Describing Soil pH Profiles and Their Effect on Yield of Cereal Crops

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Abstract

The yield of cereal crops, relative to their potential yield without limitations due to soil acidity in the root zone, has been described as a function of a simplified description of the soil pH profile: the pH in the 0-10 cm and 10-20 cm layers and the pH profile-class of the 20 to 50 cm layer. A pH profile-class groups soils which have similar pH trends with depth in the soil below 20 cm. Using data from a soil survey completed in the wheat-belt of southern NSW and north-eastern Victoria (1), maps of the $pH_{0\text{-}10\ cm}$, $pH_{10\text{-}20\ cm}$ and the pH profile-$class_{20\text{-}50\ cm}$ were produced for the NSW portion of the survey area. Yield maps, in which yields are expressed relative to the potential yield without acidity limitations, were produced for cereal cultivars that are tolerant (similar to *cvv.* Millewa and Dollarbird wheat and cv. Currency triticale) and sensitive (similar to cvv. Clipper and Schooner barley or *cvv*. Janz and Egret wheat) to acidity using a yield model similar to that described by Helyar (3).

Key words: Soil pH, subsoil acidity, yield, wheat, barley, triticale.

Acidity of the soil in the root zone can affect plant yield. This study of survey data from south-eastern Australia models the effects of subsoil acidity on the yield of cereal cultivars. All pH values were measured in the supernatant solution of a 1:5 soil to 0.15M $CaCl_2$ solution. This model takes account of the effect of the acidity of three soil layers on yield and describes how the plants' response to surface and sub-surface acidity depends on the relative pH of the three layers. The model was fitted to yield responses of tolerant and sensitive cereal cultivars to pH variation in the 0-10 and 10-20 cm layers (5), to responses to variation in the 0-10 cm pH on soils with contrasting pH profiles below this depth (K.Helyar, A.Ridley, and W.Slattery, *pers. comm.*) and to data describing the variation in the yield of the tolerant wheat *cv.* Dollarbird, due to variation in the pH of? the 20-80 cm layer (4). No data describing yield variation in barley due to pH at 20-50 cm in the soil profile were available, so an estimate was made based on the relative sensitivity of the barley and wheat cultivars.

Fourteen profile-classes describing different pH trends for soil pH below 20 cm were established to simplify the description of the pH in the lower profile. Maps of the $pH_{0\text{-}10\ cm}$, $pH_{10\text{-}20\ cm}$ and of the profile-$class_{20\text{-}50\ cm}$ were produced for the NSW portion of the survey area. A yield model, based on equations described by Helyar (3) was fitted to the experimental data, and used to produce relative yield maps (where a relative yield of 100 is the yield expected without acidity limitations in the root zone), for the NSW portion of the survey area. Maps showing relative yield responses of acid-tolerant and acid-sensitive cereal cultivars for this region are presented.

Results

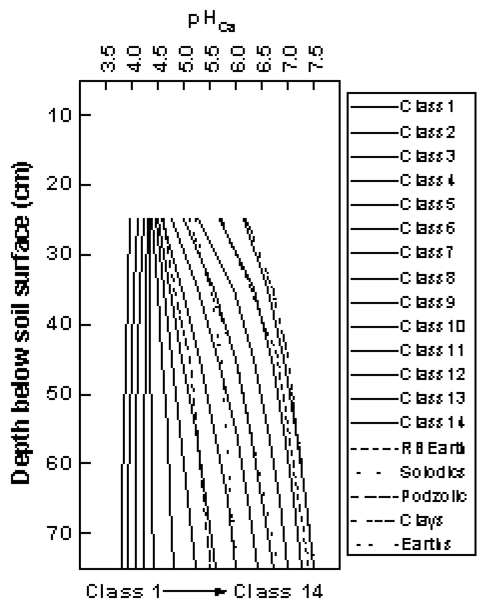

Figure 1

Fourteen profile-classes were derived to describe the pH trends below 20 cm (Fig. 1). These classes were based on data from a soil survey completed in the wheat-belt of southern NSW and north-eastern Victoria (1) and on pH profile data from a number of the sites where yield experiments were conducted. The shape of the profile-class trends was taken from the mean pH trends for soil types in the survey. A profile-class for the 20-50 cm layer for each sampling site in the survey was calculated from the profile pH data at each respective sampling site after weighting the depths in proportion to the typical proportion of roots in a given layer (2).

