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FARMING SYSTEMS AND AGRONOMICS

FROST MITIGATION THROUGH VARIETY SELECTION AND MANAGEMENT OF WHEAT

Genevieve Clarke (BCG)

TAKE HOME MESSAGES

- Late grazing delayed flowering by up to three weeks.
- With adequate recovery conditions, grazed spring wheats yielded similarly to ungrazed.
- Grazing can shift flowering out of a high-risk window however, frost timing is unpredictable.

BACKGROUND

Frost damage is a risk to all winter cereals across the Wimmera and Mallee and can cause significant yield losses. No crop is resistant to frost damage so management is the only way to reduce this risk.

It is difficult to predict when frost will occur and a number of complexities come into play when understanding severity and whether it will cause crop damage. Damage can occur at all stages of development however crops are most susceptible to frost damage at flowering. While frost does not occur at the same time every season, avoiding flowering in a higher risk window is a good risk management tool. The optimal flowering windows for wheat—a window of reduced risk of frost and heat damage—have been defined for different locations (Table 1).

Table 1. Optimal flowering windows and soil types for locations across western Victoria, adapted from Flohr et al 2017. (a) and (b) refer to different soil types in the same location.

Location	Start of window	End of window	Soil type
Hopetoun (a)	7 September	11 September	Loamy sand
Hopetoun (b)	4 September	9 September	Clay loam
Walpeup	8 September	17 September	Swale loamy sand
Charlton	21 September	30 September	Clay loam
Longerenong	6 October	10 October	Clay

Targeting flowering for these optimal windows lowers risk in most years. Manipulation of flowering and spreading flowering timing across a wider window across a cropping program will also help to reduce the overall risk of frost damage. This can be achieved through variety selection, sowing date and management.

Matching phenology to sowing timing is one way to target these lower risk flowering windows. Maturity drivers of different wheat varieties will determine optimal sowing windows to align with flowering. Driven by either day length, temperature or a combination, spring wheats have the ability to be sown across a two to four week window. Winter wheats have an additional vernalisation requirement and a much wider sowing window. This is due to the need to accumulate cold temperatures before switching from vegetative to reproductive growth, providing a more stable flowering timing across a wider sowing window (Clarke et al, 2018).

Late grazing, or mechanical defoliation of early sown spring wheat after initiation of stem elongation, has been found to manipulate this flowering timing by up to two weeks, delaying maturity through removing biomass and apical growing tips (Porker et al, 2021). Yield recovery in some cases was equivalent to yields of early sown winter wheats that were not defoliated. While this is an uncertain result in low rainfall environments, there may be opportunity in some seasons to use it as a tool to manipulate flowering timing to avoid frost risk without the need to carry a winter wheat variety to provide an opportunity to open up the sowing window without risking early flowering (Porker, 2019).

This work further investigates the manipulation of flowering timing through sowing timing, variety selection and late grazing for frost mitigation in a low rainfall, frost-prone environment.

AIM

To investigate the effect of variety selection, late grazing and time of sowing on flowering timing of wheat production in a frost-prone environment.

PADDOCK DETAILS

Location:	Watchupga
Crop year rainfall (Nov–Oct):	234mm
GSR (Apr–Oct):	172mm
Soil type:	Sandy clay
Paddock history:	Vetch hay

TRIAL DETAILS

Crop type:	Wheat
Treatments:	Refer to Table 2
Target plant density:	130 plants/m ²
Seeding equipment:	Knife points, press wheels, 30cm row spacing
Sowing date:	Refer to Table 2
Replicates:	Four
Harvest date:	December 6
Trial average yield:	3t/ha

TRIAL INPUTS

Fertiliser: Granulock® Supreme Z + Flutriafol (200mL/100kg) @ 60kg/ha at sowing and 60kg/ha of urea applied 10 May and 80kg/ha urea applied 15 July.

Trial managed as per best practice for pests, weeds and disease.

METHOD

A replicated field trial was sown using a split plot design with time of sowing (TOS) as whole plots. Irrigation (10mm) was applied following TOS1 to ensure early establishment. TOS2 was established after rainfall. Simulated crash grazing was applied using a lawn mower on 21 June (TOS1) and 5 August (TOS2) at growth stage Z31/32 for spring wheats and tillering for winter wheats. Assessments included establishment scores, phenology observations, grazing biomass and feed value, hay yield and biomass at growth stage 71 just post-flowering, frost induced sterility scoring and grain yield and quality assessments.

Table 2. Trial treatment outline. Grazing simulated as defoliation by lawn mower.

