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

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Key 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 aluminium 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

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

Background

Aluminium 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, aluminium 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 aluminium toxicity.

Demonstration of practices to identify aluminium 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 environments.

In the trial, three ameliorants (lime, gypsum & biochar) were applied to address the aluminium constraint. The 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 aluminium to form inert non-toxic aluminium 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 investigating these ameliorant options for reducing toxic aluminium in the soil, and which is the 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	2020 wheat, 2019 wheat, 2018 wheat
Sowing date	24/05/2021
Sowing rate	50 kg/ha Scepter Wheat
Fertiliser	24/05/2021 - 45 kg/ha Urea; 40 kg/ha MAPSZC3:1DAPSZC 29/06/2021 - 50 kg/ha Urea 08/07/2021 - 20 L/ha UAN
Herbicides, Insecticides & Fungicides	30/03/2021 - 2 L/ha Glyphosate 450, 500 ml/ha Ester 680 23/05/2021 - 2.4 L/ha Glyphosate 450, 300 ml/ha Ester 680, 2.4 L/ha Boxer Gold, 1.6 L/ha Trifluralin 08/07/2021 - 1 L/ha Jaguar, 300 ml/ha LVE Ester

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 Analysis

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

2020 Yield

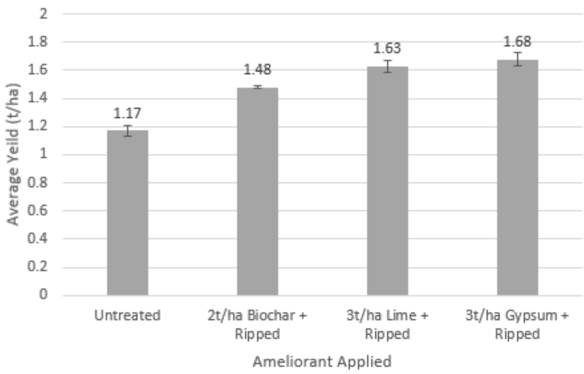

Figure 1: Yield (t/ha) of Scepter Wheat in the aluminium toxicity trial at Dalwallinu in 2020. Error bars are ± 1 S.E.

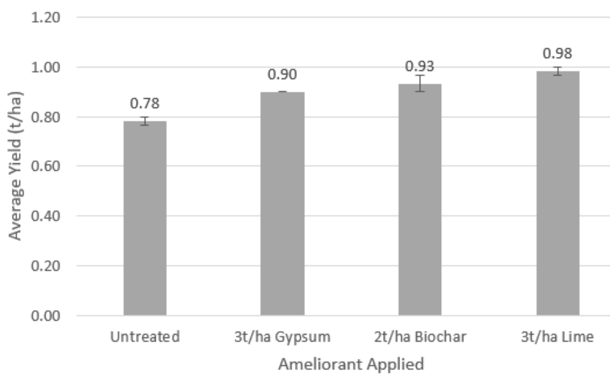

Figure 2: Yield (t/ha) of Scepter Wheat in the aluminium toxicity trial at Dalwallinu in 2021. Error bars are ± 1 S.E.

All ameliorants had a positive yield effect (1 and 2) over the untreated control in both seasons. The biochar treatments had lower yields than the lime and gypsum treatments in 2020, however this trend was not as apparent in 2021. There was not much difference in yield between lime and gypsum in either year.

Table 1: Soil composition test results in the aluminium toxicity trial at Dalwallinu taken 1 year apart, pre (2020) and post (2021) treatment.

