Lime effects on the control of annual ryegrass and wild radish in low pH soils

Abul Hashem and Catherine Borger, Department of Agriculture and Food WA, Northam and Merredin

Key messages

- Lime applied in 2010 season increased soil pH by 0.67−1.23 units at 0–10 cm depth, 0.22–0.87 units at 10–20 cm and 0.08–0.35 units at 20–30 cm in 2013 season.
- Lime did not influence initial density of weeds in 2010 to 2012 seasons but reduced density of weeds in 2013 barley crops at all sites and increased grain yield by 6–7% at two out of four sites.
- Herbicides (Sakura®, Boxer Gold®, simazine, or Velocity®) effectively controlled weeds in all seasons and increased grain yield of crops by 6–138% in 2013 season across all sites.
- A clear interaction effect of lime and herbicide on weed control or crop yield was not evident in this comparatively short-term lime study.

Aims

Wheat yield can be reduced by 50% from annual ryegrass competition (Hashem et al. 1998). A potential option of increasing the competitive ability of crops against annual ryegrass in low pH soil is through the application of lime. Gazey and Andrew (2010) have demonstrated that the application of lime increased the biomass of a barley crop and decreased the biomass of annual ryegrass on large plots with markedly different soil pH profiles, in a long-term lime trial at Kellerberrin, WA. However, there is little data available on the influence of lime applied at different rates on the growth of annual ryegrass and the performance of herbicides for wheat and barley crops from designed field studies. It is therefore important to examine if lime can improve or reduce the efficacy of soil applied herbicides such as Sakura® (Pyroxasulfone; Group K) and Boxer Gold® (Prosulfocarb and metolachlor, Group J & K) on annual ryegrass in a wheat-wheat-lupin-barley rotation.

The presence of 10 – 75 wild radish plants/m^2 can reduce wheat yields by 7–56% and lupin yields by 28–92% (Hashem et al. 2006). Wild radish showed signs of being less competitive at soil pH between 6 and 7 due to reduced wild radish growth. The reduced growth of wild radish probably resulted from an increase in molybdenum and selenium and a decrease in manganese and iron in wild radish plants (Willis 2006). Reduced efficacy of Velocity® (210 g ai/L bromoxynil (Group C) + 37.5 g ai/L pyrasulfotole (Group H) + 9.4 g ai/L mefenpyr-diethyl) on wild radish occurred in some situations primarily due to inadequate herbicide coverage onto weed leaves. Anecdotal observations indicate that use of lime may improve wild radish control. However, there is little research available on the effect of lime on wild radish control in wheat and barley crops from designed field studies.

The aim of this study was to examine the impact of lime and herbicides on the control of annual ryegrass or wild radish in low pH soils. The study hypothesised that application of lime would improve weed suppression and increase grain yield in a wheat-wheat-lupin-barley rotation.

Methods

A four-year study investigated if lime applied to low pH soils could suppress weeds and influence the efficacy of herbicides on annual ryegrass (Merredin and Wongan Hills) and wild radish (Eradu and Wongan Hills). The crop rotation at all four sites was wheat-wheat-lupin-barley, grown from 2010 to 2013. Each trial site was set up in a split plot design, with four rates of limesand (0, 1.25,

2.5 and 5 t/ha) in the main plots (applied in 2010 prior to sowing the wheat crop) and five rates of selective herbicide applied in the sub-plots (replicated four times, with plot size of 20 m by 2 m).

Annual ryegrass treatments at Merredin and Wongan Hills

2010 Wheat crop: Four rates of limesand (0, 1.25, 2.5 and 5 t/ha) applied in the main plots and five rates of Sakura® (0, 60, 90, 120, 150 g/ha) in the sub-plots.

2011 Wheat crop: Sakura® at 0, 60, 90, 120, 150 g/ha applied in the sub-plots.

2012 Lupin crop: Lupin crop was grown with simazine at 2 L/ha incorporated by sowing (IBS) and Brodal® 100 mL/ha + metribuzin 150 g/ha at 4-5-leaf stage of lupins on all the plots except in the untreated (no herbicide) control.

2013 Barley crop: Boxer Gold® at 0, 1000, 1500, 2000 and 2500 mL/ha applied in the sub-plots.

Selective post-emergent herbicides were applied to control broadleaf weeds in cereal crops. No post-emergent grass control herbicide was applied in any cereal crop.

