressions of the impact of the variables and their interactions on yield. The main focus of this preliminary analysis was on the wheat subset as it provided the largest number of observations.

Results

Crop yields in the data set ranged from 0.6 t/ha to 6.7 t/ha. There were differences between the crop species in their responses to lime. The analysis suggested significant effects of year, soil group, lime rate and years since lime application on the yield of barley (Figure 2a). While there is a visual suggestion of a linear increase in barley yield with lime rate, there was not a significant relationship. In contrast, the yield of lupin tended to remain unchanged, or even decline, with lime application (Figure 2b). There was no effect of lime rate, but significant effects of the years since lime and number of applications of lime (in addition to year and soil group).

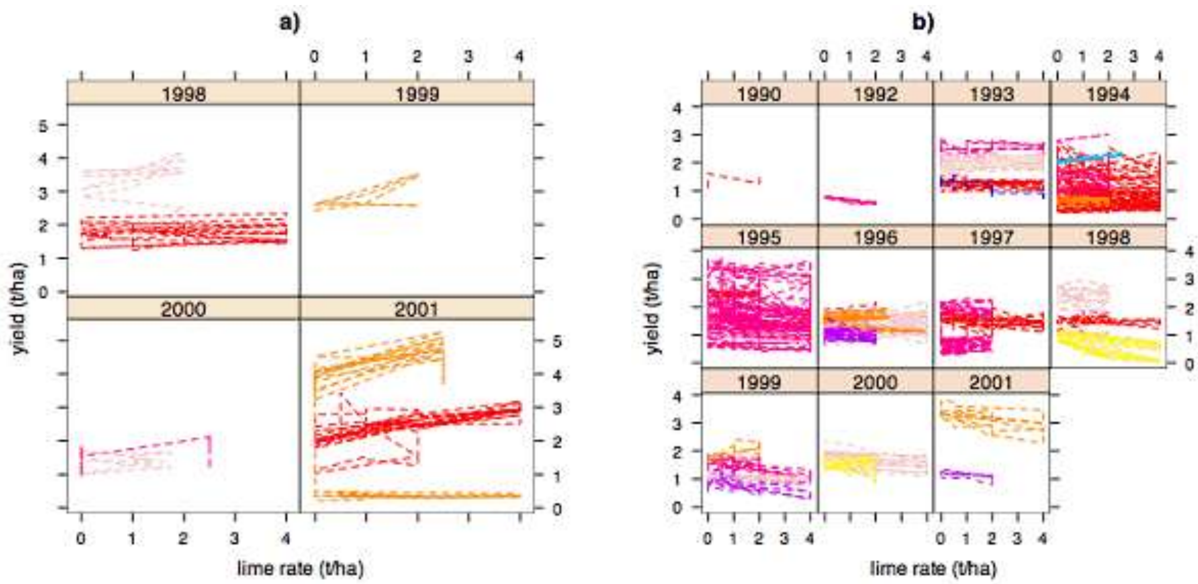


Figure 2. Yield responses of barley and lupin with rate of lime application for trials carried out between 1990 and 2001 a). Barley: colours are for the years since lime application; 0 years (red), 1 year (deep pink), 2 years (pink), 3 years (orange). b) Lupin: colours for the years since lime application; 0 years (red), 1 year (deep pink), 2 years (pink), 3 years (orange), 4 years (yellow), 5 years (purple), 6 years (sky blue), 7 years (mid-blue).

