Final Technical Results Report

2021-2022

Farming systems & Agronomic Changes for Integration of Long Coleoptile Wheat in the West Region

Project code:	SLR2103-001RTX
Prepared by:	Kate Witham Kate.witham@slragriculture.com.au Michael Lamond Michael.lamond@slragriculture.com.au SLR Agriculture
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REPORT SENSITIVITY

Does the report have any of the following sensitivities?

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Results are incomplete	YES ☐ NO ☐
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Contents

ABSTRACT

The novel *Rht18/Rht13* dwarfing genes allow for an elongated coleoptile: a sheath that protects the emerging wheat seedling shoot. While convention varieties such as Mace/Scepter have 40-60 mm coleoptiles, the introduction of the *Rht18* or *Rht13* gene (e.g. Mace-18) allows wheat coleoptiles to extend to 120-140 mm.

Two years of scoping studies across WA wheat growing regions found that sowing at depth with *Rht18* and *Rht13* genes allowed for increased plant establishment rates (90-120 mm), improved emergence through warm soils, improved emergence in ameliorated soils, and greater emergence through furrow-fill from wind and rain events. Other observations for long coleoptile varieties were increased vigour, greater weed out-competition capabilities, and avoidance of *rhizoctonia* when sown at depth.

These long coleoptile genes may be particularly advantageous in the face of climate variability and a shift in main season breaks. By being able to chase moisture at depth, the reliance on dry sowing may be reduced, allowing greater control around sowing windows. By sowing earlier, growers may fit in ever-growing programs and overall increasing root and shoot growing periods for an improved grain yield.

Further study around herbicide crop safety across sowing depths, nutrition placement, grower equipment emulation, and soil borne disease interactions will further allow for integration of long coleoptile wheat to WA growers.

P PO Box 5367 Kingston, ACT 2604 Australia
T +61 2 6166 4500 **F** +61 2 6166 4599 **E** grdc@grdc.com.au

EXECUTIVE SUMMARY

This two-year scoping study assessed various aspects of long coleoptile wheat's application to Western Australian Farming systems. Varieties with coleoptiles of various lengths, including CSIRO developed Rht-18 and Rht-13 long coleoptile varieties, were assessed across 7 trials in 2022 following on from 6 field trials in 2021. Research targeted areas around emergence (emergence through depth, emergence through various soil temperatures, emergence through renovated soils), vigour, grass weed interactions, grain yield, rhizoctonia, and an additional herbicide tolerance screen. Both seasons had early season breaks and consistent rainfall, with conditions very conducive for wheat production.

There were several observations made during the 2021 growing season that were not considered initially in the project scope, such as improvement in plant emergence where there was furrow fill from wind or rainfall, particularly where there was pre-emergent herbicide interaction, improvement in emergence where there was transient waterlogging and the "escape" from rhizoctonia when sowing deep into moisture verses sowing shallow dry with wheat varieties that had longer coleoptiles than the conventional lines. These observations have implications for main season plantings as well as early season opportunistic plantings which was the initial reason for the project to be initiated.

Many field trial extension days with growers and industry professionals created discussions around various aspects around long coleoptile wheat integration, such as plant establishment improvements, herbicide use patterns, sowing methods, disease management, soil amelioration interactions and effects on yield. 900+ growers went across the sites over 2021 and 2022 growing seasons.

Overall, there was a positive relationship with coleoptile length and wheat emergence across the two years, particularly in 5 2022 trials. Halberd, Rht13 variety Magenta-13, and Rht18 varieties Mace-18 and Yitpi-18 consistently had 95-100% emergence when sown at depth. Shorter coleoptile varieties had significantly less plants emerge by comparison, such as Scepter (60-75% emergence from depth), and Mace (50-70% emergence from depth). Emergence was significantly faster for Mace-18 compared to varieties such as Scepter and Calibre when sown at depth (120 mm) into soil temperatures below 10 degrees Celsius. Mace-18's coleoptile elongated twice as much as Calibre's at 8 DAS.

The Muntadgin trial exhibited how longer coleoptile wheat had significantly more plants emerged and emergence at faster rates than shorter coleoptile varieties (100mm+ sowing) across uneven soil platforms following soil amelioration.

Preliminary 2021 observations when sampling wheat found the "escape" from rhizoctonia when sowing deep into moisture verses sowing shallow dry with wheat varieties that had longer coleoptiles than the conventional lines. Further sampling ion 2022 found rhizoctonia to be prevalent in most shallow-sown plant samples (sown 35 mm dry) compared to deep sown wheat (100 mm into moisture) which exhibited very few spear-tipping symptoms in Ballidu.

More vigorous Rht18 varieties such as Mace-18 had significantly less annual ryegrass weeds in deep sown plots compared to Mace sown deep across three assessed locations in 2022. Shallow-sown Mace-18 was more vigorous than Mace, also leading to weed out competition in conventional sowing situations. In Ballidu, deep-sown mace had significantly higher weed infestation (nearly three times the weed counts) than Mace-18 sown deep.

Overall, there was the same yield result (100-200 kg/ha difference) between shallow sown Mace and Mace-18 at 5 locations in 2022. At three of the five locations, Mace-18 yielded better than Mace when sown deep. In dry conditions with moisture in subsoils, deep sown plots yielded greater than shallow sown varieties seeded at the same time. Long season varieties had the highest yields at Yuna, with no significant yield difference between deep and shallow sowings of most varieties. Where there were deep and shallow sowings on the same date in Muntadgin to full soil moisture profiles, shallow plots on average had 0.4 t/ha greater grain yields compared to deeper sown plots regardless of variety. Deep-sowing resulted in a 180 kg/ha reduction for Mace-18, and a 660 kg/ha reduction for Mace compared to respective shallow sowings.

Separation in deep and shallow sowing dates in Meckering saw shallow, later sown varieties to have on average 84% the yields of deeper, earlier sown varieties regardless of variety. Analysis of each variety found most yielded similarity when sown at 120 mm and 35 mm. Pingaring yields found deep (90 mm TOS 1) wheat to have greater grain yields by 0.44 t/ha compared to shallow (35 mm TOS 2) sowing, regardless of variety. Rht18 varieties and their corresponding non-Rht varieties (Mace-18, Mace, Yitpi-18, Yitpi) had no significant difference in yields between deep and shallow sowings.

There were few differences in emergence and yield where various IBS and EPE herbicides were applied to shallow and deep sown wheat. Long coleoptile wheat was shown to improve crop safety where trifluralin was applied IBS, with 90 mm sown wheat demonstrating reduced coleoptile thickening and greater seedling vigour across multiple treatments compared to 35 mm sowings.

BACKGROUND

This trial was designed as a scoping study to investigate various aspects of long coleoptile wheat relative to WA farming systems for eventual grower integration. However, this report outlines both observations as well as extensive data that was collected and analysed, despite the original aim of the trail to be more investigatory than data-driven in nature.

The main area of research was investigating the novel Rht18 gene in wheat, which allows for an elongated coleoptile: a protective sheath around the emerging shoot from a seed. Mace/Scepter typically have 40-60 mm coleoptiles (depending on environmental factors). New varieties developed by CSIRO with the Rht18 gene can extend to 12-140 mm by comparison.

Such research is important in the face of climate shifts, where rainfall patterns point to more summer rainfall and a later main season break. WA already has significant natural climate variability, which will only increase along with storm intensity and duration of dry/hot spells. Latest climate projections predict WA annual temperatures to rise by 0.5–1.3°C (2030). To prevent a decline in crop productivity following shifts to rainfall quantities and timing, innovation and adaptation is required.

Long coleoptile wheat can allow for deeper sowing, accessing moisture at depth to reduce reliance on Autumn breaks or the need for dry sowing. Long coleoptile wheat may also improve emergence at higher soil temperatures, and offer greater control for sowing windows, reducing grower risk around emergence timing and plant establishment. Increased vigour conferred by the long coleoptile gene also improves plant establishment numbers and biomass, leading to improved weed management through crop out-competition.

Practices such as deep ripping pose issues to growers, who struggle to achieve uniform seeding depth and variable plant establishment rates after ameliorating soils. While it can be challenging to achieve uniform seed placement in such renovated soils, long coleoptile wheat was found to be a valuable tool for emergence and increasing plant establishment following variable sowing depths. Similarly, furrow fill from wind and rain events can lead to unintentional deep sowing. Long coleoptile wheat may again aid in improved emergence rates in such instances.

Rhizoctonia survives just below soil surfaces and has been found to benefit from summer rainfall events (green bridges) and break of season rainfall, which aids in disease development. Fast growing wheat (such as Rht18 varieties) allow roots to push past infected topsoil, and findings have pointed to sowing deep with Rht18 varieties avoids rhizoctonia and aids in establishment in disease-free soil zones. Further study is required to determine if these preliminary observations are a result of mechanical disturbance, timing, spatial avoidance, or other factors.

This 2-year project has assessed long coleoptile wheat applications to farming systems in WA across emergence, establishment, weed competition, rhizoctonia impacts, herbicide interactions and yield. Extension across sites has aided in discussions with growers and areas requiring further study for integration to grower systems. While investigatory in nature, 2022 trials outlined in this report aimed to be more data driven in nature than trials conducted in 2021.

PROJECT OBJECTIVES

The two-year scoping study aimed to achieve the following objectives for investigate various aspects of long coleoptile wheat relative to WA farming systems for eventual grower integration:

- Extend long coleoptile findings and discussions to growers across agricultural regions of Western Australia
- Quantify differences in emergence from deep and shallow sown varieties with varying coleoptile lengths.
- Investigate emergence through furrow fill from wind and rain events.
- Investigate emergence from uneven soil platforms, such as from deep-ripping
- Investigate emergence through both low and high soil temperatures.
- Explore biomass and vigour differences between varieties with and without the Rht18 gene.
- Quantify differences in annual ryegrass competition and wheat vigour interactions with grass weeds.
- Explore herbicide interactions across depths of sowing to investigate crop safety and ways of adjusting/changing IBS and EPE herbicides.
- Explore rhizoctonia wheat root infection between depths of sowing.
- Analyse grain yield of various varieties and coleoptile lengths, including Rht18 wheat.

METHODOLOGY

Both years of trial work had similar methodology, assessments, and trial layouts. The first established trial in York, 2021, was established specifically to gain detailed emergence data under heat, and was not planned to be harvested as the genetic material in the trial was not suited for very early planting. The other main 4 sites were sown in April (3) and May (1), and all had the same varieties and assessments. A smaller-scale trial was sown in June at Bodallin at the request from growers in the low rainfall regions to demonstrate the shallow and deep plantings. In 2021, trials were seeded with an 8 Tyne DBS plot seeder. The closing plate was extended to full depth and an extra tube added to seed delivery boot to position the seed at 120 mm for the deep sowing. The closing plate was lifted, and the extension tube removed leaving the ripping point at the same depth for the shallow sowing treatment.

In the second year of the project (2022) The scoping study trials were designed to determine the different characteristics of wheat varieties carrying the Rht18 gene (Y69-212, M70-1 and Mace-18) and the traditional mid to short coleoptile grown in WA (Yitpi, Mace and Scepter) as well as elite breeder lines selected with longer coleoptiles.

A total of six trials were established on commercial farms across Western Australian dryland cropping regions. Each variety had a total of four replicates sown at two different depths: the conventional 20 to 30 mm (shallow) and 120 mm (deep) into moisture.

In the second year of the project (2022), 7 field trials (factorial RCB, 4 replications, figure 1) were established across 6 locations in Western Australia. For 6 of the trials, 12 varieties were sown at two depths: deep (90-120 mm) and shallow (30-40 mm). Varieties included wheat with the *Rht18* gene conferring a long coleoptile (Mace-18. Yitpi-18), as well as commercial varieties bred to have a "longer" coleoptile (e.g. Calibre), shorter coleoptile varieties (Mace and Scepter, *Rh2* gene), and Halberd, a non-semi dwarf variety with a naturally long coleoptile. Varieties utilised are outlined in table 2. Plots were sown to 175 plants/m^2 based on 1000 grain weight calculations.

A 7 tyne small plot seeder (Groundhog tynes on a parallelogram) built specifically for deep sowing was utilised in 2022, with a similar seed boot setup to 2021.

Table 1. Wheat varieties included across trials in 2021 and 2022

Variety	Coleoptile Length	Rht18 Gene	Years included in trials
Halberd	Long	N	2021, 2022
Yitpi-18 (Y69-212)	Long	Y	2021, 2022
Yitpi	Mid-Long	N	2021, 2022
Y69-212	Long	Y	2021
M70-1	Long	Y	2021
Mace	Mid	N	2021, 2022
Mace-18	Long	Y	2021, 2022
Scepter	Mid	N	2021, 2022
Calibre	Mid-Long	N	2021, 2022
IGW6752	Mid	N	2021, 2022
IGW6794	Longer	N	2021
IGW6773	Longer	N	2021
Valiant CL Plus	"Long"	N	2022
Magenta	Mid-Long	N	2021, 2022
Magenta-13	Long	Rht13	2022
LRPB Dual	Long	Y	2022
LRPB Bale	Long	Y	2022
Cutlass	Mid-Long	N	2022
Illabo	Mid	N	2022
Denison	Mid	N	2022

Assessments included emergence counts, vigour ratings, annual ryegrass counts (Muntadgin, Meckering and Ballidu), grain yield (excluding Ballidu due to pest grain damage), *rhizoctonia* root effects (Ballidu) and stem counts (Meckering).