Wild radish treatments at Eradu and Wongan Hills

2010 Wheat crop: Four rates of limesand (0, 1.25, 2.5 and 5 t/ha) applied in the main plots and five rates of Velocity® (0, 250, 350, 500 and 670 mL/ha in the sub-plots at 3-leaf stage of wild radish.

2011 Wheat crop: Velocity® applied at 0, 250, 350, 500 and 670 mL/ha in the sub-plots.

2012 Lupin crop: Lupin crop was grown with simazine at 2 L/ha as IBS and Brodal® 100 mL/ha + metribuzin 150 g/ha applied at 4-5-leaf stage of lupin crop in all the plots except the untreated (no herbicide) control.

2013 Barley crop: Velocity® at 0, 250, 350, 500 and 670 mL/ha applied in the sub-plots.

In cereal crops, trifluralin was applied as IBS to control grass weeds. No post-emergent broadleaf weed herbicide was applied in any cereal crop except at Eradu in 2013. Since the radish density was very high at this leased-in site of Eradu, Logran® and 2,4-D amine were applied at late growth stages of barley crop to minimise the seed production of wild radish.

Results

Trials in 2010

The density of wild radish or annual ryegrass in 2010 was very low across all sites, due to low rainfall during the growing season. No measurable effect of lime or herbicides was observed on weeds or the wheat crop in 2010.

Trials in 2011

Lime effect on soil pH: Lime alone did not influence weed control of annual ryegrass or wild radish at any site. Yield of the wheat crop was also not influenced by lime despite an increase in soil pH ($CaCl_2$) (Hashem and Borger, 2012 Crop Update). It appears that sub-surface acidity remained a constraint at all sites in 2011 season.

Herbicide effect on broadleaf weed control: Although Velocity® improved control of broadleaf weeds (wild radish, capeweed and blue lupins) both at Eradu and Wongan Hills, no interaction effect of lime and Velocity® was found on weed control or crop growth and yield. Velocity® at lower rates was more effective on wild radish at Eradu than at Wongan Hills regardless of rate of

applied lime, and increased wheat grain yield by 17—18% (data not presented). Crop vigour was not influenced by lime but increases in herbicide rates improved crop vigour at both locations.

Herbicide effect on grass weed control: At Wongan Hills, increasing rates of Sakura® improved control of grass weeds (annual ryegrass, barley grass), crop vigour, crop head number and grain yield of wheat. At Merredin, increasing rates of Sakura® improved control of annual ryegrass and improved wheat grain yield by 4−8% in 2011 (data not presented). No clear interaction of lime and herbicide was found on crop growth or yield at either site.

Trials in 2012

Lime effect on soil pH, weeds and crop: Lime increased soil pH up to a depth of 20 cm although the increase was not up to the recommended target level at the sub-surface layers. As such lime did not influence density of weeds (wild radish, capeweed, annual ryegrass or barley grass) or grain yield of lupin crop at any site in 2012 season (data not presented).

Herbicide effect on weeds: Simazine (0 or 2 L/ha), together with the cumulative effect of herbicides applied in 2010 and 2011 seasons, significantly increased control of broadleaf weeds (wild radish, capeweed) and grass weeds (annual ryegrass and barley grass) and increased lupin grain yield by 62—227% with an exception at Merredin where lupin growth was very poor due to low rainfall in 2012 season.

Trials in 2013

Lime effect on soil pH: Lime applied in 2010 season and incorporated by sowing crops increased soil pH($CaCl_2$) by 0.67−1.23 units at 0–10 cm depth, 0.22–0.87 units at 10–20 cm and 0.08–0.35 units at 20–30 cm in 2013 season measured before sowing barley crop (Figure 1). Lime has also increased exchangeable Calcium and Magnesium and decreased soil Al ($CaCl_2$) in some sites (data not presented).

