Amelioration of Subsoil Aluminium Toxicity for Improved Productivity in the Northern Agricultural Region of WA – Dalwallinu

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Take Home Messages
- Soil sampling to depth identified that aluminium (Al) toxicity was present as a soil health and crop growth constraint.
- All amelioration techniques of subsoil al toxicity had a positive yield response.
- The ameliorant treatments did not show a net positive effect on the enterprise earnings in the first year.
- The biochar treatments had significantly higher plant numbers than the lime or gypsum treatments but significantly lower yields.
- The untreated control had higher crop and lower weed numbers than any other treatment but significantly lower yield.

Aim
1. To demonstrate the soil health and crop growth benefits of using soil ameliorants combined with cultivation to depth to address subsoil aluminium toxicity.
2. To increase awareness and support the adoption of tools and methods to identify and effectively manage aluminium toxicity.

Background
Aluminium (Al) toxicity in the subsoil is a major problem associated with acidic soils across the Western Australian Wheatbelt. In most Wheatbelt soils, where the subsoil pH is below 4.8, Al concentrations will reach levels that are considered toxic and yield limiting to crops. Current practices to ameliorate surface soil (0-20cm) acidity have been successful and farmers are now seeking validation on practices that ameliorate subsoil (below 20cm depth) acidity and Al toxicity.

Demonstration of practices to identify Al toxicity using existing tools such as soil sampling to depth and methods to ameliorate the constraint will provide farmers with the confidence to trial these practices in their own environments.

In the trial, three ameliorants (lime, gypsum & biochar) were applied to address the Al constraint. Lime application increases soil pH which subsequently converts toxic Al^{3+} to inert gibbsite (Anderson, Pathan, Sharma, Hall, & Easton, 2019). Application of gypsum increases the soil solution sulphate, which can bond with toxic Al to form inert non-toxic Al sulphate (Anderson, Pathan, Sharma, Hall, & Easton, 2019). The oxidising introduced carboxylic functional groups (- charge sites) on biochar surfaces can serve as binding sites for Al^{3+}, rendering it inert and non-toxic (Lin, et al., 2018). The Liebe Group are seeking to investigate these ameliorant options for reducing toxic Al in the soil, and which is most cost effective to implement on property.

Trial Details

Trial Location	Shannon and Jody Fry's property, East Dalwallinu
Plot size & replication	12m x 300m x 2 replications
Soil type	Acidic white sand
Paddock rotation	2017 Wheat, 2018 Wheat, 2019 Wheat
Sowing date	01/05/2020
Sowing rate	50 kg/ha Scepter wheat
Fertiliser	01/05/2020: 45 kg/ha Urea, 30 kg/ha (50%MAP 50%DAP) 25/06/2020: 20 L/ha UAN 19/06/2020: 30 kg/ha Urea
Herbicides, Insecticides & Fungicides	30/04/2020: 1.5 L/ha glyphosate 600, 1.6 L/ha Trifluralin, 2.4 L/ha Boxer, 400 ml/ha ester 680 25/06/2020: 1 L/ha Jaguar, 300 ml/ha LVE

Treatments

	Treatment
1	No ameliorant, no cultivation
2	Lime applied at 3 t/ha, cultivated
3	Gypsum applied at 3 t/ha, cultivated
4	Biochar applied at 2 t/ha, cultivated

Soil Composition

Depth (cm)	pH ($CaCl_2$)	Col P (mg/kg)	Col K (mg/kg)	S (mg/kg)	N (NO_3) (mg/kg)	N (NH_4) (mg/kg)	EC (ds/m)	OC (%)	Al $CaCl_2$ (mg/kg)
0-10	6.1	41	33	4	9	2	0.03	0.47	<1
10-20	4.4	20	19	12	16	<1	0.05	0.41	9
20-30	4.3	<2	<15	35	10	<1	0.04	0.19	17
30-40	4.1	<2	<15	49	8	<1	0.04	0.13	20
40-50	4.2	<2	<15	55	7	<1	0.04	0.09	20

Results

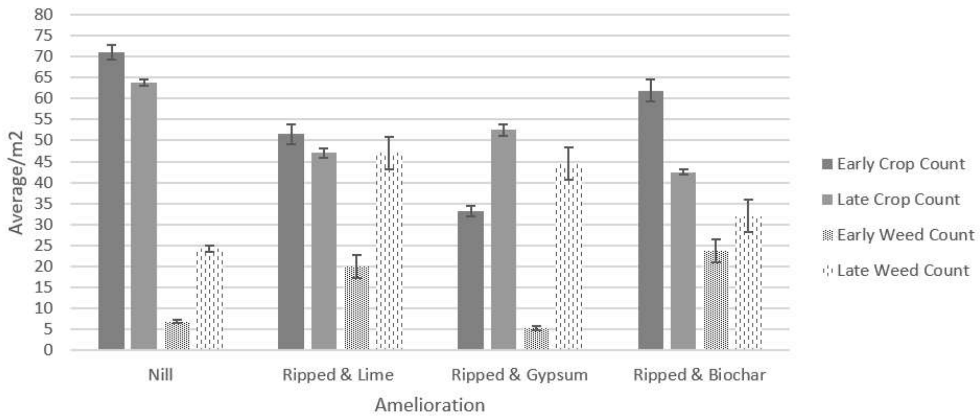

Figure 1: Average early (16/06/2020) and late (20/08/2020) crop and weed density (per m^2) in Scepter wheat in aluminum toxicity trial at Dalwallinu. Error bars are ± 1 S.E.