Buffer	801 18 Shallow B6	802 6 Deep B6	803 5 Deep B5	804 20 Shallow B8	805 7 Deep B7	806 13 Shallow B1	807 11 Deep B11	808 15 Shallow B3	809 10 Deep B10	810 16 Shallow B4	811 12 Deep B12	812 23 Shallow B11	Buffer
Buffer	701 14 Shallow B2	702 1 Deep B1	703 2 Deep B2	704 19 Shallow B7	705 3 Deep B3	706 21 Shallow B9	707 4 Deep B4	708 24 Shallow B12	709 8 Deep B8	710 17 Shallow B5	711 9 Deep B9	712 22 Shallow B10	Buffer
Buffer	601 16 Shallow B4	602 8 Deep B8	603 10 Deep B10	604 24 Shallow B12	605 9 Deep B9	606 23 Shallow B11	607 3 Deep B3	608 13 Shallow B1	609 5 Deep B5	610 19 Shallow B7	611 6 Deep B6	612 14 Shallow B2	Buffer
Buffer	501 22 Shallow B10	502 12 Deep B12	503 4 Deep B4	504 17 Shallow B5	505 11 Deep B11	506 15 Shallow B3	507 1 Deep B1	508 20 Shallow B8	509 7 Deep B7	510 21 Shallow B9	511 2 Deep B2	512 18 Shallow B6	Buffer
Buffer	401 24 Shallow B12	402 7 Deep B7	403 6 Deep B6	404 15 Shallow B3	405 1 Deep B1	406 16 Shallow B4	407 5 Deep B5	408 14 Shallow B2	409 11 Deep B11	410 22 Shallow B10	411 8 Deep B8	412 21 Shallow B9	Buffer
Buffer	301 23 Shallow B11	302 4 Deep B4	303 3 Deep B3	304 13 Shallow B1	305 10 Deep B10	306 18 Shallow B6	307 9 Deep B9	308 19 Shallow B7	309 12 Deep B12	310 20 Shallow B8	311 2 Deep B2	312 17 Shallow B5	Buffer
Buffer	201 17 Shallow B5	202 9 Deep B9	203 8 Deep B8	204 14 Shallow B2	205 12 Deep B12	206 22 Shallow B10	207 7 Deep B7	208 23 Shallow B11	209 6 Deep B6	210 15 Shallow B3	211 4 Deep B4	212 13 Shallow B1	Buffer
Buffer	101 20 Shallow B8	102 2 Deep B2	103 11 Deep B11	104 21 Shallow B9	105 5 Deep B5	106 19 Shallow B7	107 10 Deep B10	108 16 Shallow B4	109 3 Deep B3	110 18 Shallow B6	111 1 Deep B1	112 24 Shallow B12	Buffer

Figure 1. Trial layout of 12 varieties at two depths. Varieties (factor B) changed depending on location.

Statistical analysis

Data was recorded in Agriculture Research Manager and statistically analysed using an analysis of variance with mean values summarised and separated using Least Significant Test (LSD) at the 5% level of probability. Factorial analysis (LSD) additionally occurred on factor A (depth) and B (variety).

Herbicide screen field trial: An additional herbicide trial was established in 2022 (factorial RCB, 4 replications) assessing a long coleoptile variety, LRPB Bale, subject to an untreated control, 6 IBS herbicides and 5 EPE herbicides at two depths (30 mm and 90 mm). Figure 2 outlines treatments and trial layout.

Emergence counts, plant height, coleoptile length, coleoptile thickening and grain yield were assessed at this trial.

801 19 Deep B7	802 20 Deep B8	803 2 Shallow B2	804 1 Shallow B1	805 23 Deep B11	806 5 Shallow B5	807 17 Deep B5	808 9 Shallow B9	809 8 Shallow B8	810 15 Deep B3	811 3 Shallow B3	812 18 Deep B6
701 13 Deep B1	702 14 Deep B2	703 7 Shallow B7	704 8 Shallow B8	705 22 Deep B10	706 11 Shallow B11	707 13 Deep B1	708 7 Shallow B7	709 2 Shallow B2	710 21 Deep B9	711 6 Shallow B6	712 24 Deep B12
601 15 Deep B3	602 16 Deep B4	603 9 Shallow B9	604 10 Shallow B10	605 18 Deep B6	606 12 Shallow B12	607 22 Deep B10	608 5 Shallow B5	609 11 Shallow B11	610 20 Deep B8	611 1 Shallow B1	612 14 Deep B2
501 17 Deep B5	502 21 Deep B9	503 3 Shallow B3	504 4 Shallow B4	505 24 Deep B12	506 6 Shallow B6	507 19 Deep B7	508 10 Shallow B10	509 4 Shallow B4	510 23 Deep B11	511 12 Shallow B12	512 16 Deep B4
401 16 Deep B4	402 21 Deep B9	403 8 Shallow B8	404 11 Shallow B11	405 24 Deep B12	406 7 Shallow B7	407 13 Deep B1	408 10 Shallow B10	409 6 Shallow B6	410 23 Deep B11	411 7 Shallow B7	412 14 Deep B2
301 18 Deep B6	302 22 Deep B10	303 5 Shallow B5	304 2 Shallow B2	305 15 Deep B3	306 1 Shallow B1	307 16 Deep B4	308 2 Shallow B2	309 4 Shallow B4	310 15 Deep B3	311 3 Shallow B3	312 18 Deep B6
201 19 Deep B7	202 20 Deep B8	203 9 Shallow B9	204 10 Shallow B10	205 23 Deep B11	206 12 Shallow B12	207 20 Deep B8	208 12 Shallow B12	209 5 Shallow B5	210 17 Deep B5	211 1 Shallow B1	212 21 Deep B9
101 13 Deep B1	102 14 Deep B2	103 3 Shallow B3	104 4 Shallow B4	105 17 Deep B5	106 6 Shallow B6	107 19 Deep B7	108 8 Shallow B8	109 9 Shallow B9	110 22 Deep B10	111 11 Shallow B11	112 24 Deep B12

Trt	Description	Trt	Description
1	Shallow;UTC	13	Deep;UTC
2	Shallow;Sakura 118 g/ha IBS;Trifluralin 2 L/ha IBS	14	Deep;Sakura 118 g/ha IBS;Trifluralin 2 L/ha IBS
3	Shallow;Luximax 500 mL/ha IBS;Trifluralin 2 L/ha IBS	15	Deep;Luximax 500 mL/ha IBS;Trifluralin 2 L/ha IBS
4	Shallow;Overwatch 1250 mL/ha IBS;Trifluralin 2 L/ha IBS	16	Deep;Overwatch 1250 mL/ha IBS;Trifluralin 2 L/ha IBS
5	Shallow;Terrain 120 g/ha IBS;Trifluralin 2 L/ha IBS	17	Deep;Terrain 120 g/ha IBS;Trifluralin 2 L/ha IBS
6	Shallow;Overwatch 1250 mL/ha IBS;Callisto 200 mL/ha IBS	18	Deep;Overwatch 1250 mL/ha IBS;Callisto 200 mL/ha IBS
7	Shallow;Terbyne 1.2 kg/ha IBS	19	Deep;Terbyne 1.2 kg/ha IBS
8	Shallow;Arcade 2 L/ha EPE	20	Deep;Arcade 2 L/ha EPE
9	Shallow;Jaguar 750 mL/ha EPE;Arcade 2 L/ha EPE	21	Deep;Jaguar 750 mL/ha EPE;Arcade 2 L/ha EPE
10	Shallow;Boxer Gold 2.5 L/ha EPE	22	Deep;Boxer Gold 2.5 L/ha EPE
11	Shallow;SYN Coded A 3 L/ha EPE	23	Deep;SYN Coded A 3 L/ha EPE
12	Shallow;Mateno 1 L/ha EPE	24	Deep;Mateno 1 L/ha EPE

Figure 2. Herbicide trial layout

LOCATION

Where field trials have been conducted, provide the following location details in the table below: latitude and longitude, or nearest town. (Add additional rows as required.)

Site #	Latitude (decimal degrees)	Longitude (decimal degrees)	Nearest town
Trial Site #1	-31.7834	116.7069	York
Trial Site #2	-31.5802	118.1315	Hines Hill
Trial Site #3	-30.5943	117.9367	Beacon
Trial Site #4	-29.6373	116.2881	Latham
Trial Site #5	-32.6056	119.5462	Holt Rock
Trial Site #6	-31.372228,	118.841430	Bodallin
Trial Site #7	-28.6055882	115.3948794	Yuna
Trial Site #8	-28.7875522	114.7614046	Ballidu/Pithara
Trial Site #9	-31.7351305	116.9618963	York
Trial Site #10	-31.794909	118.670950	Merredin
Trial Site #11	-33.347549	121.371320	Esperance
Trial Site #12	-32.7955920	118.5306980	Pingaring

RESULTS AND DISCUSSION

2021

Crop establishment

Emergence counts 18-21 days post-sowing found conventional WA varieties Mace, Scepter and Yitpi to have less emerged plants when sown deep (120 mm). Plant samples of emerged and un-emerged plants taken from all sites at mid-tillering stages had similar results, with a high proportion of un-emerged seedlings when rows were sampled. By comparison, greater crop establishment was achieved in treatments that contained the Rht18 gene with more plants counted per square meter.

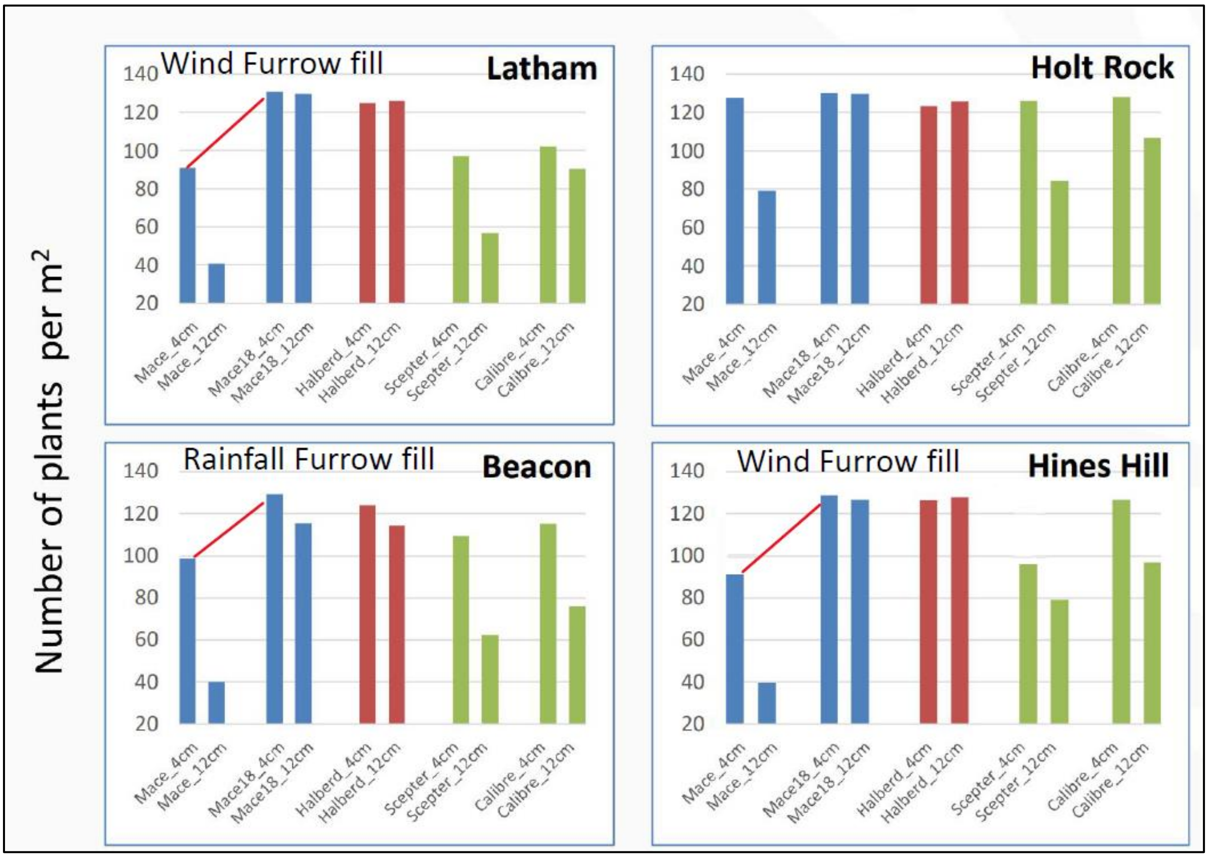


Figure 3. Plant counts across four sites (18-21 days post-sowing). LSD's 8(L) 16 (HH) 6 (B) 6 (HH)

Figure 4. Beacon. Short coleoptile sown at 120 mm (front), mid-long coleoptile sown at 120 mm (centre), short coleoptile sown at 35 mm (back).