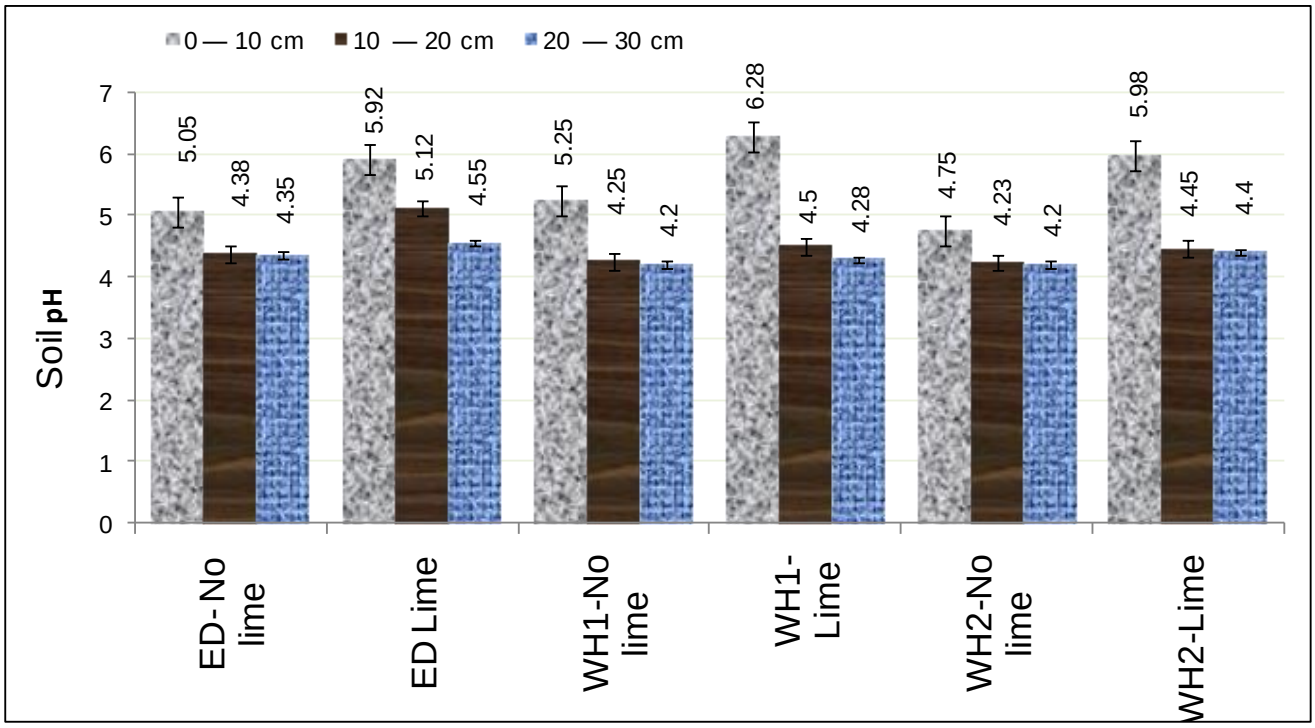

Figure 1 Effect of lime applied in 2010 on the soil pH at different soil depths in 2013 season before sowing the crop at Eradu (ED), Wongan Hills wild radish site (WH1) and

Wongan Hills annual ryegrass site (WH2) compared to no lime control. Soil pH data presented are for lime at 5 t/ha only.

Lime effect on wild radish in 2013: Lime significantly reduced the initial density of wild radish (capeweed was also present at low density) by 13—48% at Eradu where wild radish density was 120 plants/m^2 in the untreated control (no post-emergent herbicide) (Table 1). In contrast, wild radish density at Wongan Hills was only 2 plants/m^2 in the untreated control. Even though wild radish density was reduced by 50% at this site, this reduction in wild radish density by lime was not significant (Table 1).

Weed control assessment performed at the heading stage of the barley crop showed that application of lime improved weed control by only 2% at Eradu and 5−6% at Wongan Hills compared to the untreated control (no lime) (Table 2) even though reduction in initial radish density due to lime was high (Table 1).

Herbicide effect on wild radish in 2013: Velocity® was effective on wild radish at both sites. Broadleaf herbicides sprayed on wild radish in 2010, 2011 and 2012 had a cumulative effect on the reduction of wild radish. Density of wild radish counted at the tillering stage of the barley crop was reduced from 163 to 63 plants/m^2 (64% reduction) at Eradu and 5.1 to 0.1 plants/m^2 (98% reduction) at Wongan Hills before spraying Velocity® in 2013 season.