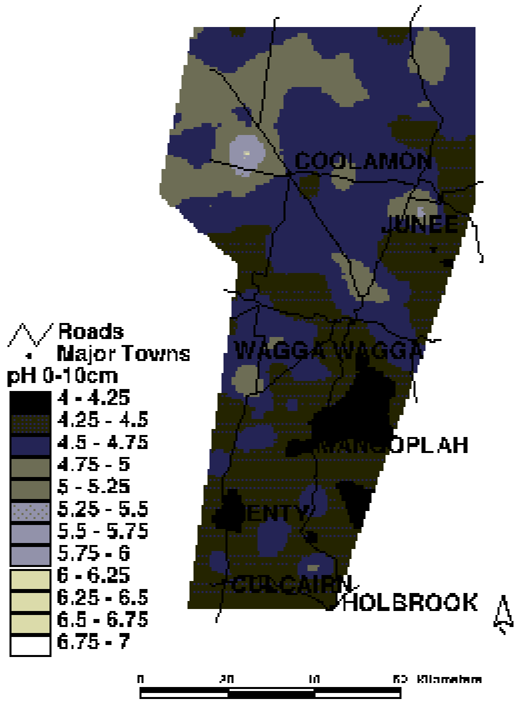

Figure 2

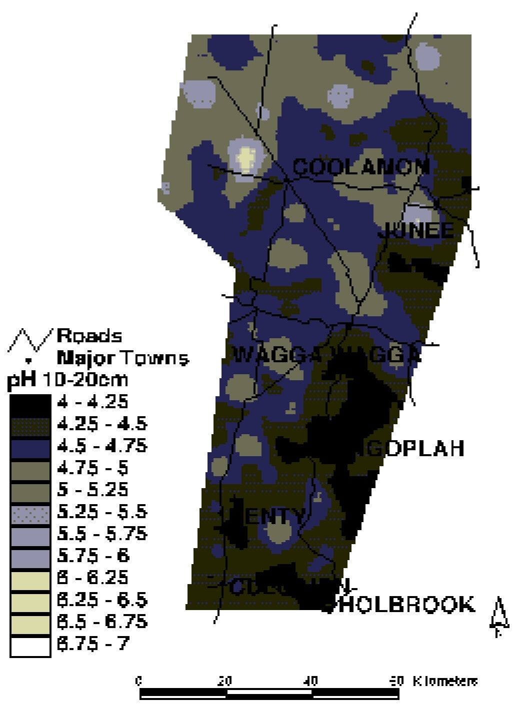

Figure 3

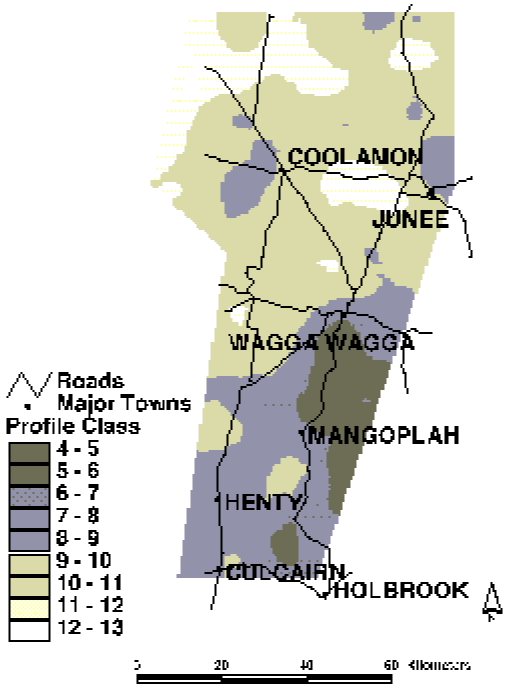

Figure 4

Soil pH measurements taken from 253 sites on a 4 km grid were krigged to form pH contours for the 0-10 cm, 10-20 cm layers and the profile-class (20-50 cm). Maps were then produced for each of these layers (Fig. 2, 3 and 4). The pH is generally higher in the north-west of each map and lower in the south-east throughout the profile and the pH generally increases with depth (Fig. 2, 3 and 4). However, where the surface pH was below about 4.5, the pH of the 10-20 cm layer was usually as low, and sometimes lower, than the pH of the surface 10 cm.

The equation relating the pH of the 0-10 and the 10-20 cm layers to yield is an inverse hyperbola with the general form:

