Lime response of winter crops on a duplex soil at Oolong in SE NSW

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Abstract

Acidification is continuing to reduce the sustainability of pasture/livestock production on the central and southern tablelands and slopes of New South Wales. Liming costs are high, but a short cropping phase with lime responsive winter crops may offset costs and allow diversification prior to re-establishing the perennial pasture. Further, the use of reduced tillage and direct drill techniques provide safer land management practices for cropping the fragile duplex soils on the tablelands. Here we report on the results of a liming experiment on a Sodosol that had been limed with 2.2 or 4.4 t/ha of lime in February 1998. Soil pH_{Ca} in the surface 4 cm soil layer was increased from 4.2 to 5.1 and 5.7 at the low and high rates of lime application, respectively by 1999. The winter crops grown were – wheat 1998 - 2000, canola 1998-1999 and faba beans 1999. The level of response to lime application varied between the crops, with wheat demonstrating negative (1998, 1999) or minimal responses (2000); canola demonstrating marked (1998) and minimal (1999) increases; and faba beans demonstrating a substantial response in 1999 (46%). The marginal grain yield responses to lime application demonstrated the need for caution when generically advocating lime to increase soil pH on a duplex soil. The increased risk and greater management skills required for growing high yielding crops of wheat and canola will require more agronomic research on the sub-soil constraints and micro nutrient deficiencies that could be restricting grain production on these duplex soils.

Keywords

Soil acidity, high rainfall cropping, lime movement, duplex soils, winter crops

Introduction

Acidification is continuing to reduce the sustainability of pasture/livestock production on the central and southern tablelands and slopes of New South Wales. It remains one of the most serious land degradation issues in Australian agriculture. The process of acidification is associated with the wider issue of poor water utilisation, which is reducing farm profitability as well as increasing dryland salinity and water table damage to road infrastructures. Currently, the preferred option to address increasing soil acidity is to surface apply lime to pasture, and wait for lime dissolution and movement downward into the soil profile for a possible increase in production from the pasture (1). However, the high cost of lime application on permanent pastures and delayed recovery of increased returns precludes many farmers from addressing the acid soil problem.

The recent interest in cropping in high rainfall pasture areas (2, 3, 4) has highlighted the potential for diversifying enterprises and improving landholder income (5). The combination of lime use and cropping is an option for the tablelands, where cropping is used as a vehicle for the recovery of liming costs, an approach that was recognised earlier in mixed farming (cropping) areas. Oats and triticale (both acid soil tolerant) have been joined by dual purpose, long growing season winter wheat with acid soil tolerance (6) as the crops of choice for tableland soils. The next step is to integrate more lime responsive brassica and pulse crops with the cereal option as part of a short term cropping phase.

The ultimate aim of our research is to quantify the impact of lime application and methods of lime incorporation (tillage) on the profitability of pasture and crop production on the highly acidic soils of the central and southern tablelands. The present paper describes the dry matter and grain yield response of wheat, canola and faba bean crops to lime application following a long-term pasture.

Materials and methods

The experimental site was located on an acidic (pH_{Ca} = 4.3) coarse SCL classified as a Sodosol (7) at Oolong (Lat. 34? 46'S; Long. 140? 10'E; Alt. 630 m; AAR 655 mm), 30 km north of Yass, NSW. Soil drainage was imperfect. Exchangeable aluminium was 0.65 meq/100gm and manganese was 72 mg/kg. Pasture was based on C3 and C4 native perennial grasses, with vulpia, brome grasses and annual ryegrass present.

Experimental design and statistical analysis

The experiment was a split plot design with method of incorporation as the main plot, lime application as the subplot and crop (wheat, canola, faba bean) as the sub-sub-plot (termed plots for convenience). Plot size was 25 by 4 m with 16 rows spaced 25 cm apart. There were 3 replicates of each treatment. The data were analysed by ANOVA using GENSTAT 5. Differences between treatment means were compared using least significant differences (l.s.d.) at P = 0.05.