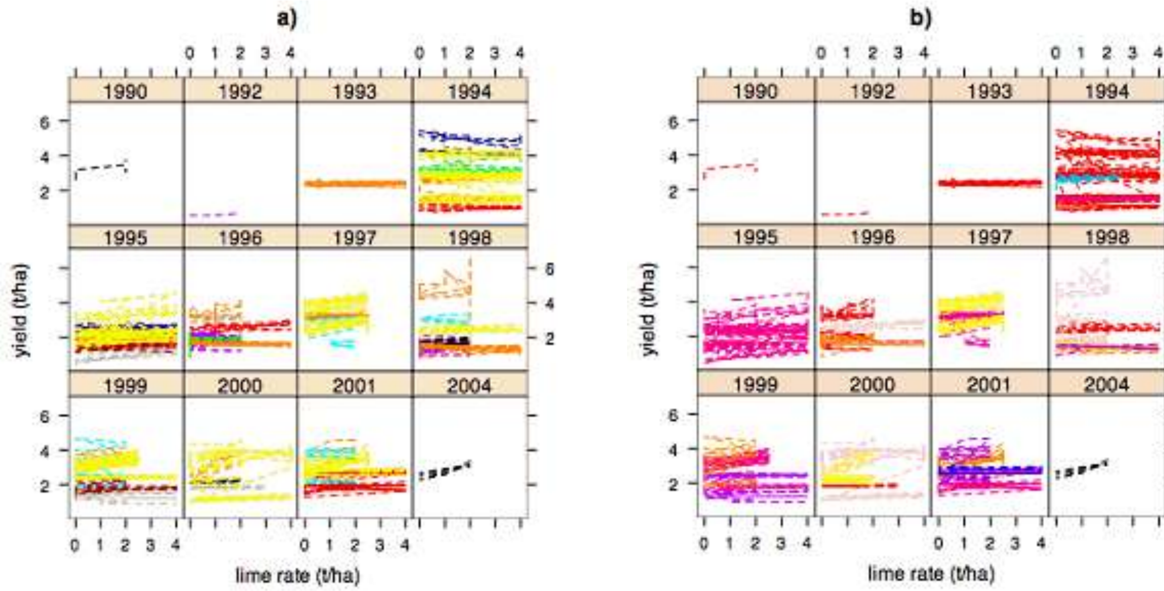


Figure 3. Wheat yield responses with rate of limesand application for trials in 1990, 1992-2001 and 2004.

a) Colour scheme is for soil groups; yellow sandy earth (yellow), yellow deep sand (orange), acid yellow deep sand (bright red), acid yellow sandy earth (purple), pale deep sand (dark blue), duplex sandy gravel (green), grey deep sandy duplex (black), grey shallow sandy duplex (light grey), red shallow loam (dark red). Remaining soils are coloured light blue.

b) Colour scheme is for the years since lime application; 0 years (red), 1 year (deep pink), 2 years (pink), 3 years (orange), 4 years (yellow), 5 years (purple), 6 years (sky blue), 7 years (mid-blue), 8 years (black).

The subset of wheat that had ‘received’ limesand applications (0 to 4 t/ha) comprised 1925 data points and had a mean yield of 2.4 t/ha (? 0.93). An analysis of variance of this subset indicated significant effects of year of harvest, soil group, rate of lime application, years since lime application, number of applications and the interaction of year with soil group and with years since lime application (Figure 3a and 3b).

Discussion and Conclusion

Visualisation and preliminary analysis of this data set illustrates considerable variation in the yield response of crops to lime in the agricultural areas of WA. Visualisation of these data reinforced previously established conclusions such as the responsiveness of sensitive species like barley and the lack of response, and even negative response, of species such as lupin. (This is in part due to the fact that much of the data that we used were those used to draw the original conclusions; a point that is discussed further below.) The analysis highlighted the range of yield results for wheat following liming. While only preliminary at this stage, we have gone part of the way to identifying factors that explain this variability. The importance of lime rate and the time since lime application were highlighted as was the complexity of the interaction (up to third order). Further analysis is required to identify the components of this interaction. This complexity of the response needs to be understood in order to produce clear messages.

The pH of the soil is a key variable that was not included in this preliminary analysis. The significant effects of soil group and years since lime are likely to be due to them being surrogates for soil pH. Measurements of soil pH profiles to 30 cm (and to a lesser extent soil aluminium concentrations) exist for most of the plots in most of the trials for at least some of the years. These data were omitted due to time constraints and the exploratory nature of this analysis. Clearly this important information needs to be included in any further analysis.

In addition to the inclusion of data on soil pH and aluminium concentration, further work to understand the determinants of the variability of the yield response to liming will benefit from the inclusion of additional data from concluded and on-going trials. At least two more substantial sets of long-term trial data are available and there are at least 20 on-going trials, some of which are at the same locations as those that were used in this analyses. Expansion of the data set will enable a more meaningful analysis for crops other than lupin and wheat.

This analysis has reiterated the fact that yield responses are rarely seen immediately after liming application, but occur with time (Davies et al 2006). In addition, we have shown that the magnitude of the response and the delay in measured response is dependent on an interaction with soil type and season. While this can be simplified into the extension message that “lime takes time”, there is the danger that this is an over simplification. The visualisation of these data suggest that part of this three-way interaction may be due to the pH of the soil or other soil properties. This suggests other important considerations associated with the economics of treating soil acidity. For example, what are the implications if liming is not adopted early? Will the delay in the realisation of economic responses mean that more lime, more time and greater expense are needed to get back to the same position?

With the continuing decline in the terms of trade and the unlikeliness that this will change it is increasingly important that resources are used in the most effective manner. With respect to managing soil acidity there are several ways that this can be achieved. Through analyses of this type we gain a better understanding of the factors affecting a crop’s response to the application of lime and therefore can more accurately predict the circumstances where a return on investment is likely. Alternatively, we may be able to identify situations where liming can be used as a prophylactic treatment to avoid costly losses and more expensive amelioration treatments in the future.

This preliminary analysis has shown the potential to move beyond general recommendations when talking about the response of crops to liming. Further work will be undertaken utilising an expanded data set. This should enable further elucidation of the interactions between levels of the main factors and thus provide the basis for more specific recommendations to farmers.

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