$y = 1/(a + b * (pH_{layer} - pH_0))$;? $pH = pH_0$ if $pH_{0?????????}$ (i)

where: (1/a) is the potential yield that is approached as the pH of the layer increases and pH_0 and (b/a) are coefficients related to the pH at which the yield is zero and the shape of the curve, respectively. Both pH_0 and (b/a) vary with the tolerance of the plant to acidity and with interactions between the surface and sub-surface acidity on the response curve.

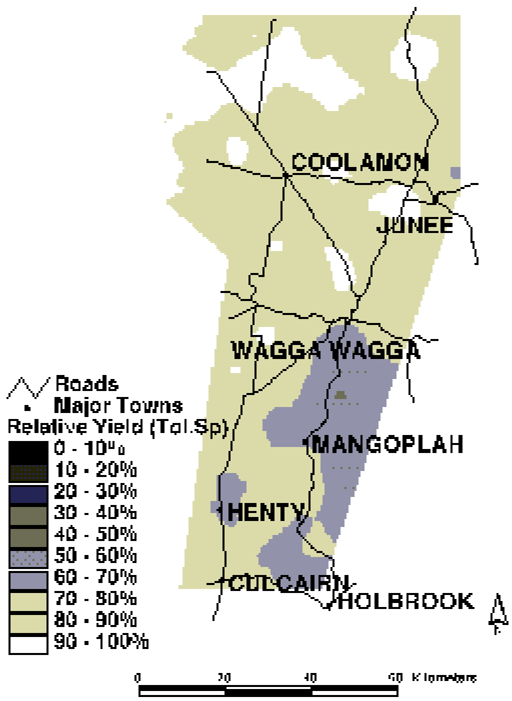

Figure 5

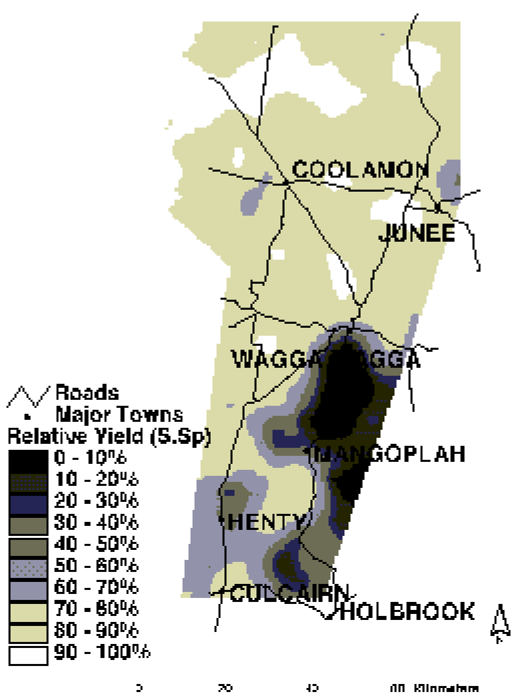

Figure 6

The potential yield due to acidity limitations in the 20 to 50 cm layer is a linear function of the pH profile class (PC) in this layer. The complete yield equation that describes the yield as a function of the pH and PC of the various layers is shown in Table 1.