Treatment	Nil Control		Lime		Gypsum		Biochar	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
pH 0-10cm	5.1	6.3	5.1	6.2	4.1	5.8	5.8	5.8
pH 10-20cm	4.9	5.7	5.3	5.5	6.1	5.6	4.4	4.9
pH 20-30cm	4.4	5.6	4.3	5.4	4.3	5.3	4.4	4.6
pH 30-40cm	4.2	5.3	4.2	5.6	4.3	5.1	4.2	4.7
pH 40-50cm	4.2	5.0	4.1	5.1	4.1	4.9	4.3	4.6
NO3 (mg/kg)	11	8	9	6	8	6	10	4
NH4 (mg/kg)	3	1	4	1	2	1	2	1
Col P (mg/kg)	23	37	25	37	32	35	21	34
Col K (mg/kg)	20	38	23	34	16	21	23	25
KCl S (mg/kg)	29	3	31	6	35	47	33	6
OC (%)	0.3	0.5	0.3	0.6	0.2	0.4	0.3	0.4
EC (dS/m)	0.04	0.05	0.04	0.05	0.04	0.10	0.04	0.03
PBI	N/A	26.8	N/A	29.7	N/A	26.9	N/A	30.9
Exc. Al 0-10 cm (meq/100g)	0.49	0.16	0.48	0.15	0.80	0.21	0.10	0.16
Exc. Al 10-20 cm (meq/100g)	0.31	0.09	0.25	0.08	0.09	0.04	0.58	0.08
Exc. Al 20-30 cm (meq/100g)	0.37	0.11	0.45	0.11	0.45	0.08	0.52	0.30
Exc. Al 30-40 cm (meq/100g)	0.62	0.15	0.69	0.12	0.64	0.09	0.73	0.16
Exc. Al 40-50 cm (meq/100g)	0.59	0.20	0.75	0.10	0.71	0.22	0.76	0.33

Both pH levels and exchangeable aluminium concentrations improved across the site from year one to year two regardless of treatment (Table 1). Differences between treatments were less pronounced, and no clear treatment effects can be observed from these tests.

Comments

Aluminium is considered to have a negative impact on the growth of susceptible plant species when it reaches concentrations above 5mg/kg (in CaCl2). At the site, before the application of ameliorants, aluminium levels were above 5mg/kg (CaCl2) throughout the subsoil (10-50cm). Therefore, subsoil aluminium toxicity could be considered a significant constraint to crop performance.

Changes to soil pH and Aluminium from year one to the year two sample times are likely due to the high rainfall over summer (>100mm). High summer rainfall can wash both hydrogen and aluminium ions through the soil profile and out of the soil testing zone, however, these constraints still exist at depth and may be drawn back up through the soil profile in subsequent years through evaporation.

It also is worth noting the soil testing and plant tissue testing conducted in 2020 identified potassium (K) as being deficient in all treatments. With no additional K fertiliser applied in 2021 it is likely that this would have again limited the potential for any responses to the amelioration treatments indicating that K supply may be one of the major constraints to productivity.

Furthermore, In this trial it is difficult to ascertain the benefits of the ameliorants over and above the deep ripping effect as the 'nil' treatment was not ripped and there was no 'ripping only' treatment, as such results must be interpreted with this in mind.

Poor yield results could have been the result of a combination of frost damage, issues with pre-emergent herbicides washing into the furrow at seeding time, fertiliser leaching and potassium deficiency.

Acknowledgements
Thanks to the Shannon and Jodi Fry and the Fry family for their assistance hosting, implementing and managing the trial as well as their involvement in our virtual field walk. Thanks to Kalannie Gypsum Supplies for the donation of the gypsum for the trial. Thanks to Angus McAlpine CSBP for assistance with the analysis of the soil sample testing results.

References
Anderson, G., Pathan, S., Sharma, R., Hall, D., & Easton, J. (2019, February 26). Soil solution concentrations and aluminium species of an eastern wheatbelt acidic soil of WA treated with lime and gypsum. Retrieved from Grains Research and Development Corporation: https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2019/02/soil-solution-concentrations-and-aluminium-species-of-an-eastern-wheatbelt-acidic-soil-of-wa-treated-with-lime-and-gypsum.

Lin, Q., Zhang, L., Riaz, M., Zhang, M., Xia, H., Lv, B., & Jiang, C. (2018, October 15). Assessing the potential of biochar and aged biochar to alleviate aluminium toxicity in an acid soil for achieving cabbage productivity. Ecotoxicology and Environmental Safety, pp. 290-295.

Peer Review
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