Establishment

Lime was spread in February 1998 at rates of 2.2 and 4.4 t/ha, and was applied using a lime spreader (8). Lime rates were estimated to produce soil pH_{Ca} in the surface 10 cm of about 5.0 and 5.5 respectively. Incorporation of the lime consisted of either a deep incorporation (offset disc followed by scarifying), a shallow incorporation [non-inversion tillage with a modified scarifier (9)] or no incorporation. For this paper, results have been meaned over incorporation methods. Plots were sown to either wheat (*Triticum aestivum* L. cv. Whistler) in 1998, 1999, 2000 at 75 kg/ha; canola (*Brassica napus* L. cv. Pinnacle) in 1998 and1999 at 3 kg/ha or faba bean (*Vicia faba* L. cv. Fiesta) in 1999 at 100 kg/ha using a small plot seeder. In 1999 and 2000, land preparation for the cropping phase involved either two cultivations (disc followed by scarifying); one cultivation (non-inversion tillage with a modified scarifier) or no cultivation (chemically fallowed)**.** All plots were fertilised each season with Granuloc 15 (14.7%N;11.8%P; 11.8%S) at 200 kg/ha (1998) or 150 kg/ha (1999, 2000) and sown on 11th May 1998, 26th March 1999 and 6th April 2000. Wheat and canola crops were top-dressed with 30 kg N/ha in September of 1999 and 2000.

Soil measurements

Soils were sampled to a depth of 100 cm in September 1998 (6 months after lime was applied**)** and again in February 1999 and 2000 with only data for 1999 presented in this paper. Water content, exchangeable cations and pH_{Ca} were determined.

Results

Climate

Growing season rainfall at Oolong was above the long-term average of Gunning (10 km east of Oolong) in the 1998 and 2000 season and similar to the long-term average in 1999. Large rainfall events occurred between June and August 1998; October 1999 and August 2000. Growing season rainfall (April to October) varied from 600 mm (1998), 392 mm (1999) to 437 mm (2000).

Soil pH profiles

The application of 2.2 t/ha of lime in February 1998 significantly increased soil pH_{Ca} to a depth of 6 cm and 4.4 t/ha of lime increased soil pH_{Ca} to a depth of 15 cm when sampled in February 1999. Despite the increase in pH at depth the low and high rate of lime increased soil pH_{Ca} above 5 to a depth of only 2 cm and 4 cm respectively (Table 1). Method of lime incorporation significantly increased pH_{Ca} to a depth of 6 cm with no incorporation (pH 4.53), 8 cm with shallow incorporation (pH 4.50) and 10 cm with deep incorporation (pH 4.74) when 4.4 t/ha of lime was applied.

Plant dry matter

Dry matter production of wheat was not increased by lime application in either 1998, when sampled 130 days after sowing (DAS) or 1999 (122 DAS), but was increased in the 2000 season by more than 40 per cent (63 DAS). Similarly canola did not respond to lime application in 1998 (130 DAS) but showed more than a 60 per cent increase in dry matter in 1999 (Table 2; 122 DAS). Faba bean dry matter in 1999 (122 DAS) was not increased by liming in 1998, but nodulation was increased from 0.011 g (unlimed plots) to 0.037 g/plant (limed plots).

Table 1. Effect of lime application on soil pH_{Ca} in February 1999. Values are means of all lime incorporation methods and those followed by different letters in the same row are significantly different (*P*=0.05)

Depth (cm)	**Lime application rate (t/ha)**		
	0	**2.2**	**4.4**
2	4.32a	5.32b	5.88c
4	4.13a	4.85b	5.64c
6	4.19a	4.55b	4.98c
8	4.16a	4.38a	4.68b
10	4.14a	4.26a	4.62b
15	4.18a	4.27a	4.48b
20	4.26a	4.41a	4.47a
30	5.02a	5.08a	5.20a

Table 2. Dry matter of wheat, canola and faba bean crops following the application of lime in February 1998

