Is it time to revisit management of acid soils?

Helen Burns and Dr Mark Norton
NSW Dept of Primary Industries, Wagga Wagga, NSW

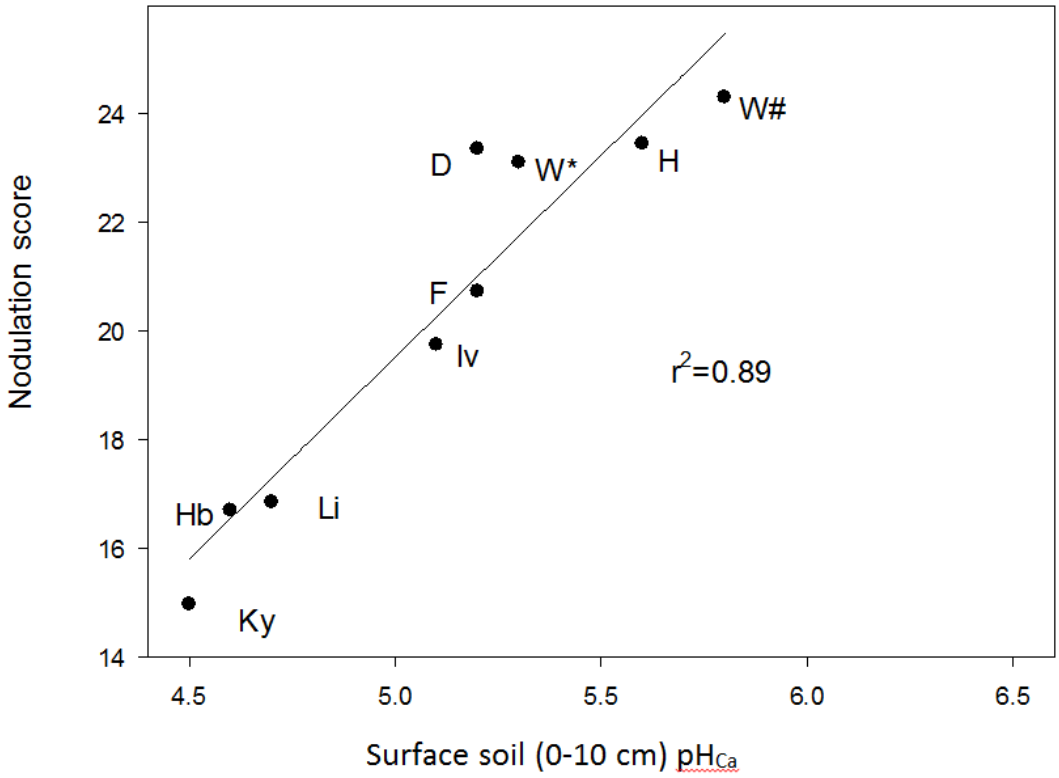
Key messages:

- Surface applied lime that is not incorporated may result in pH stratification.
- Bulked soil samples from 0-10cm may deliver misleading soil pH results.
- An acid throttle at 5-15 cm is a hostile environment for establishing seedlings.
- Rhizobia survival and nodulation is compromised at pH_{Ca} below 5.0.

Findings from a NSW DPI project supported by GRDC indicate that it is time to revisit current management practices on acidic soils and assess the impact of soil acidity on the production and persistence of some pasture species. The project is investigating constraints to the performance of legume crops and pastures in the high rainfall zone of south-eastern Australia and soil acidity appears to be a standout culprit.

Commercial legume crops and pastures are being monitored in NSW, SA, VIC and Tasmania as part of this project. The impact of soil acidity was highlighted when pH of the 0–10 cm surface soil was linked to poor nodulation of faba bean crops in 2015. Analysis of nodulation scores and soil pH of the monitored paddocks showed a strong correlation (r^2=0.89) and indicated that nodulation of faba bean is sensitive to soil pH (Figure 1).

Figure 1. The effect of surface soil pH (0-10cm) on nodulation of faba bean across the south eastern Australian high rainfall zone in 2015. Nodulation scored according to Colombia protocol (Anon 1991). Score of 20-25 – effective nodulation; 15-19 – less effective nodulation, N fixation compromised; 0-14 – unsatisfactory nodulation and N fixation.



Sites of sampling include Kybybolite, S.A. (Ky), Holbrook, NSW (Hb), Lismore, Vic (Li), Inverleigh, Vic (Iv), Frances, SA (F), Darlington, Vic (D), Willaura, Vic (W) and Henty, NSW (H). W* = after wheat, W# = after canola.