Variety	Maturity	Time of sowing (TOS)	Grazing
Vixen	Quick spring	TOS 1: 15 April	Grazed
Razor CL Plus	Quick-mid spring	TOS 2: 7 May	Ungrazed
Scepter	Mid spring		
Catapult	Mid-slow spring		
Illabo	Quick winter		
DS Bennett	Mid winter		

RESULTS AND INTERPRETATION

Phenology

Maturity drivers differed across varieties in this trial (Table 3). Wheats are sensitive to thermal time, and increased development rate with increased temperatures, but can also have sensitivities to photoperiod (day length) and vernalisation (winter wheats). In the case of the spring wheats there is very weak photoperiod sensitivity so growth is dictated through temperature. Catapult has a weak sensitivity to photoperiod but a larger thermal requirement and is therefore slower to mature. The winter wheats require vernalisation to be satisfied, with DS Bennett having a larger requirement than Illabo, before a switch to vegetative growth and therefore were further behind in maturity at grazing timings than the spring wheats (Table 3).

Late grazing, after the initiation of stem elongation, delayed flowering timing by up to three weeks in the spring wheats (Table 3). Grazing had little effect on the flowering time of Catapult (long spring wheat) DS Bennett and Illabo (winter wheats) from either of the sowing times. This could be expected in the winter wheats as at the time of grazing they were not at elongation growth stages.

Table 3. Flowering dates, growth stage at grazing and delay in flowering from grazing across all treatments. TOS1 grazing applied with lawn mower on 21 June and TOS2 grazing applied 3 August.

Variety	TOS	Growth stage at grazing	Ungrazed flowering date	Grazed flowering date	Flowering delay from grazing (days)
Vixen	1	GS32	16 August	6 September	21
Razor CL Plus	1	GS31	16 August	6 September	21
Scepter	1	GS31	26 August	10 September	15
Catapult	1	GS31	2 September	6 September	4
Illabo	1	GS23	23 September	23 September	0
DS Bennett	1	GS24	7 October	7 October	0
Vixen	2	GS32	10 September	1 October	21
Razor CL Plus	2	GS32	10 September	23 September	13
Scepter	2	GS32	17 September	1 October	14
Catapult	2	GS31	21 September	27 September	6
Illabo	2	GS30	27 September	1 October	4
DS Bennett	2	GS27	12 October	15 October	3

Early biomass and grazing quality

Although irrigated after sowing, dry and warm early growing conditions limited biomass production, while phenology progressed quickly on TOS1 treatments. Early biomass (taken at grazing timing) found TOS2 produced much greater biomass than TOS1 at the time of grazing with an average of 1.7t/ha and 0.3t/ha respectively ($P < 0.001$).

TOS1 had higher feed quality at the time of grazing (Figure 1) however the amount of biomass available at this growth stage would realistically not have been enough to warrant grazing.

Decline in feed quality with progression of wheat maturity was evident, with lower feed value from varieties that were further along at the time of grazing.

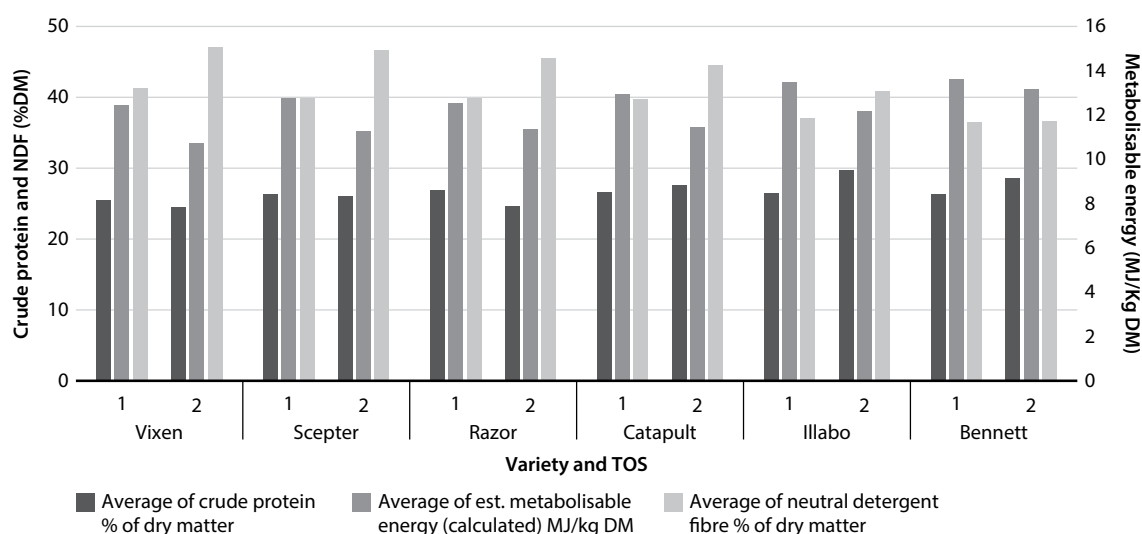


Figure 1. Crude protein, Neutral detergent fibre (NDF) (%DM) and metabolisable energy (MJ/Kg DM) of early biomass at grazing timing of respective sowing timings.