There was a significant weed burden across the site consisting primarily of ryegrass with some capeweed present. The weed burden increased between the two counts (Figure 1) and ripped treatments had a higher weed density. Crop establishment was staggered but even across each treatment by the second count. The untilled (control) plots had significantly higher establishment numbers, but there were no significant differences between establishment numbers in the other treatments.

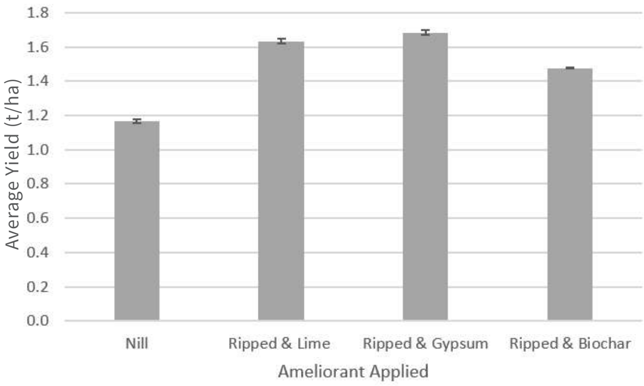

Figure 2: Yield (t/ha) of Scepter wheat in aluminum toxicity trial at Dalwallinu. Error bars are ± 1 S.E.

All ameliorants had a positive yield effect (Figure 2) despite the decreased establishment numbers on the ripped soils (Figure 1). The biochar treatments had significantly lower yields than the lime and gypsum treatments, but lime and gypsum were not significantly different (Figure 2).

Comments

Aluminium is considered to have a negative impact on the growth of susceptible plant species when it reaches concentrations above 5 mg/kg. At the site, prior to application of ameliorants, aluminium levels were above 5 mg/kg throughout the sub soil (10-50cm). Therefore, subsoil Al toxicity would be considered a significant constraint to crop performance.

Table 1: Cost benefit analysis of different ameliorants applied to acid soil with Al toxicity present in Dalwallinu.

Amelioration Treatment		**Nil**	**Lime**	**Gypsum**	**Biochar**
Yield	t/ha	1.17	1.63	1.68	1.48
Average Grain Price (APW1)	$/t	303	303	303	303
Income	$/ha	354	495	510	447
Variable Operating Costs	$/ha				
Seed, Treatment & EPR's		20	20	20	20
Grain Freight		29	41	42	37
Grain Handling Charges		10	14	15	13
Crop Contract		35	35	35	35
Other Crop Costs & Crop Ins		22	22	22	22
Wages Gross		28	28	28	28
R&M Mach./Plant/Vehicle		42	42	42	42
Fuel & Oil		27	27	27	27
Amelioration Including Ripping and Spreading Cost		0	175	160	685
Pesticide		30	30	30	30
Variable Operating Costs	$/ha	243	434	421	939
Operating Gross Margin	$/ha	111	61	89	-491
Fixed Operating Costs	$/ha	133	133	133	133
Total Operating Costs	$/ha	376	567	554	1,072
Operating Profit (BIT)	$/ha	-22	-72	-44	-624
Finance Costs		36	36	36	36
Earnings Before Tax (EBT)	$/ha	-58	-108	-80	-660

All ameliorants have demonstrated a positive effect on yield, however this has not translated to a positive effect on the ROI in the first year (Table 1). It has been shown in other research (Anderson, Pathan, Sharma, Hall, & Easton, 2019) that amelioration can have positive yield benefits over a number of years. As such, the Liebe Group are exploring the opportunity to extend the monitoring of this project into future seasons.

Tissue testing was also performed on each plot, but no significant differences were found between any of the nutrient levels of the treatments. However, it should be noted that the plant tissue testing identified potassium (K) as being deficient in all treatments. This would have limited the potential for any responses to the amelioration treatments. The soil test levels of potassium were also very low, indicating that K supply may have been one of the major constraints that reduced productivity at this site.

The results from this project have provided greater understanding of soil health characteristics and crop growth responses to Al toxicity, the identification of potential management practices, and support for local growers to improve their practices to contribute to positive soil health changes in the region. Validating the quantifiable economic benefits for growers is an important step in the adoption of long-term and sustainable land management practices.

Additionally the benefits of soil sampling to depth have been introduced as an effective tool to measure positive changes in soil health due to on-farm practices, which will be highlighted further with the second set of soil tests that will be taken post-harvest 2020. This second sampling activity will assist in determining the effect each ameliorant had on aluminium concentrations and pH in the soil profile.

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References

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Peer review

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