Assessment of wild radish control at heading stage of the barley crop showed that Velocity® controlled wild radish by 98−100% at Eradu and 97−100% at Wongan Hills in 2013 (Table 2) despite late emergence that occurred due to late rainfalls at both sites.

Lime effect on grass weed in 2013: Increases in lime rate reduced initial density of barley grass from 37 to 12 plant/m^2 (67% reduction) and annual ryegrass from 28 to 16 plant/m^2 (41% reduction) at Wongan Hills and reduced annual ryegrass from 139 to 56 plants/m^2 (59% reduction) at Merredin site (Table 1).

Table 1 Cumulative effect of lime applied in 2010 and herbicides applied in different seasons from 2010 to 2013 on the initial density of weeds recorded after crop emergence and before application of post-emergent herbicides in 2013 season at different locations.

Lime/ Herbicide[1]	Rate	Wild radish (plants/m^2)		Barley grass (plants/m^2)	Annual ryegrass (plant/m^2)	
		Eradu	Wongan Hills	Wongan Hills	Wongan Hills	Merredin
Lime t/ha	0	120	2	37	28	139
	1.25	105	2	16	26	114
	2.5	63	1	17	19	82
	5	66	1	12	16	56
	Lsd(5%)	39.4	NS[2]	14.8	11.1	35.3
Herbicides	Rate 1	163	5.1	96	86	235
	Rate 2	63	1.4	3	9	114
	Rate 3	65	0.5	1	7	87
	Rate 4	72	0.5	1	5	34
	Rate 5	78	0.1	1	3	19
	Lsd(5%)	39.5	1.27	32.6	14.6	82.6

[1]For wild radish, Velocity® in 2010, 2011, 2013 at 0, 150, 250, 350, 500 and 670 mL/ha applied at 3-leaf stage and simazine in 2012 at 0 or 2 L/ha applied as IBS; For grass weeds, Sakura® in 2010, 2011 at 0, 60, 90, 120, 150 g/ha, simazine in 2012 at 0 or 2 L/ha and Boxer Gold® in 2013 at 0, 1000, 1500, 2000 and 2500 mL/ha at pre-seeding; Lime values are averaged over herbicide treatments and herbicide values are averaged over lime treatments; [2]NS = Not significant.

Herbicide effect on grass weeds in 2013: At Wongan Hills, Boxer Gold® reduced barley grass density from 96 to 1 plant/m^2 (99% reduction) and annual ryegrass from 86 to 3 plants/m^2 (96% reduction), and at Merredin, Boxer Gold® reduced annual ryegrass from 235 to 19 plants/m^2 (92% reduction) in 2013 season (Table 1).

However, assessment of grass weeds at the heading stage of the barley crop showed that Boxer Gold® controlled grass weeds by 85−92% at Wongan Hills (annual ryegrass and barley grass) and by 71−94% at Merredin (annual ryegrass) (Table 2).

This could be attributed to the combined effect of herbicides, drought-induced mortality of barley grass and annual ryegrass plants in June-July, and increased crop competition due to increased vigour in herbicide treated plots.

Table 2 Cumulative effect of lime applied in 2010 and herbicides applied in 2013 and before on the weed control assessed visually at the heading stage of barley crop in 2013 at different locations.

Lime/ Herbicide[1]		Wild radish control (%)		Grass weed control (%)[2]	
	Rates	Eradu	Wongan Hills	Wongan Hills	Merredin
Lime t/ha	0	78	93	71	64
	1.25	80	98	71	66
	2.5	80	99	72	69
	5	80	99	72	66
	Lsd(5%)	0.88	1.1	NS[3]	NS
Herbicides	Rate 1	0	0	0	0
	Rate 2	98	97	85	71
	Rate 3	99	100	88	79
	Rate 4	100	100	88	88
	Rate 5	100	100	92	94
	Lsd(5%)	0.99	1.3	6.1	2.9

[1]For wild radish, Velocity® in 2010, 2011, 2013 at 0, 150, 250, 350, 500 and 670 mL/ha applied at 3-leaf stage and simazine in 2012 at 0 or 2 L/ha applied as IBS; For grass weeds, Sakura® in 2010, 2011 at 0, 60, 90, 120, 150 g/ha, simazine in 2012 at 0 or 2 L/ha and Boxer Gold® in 2013 at 0, 1000, 1500, 2000 and 2500 mL/ha at pre-seeding; Lime values are averaged over herbicide treatments and herbicide values are averaged over lime treatments; [2]Grass weeds include both annual ryegrass and barley grass at Wongan Hills and only annual ryegrass at Merredin; [3]NS = Not significant

Grain yield of barley crop in 2013

Lime effect on grain yield: Lime increased barley grain yield by 6% at wild radish site of Wongan Hills and 7% at grass weed site of Wongan Hills (Table 3). At the high weed density sites of Eradu and Merredin, high reduction in weed density (Table 1) due to lime did not result in significant increases in barley grain yield (Table 3).