Hay yield and quality

Hay cuts were taken just after flowering (GS71) from ungrazed plots to assess hay as a salvage option. Cut date differed between time of sowing and variety. Time of sowing had no effect on final yield, however variety was a determinant of hay yield. The faster maturing varieties, Razor CL Plus and Vixen ultimately produced less hay than other trialled varieties (Table 4).

Table 4. Hay yield (t/ha) and cut timing (of each TOS) for different varieties.

Variety	Hay yield (t/ha)	TOS1 Cut date	TOS2 Cut date
DS Bennett	4.6 ^a	19 October	26 October
Scepter	4.2 ^{ab}	14 September	28 September
Catapult	4.2 ^{ab}	14 September	1 October
Illabo	4.1 ^{ab}	4 October	12 October
Razor CL Plus	3.8 ^b	6 September	23 September
Vixen	3.7 ^b	6 September	21 September
Sig. diff.	0.019		
LSD (P=0.05)	0.5		
CV %	12		

While there was some difference in hay quality indicators across varieties and sowing timing, all hay was high quality and would have received high quality results (Table 5).

Table 5. Hay yield (t/ha) and quality results from cuts taken as treatments reached Z71.

Variety	TOS	Hay yield (t/ha)	Crude Protein (% of DM)	Neutral detergent fibre (% of DM)	Digestibility (% of DM)	Metabolisable Energy (MJ/kg DM)	Water soluble carbohydrates (% of DM)
Vixen	1	3.6	12.5	50	67.7	10.0	19.8
Scepter	1	4.3	13.2	46.7	70.0	10.4	22.9
Razor CL Plus	1	3.5	12.0	49.2	67.4	10.0	20.9
Catapult	1	4.2	12.7	47.5	69.1	10.3	23.1
Illabo	1	3.9	13.3	43.5	74.2	11.2	27.3
DS Bennett	1	4.2	11.5	45.8	69.7	10.4	26.8
Vixen	2	3.8	12.5	43.4	72.0	10.8	27.7
Scepter	2	4.1	13.1	39.2	76.2	11.5	30.4
Razor CL Plus	2	4.0	12.7	43.1	73.5	11.0	28.7
Catapult	2	4.1	12.6	42.6	73.6	11.0	28.8
Illabo	2	4.8	13.2	44.7	72.4	10.8	25.0
DS Bennett	2	4.9	10.7	43.6	70.9	10.6	27.2

Grain yield and quality

Yield and grazing recovery were better in the earlier sown and earlier grazed treatments. At the first time of sowing, all varieties recovered and yielded similarly to ungrazed treatments. Grazing recovery in TOS2 was not as good, with larger differences in grazed and ungrazed yields seen in faster maturing varieties that were grazed at GS32 and did not have as long to recover before reaching maturity. DS Bennett benefitted from late season rains, yielding higher from later sowing and maturing. Illabo is a winter wheat but matures quickly after vernalisation and therefore TOS2 treatments did not benefit from late rains to the same degree as DS Bennett (Figure 2).

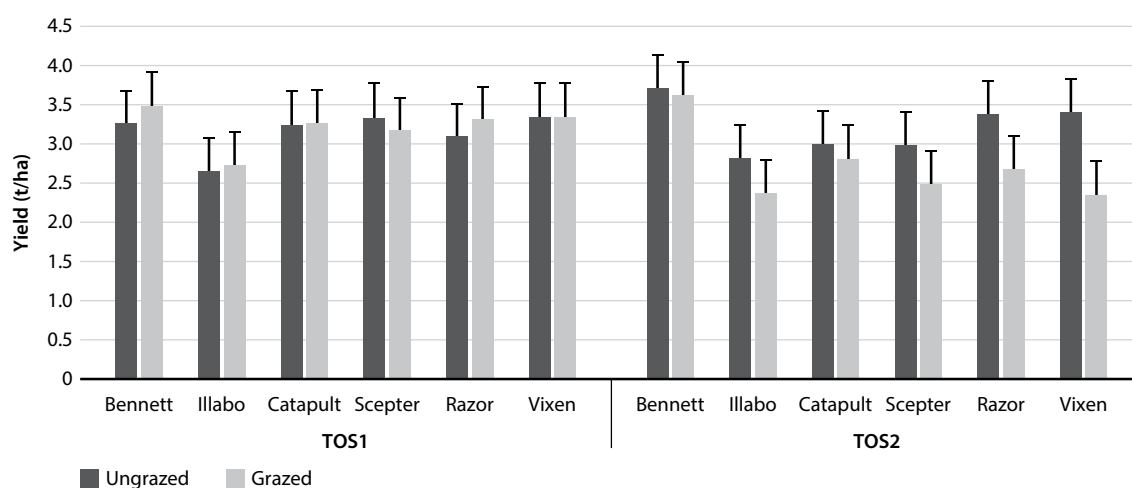


Figure 2. Mean grain yield (t/ha) of all trial treatments. TOS*Var*Graze. Stats: P=0.007, LSD 0.487t/ha, CV 6.1%.