Latham

The site was a prime example of how varieties with the Rht18 long coleoptile gene demonstrate emergence capabilities, with the site experiencing furrow fill and herbicide damage following strong winds shortly after sowing. Silly-seedling syndrome was seen to affect shorter coleoptile varieties such as Mace to a greater extent than Mace-18, with distortion of emerging seedlings observed following furrow fill. Shallow-sown seedlings also exhibited coleoptile thickening and shortening from trifluralin resulting from the furrow-fill.

Plant-counts 18 days post-sowing found traditional varieties Yitpi, Mace and Scepter to have significantly reduced emergence rates when sown deep (P=0.05, CV=16) compared to conventional sowing, while all longer coleoptile varieties had similar mean emergence rates between deep and shallow sown plots. Mace-18 was observed to have similar plant numbers in deep-sown and shallow sown plots, whereas Mace had a reduction of about 60% in the deep sown plots and about 25% reduction in the shallow sown plots. Mace plants emerging from both 120 mm-sown plots and 40mm-sown plots appeared less robust and less vigourous than emerged plants containing the Rht18 gene (Y69-212, M70-1 and Mace-18).

Figure 5. Latham root rot of Mace-18 sown at 120 mm. June 22nd

Figure 65. Mace sown 40 mm exhibiting silly seedling syndrome at Latham from furrow fill. May 21st

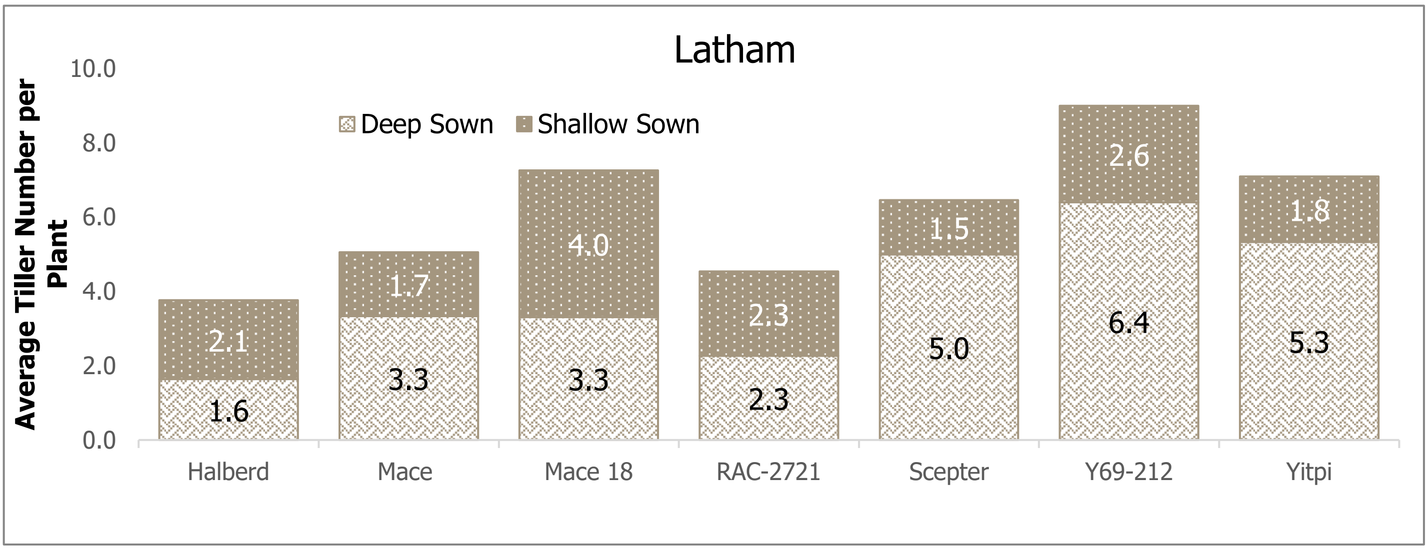
Figure 76. Mace sown 40 mm (left) and Mace-18 sown shallow (right), both affected by furrow fill.

Beacon

The Beacon site had similar findings 19 days post-sowing, where IGW6773, Halberd and Mace-18 had equivalent emergence for both depths of sowing, while all other varieties had higher rates of emergence and biomass data when sown shallow (40 mm).

The site had a full soil moisture profile at sowing in April and received 50 mm in the days after planting. The transient waterlogging following the rainfall event was thought to reduce the plant density of the conventional Scepter and Mace lines, with very few plants emerging from 120 mm sown plots. Biomass imagery found these varieties to have green canopy coverage at 21% and 6% respectively while Mace-18 plots sown deep had canopy coverage over 35% by comparison. Overall, the heavy soil type in Beacon was observed to heighten the differences between coleoptile length and plant numbers and early vigour, with Rht18 genes performing best earlier in the season.

Figure 87. Mace-18 sown at 120 mm (left) and Mace sown at 35 mm (right). June 9th 2021. Beacon



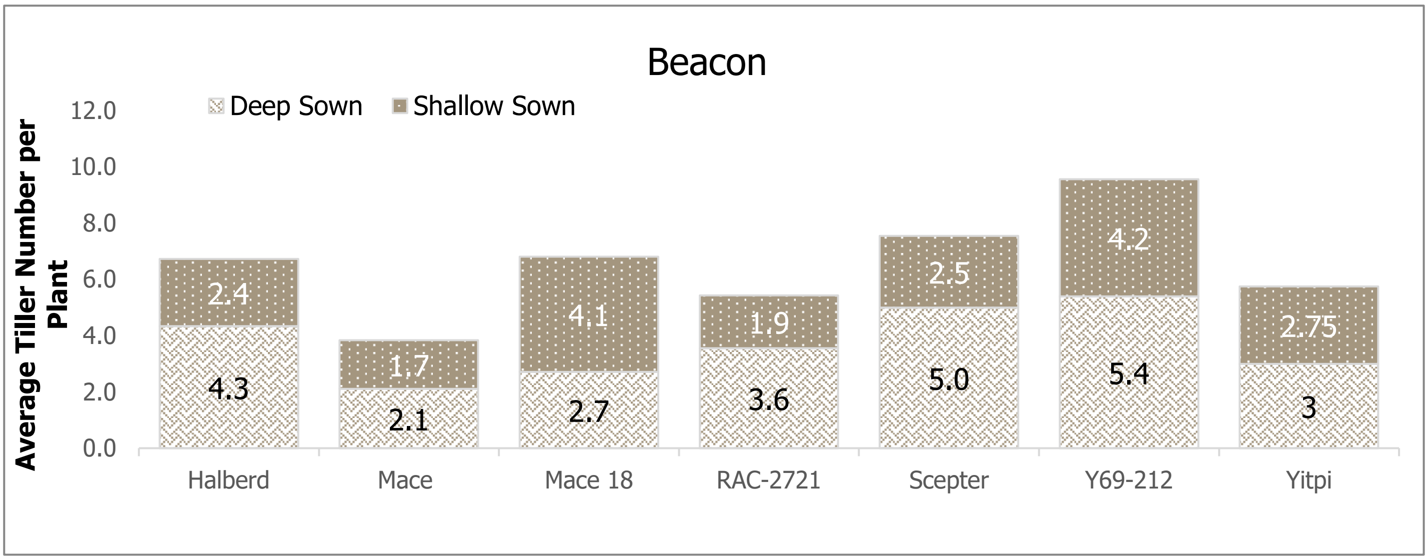


Figure 98. Tiller numbers of varieties sown deep and shallow at two sites (assessed 22nd June 2021)

Figure 10. Mace-18 sown 120 mm

Figure 11.Mace sown 120 mm

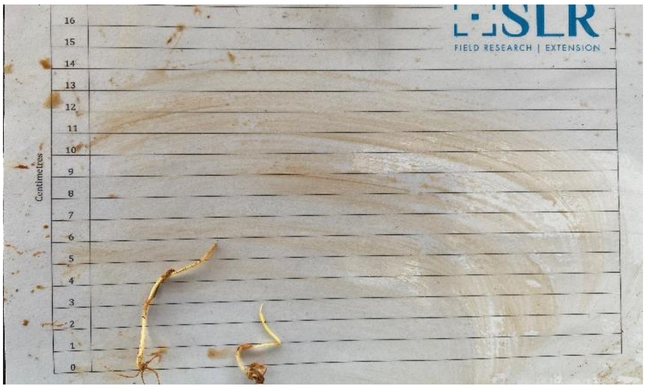


Figure 12. Unemerged Mace-18 sown 120 mm

Figure 139. Unemerged Mace sown 120 mm

Hines Hill

Shallow sowing at 35 mm was into dry soil, while the deeper 120 mm sowing was into moisture. The soil profile meant a difference in emergence timing from deep to shallow was 15-22 days, where the deeper sown wheat started to germinate in the days following seeding due to soil moisture present at depth. The shallow sown wheat germinated after rain events that fell on the 4th and 5th of May. The soil moisture profile at Hines Hill site allowed for the discussion around the coleoptile length requirements in a drying-out soil profile. Sowing long coleoptile wheat into moisture with the knowledge seeds will germinate may provide growers with the ability to choose wheat varieties based on season length and control the flowering window to a greater extent.

Plant emergence data was collected 21 days after seeding. Observations included longer-coleoptile varieties RAC2721, Y69-212, Halberd, Mace-18 and IGW6773 to have a greater rate of emergence when sown deep, with a significantly greater emergence rate (P=0.05) observed for IGW6752 sown both shallow and deep, and IGW6773 sown deep. These treatments had approximately 120 plants per square meter.

On August the 31st, growth stages between shallow and deep sowing were similar for most varieties. Differences between sowing depths were exhibited for commercial Yitpi and Mace, which exhibited earlier maturity stages where deep sown. Tiller counts of 20 plants per plot found the deep sowing of most varieties to have greater tiller numbers than when sown shallow. Y69-212 sown at 120 mm had a twice the average tiller number compared to conventional Yitpi sown at 120 mm at all three sites sampled (Latham, Beacon, Hines Hill). This was also able to be observed in whole plot biomass (image 12).

Figure 14. Hines Hill, 120 days after sowing, August 19th. Biomass difference between conventional Yitpi at standard sowing depth, and Y69-212 (Yitpi-18) sown at 120 mm. Earlier tiller counts (assessed 21 days after sowing) found Yitpi-18 to have a greater number tillers when sown deep compared to conventional Yitpi (sown either deep or shallow) across three sites. Rht18 genes have been found to confer greater cell size and biomass.

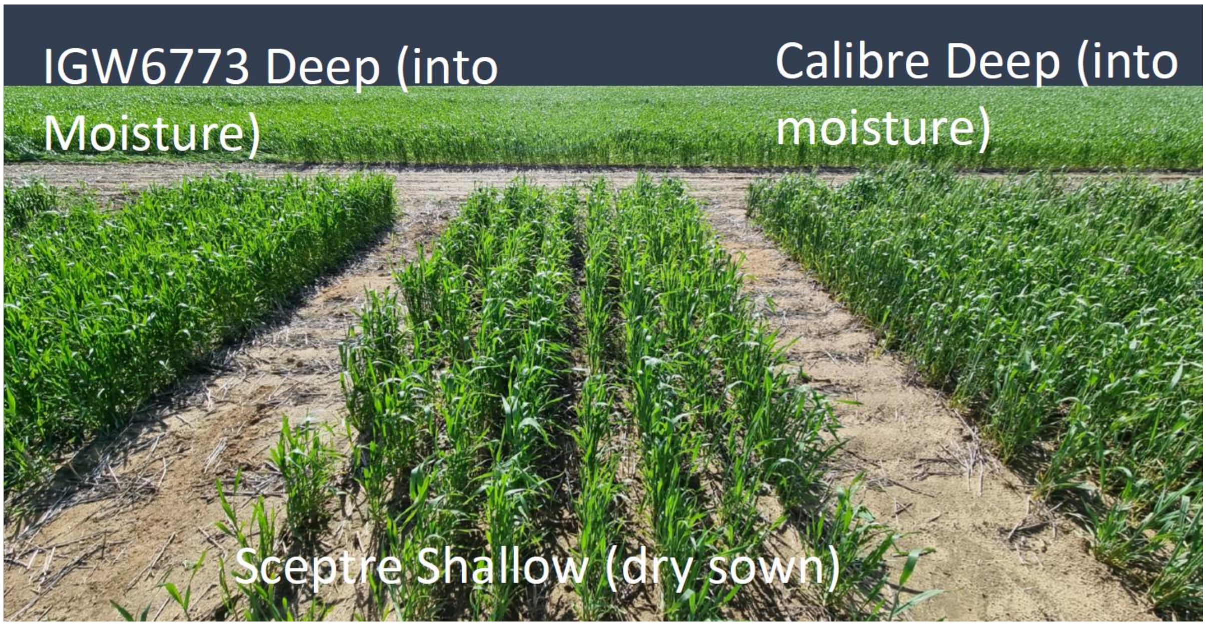


Figure 15. Differences in plot biomass at Hines Hill, 19th August where longer coleoptiles sown into moisture had greater tiller numbers and green area coverage than Scepter shallow-sown into dry soil.