Faba bean is reportedly sensitive to aluminium and pH_{Ca} below 5.0 and the survival of Group F rhizobia (specific to faba bean) is compromised at pH below 5.0. Group F rhizobia are more sensitive to low pH than Group C (clover) rhizobia and more tolerant than Group AL (lucerne) rhizobia (Drew et al 2012).

Some growers had specifically tested 0-10 cm topsoil samples, to ensure pH levels were suitable to support faba bean. For example the pH_{Ca} of 0-10 cm sample from the Holbrook site tested 5.2. Further investigation of the Holbrook, Kybybolite and Lismore sites and other poorly nodulated crops reported by consultants revealed that root development was concentrated near the soil surface.

The fact that most of these crops were sown into paddocks with a recent lime history, surface-applied but not incorporated, prompted the project team (Dr Mark Norton and Helen Burns of NSW DPI, Wagga Wagga Agricultural Research Institute) to collect soil samples at intervals to a depth of 15 cm. At the Holbrook site the average pH_{Ca} of the surface 0-2 cm is 6.5, but ranges from 5.2 to 7.5, and is only 4.2 at a depth of 8-10 cm. The combination of soil acidity and aluminium toxicity (35% exchangeable aluminium below 10 cm) is an 'acid throttle', which severely restricted root growth and nodulation of faba bean plants (Figure 2).

Figure 2. Faba bean plants collected at early flowering stage from the Holbrook (NSW) crop were poorly nodulated with root growth restricted by acidic layers at about 6 cm. Despite a history of 4t/ha of lime since 2009, the pH_{Ca} of the surface 0-2 cm averaged 6.5 (range of 5.2 to 7.5), 5.0 at 4-6 cm, 4.2 at 8-10 cm (range of 4.1 to 5.0), and 4.3 at 12-14 cm.

Table 1. The pH_{Ca} readings from soil collected from commercial paddocks show that surface-applied lime with limited incorporation has had limited effect on increasing subsurface pH, compared with incorporation to 10 cm.

Depth (cm)	Wickliffe, Victoria			Holbrook, NSW
	Lime not incorporated*		Lime incorporated to 10cm**	pH_{Ca} – representative of paddock#
	Area of poor crop growth	Area of good crop growth		
0 – 2	5.3	7.3	6.8	6.5
5 – 7	3.8	4.8	5.3	4.9
12 – 14	3.8	4.3	4.8	4.3

*Lime surface-applied at 2.5t/ha in 2006 and 2013, not incorporated.
** Lime surface applied at 2.5t/ha in 2006, not incorporated. Limed again in 2012 and incorporated to 10 cm.
# Lime surface-applied at 2t/ha in 2010 – not incorporated, and 2t/ha in 2015 - shallow incorporation with a speed tiller.

The soil pH results from commercial paddocks show that surface-applied lime, which is not incorporated, has very little effect below the surface layers. The faba bean experience suggests that the common practice of lime application with minimal incorporation may not adequately increase soil pH in the rooting zone to ensure establishment and persistence of key pasture species, including lucerne, clover, phalaris, ryegrass and tall fescue.

The issue of pH stratification in the topsoil and an acid throttle in the upper layers of the rooting zone was reported in the 1980s before lime application was widely adopted (Bromfield et al, 1983, 1987; Conyers and Scott 1989), and later in mixed farming areas with a history of lime application (Gummer et al 2006). The recommendations for managing topsoil acidity advise that lime should be incorporated to a depth of 10 cm in order to achieve a rapid lime response. In addition, based on research results from the long-term lime experiment near Wagga Wagga in southern NSW (Conyers and Li, 2006), subsoil pH can be increased slowly over time by liming sufficiently to maintain a pH_{Ca} of 5.5 in the top 10 cm.

The link between soil pH and poor nodulation of faba bean crops highlights a need to review the current approach to acid soil management. We need to assess the impact of pH stratification on nodulation of legume species and the establishment, root growth and, therefore, persistence of those pasture species sensitive to acid soils. The widespread adoption of no-till systems means that lime incorporation is often inadequate. The benefits of a strategic cultivation need to be weighed against potential cost. Conyers (2015) reports that a single cultivation will cause minimal damage to soil physical properties and that the bulk of recovery will occur in one to two years.

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