Ungrazed treatments returned higher grain protein than grazed treatments (Table 6). This is likely due to nitrogen being used for grazing recovery in those treatments where it was needed and mobilised in grain for treatments that did not have to recover from grazing. Grazing also resulted in higher test weights (Table 6).

Table 6. Mean protein (%) and test weight (kg/hL) of grazed and ungrazed treatments across the times of sowing.

Treatment	Protein (%)	Test weight (kg/hL)
Grazed	13.1 ^a	78.4 ^a
Ungrazed	13.8 ^b	77.8 ^b
Sig. diff.	<0.001	0.002
LSD (P=0.05)	0.3	0.3
CV %	5.0	1.1

Protein was high across the trial. Lower yields in TOS2 treatments can be linked to higher protein with the exception of the winter varieties that yielded similarly across the sowing timings. Screenings were higher in TOS1 spring treatments, likely attributed to moisture stress during grain fill, however no treatments were above thresholds. Test weights were similar between sowing timings within a variety with the exception of winter wheats that returned a higher test weight from TOS2, displaying their ability to take advantage of late rains during grain fill (Table 7).

Table 7. Mean protein (%), test weight (kg/hL) and screenings (%) for varieties at different sowing times.

TOS	Variety	Protein (%)	Test weight (kg/hL)	Screenings (%)
1	Illabo	15.4 ^a	73.8 ^e	1.1 ^b
2	Illabo	14.6 ^{ab}	76.8 ^d	0.9 ^a
2	Vixen	13.9 ^{bc}	77.5 ^d	1.4 ^{cd}
2	Scepter	13.7 ^{cd}	78.5 ^c	1.5 ^{de}
1	Vixen	13.4 ^{cd}	77.6 ^d	2.0 ^f
1	Scepter	13.2 ^{cde}	78.9 ^c	2.0 ^f
2	Catapult	13.1 ^{cde}	78.7 ^c	1.4 ^{cd}
1	DS Bennett	13.1 ^{cde}	80.3 ^b	1.3 ^{bc}
1	Catapult	13.0 ^{cde}	78.7 ^c	1.6 ^e
2	Razor CL Plus	13.0 ^{cde}	77.2 ^d	1.4 ^{cd}
2	DS Bennett	12.7 ^{de}	81.6 ^a	1.4 ^{cd}
1	Razor CL Plus	12.4 ^e	77.2 ^d	1.9 ^f
Sig. diff. (TOS* Var)		0.033	<0.001	<0.001
LSD (P=0.05)		0.7	0.4	0.2
CV %		5	1.1	13.6

Frost timing and damage

The site experienced 191 hours at or below zero degrees at canopy height across 33 events throughout the growing season. Significant events occurring regularly through September placed crops flowering in that window at risk of experiencing frost (Table 8).

Table 8. Notable frost events at the trial site throughout September around the optimal flowering window for this environment.

Date	Minimum temperature at canopy height reached (°C)	Consecutive hours below zero
7 September	-0.4	0.5
8 September	-2.6	6.5
14 September	-4.9	7.75
15 September	-4.6	6.75
16 September	-3.4	8
19 September	-0.9	6.5
21 September	-0.1	0.25
24 September	-1.4	2.75
26 September	-5.1	8.5

Higher levels of frost induced sterility were seen across the second time of sowing at an average of 13.2% compared to 10.3% in earlier sown treatments (P=0.021). Although flowering within the lower risk window, the timing of frost events this season resulted in greater damage which was reflected in final yield (Figure 3).