York

Several rainfall events in early March provided the opportunity to sow into moisture at 110-120 mm and shallow into a drying profile at 50 mm. High temperatures (32-38°C) across sowing and emergence subject seedlings to emergence under heat stress, conditions known to shorten coleoptile length and reduce establishment.

Emergence notes and photos of each plot were taken every one to three days from sowing until emergence of all plots. Most varieties had emerged 3 days after sowing for deep sown plots, with Mace having the lowest rate of emergence and the lowest number of established plant numbers by the end of April across deep-sown plots.

Emergence notes were additionally taken following a rainfall event in April. Shallow plots with inadequate moisture for seeds to emerge provided a good simulation of sowing into a drying profile. Detailed measurements were taken of coleoptile length from each of the varieties sown deep and shallow. Sampling from deep-sown plots found Halberd-Rht12 to have an average coleoptile length of 90 mm, with Mace at 45-55 mm and Mace-18 at 75-85 mm.

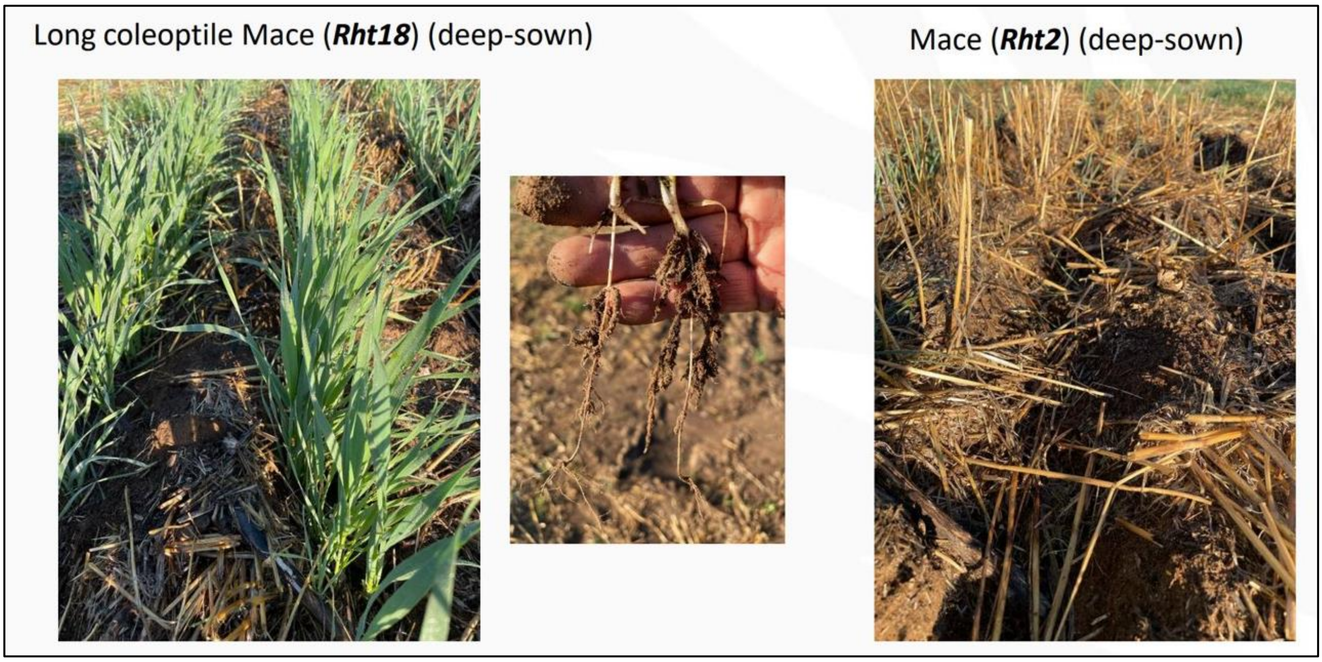


Figure 1610. Comparison of Mace-18 and Mace sown early and deep at York during at temperatures between 32-38 degrees.

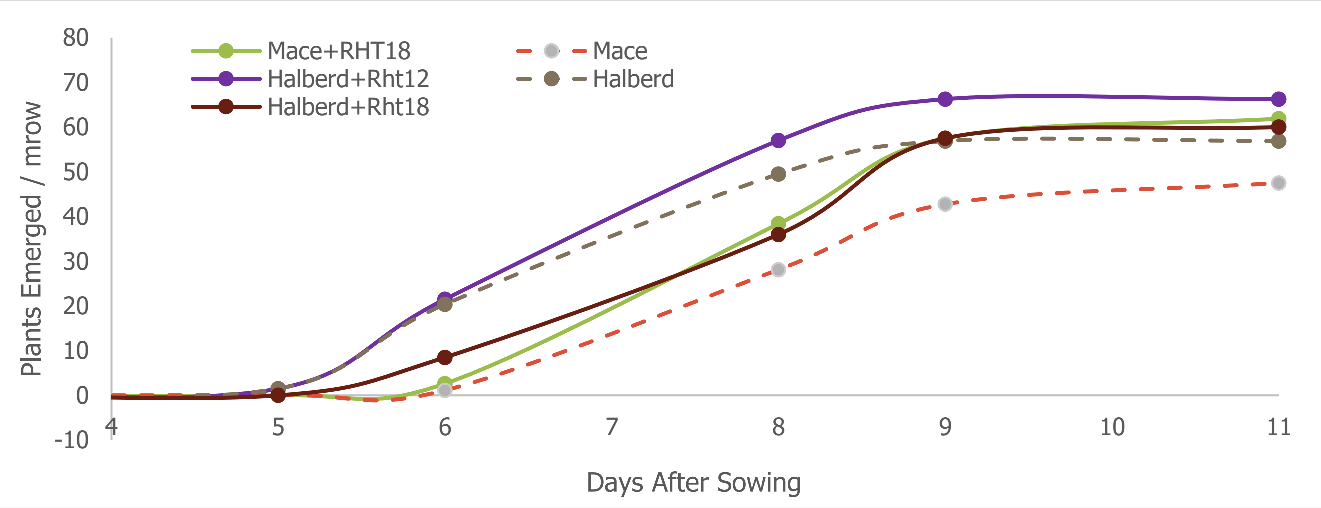


Figure 1711. Rates of Emergence for deep sown plots of Mace, Mace-18, Halberd, Halberd-18 and Halberd-12, York.

Bodallin

The Bodallin trial was established as an opportunistic site requested by the local growers. Sowing occurred in June using 6 varieties from the limited supplies of seed left.

The site gave surprising results following furrow fill from rain and transient waterlogging, resulting in the long coleoptile varieties emerging with more plants in the shallow and deep sowing. The longer coleoptile varieties such as Calibre (RAC-2721) had greater emergence than Mace and Scepter, although not as high as the lines with the Rht18 gene. Final yield data was inconclusive, with the lowest yielding treatment, Mace sown at 40 mm, yielding 1.2 t/ha (compared to other treatments averaging 1.5-2 t/ha).

This site was showcased during a Merredin Farms tour of managers' and local growers, with many commenting that the longer and long coleoptile lines would make it easier to obtain even emergence with inexperienced operators when sowing large programs over varied soil types.

Figure 18. Bodallin waterlogging (left), and site at harvest (right).

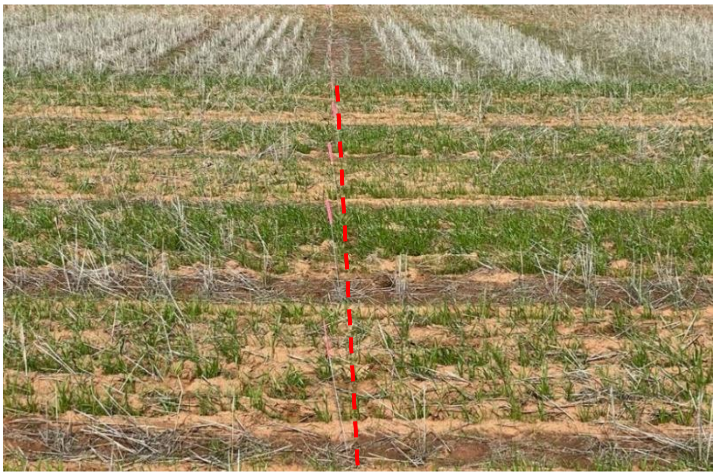


Figure 1912. Variation in crop establishment at Bodallin

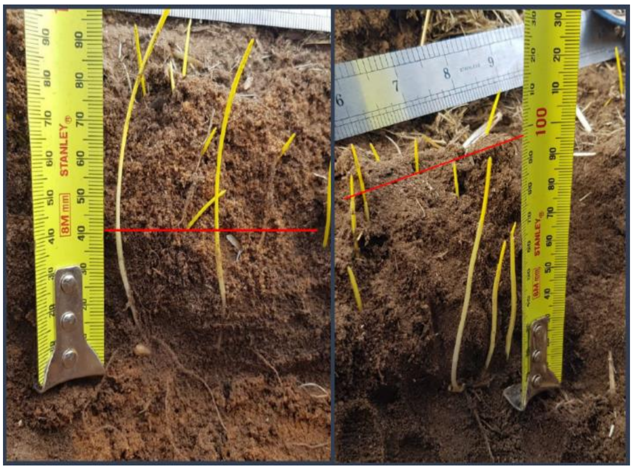


Figure 20. Coleoptile lengths of Mace (left) and

Holt rock

All shallow sowings had significantly greater plants emerged than deep sowings for all varieties excluding Mace-18, which had equivalent plants per meter row when sown at 40 and 120 mm. The greatest rate of emergence was for shallow-sown IGW6752, IGW6794, Yitpi and IGW6773 (approx. 25-30 plants meter row), followed by RAC2721, Halberd and Y69-212 (20-25 plants per meter row).

Traditional varieties Scepter and Mace, as well as Y69-212 and M70-1, had the poorest emergence when sown deep with approximately 5 plants per meter row. Alternatively, longer coleoptile varieties RAC2721, IGW6752, IGW6773 and Mace-18 had the greatest emergence of the deep sown varieties with approximately 2-3 times the emergence at 10-15 plants per meter row. These varieties also exhibited increased seedling vigour.

Growth stage differences were noted in early July, where Mace was at the 4-leaf growth stage compared to Mace-18 at 5-6 leaf (early tillering).

Figure 2013. Roots of Mace-18 sown deep (left) and Mace sown shallow (right). Rhizoctonia affected roots from shallow-sowing presented with reduced root biomass and spear tipping.

Yield

Non-frosted site yields were inconclusive, though no significant yield penalty was observed for varieties containing the Rht18 gene, with indications that Mace sown deep yielded less than Mace-18 sown deep across Latham, Holt Rock and Beacon.

The site at Hines Hill was severely frosted, with most plots yielding below 1 tonne per hectare. An interesting observation was that the InterGrain variety IGW6752 exhibited very little frost damage and had significancy higher yields than all other varieties. IGW6752 was at an earlier grow stage (booting) to most other varieties (flowering – early dough) when assessed on the 31st of August.