This model was the simplest that gave a reasonable description of the experimental data and predicted yields conforming with the relative and absolute yield performance of sensitive and tolerant cultivars on farms.

The yield model was run for the krigged soil pH and profile-class values to produce maps of relative yield typical of acid-tolerant cereal cultivars similar to cvv. Millewa and Dollarbird wheat, or Currency triticale and acid-sensitive cereal cultivars similar to cvv. Clipper and Schooner barley, or cvv. Janz and Egret wheat (Fig. 5 and 6).

Discussion

The effect of soil acidity on yield of crops varies with the proportion of the root zone that is acidified. The results generated by the model reflect the calibration data in that both the surface 10 cm and the next layer (10 to 20 cm) have large effects on the yield of sensitive species. In addition, the pH of the deeper root zone also affects yield. To fit all the data, it was necessary to include a function to account for the dependence on the sub-surface pH of the response of sensitive species to liming the surface layer. Sensitive cultivars become more sensitive to pH in 0-10 cm layer as the sub-surface pH declines into the toxic range. In contrast, the curvat-ure of the response curve of tolerant cereal cultivars is not greatly affected by the acidity of the sub-surface soil layers.

The yield of tolerant cereals is not greatly reduced when the pH is above 4.5 in the 0-20 cm layer, and the subsoil is not acidified (Fig. 2, 3 and 5). However, their yield is reduced considerably when the subsoil is acidif-ied (Fig. 4 and 5). In the west of the mapped area, sensitive cultivars produce high relative yields when surface pH is low because of higher subsoil pH (Fig. 2, 3, 4 and 6). However, when the subsoil pH becomes acidified the yields are very low. This highlights the importance of avoiding acidification of the subsoil.

About 35% of the cereal root system is in the 0-10 cm layer (2) so large responses to elimination of toxicities in this layer could be expected. Furthermore, acidity in the 0-10 cm layer can be reasonably easily managed in the short term via the application of lime. In the 10-20 cm layer, however, the effect of acidity on yield is nearly as great as the effects of surface acidity, especially in drier years (5). Hamblin and Hamblin (2) found that 16% of wheat roots were found in the 10-20 cm layer. The results indicate that the root system in this sub-surface layer is particularly important, either directly, or as the necessary link to the deeper root system.

There is limited data on the effect of subsoil acidity on yield. A linear relationship was demonstrated be-tween the acidity of the 20-50 cm layer and wheat yield in one study (4) and Scott *et al*. (5) found that aluminium-sensitive barley was highly responsive to the amelioration of sub-surface acidity. They also suggested that in deep acid profiles, yield increases in response to the surface application of lime may not occur until sub- surface acidity has been corrected. These data indicate the importance of approximately one-third of the root system that occurs in the 20-50 cm layer (2). The roots below 50 cm (approximately 10% of the root system) are likely to have smaller effects on yield.

Conclusion

A yield model has been developed that describes the effects of soil pH profiles on relative yield of tolerant and sensitive cereal cultivars. The model is potentially useful in assessing the effects on yield of current soil acidification rates, of historic soil acidification and of the profitability of amelioration programs. Application of this model for a large area in southern NSW, has been demonstrated.

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References

1. Chartres, C & Geeves, G. 1992. *Aust. J. Soil & Water Cons.* **5**(4), 39-43.

2. Hamblin, A.P. & Hamblin, J. 1985. *Aust. J. Agric. Res.,* **36**, 63-72.

3. Helyar, K.R. 1991. In "Plant-soil interactions at low pH". Edited by R.J. Wright *et al.. Kluwer Academic Publishers*, Netherlands, pp. 365-382.

4. Helyar, K.R., Conyers, M.K. & Li, G.D. 1997. Final Report - Managing Acid Soils through Efficient Rotations. International Wool Secretariat. *NSW Agriculture*, Wagga Wagga.

5. Scott, B.J., Conyers, M.K., Poile, G.J. and Cullis, B.R. 1997. *Aust. J. Agric. Res.*, **48**, 843-54.