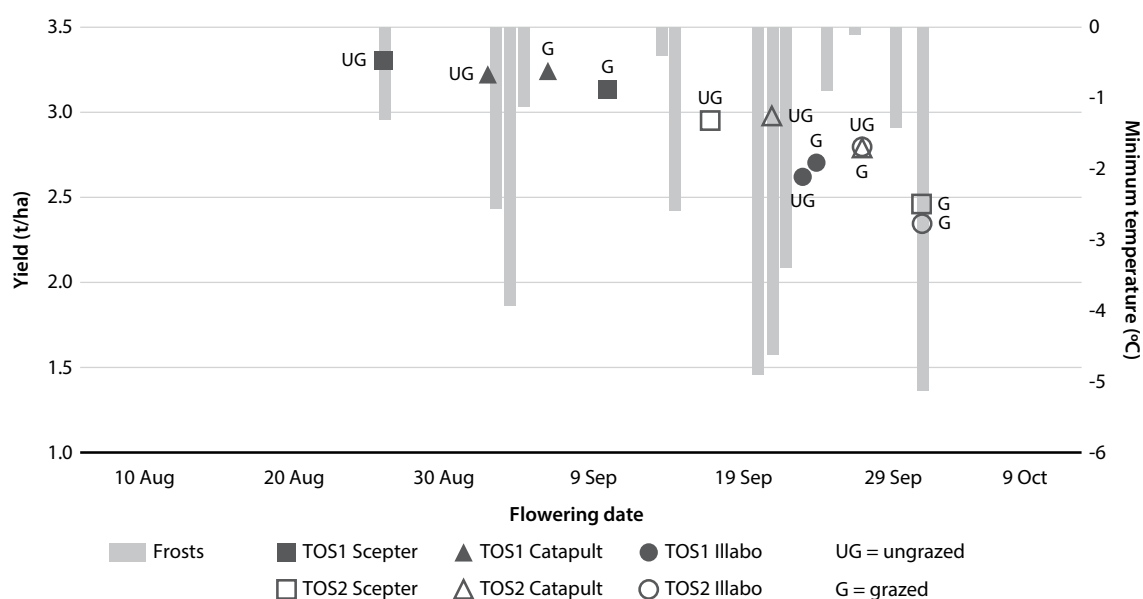


Figure 3. Yield (t/ha) of a selection of varieties and their respective flowering dates overlaid with frost events (°C). TOS*Var*Graze. Stats: P=0.007, LSD 0.487t/ha, CV 6.1%.

Grazing reduced sterility levels due to delaying flowering timing in TOS1, mostly to the first week of September and the beginning of October which, in this season meant frost events experienced in the second and third week of September caused less sterility in these grazed treatments on average, at 9.6% compared to 13.8% sterility ($P < 0.001$).

COMMERCIAL PRACTICE AND ON-FARM PROFITABILITY

Time of sowing, grazing after stem elongation and variety selection all proved to be tools for manipulating flowering timing in wheat. The exception was winter wheats that retain a more stable flowering period regardless of sowing timing due to their requirement for vernalisation. Grazing after stem elongation delayed spring wheat flowering time by up to three weeks, pushing early sown treatments into an optimal flowering window.

Understanding how to manipulate the time of flowering in wheat can be an important risk management tool, allowing the targeting of a reduced risk flowering window. This window is identified as an optimum period for flowering, providing conditions in the majority of seasons where a crop is flowering in the 'sweet spot' between frost risk and heat shock. Frost events during September 2021 presented a high risk of yield loss in varieties flowering within the identified optimal window for this environment.

While the 2021 season has proven time of sowing isn't always a frost avoidance tool if frosts occur late, grazing can provide an option to slow the maturity of a quick variety that for one reason or another—for example, unexpected rain after dry sowing—is moving too quickly to promote flowering in a less risky window. Simulated grazing with a lawn mower is much more even and more representative of crash grazing with a high stocking rate over a short period. This may provide some feed to stock during the autumn feed gap.

In some cases grazing improved the gross margin compared to grain production, particularly where no yield loss occurred as a result (Table 9).

Table 9. Grazing gross margin, dual purpose gross margin and ungrazed grain gross margin. DSE grazing days calculated including estimated 20% wastage. *based on \$77/DSE gross margin according to PIRSA 2021 gross margin guide.

TOS	Variety	DSE grazing days	Gross margin prime lamb/ merino ewe enterprise grazing value (\$/ha)*	Grazed treatment yield (t/ha)	Yield loss from grazing (t/ha)	GM dual purpose graze grain (\$/ha)	GM Grain only (ungrazed) (\$/ha)
1	Vixen	199	43	3.3	0.0	1240	1197
1	Scepter	200	43	3.1	0.2	1176	1192
1	Illabo	200	43	2.7	0.0	1017	945
1	Catapult	201	44	3.2	0.0	1209	1158
1	Razor CL Plus	216	47	3.3	0.0	1092	978
1	DS Bennett	192	42	3.5	0.0	1416	1030
2	Vixen	1436	311	2.3	1.1	1148	1216
2	Illabo	1136	246	2.3	0.4	1091	1004
2	DS Bennett	1255	272	3.6	0.0	1416	1171
2	Scepter	1216	263	2.5	0.5	1150	1064
2	Catapult	1294	280	2.8	0.2	1282	1070
2	Razor CL Plus	1022	221	2.7	0.4	1065	1067

A mower or slasher may be used to achieve even defoliation, but this doesn't allow for feed value from biomass removed to be realised.