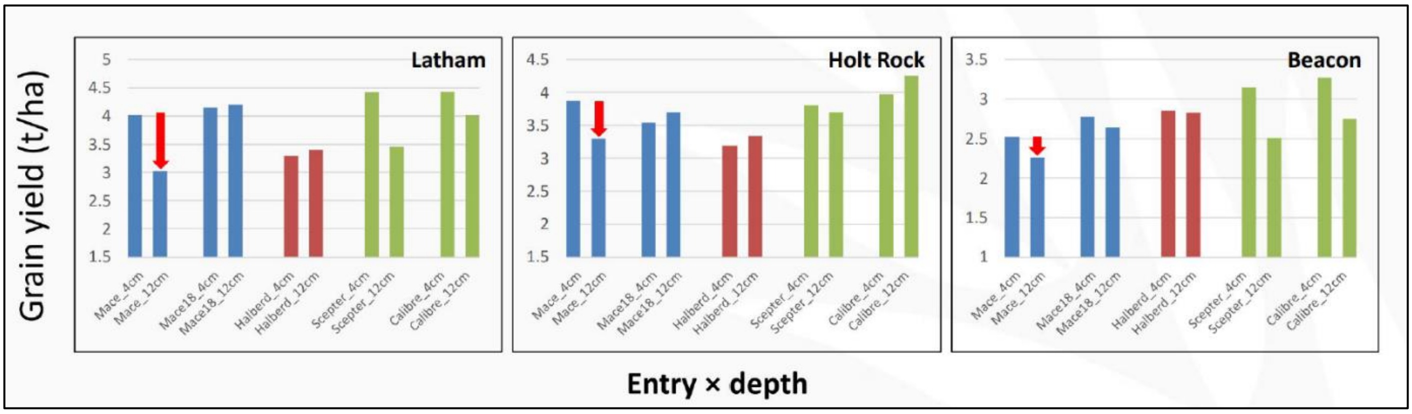


Figure 2114. Yield data (Hines Hill frosted). Arrows indicate yield penalty from deep sowing. LSD's: 0.1 (L), 0.94 (HR), 0.46 (B)

2022

Plant establishment and yield

Yuna

Sowing depths were 40 mm (shallow, dry) and 90-100 mm (deep, into moisture) at Yuna. Factorial analysis of shallow and deep sown plots at 21 DAS found a significant difference in plants per square metre counts, with greater emergence in shallow plots across varieties by approximately 50 plants per m^2. For deep-sown varieties, the lowest rate of emergence was observed for Scepter, Calibre, Denison, Cutlass and Valiant (<130 plants/m^2, plots sown to 175 seeds/m^2). Factorial analysis found no significant difference between deep and shallow sown plants emerged for IGW6752 and *Rht18* varieties Mace-18 and Yitpi-18. Compared to their respective shallow sowings, significantly less plants emerged at depth for Halberd (-38 plants/m^2), Yitpi (-45 plants/m^2), Valiant (-60 plants/m^2), Denison (-61 plants/m^2), Mace (-67 plants/m^2), Bale (-69 plants/m^2), Calibre (-75 plants/m^2), Cutlass (-82 plants/m^2) and Scepter (-88 plants/m^2). There was a moderate relationship between coleoptile length and emergence rate (R^2=0.7) as outlined in figure 3.

Factorial analysis of biomass found no significant difference between deep and shallow for each variety, however deep sown plots had 16% less biomass on average than shallow sown plots based on vigour ratings.

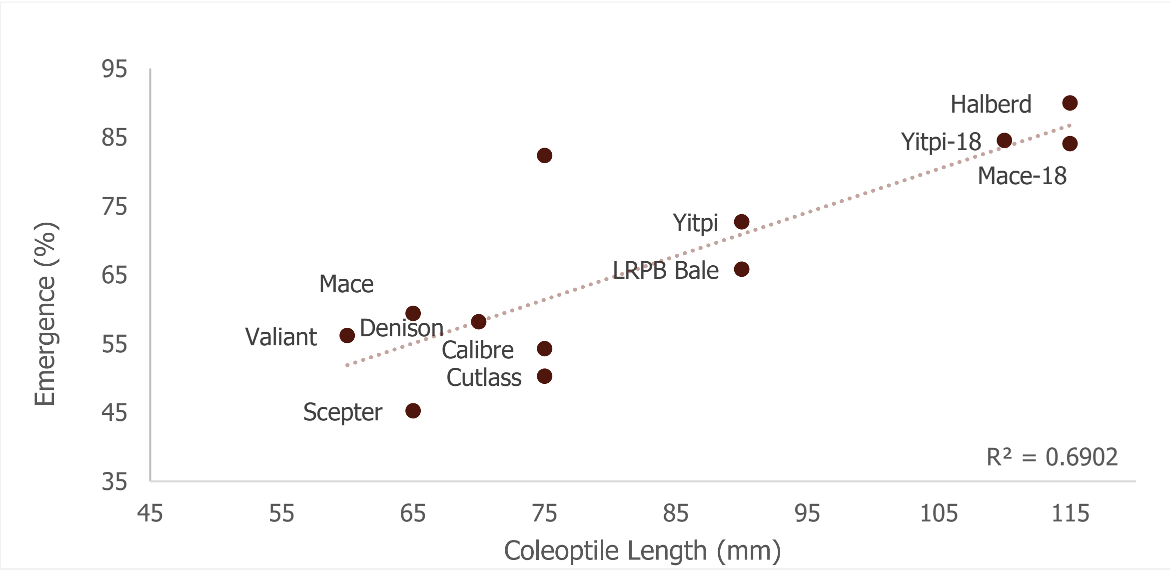


Figure 2215. Coleoptile length and emergence (calculated as a percentage of deep sown plant numbers to shallow sown plant numbers) Yuna 21 DAS

On average, deep sown plots yielded greater than shallow sown plots by 0.23 t/ha regardless of variety. Long season varieties such as Denison, Valiant and Cutlass had the highest yields between 3.1 and 3.6 t/ha (average across both sowing depths). There was no significant yield difference between deep and shallow sowings of Halberd, Bale, IGW6752, Denison, Cutlass, Mace-18, Valiant, Yitpi and Yitpi-18.

Meckering

There was no significant difference in plants emerged per square metre between 120 mm (TOS 1) and 35 mm (TOS 2) seeding depths for Halberd (167 and 156 plants/m^2), Magenta-13 (140 and 137), Mace-18 (169 and 160) and Yitpi-18 (173 and 158). All other varieties had significantly less plants emerged for 120 mm sowing compared to 35 mm sowing. Mace-18 had significantly greater plants emerged than Mace, highlighting the increased ability of plants to emerge from depths with the *Rht18* gene. Overall, for deep-sown plots, there was a positive relationship (R^2=0.85) between coleoptile length and plants emerged per square metre (fig. 4). Increased seedling vigour and coleoptile lengths are highlighted in figure 6.

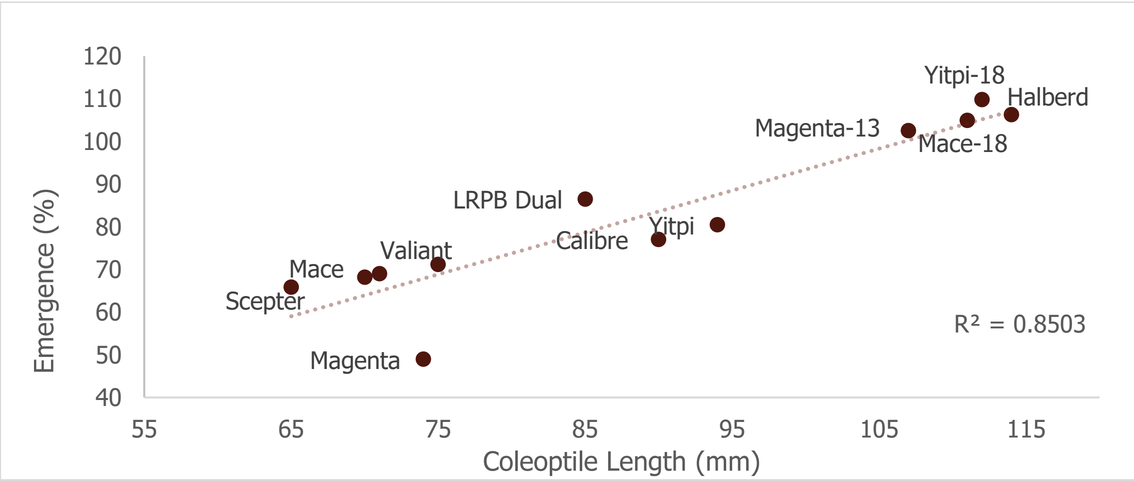


Figure 2316. Coleoptile length and emergence (calculated as a percentage of deep sown plant numbers to shallow sown plant numbers). Meckering 18 DAS. 120mm TOS 1 2nd May 18 DAS.

Figure 2417. Mace (left) and Mace -18 (right) at Meckering. Greater vigour and plant growth evident for *Rht18* Mace-18, which also had a longer coleoptile by comparison.

Temperature probes highlighted more rapid emergence from depth of *Rht18* at low (>10°C) soil temperatures. At 6 DAS, Mace-18 had elongated to 60 mm below the bottom of the furrow in deep sown plots. By 8 DAS, Mace-18 was emerging from 120 mm, while Scepter and Calibre were unmerged at 40-50 mm and 60 mm coleoptile extension. This is highlighted in figure 6.

Figure 2518. Left: Mace-18 8 DAS emerging to the surface from 120 mm sowing. Right: Scepter at 50 mm, unmerged at 8 DAS. Temperatures between 10-18 degrees at 120-60 mm below the bottom of the furrow. Surface temperatures around 31 degrees Celsius.

Biomass/vigour ratings found similar biomass (canopy coverage) between deep and shallow plots for all varieties excluding Calibre, Magenta, Valiant and Yitpi. These had reduced biomass in 120 mm sown plots compared to 35 mm plots by 10-20%. There were varietal differences due to growth habits, where Halberd and Yitpi-18 had the highest average biomass scores at 8.3 and 8.4 respectively (1-9 scale), followed by Mace-18 at 7.8 across deep and shallow sowings. In comparison, Mace and Scepter had average scores of 7.

Wheat stem counts (Scepter, Calibre, Magenta, Magenta-13, Mace, Mace-18 only) found no significant difference in the number of stems per metre of row at crop maturity (47-59 per metre row) suggesting plants had compensated for differences in establishment through tillering.

Factorial analysis of yield data found a significant difference between 120 mm and 35 mm sowing depths across varieties, where deeper sown varieties at the first time of sowing had greater yields than shallow sown plots seeded 22 days later average. Despite differences in early establishment across varieties, sowing 22 days earlier offered a yield benefit to most varieties. Factorial analysis found shallow, later sown varieties had on average 84% the yields of deeper, earlier sown varieties regardless of variety.

There were significantly greater yields for Halberd, Scepter and IGW6752 sown earlier at 120 mm than 22 days later at 35mm, while all other varieties yielded similarity when sown at 120 mm and 35 mm.

Muntadgin

The Muntadgin trial had sowings at 35 mm and 90 mm respectively due to compacted subsoils making sowing at depth difficult. Select varieties were sown in a secondary trial in deep-ripped soil. This allowed depths of 100 mm+ to be achieved, with sowing variability due to the uneven soil platform following amelioration. As growers have voiced their concerns surrounding plant emergence following deep-ripping, this trial showcased how *Rht18* varieties were able to achieve better establishment than shorter coleoptile varieties where soil renovation led to furrow fill and variable seed placement (fig 7).

Figure 2619. Mace left. Mace-18 right. Both sown 100 mm in deep ripped soil.

Emergence counts found a significant difference in plants per square metre, with greater emergence for shallow sown varieties by approximately 24 plants per m^2. For deep-sown varieties, there were significantly lower rates of emergence for deep sowings compared to shallow sowings for half of the varieties. Plant per square metre counts were significantly lower for Scepter (116), Cutlass (117), Illabo (122), Mace (91), Yitpi (118) and Valiant (109). *Rht18* varieties Yitpi-18 and Mace-18 had no difference in emergence between deep and shallow sowings. All shallow sown plots had emergence between 149-179 plants/m^2.

There was a moderate, positive relationship between coleoptile length and emergence rates (R^2=0.84) (figure 8) for deep sown plots. Halberd and *Rht18* varieties Mace-18 ad Yitpi-18 had the highest rate of emergence (100%) and the longest coleoptiles (full extension to surface, 90-100 mm). Across sites, the relationship between coleoptile length and

P PO Box 5367 Kingston, ACT 2604 Australia
T +61 2 6166 4500 **F** +61 2 6166 4599 **E** grdc@grdc.com.au

emergence grew weaker where counts were conducted later, and "deep" sowings were closer to the bottom of the created furrow.

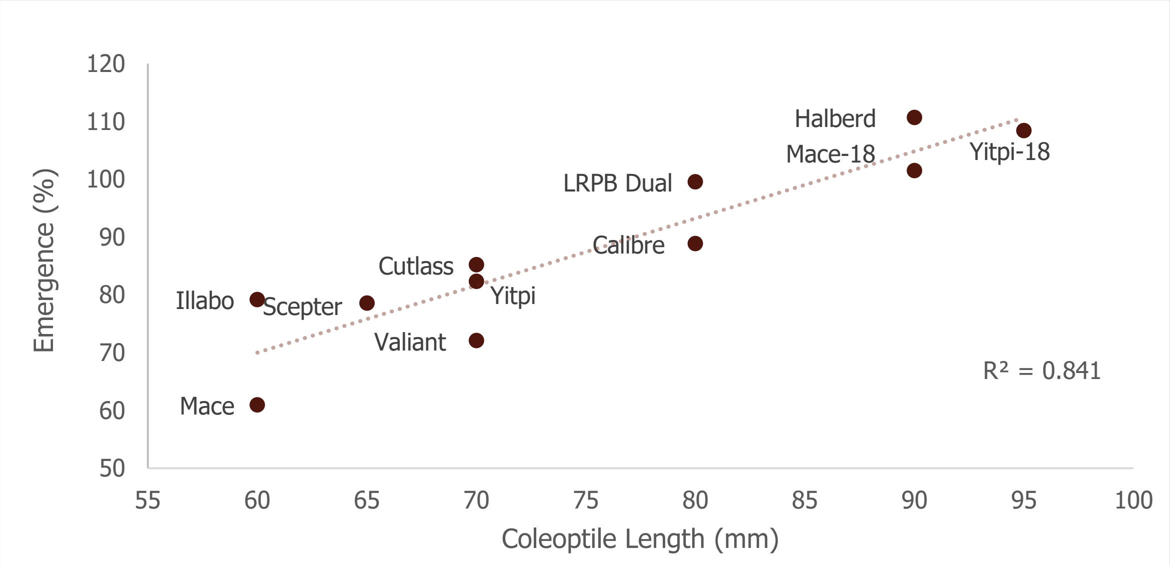


Figure 2720. Coleoptile length and emergence (calculated as a percentage of deep sown plant numbers to shallow sown plant numbers). Muntadgin 27 DAS. 90 mm TOS 1 2nd May.