Herbicide effect on grain yield: Velocity® increased barley grain yield by 132−138% at Erdau, 7−9% at Wongan Hills (Table 3). Boxer Gold® increased grain yield of barley crop by 6−16% at Wongan Hills and 79−116% at Merredin (Table 3). Grain yields of barley crop at Eradu and Wongan Hills were 3−3.5 times greater than at Merredin.

Table 3 Cumulative effect of lime applied in 2010 and herbicides applied from 2010 to 2013 seasons on the grain yield of barley crop in 2013 season at different locations.

Lime/ herbicide[1]	Rate	Barley grain yield (t/ha) [2]			
		Eradu (Radish)	Wongan Hills (radish)	Wongan Hills (grass weeds) [2]	Merredin (annual ryegrass)
Lime (t/ha)	0	3.28	3.96	3.36	1.11
	1.25	3.3	4.09	3.36	1.11
	2.5	3.35	4.18	3.59	1.13
	5	3.33	4.21	3.56	1.16
	Lsd(5%)	NS[2]	0.123	0.194	NS
	P-value	0.93	0.002	0.03	0.88
Herbicides	Rate 1	1.6	3.84	3.13	0.62
	Rate 2	3.71	4.09	3.43	1.11
	Rate 3	3.81	4.18	3.62	1.20
	Rate 4	3.72	4.15	3.56	1.33
	Rate 5	3.72	4.14	3.60	1.34
	Lsd(5%)	0.197	0.138	0.217	0.184
	P-value	<.001	<.001	<.001	<.001

[1]For wild radish, Velocity® in 2010, 2011, 2013 at 0, 150, 250, 350, 500 and 670 mL/ha applied at 3-leaf stage and simazine in 2012 at 0 or 2 L/ha applied as IBS; For grass weeds, Sakura® in 2010, 2011 at 0, 60, 90, 120, 150 g/ha, simazine in 2012 at 0 or 2 L/ha and Boxer Gold® in 2013 at 0, 1000, 1500, 2000 and 2500 mL/ha at pre-seeding; Lime values are averaged over herbicide treatments and herbicide values are averaged over lime treatments [2]Grass weeds include both annual ryegrass and barley grass at Wongan Hills and only annual ryegrass at Merredin.

Conclusions

Application of lime increased soil pH to a depth of 30 cm, with a greater increase in the surface soil than the sub-surface layers in 2013. However, increases in soil pH in the sub-surface layers were rather smaller than the recommended target level of 4.8. At all sites except Eradu, the pH in the sub-surface layers (20 cm or deeper) with or without lime remained at or below 4.5. These results suggest that soil acidity at the sub-surface layers was restricting barley crop root growth even three years after lime application. Despite these small increases in soil pH, a significant reduction in the initial density of annual ryegrass, barley grass and wild radish was found in 2013 even though lime did not suppress weeds or increased crop yield in 2010, 2011 or 2012 season.

This reduction in weed density due to lime has also resulted in an increase of crop grain yield at two out of four sites for the first time (in 2013), four years after application of lime. Herbicides (Boxer Gold®, Sakura®, simazine or Velocity®) effectively controlled these weeds in all seasons and increased crop yield in 2011, 2012 and 2013 seasons across all sites. There is no evidence to date from this comparatively short-term lime study to indicate that growers can reduce herbicide rates because they have applied lime. Nevertheless, the results reinforce the fact that lime takes a long time to move down the sub-surface layers of soil to alleviate the soil acidity problem and suggest the necessity of continuing to monitor the limed plots for a longer period of time.

Key words

Lime, soil pH, soil acidity, herbicides, wild radish, annual ryegrass, barley grass, weed control, crop grain yield.

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