Grazing recovery requires suitable growing conditions, ample nutrition and time. After early sowing and grazing in June, spring wheats were able to recover without losing yield. Grazing on later sown treatments in August did not reflect these results with large differences in yield seen between grazed and ungrazed early maturing, slightly further progressed varieties due to warming temperatures, tough conditions and a lack of time to recover before grain fill. Results suggest late grazing, by about 20 June, allows time for yield recovery in quick spring wheats but should ideally occur before GS32.

Enterprise diversification is another way to manage risk. If a crop is frosted at flowering there may be the opportunity to cut it for hay as a salvage option. A good understanding of the breadth and severity of damage is required before making this decision, along with considering economics. The return from hay this season was not as profitable as grain, largely because of prices (Table 10).

Yield trends highlighted the loss of potential with later sowing/flowering, particularly in spring varieties. While early sowing opens the potential of flowering in a high frost risk window (but with low heat shock risk), it allows for time to build early biomass and yield potential where later sown crops don't have the same opportunity.

Grazing or defoliation may provide a tool to delay flowering in certain situations, however yield potential can be lost, depending on timing, seasonal conditions and fertiliser management. Increasing machinery sizes will result in larger seeders covering ground more efficiently and offering the ability to tighten sowing windows. In frost-prone environments, particularly frost-prone paddocks, steering a crop to flower in the optimal window will aid overall farm business risk management.

Research suggests frost damage is likely to occur when tissue temperatures reach -3.5°C and will be more significant at lower temperatures and when plants are moisture stressed (NSW DPI, 2008). The dry and frosty spring experienced this season did not favour later sown spring wheats in this trial. There is no genetic resistance to frost so it is impossible to avoid frost all the time but risk can be minimised with variety selection and careful management.

Table 10. Gross margin for hay and grain production across treatments. Prices taken from *The Weekly Times* 22 December 2021 based on cereal hay at \$170/t, assuming three bales per tonne and GrainFlow website (AWB cash price) for wheat Birchip 23 December 2021 \$318.25 ASW1 and \$360 H1.

Variety	TOS	Hay yield (t/ha)	Gross margin (\$/ha)	Gross margin grain (ungrazed) (\$/ha)	Grain quality
Vixen	1	3.6	612	1197	H1
Scepter	1	4.3	731	1192	H1
Razor CL Plus	1	3.5	595	978	ASW1
Catapult	1	4.2	714	1158	H1
Illabo	1	3.9	663	945	H1
DS Bennett	1	4.2	714	1030	ASW1
Vixen	2	3.8	646	1216	H1
Scepter	2	4.1	697	1064	H1
Razor CL Plus	2	4.0	680	1067	ASW1
Catapult	2	4.1	697	1070	H1
Illabo	2	4.8	816	1004	H1
DS Bennett	2	4.9	833	1171	ASW1

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COMPARING SEEDER PERFORMANCE WHEN ESTABLISHING BEANS

Genevieve Clarke (BCG), Glenn McDonald (University of Adelaide)

TAKE HOME MESSAGES

- Precision planters will place beans more evenly than conventional seeders.
- More even placement did not result in equivalent yields at lower sowing rates.
- Precision planters are a large investment for an unpredictable return.

BACKGROUND

Seeder selection and setup is known to have an impact on crop establishment. In years with a dry start such as 2021, differences between seeders, seeder setup and tweaks are likely to become evident when conditions are challenging.

BCG has run trials investigating crop establishment using different seeder types, sowing rates and row spacings over the past four seasons with the aim of optimising plant establishment in Wimmera and Mallee environments. Part of this work has involved comparison of conventional and precision (singulation) seeding systems.

More commonly used in summer crops, precision planters for winter grains have been limited. Seed size, shape and high sowing rates contribute to the challenges of being able to adapt this technology. In theory, precision planters are able to evenly distribute seeds along a row providing equal area for each seed to draw resources from, allowing for optimal yield from each plant. With such distribution, the question is: will this allow for sowing rates to be dropped without compromising yield equivalent to a conventional seeder?

The research conducted by BCG and across the broader project through South Australia and Western Australia has returned varying results across environments and seasons. Research has focused on lentils, canola and faba beans focusing on higher value seed crops to investigate whether savings in seed cost might justify investment in new machinery.