Biomass/vigour ratings found similar ratings between deep and shallow plots for all varieties excluding Cutlass, Dual. Illabo, Mace and Valiant, which had 10-20% less plant vigour in deeper sown plots compared to shallow sown plots. These seedlings appeared more "spindly" and shorter by comparison.

Yield results found shallow plots on average to have 0.4 t/ha greater grain yields to deeper sown plots regardless of variety. However, analysing each individual variety, yields were not significantly different between shallow and deep sowings. Comparison of yields from the deep-ripped trial to the standard, non-ameliorated trial found a yield benefit from sowing into the renovated soil. There was a 1 t/ha yield increase for Scepter (at both at deep and shallow plantings) by sowing into deep-ripped soil. Figure 9 highlights Mace and Mace-18 yields across the three sowing methods. Mace-18 and Mace yielded similarly for shallow sowings. Deep-sowings (non-ameliorated) resulted in a 180 kg/ha reduction for Mace-18, and a 660 kg/ha reduction for Mace by comparison to shallow sowing. Mace-18 yielded 300 kg/ha more than Mace in ameliorated soil. There was a 0.72 t/ha and 0.96 t/ha benefit between deep sowing in ameliorated soil compared to non-ameliorated soil for Mace-18 and Mace respectively.

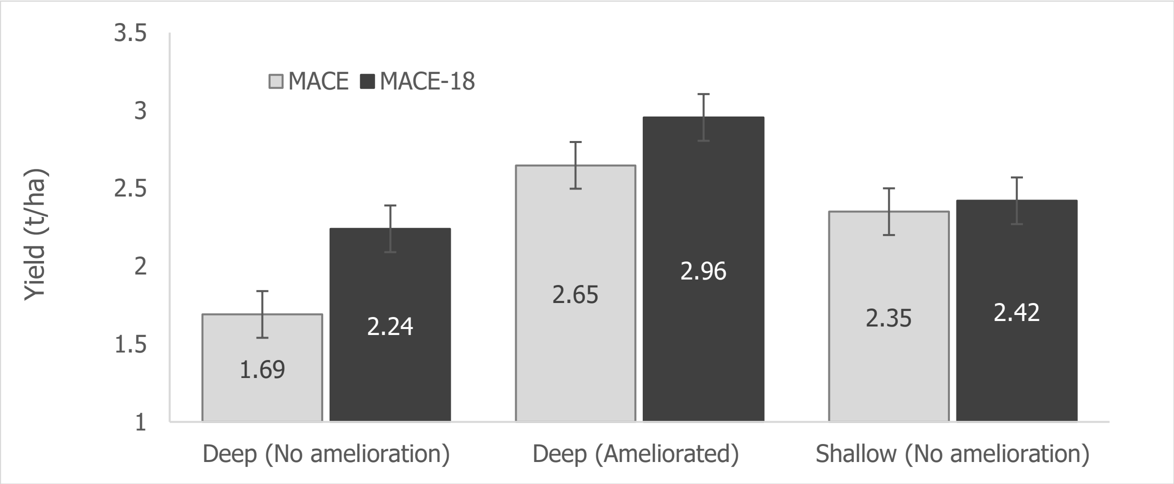


Figure 2921. Grain yields for Mace-18 and Mace across three sowing methods: deep (90 mm non deep-ripped), 100+ mm into deep-ripped soil, and shallow (35 mm).

Ballidu

Deep (100 mm) sowing occurred on April 14th into moisture. The surface remained dry until just after the 11th of May, where shallow (35 mm), dry sowing occurred. This simulated benefits long coleoptile wheat could offer growers, where chasing moisture earlier could reduce reliance on seasonal breaks and the need for dry sowing. The prolonged heat after seeding appeared to shorten coleoptiles, however *Rht18* varieties had greater seedling vigour and more rapid emergence despite soil temperature. Mace-18 had more leaves and greater plant height in relation to Mace at 27 DAS, as did Yitpi-18 in comparison to Yitpi (fig. 11).

Figure 3022. Bottom and top left: Mace sown at 100 mm at 9 DAS. Top and bottom right: Mace-18 sown 100 mm 9 DAS with greater seedling vigour and rates of emergence.

Two emergence counts were conducted on deep sown plots at 9 and 27 DAS (figure 12). All plants had emerged for longer coleoptile varieties by the first count, including *Rht18* long coleoptile varieties Mace-18 and Yitpi-18. There was delayed emergence for Scepter, Magenta Mace and Valiant (shorter coleoptile varieties) and had plant establishment numbers below 90 and 120 plants/m^2. Overall, there was a positive relationship between coleoptile length and emergence rate for deep sown varieties at 27 DAS (R^2=0.75, figure 13).

Figure 3123. Left: Yitpi at 100 mm. Right: Yitpi-18 at 1100 mm. Both 27 DAS

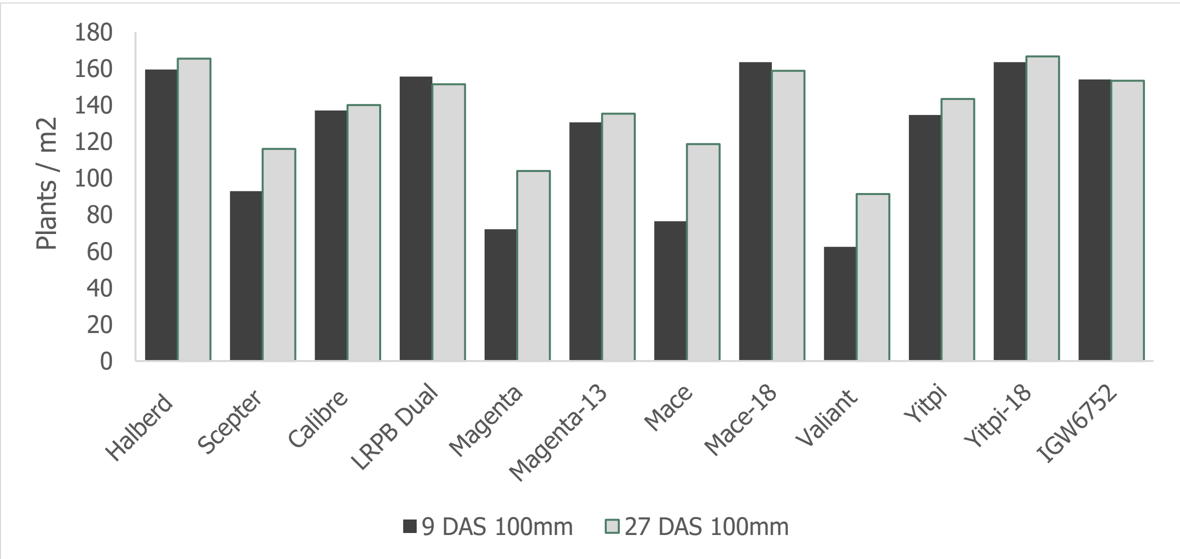


Figure 3224. Emergence counts for deep sown (100 mm) varieties at 9 and 27 days after sowing into moisture. LSD's(P=0.05) = 23 (9 DAS) and 28 (27 DAS) plants/m^2. CV's = 12.5 (9 DAS) and 11.5 (27 DAS).

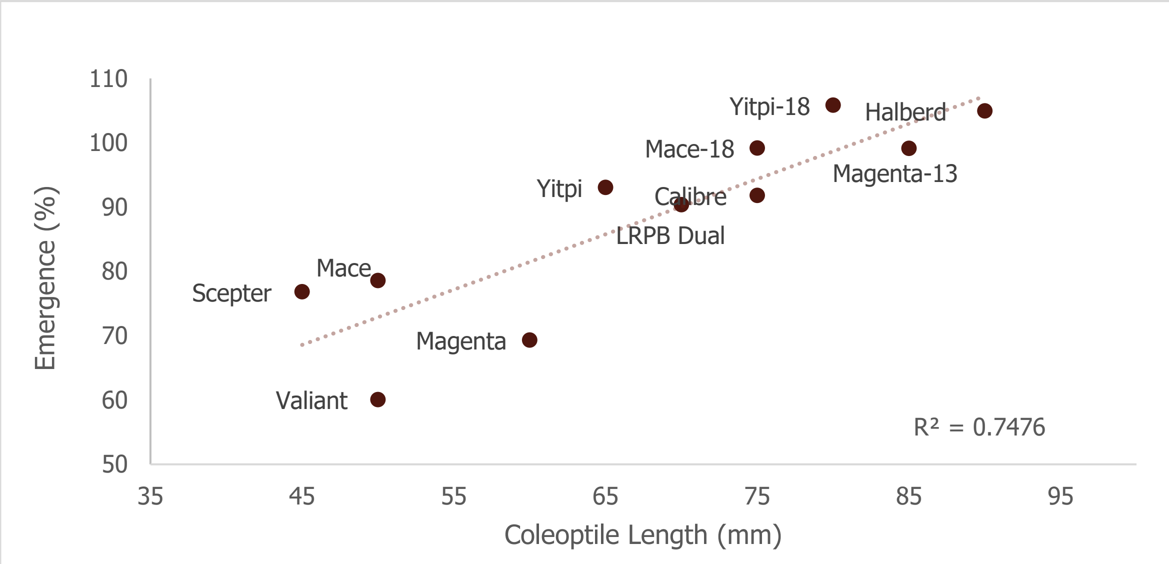


Figure 3325. Coleoptile length and emergence (calculated as a percentage of deep sown plant numbers to shallow sown plant numbers). Ballidu 27 DAS. 100 mm TOS 1 14th April

Pingaring

Deep (100 mm, April 27th) and shallow (35 mm, May 25th) sowings were both into soil moisture at Pingaring. There was no significant reduction in plant establishment numbers from sowing at 90 mm for Halberd, Dual, Bale, Mace-18 and Yitpi-18. Mace-18 had 37% greater emergence than Mace at depth, while Yitpi-18 had 29% greater plants emerged than Yitpi. Scepter and mace had the lowest emergence at ~60% (fig. 14).

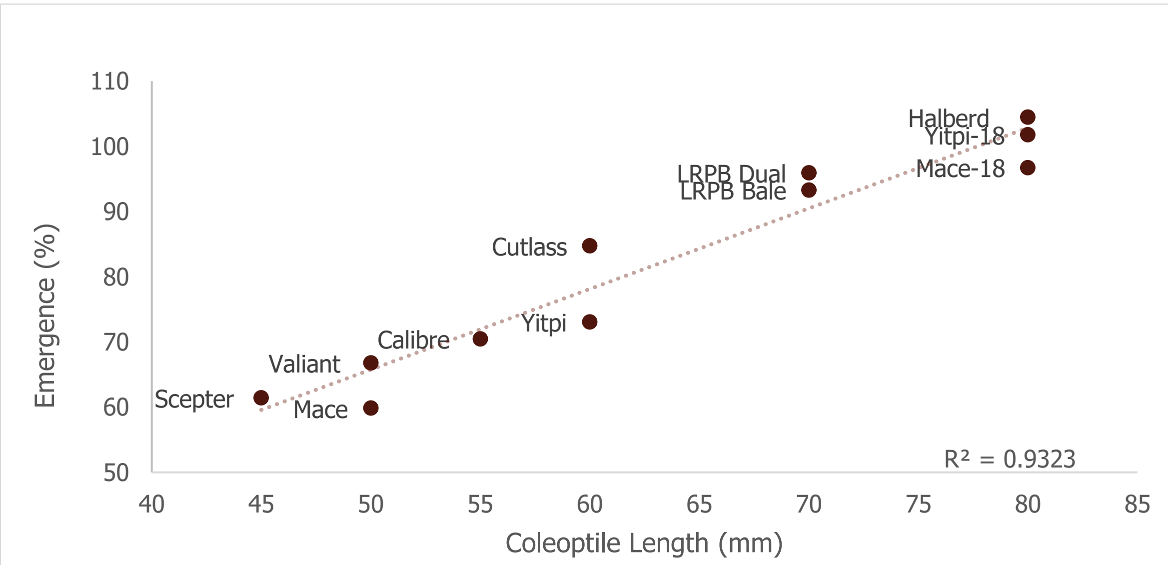


Figure 3426. Coleoptile length and emergence (calculated as a percentage of deep sown plant numbers to shallow sown plant numbers). Pingaring 90 mm 29 DAS

Grain yield found 90 mm TOS 1 wheat to have greater grain yields by 0.44 t/ha compared to 35 mm TOS 2 sowing, regardless of Variety. Halberd, Dual, Valiant and Yitpi (all longer season varieties) had significantly greater yields for TOS 1 deep sowing compared to their corresponding shallow TOS 2 yields. All other varieties had similar grain yields between deep and shallow sowings.