	Dry matter (kg/ha)			
	Wheat	**Canola**	**Beans**	**Nod[1]**

Lime	1998	1999	2000	1998	1999	1999	1999
Unlimed	386	2260	1120	480	1160	1580	0.011
2.2 t/ha	392	2440	1640	460	1920	1280	0.036
4.4 t/ha	482	2720	1720	420	2020	1300	0.038
l.s.d. (*P*=0.5)	n.s.	n.s.	196	n.s.	540	n.s.	0.013

[1]Nod – nodule dry weight (gm) per faba bean root system

Grain yield

Lime application had no significant effect on grain yield of wheat in 1998, decreased grain yield in 1999 by 13 per cent and increased grain yield in 2000 by 12 per cent for an overall grain yield loss of 4 per cent for the three years. Average water use efficiency (WUE) varied from 1.9 kg/ha/mm in 1998 to 10.8kg/ha/mm in 2000. In contrast, the seed yield of canola was increased by 73 per cent in 1998 and 17 per cent in 1999 for an overall yield increase of 45 per cent. WUE varied from a low of 0.9 kg/ha/mm in 1998 to 7.4 kg/ha/mm in 1999. Faba bean grain production was significantly increased by 73 per cent in 1999 (Table 4) with an overall WUE of 7.9 kg/ha/mm.

Table 3. Grain yield of wheat, canola and faba bean crops following the application of lime

	Grain yield (t/ha)					
	Wheat			Canola		Beans
Lime	**1998**	**1999**	**2000**	**1998**	**1999**	**1999**
Unlimed	1.08	3.57	3.15	0.26	1.77	1.29
2.2 t/ha	0.97	3.16	3.59	0.40	1.97	2.12
4.4 t/ha	0.93	3.03	3.46	0.49	2.18	2.35
l.s.d (*P*=0.5)	n.s.	0.38	0.26	0.07	0.22	0.64

The low grain yield of both wheat and canola in 1998 highlight a major problem when a permanent pasture paddock is used for growing crops. Diseases (yellow leaf spot and take-all) adversely affected growth and grain production of wheat, especially after anthesis, while insects (red-legged earth mite and red-headed pasture cockchafer) reduced plant populations of canola from a target of 60 back to 12 plants per m^2. The application of lime in February 1998 had no impact on the vegetative growth of the 1998 sown canola crop, but increased seed yields of canola, suggesting the need for much earlier lime application and greater time for equilibration with the soil.

Much higher grain yields from all three crops, as well as larger dry matter and grain yield responses to liming, than those achieved in 1999 and 2000, are essential on these duplex soils to justify the expense of liming. That such yields are possible was demonstrated by an associated experiment on a Kandosol. Possible sub-soil constraints and micronutrient deficiencies may have adversely affected the WUE's achieved in this experiment. The WUE of 7.4 kg/ha/mm (GSR of 392 mm in 1999) is similar to the WUE of 6 kg/ha/mm calculated for canola after an above average growing season rainfall of 610 mm on a duplex soil at Cowra in 1990 (10). Increases in grain yield of 0.3 t/ha (canola 1999) and 0.4 t/ha (wheat 2000) are at the lower limits for justifying lime application on these soils. Although grain yield of faba bean was increased by almost 1 t/ha the overall grain yield was still low at 2.4 t/ha. The high production cost, specialised machinery and greater management skills preclude its growing by the majority of farmers on the tablelands.

Conclusion

Lime application on the duplex acid soil at Oolong produced variable plant responses in all three crops following lime application in 1998. The marginal grain yield responses to lime application demonstrated the need for caution when generically advocating lime to increase soil pH on a duplex soil. The increased risk and greater management skills required for growing high yielding crops of wheat and canola will require more agronomic research on the sub-soil constraints and micro nutrient deficiencies that could be restricting grain production on these duplex soils. The growing of crops that are sensitive to soil acidity should be delayed at least 12 months after liming to maximise plant growth and grain yield.

Acknowledgements

This research was supported by NSW Agriculture through the Acid Soils Action Initiative. We thank Mr Barry Medway "The Gables", Oolong for the site used for this experiment. We appreciate the donation of lime by Omya Southern Pty Ltd and fertilizer by Incitec Fertilizers Ltd. Soil samples were analysed by Incitec Fertilizers Ltd.

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