Field assessment of new root traits for improved acid-soil tolerance in wheat

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Purpose: Assess the value of several traits that aim to improve the acid-soil tolerance of wheat under field conditions.

Location: Peter Negus, "Cooligee", Dandaragan Rd, Dandaragan

Soil Type: Deep yellow sand

Soil Test Results: Indicative site soil pH (CaCl2)

0-10 cm = 5.4; 10-20 cm = 4.2; 20-30 cm = 4.3; 30-40 cm = 4.3

BACKGROUND SUMMARY

In WA subsoil acidification results in an increase in aluminium (Al) availability in the soil as the pH declines to <4.5 ($CaCl_2$) and this Al is toxic to root growth. Even though many Australian wheat cultivars possess the major gene for Al tolerance of root growth (the "malate gene"), they lack Al tolerance for root hairs. Basically even if the roots grow in an acid soil they lack root hairs and are likely to be less efficient in taking up nutrients like P. Wheat lines have been developed that possess a trait to improve growth of root hairs in acid soils (large rhizosheath lines; see Figure 2).

In addition, other lines incorporate a trait (citrate lines) that may provide additional Al tolerance for root growth. Both the malate and citrate genes serve to protect root growth by enabling the root tips to secrete substances that bind up the Al to allow root growth to continue. The purpose of the field trial is to establish whether these traits confer a benefit to wheat grown the sandy acid soils of WA. It should be noted that in highly Al-toxic soils root growth is still inhibited in wheat that has the Al tolerance traits so acid tolerance should be used in combination with a liming program to ameliorate the subsoil acidity. Root growth of wheat with the Al tolerance trait still suffers from the effects of high Al in low pH soils, but they may be less affected than wheat that does not have the Al tolerance traits.

TRIAL DESIGN

Plot size: 1.5 m x 20 m

Machinery use: Sown with DAFWA cone seeder

Repetitions: 4

Seeding rates and dates: 60-77 kg/ha depending on seed size

Summary of wheat lines used:

Mace and Westonia: Check cultivars commonly grown in WA

EGA-Burke: parental Australian cultivar (northern NSW) used to develop lines "S"

lines: small rhizosheath lines essentially EGA-Burke

"L" lines: large rhizosheath lines EGA-Burke with Al tolerant root hairs (sisters of "S" lines) Null

lines: essentially EGA-Burke

Cit lines: EGA-Burke with "citrate gene" for additional Al tolerance (sisters of "Null" lines) Fronteira:

Brazilian cultivar- donor of root hair trait

Carazinho: Brazilian cultivar- donor of citrate gene

Note: all lines possess the major gene (malate gene) for Al tolerance common in many Australian cultivars

TRIAL LAYOUT

▲
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				Bank1			Bank2			bank3
rep	row	bank	tr	var	bank	tr		bank	tr	var
				buffer			buffer			buffer
1	1	1	5	Null4-9	2	9	S2_RzA61	3	11	S4_RzB64
1	2	1	7	S3_RzA30	2	3	Cit4-22	3	2	Cit4-10
1	3	1	13	Fronteira	2	12	Carazinho	3	14	Westonia
1	4	1	6	L2_Rz25	2	4	Null4-5	3	8	L4_RzA48
1	5	1	1	Burke	2	10	L1_RzB24	3	15	Mace
2	6	1	6	L2_Rz25	2	10	L1_RzB24	3	5	Null4-9
2	7	1	8	L4_RzA48	2	1	Burke	3	3	Cit4-22
2	8	1	4	Null4-5	2	14	Westonia	3	7	S3_RzA30
2	9	1	12	Carazinho	2	2	Cit4-10	3	15	Mace
2	10	1	9	S2_RzA61	2	11	S4_RzB64	3	13	Fronteira
				buffer			buffer			buffer
				buffer			buffer			buffer
3	11	1	8	L4_RzA48	2	6	L2_Rz25	3	2	Cit4-10
3	12	1	13	Fronteira	2	12	Carazinho	3	5	Null4-9
3	13	1	14	Westonia	2	10	L1_RzB24	3	4	Null4-5
3	14	1	15	Mace	2	9	S2_RzA61	3	7	S3_RzA30
3	15	1	1	Burke	2	3	Cit4-22	3	11	S4_RzB64
4	16	1	11	S4_RzB64	2	14	Westonia	3	15	Mace
4	17	1	9	S2_RzA61	2	7	S3_RzA30	3	13	Fronteira
4	18	1	8	L4_RzA48	2	4	Null4-5	3	2	Cit4-10
4	19	1	10	L1_RzB24	2	3	Cit4-22	3	5	Null4-9
4	20	1	1	Burke	2	12	Carazinho	3	6	L2_Rz25
				buffer			buffer			buffer

RESULTS

Wheat establishment at the site ranged from 100-120 plants/m2 for all of the varieties and lines tested except for Westonia which had lower establishment, averaging 88 plants/m2 (data not shown). There is some evidence of mild soil water repellence at the site that may have slightly reduced crop establishment.