Esperance

There were two times of sowing in Esperance: deep (85 mm) occurred on the 26th of April, while shallow (35 mm) occurred on the 19th of May. Sowing deep did not result in a significant difference in wheat emergence when compared to shallow seeding for each variety.

Grain yield was equivalent for deep and shallow sowings for each variety, excluding Dual and Valiant which had marginally greater yields for deep TOS 1 seeding. Overall, factorial analysis found yields to be equivalent regardless of variety between the two depths.

This trial highlighted than there was no significant difference in emergency or yield between varieties of varying coleoptile length where there was a low degree of seeding depth separation.

Annual ryegrass competition

Assessments of annual ryegrass infestation at Meckering, Ballidu and Muntadgin found an increase in weeds where emergence rate was reduced.

Mace sown deep (90-120 mm) had increased weeds compared to Mace sown shallow at Muntadgin, while Mace-18 had similar levels of annual ryegrass infestation at both deep and shallow sowings. Due to increased vigour of Mace-18 in comparison to mace, shallow sowings (35 mm) found less annual ryegrass plants for Mace-18 than Mace, thought to be a result of increase plant biomass and canopy coverage conferred by the *Rht18* gene (figure 15).

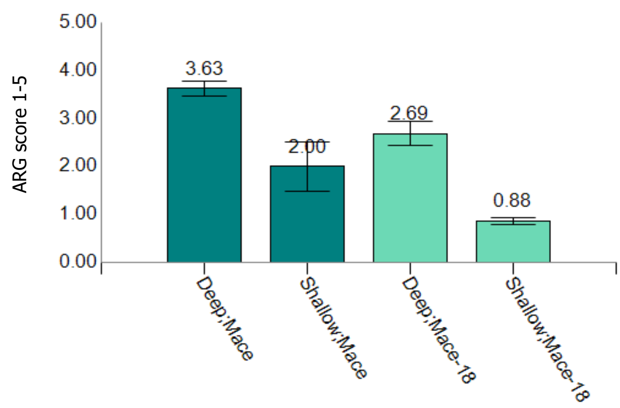


Figure 3527. Annual ryegrass infestation ratings on a 0-5 scale, where 0 = no annual ryegrass per square metre, 1 = 1 plant per square metre to 4 = 4 plants per square metre. 5 = 5+ plants per square metre.

This trend was also observed at Ballidu, where more vigourous varieties (Magenta-13 in particular) had the lowest infestation of annual ryegrass. This variety had the highest level of biomass and canopy coverage, and combined with a high emergence rate outcompeted grass weeds to a greater extend than Magenta (without the *Rht13* gene). Similarly, shallow Mace, shallow Mace-18 and deep-Mace-18 had similar weed infestation. Deep-sown mace had significantly higher weed infestation, nearly three times the level observed for Mace-18 sown deep (figure 16).

Meckering annual ryegrass counts found similar weed infestations between Mace and Magenta (9-14 weeds per square metre), while Mace-18 had significantly less grass weeds at both deep and shallow sowings. Vigour differences are highlighted in figure 37. The cleanest plots in terms of annual ryegrass infestation were observed for Magenta-13, the leafiest and more vigourous variety.

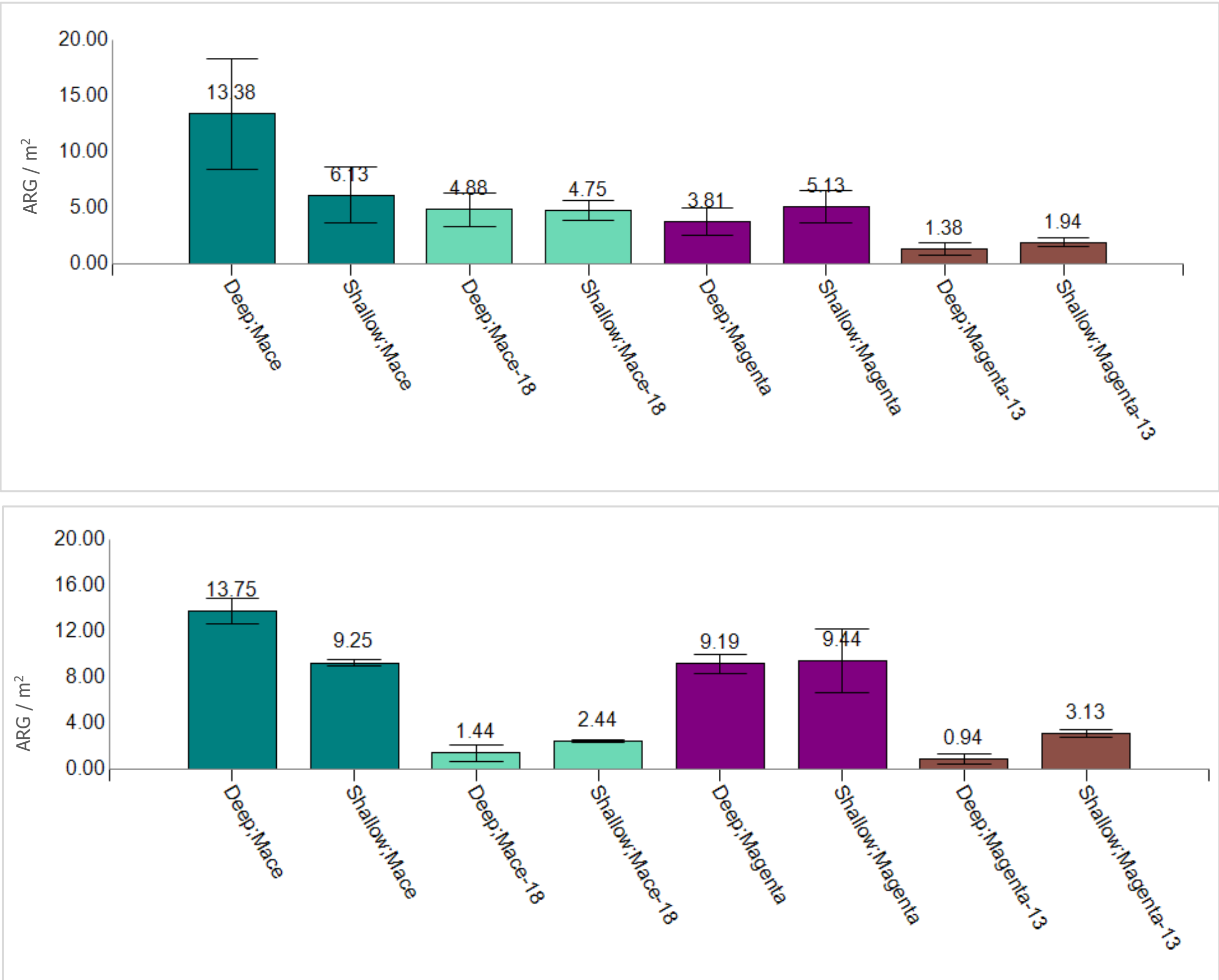


Figure 3628. Annual ryegrass counts at Ballidu (top) and Meckering (bottom). Error bars represent standard error. LSD (P=0.05) 7.2 plants/m2 (Meckering). LSD (P=0.05) = 30 plants/m2 (Ballidu)

Figure 3729. Left: Mace-18 sown at 120 mm in Meckering, with increased biomass and vigour compared to Mace (right). Highlights weed out competition from increased canopy coverage and nutrient competition.

Rhizoctonia

The grower's wheat crop in Ballidu exhibited *rhizoctonia* symptoms. Plant sampling of deep (100 mm) and shallow (35 mm) sown varieties found significantly greater disease infection (spear tipping of roots) of 35 mm dry-sown wheat, regardless of variety. Deep sown plant samples had very few disease symptoms by comparison (figures 18 and 19).

As *rhizoctonia* survives just below soil surfaces and has been found to benefit from summer rainfall events (green bridges) and break of seasons rainfall, sowing deep into moisture has been found to reduce the disease infection as roots avoid *rhizoctonia*, and establish in disease-free soil zones. Sowing deep into moisture with *Rht18* varieties is therefore thought to be a method of disease management for growers.

Figure 3830. Left: rhizoctonia in shallow (dry) sowing compared to deep (into moisture) sowing.

Figure 3931. Mace-18 sown 100 mm into moisture (left) and Mace sown 100 mm dry (right) with spear tipping and biomass reductions to roots. Ballidu

Herbicide tolerance

The herbicide screen in Meckering found no significant difference in emergence rates for any sowing depth or any IBS herbicide applied on the 28th of May. Plant sampling found coleoptiles to be thicker for most treatment containing Trifluralin in shallow (35 mm) sown plots (figure 20). Thickening was not as pronounced for the same treatments where sown deep (100 mm).

Similarly, coleoptile lengths showed shortening for various treatments for shallow sowings, particularly for 500 mL/ha Luximax + 2 L/ha Trifluralin treatment, and for 120 g/ha Terrain + 2 L/ha Trifluralin treatment. Deep sown treatments had little to no coleoptile shortening effects (figures 21 and 22).

Yield data did not show a significant difference between deep and shallow sowings for each herbicide treatment. On average, shallow sown Bale had greater yields than deep sown treatments. As both sowings were into a full moisture profile, shallow sown wheat had more rapid emergence and faster growth. The trial posed question to growers at extension days, who discussed how deeper could allow for a separation in weed-crop growth stages, particularly where a separation in germination of crop and weeds occurs following wheat sowing into moisture at depth.

Field walk discussions were made around exploiting the absence of nodal roots with pre-emergent herbicides when sowing deep, as mobile pre-emergent herbicides (Sakura, Luximax and Overwatch) may cause greater crop damage when washed into the root zone of shallow sown crops.

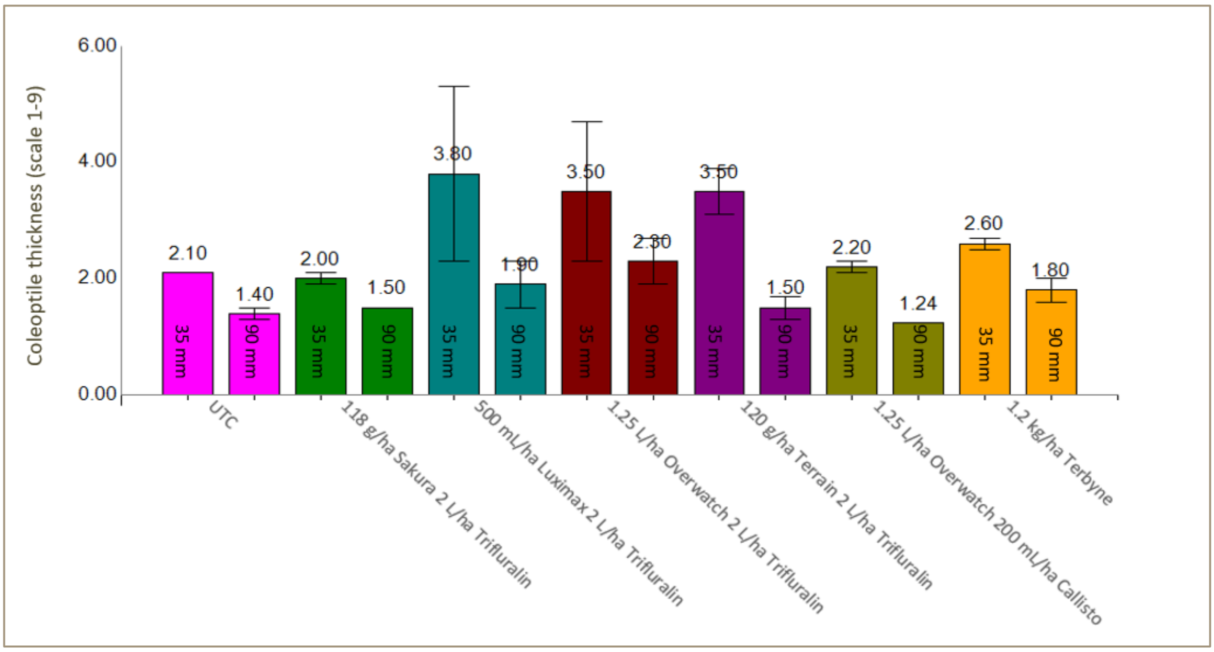


Figure 4032. Thickening of coleoptiles as a result of herbicide damage. 1-9 scale on 10 plant subsamples. IBS herbicides only.