A faba bean trial at Rupanyup in 2020 found bean yield was established at 16 plants/m² with more even seed placement achieved using a precision seeder than conventional. Larger plants showed some biomass compensation at lower plant densities however this did not necessarily translate into equivalent compensation in yield (Clarke and McDonald 2020). For Rupanyup, 2020 was a decile 6 season with a good break, dry winter and average spring.

This research aims to provide further data around the effects of row spacing, plant density and seeder type on bean establishment and yield in the Wimmera over a different season.

AIM

To determine the effect of sowing density, row spacing and seeder type on plant establishment and yield in faba beans in the Wimmera.

PADDOCK DETAILS

Location:	Wallup
Crop year rainfall (Nov–Oct):	256mm
GSR (Apr–Oct):	198mm
Soil type:	Clay
Paddock history:	Chickpeas

TRIAL DETAILS

Crop type:	Faba beans (Bendoc)
Treatments:	Refer to Table 1
Target plant density:	Refer to Table 1
Seeding equipment:	Refer to Table 1
Sowing date:	7 May 2021
Replicates:	Four
Harvest date:	30 November
Trial average yield:	3.4t/ha

TRIAL INPUTS

Fertiliser:	Ammonium polyphosphate @ 50L/ha at sowing
Herbicide:	Managed as per best practice
Insecticide:	Managed as per best practice
Fungicide:	Managed as per best practice
Seed treatment/innoculant:	P Pickle T® @ 200mL/100kg

METHOD

A replicated field trial was established in a split plot design with seeder type/row spacing as the main plot and plant density as the sub plot. Assessments included establishment rate, establishment counts, interplant distance measurements, flowering biomass, NDVI, yield and quality.

Table 1. Trial treatment outline.

Seeder type	Row spacing	Plant density (plants/m ²)
Conventional disc	12 inch	10
Precision disc	15 inch	15
		20
		30

RESULTS AND INTERPRETATION

ESTABLISHMENT AND SEED PLACEMENT

Dry conditions at sowing favoured the disc seeder however extended dry conditions after sowing meant plants did not begin to emerge until one month following sowing. Establishment rate and seedling depth did not differ significantly between the two seeders. Final establishment counts found all treatments established below the target density, averaging around 90% of the intended rate. This is likely due to dry conditions and relatively shallow seed placement (Table 2).

Table 2. Mean established plants (plants/m²) and percentage of target density achieved across density treatments.

Target density (plants/m ²)	Established plants (plants/m ²)	Percentage of target density (%)
10	9 ^a	86
15	14 ^b	91
20	17 ^c	87
30	27 ^d	89
	Sig. diff.	<0.001
	LSD (P=0.05)	1.5
	CV%	13

The number of established plants differed between seeder type, with the precision planter establishing higher overall plant numbers at 17.5 plants/m² compared to 15.6 plants/m² for the conventional seeder (P=0.019). This difference, while significant could be the result of seeds sown at a rate calculated from an average grain weight under the conventional treatment compared to actual seed number as distributed by disc singulation.

Differences in seed placement between the two seeder types were visually distinguishable with much more even distribution of seed in precision planter treatments (Figure 1).



Figure 1. Conventional seeder narrow spacing 20 plants/m² target (left) and precision planter narrow spacing 20 plants/m² target (right).

Interplant distance measurement assessments reflected this observation with much lower variation in seed placement found in precision planter treatments than conventional (Table 3).

Table 3. Mean variability in seed placement (CV%) across seeders.

Seeder type	Variability in seed placement (CV%)
Precision	38 ^a
Conventional	93 ^b
Sig. diff.	<0.001
LSD (P=0.05)	5.6
CV%	12

BIOMASS AND YIELD

Biomass at flowering indicated that only plant density was having an effect, with the highest biomass at the highest plant density target of 30 plants/m² (Table 4). Yield also reflected plant numbers, with the target densities decreasing in yield with plant numbers (Table 4).

Table 4. Biomass at flowering (t DM/ha) and yield (t/ha) across different target densities.

Target Density (plant/m ²)	Flowering biomass (t/ha)	Yield (t/ha)
30	2.1 ^a	4.0 ^a
20	1.6 ^b	3.5 ^b
15	1.5 ^b	3.2 ^c
10	1.1 ^c	2.9 ^d
Sig. diff.	<0.001	<0.001
LSD (P=0.05)	0.3	0.2
CV%	23.1	6.7

The precision planter yielded higher than the conventional seeder, averaging 3.5t/ha and 3.3t/ha respectively ($P=0.001$). This may be linked to the higher plant establishment achieved by the precision planter and the trend of higher plant density and yield (Figure 2).