Mace and Westonia both yielded 3.1 t/ha on average (Fig. 1). The two Brazilian cultivars, Carazhino and Fronteira, which were the source of the citrate and large rhizosheath genes, are poorly adapted to WA conditions both being very tall, long season wheats. Grain yield of Carazhino averaged 2.3 t/ha and Fronteira, which had to be harvested much later, 2.1 t/ha (Fig. 1).

There was evidence of a yield benefit being conferred by the large rhizosheath trait which can result in improved growth of the root hairs. Yields of the large rhizosheath 'L' lines ranged from 2.5 to 2.7 t/ha, with an average yield of 2.6 t/ha compared with the small rhizosheath 'S' lines whose yield ranged from 2.2 to 2.4 t/ha, with an average yield of 2.3 t/ha (Fig. 1).

Overall then the large rhizosheath trait gave an average yield advantage of 0.3 t/ha, a yield increase of 13%. These experimental lines are not adapted to WA and therefore did not yield as well as cultivars such as Mace and Westonia but the aim would be to introduce the trait into well-adapted lines to further increase yields. While these results are encouraging, the benefit of the large rhizosheath trait will need to be confirmed in additional trials on a range of acid soils.

There was no evidence of a yield advantage coming from the citrate trait. On average the lines with the citrate trait ('Cit' lines) yielded 2.4 t/ha and the corresponding lines without the trait ('Null' lines) yielded 2.6 t/ha (data not shown).

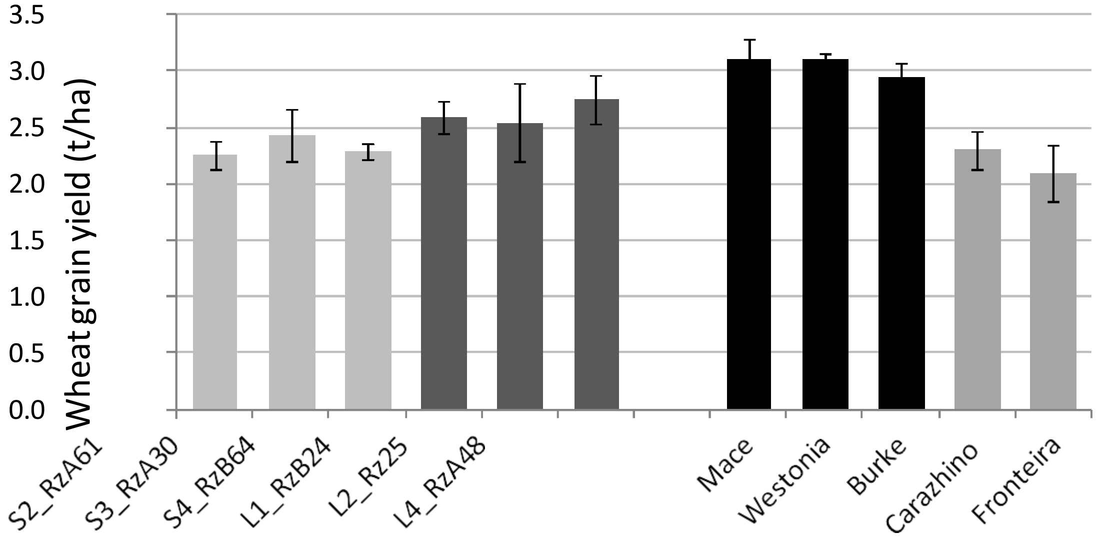

Figure 1. Grain yield of wheat lines with small ('S' lines) and large ('L' lines) root rhizosheath traits and of Australian varieties (Mace, Westonia and Burke) and Brazilian cultivars (Carazhino and Fronteira) grown on deep yellow acidic sand at Dandaragan 2013.

SUMMARY

Many wheat varieties grown in WA already have the major gene for acid soil tolerance. In this trial several other acid tolerance traits are being assessed under field conditions to determine if they confer growth and yield advantages in addition to the major gene. If the traits do prove useful they can then be back-crossed into current well-adapted WA wheat varieties and ultimately become available for growers to use. In addition to these field trials, the project aims to identify molecular markers to facilitate the breeding process. The traits are likely to be beneficial in situations where soils are being limed to correct soil acidity but are not likely to help in highly Al toxic soils in the absence of liming. This trial and others like it will help determine under what soil acidity levels the traits are likely to be beneficial.

Acid soil tolerance in wheat is not a stand-alone solution for managing acid soils, rather it complements a liming program to ameliorate subsoil acidity. Subsoil at the site is acidic to a depth of at least 40 cm as demonstrated by the indicative site soil pH ($CaCl_2$): 0-10 cm = 5.4; 10-20 cm = 4.2; 20-30 cm = 4.3; 30-40 cm = 4.3. Prior to the site being seeded 1.5 t/ha limesand was spread and this has lifted the topsoil pH to ~5.4 on average. More lime will need to be applied to the site to lift the low subsoil pH values.

Figure 2. Examples of wheat seedlings showing differences in the rhizosheath trait when grown on acid soil. The seedling on the right has more soil adhering to the roots than the seedling on the left as a result of the root hairs being protected from the toxic aluminium as shown in the close up images of the root segments.

PEER REVIEW

Craig Scanlan, DAFWA Northam

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