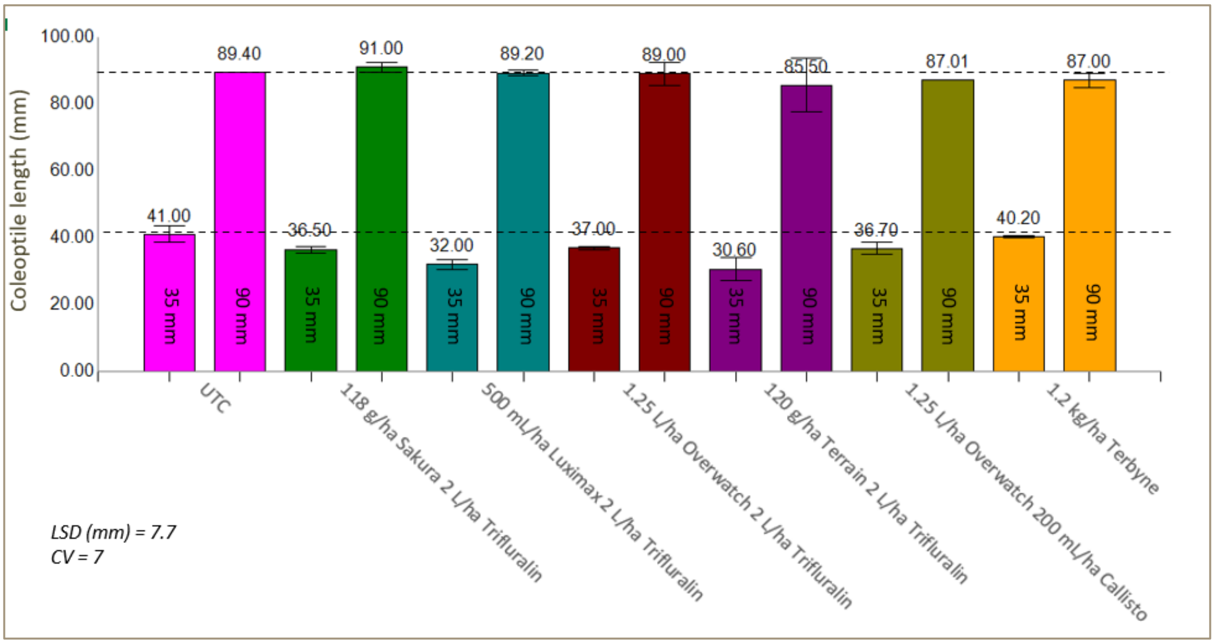


Figure 4133. Shortening of coleoptiles resulting from herbicide damage. Coleoptiles measured in mm. IBS herbicides only

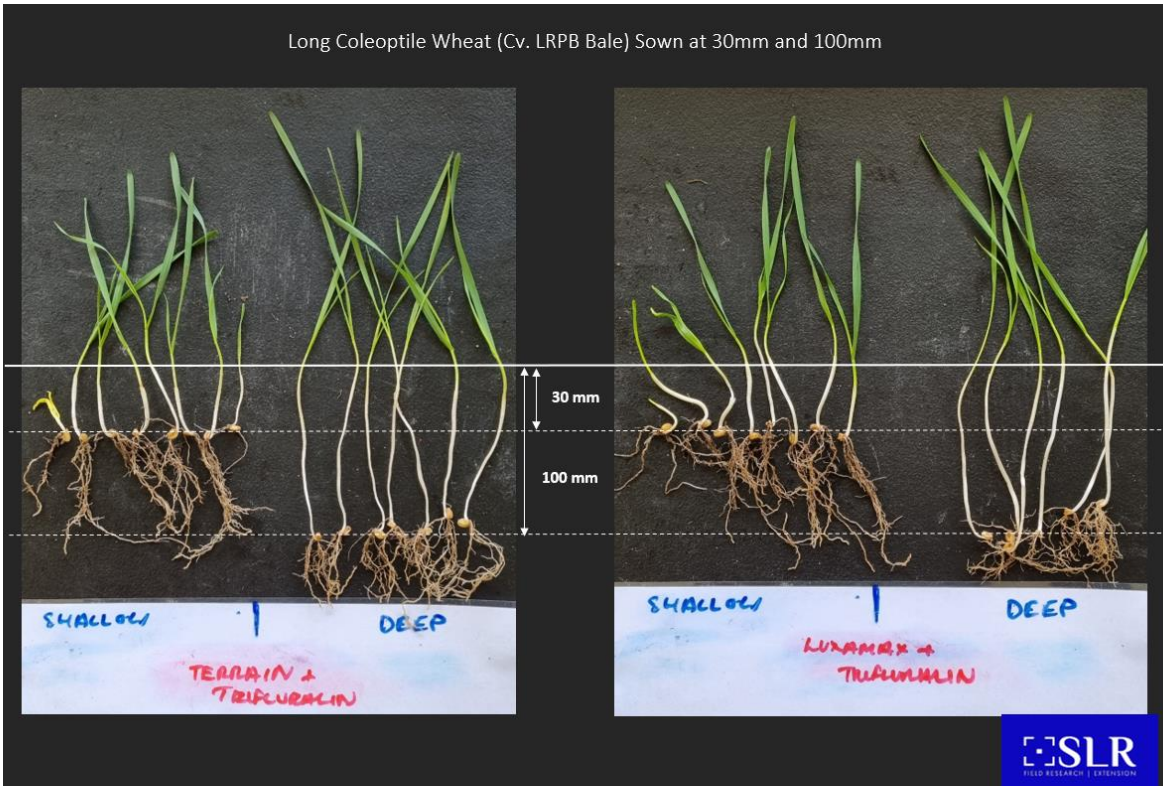


Figure 42. IBS treatments of Terrain® and trifluralin at standard rates (left) and Luximax® and trifluralin (right) highlighted increased crop safety for deep-sown wheat compared to shallow sown samples. Note thickening and shortening of coleoptiles of shallow sown wheat

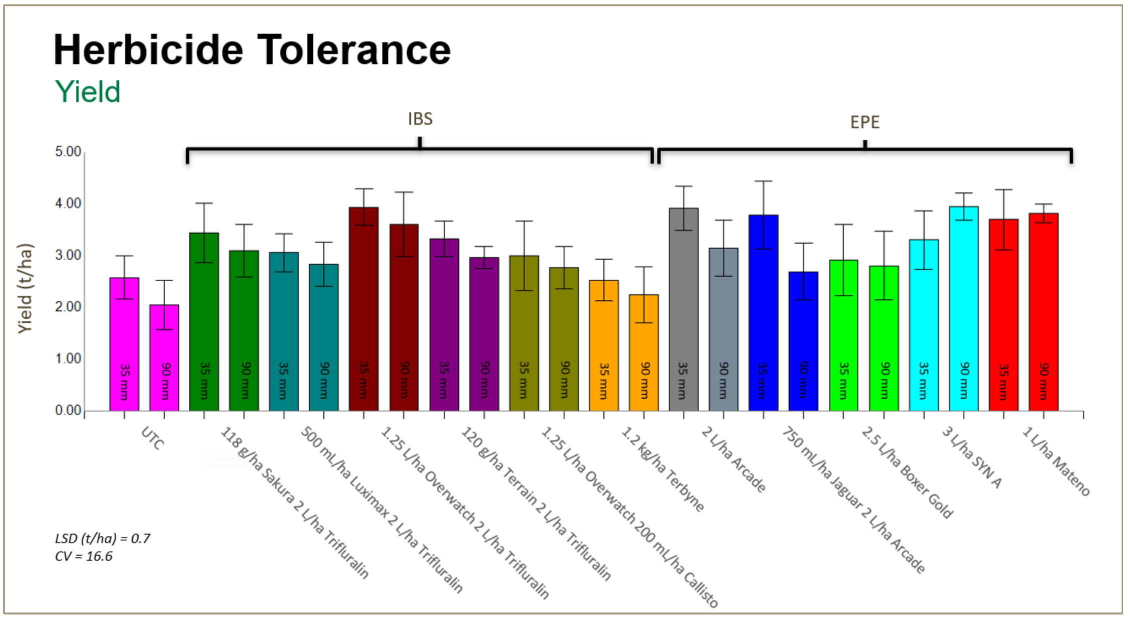


Figure 43. Grain yield of various herbicides applied pre and post emergent. Bale wheat (longer coleoptile variety) was sown at two depths.

CONCLUSION

Overall, there was a positive relationship with coleoptile length and wheat emergence in both 2021 and 2022 trials, where Halberd, Rht13 variety Magenta-13, and Rht18 varieties Mace-18 and Yitpi-18 consistently had 95-100% emergence when sown at depth. Shorter coleoptile varieties had significantly less plants emerge by comparison, such as Scepter (60-75% emergence from depth), and Mace (50-70% emergence from depth). Emergence was significantly faster for Mace-18 compared to varieties such as Scepter and Calibre when sown at depth (120 mm) into soil temperatures below 10 degrees Celsius. Mace-18's coleoptile elongated twice as much as Calibre's at 8 DAS.

The 2022 Muntadgin trial exhibited how longer coleoptile wheat had significantly more plants emerged and emergence at faster rates than shorter coleoptile varieties (100mm+ sowing) across uneven soil platforms following soil amelioration.

Rhizoctonia was prevalent in most shallow-sown plant samples (sown 35 mm dry) compared to deep sown wheat (100 mm into moisture) which exhibited very few spear-tipping symptoms in various 2021 trials, and at Ballidu in 2022.

More vigorous Rht18 varieties such as Mace-18 had significantly less annual ryegrass weeds in deep sown plots compared to Mace sown deep across three assessed locations (2022). Shallow-sown Mace-18 was more vigorous than Mace, also leading to weed out competition in conventional sowing situations. In Ballidu, deep-sown mace had significantly higher weed infestation (nearly three times the weed counts) than Mace-18 sown deep.

Overall, there was the same yield result (100-200 kg/ha difference) between shallow sown Mace and Mace-18 at 5 locations. At three of the five locations, Mace-18 yielded better than Mace when sown deep in 2022.

There were few differences in emergence and yield where various IBS and EPE herbicides were applied to shallow and deep sown wheat. Long coleoptile wheat was shown to improve crop safety where trifluralin was applied IBS, with 90 mm sown wheat, demonstrating reduced coleoptile thickening and greater seedling vigour across multiple treatments compared to 35 mm sown plots. Field walk discussions were made around exploiting the absence of nodal roots with pre-emergent herbicides when sowing deep, as mobile pre-emergent herbicides (Sakura, Luximax and Overwatch) may cause greater crop damage when washed into the root zone of shallow sown crops.

Future study will focus on further explore herbicide interactions with deep and shallow sowings, rhizoctonia interactions, applications with sowing to ameliorated soils, nutrition placement and availability at depth, and overall further data around emergence, vigour, soil/environment interactions and eventual grain yield of long coleoptile wheat varieties

IMPLICATIONS

By seeding earlier into moisture at depth, a longer growing season for root and shoot development can occur. This ultimately increases yield and can allow ever-growing cropping programs to be managed for timely seeding at the start of the season. However, there comes a point in the season that seeding at depth may reduce yields compared to convention seeding due to the delay in time to emerge through colder soils and a consequent loss of growing days.

Improving plant emergence rates, particularly where deep sown or in the case of furrow fill from wind/rain events, can also improve grower's yields. Furthermore, sowing deeper into moisture instead of dry seeding at conventional depths removes the reliance on a main season break for germination and plant establishment.

There may be many implications around herbicide use and crop safety, such as where soil renovation buries organic matter, increasing "hotness" of herbicides on wheat. Crop safety from greater separation between soil surface and roots, using post-emergent herbicides on more advanced plants, and a longer time to emerge allowing for a larger window to apply non-selective herbicides are more areas deeper sowing may improve crop safety and herbicide use. Sowing deeper may bring weed seeds to the surface that would not otherwise be germinated in conventional sowing, though this requires further investigation.

Emulating grower setups for deeper seeding would be the next stage of research, particularly around fertiliser placement. There may be machinery modifications necessary to supply optimal nutrition to growing seedlings, or reduce toxicity associated with liquid or granular fertilisers. While not quantified in this study, sowing deeper may prove to be more costly for growers, where an increase in fuel requirements would occur for seeding at depth. Further work around soil nutrition at depth is required to better understand nodal and seminal root acquisition of nutrition at various depths across soil types.

Implications around soil borne diseases such as *rhizoctonia* and crown rot require further study, particularly to determine if the reason deep-sown wheat plants tended to avoid disease was a result of timing, mechanical disturbance, physical separation from roots to disease layer, or early vigour outgrowing infection.

RECOMMENDATIONS

Further work around fertiliser placement, nutrition at various depths across soil types, implications around pre- and post-emergence herbicide crop safety, soil borne disease interactions, emergence in ameliorated soils, and pipeline of varieties to farmers are areas that growers have expressed the most interest in across two years of trial extension. Further study will allow for better understanding of such sectors.

Overall, long coleoptile wheat (particularly those with the *Rht18* gene) has many benefits to growers as highlighted in two years of trials across Western Australian wheat growing regions. While further work is required for the integration of new wheat genetics to growers, there are very few reasons why long coleoptile wheat would not be of benefit to growers on a national scale. This is particularly relevant in the face of shifting climates.