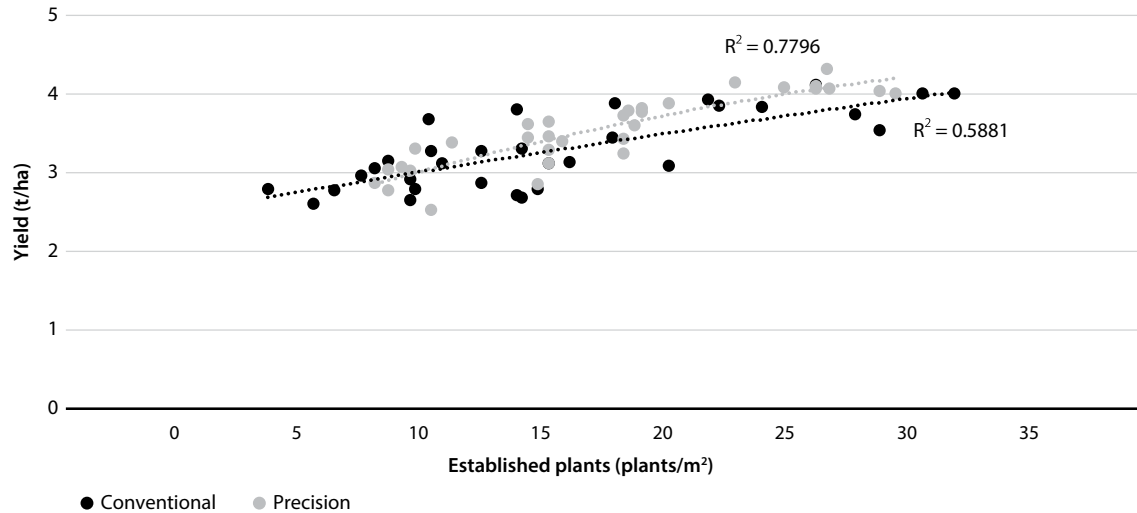


Figure 2. Established plant number (plants/m²) against grain yield (t/ha) across treatment plots of different seeder types.

Plant size increased at densities below 30 plants/m² target but were similar at lower density (Table 5). The small difference between plant size is likely due to the late start and dry seasonal conditions limiting early biomass production and the ability of faba bean plants to compensate for low plant density.

Table 5. Mean plant size (g DM at flowering) across densities.

Target density (plants/m ²)	Plant size (g DM at flowering)
10	9.4 ^a
15	9.5 ^a
20	8.5 ^{ab}
30	7.8 ^b
Sig. diff.	0.024
LSD (P=0.05)	1.2
CV%	19

COMMERCIAL PRACTICE AND ON-FARM PROFITABILITY

Different seasonal conditions have a large impact on plant growth and yield. With a tough start and slow early growth, higher plant numbers resulted in greater biomass production and higher yield; the crop had limited ability to compensate for low plant numbers. Whereas, in 2020, with good early moisture for establishment and growth, yield was optimised at only 16 plants/m², just over half that of this year. Difficulty in predicting seasonal potential at sowing limits the ability to match sowing rates to the season. The compensation response of low plant numbers and row spacing for yield is also difficult to predict.

Results from similar research last season are consistent with this season in that grain yield was strongly influenced by plant density. When selecting a sowing rate, it is important to calculate the seed cost at different rates. This season, the highest sowing density yielded highest as well as resulting in the highest return (Table 6).

Table 6. Partial gross margin (income minus seed cost) for sowing densities. Faba bean seed at a price of \$0.59/kg based on PIRSA gross margin guide 2021 and grain price of \$490/t (22 December Murtoa).

Target density (plants/m ²)	Established density (plants/m ²)	Seed cost (\$/ha)	Grain yield (t/ha)	Net income (\$/ha)
10	9 ^a	31	2.9 ^d	1390
15	14 ^b	46	3.2 ^d	1522
20	17 ^c	62	3.5 ^b	1653
30	27 ^d	92	4.0 ^a	1868

While row spacing had no effect on yield this season, understanding the ideal row spacing for your system and how this will affect competition and disease should be considered when deciding whether it is practical to manage.

Investment in machinery is a big business decision and should be made to suit the system, the grower and economics. The need for support to transition into precision planters has been identified as a major factor in adopting and retaining the system.

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ACKNOWLEDGEMENTS

This research was funded by the GRDC as part of the 'Optimising plant establishment, density and spacings to maximise crop yield and profit in the southern and western regions' project (9176134) in collaboration with The University of Adelaide.

ESTABLISHING CANOLA ON MARGINAL MOISTURE

Genevieve Clarke (BCG), Glenn McDonald (University of Adelaide)

TAKE HOME MESSAGES

- Marginal rainfall events result in false germination and patchy establishment.
- In marginal moisture conditions it is better to sow shallow rather than deep.
- Hybrid varieties are less sensitive to sowing depth than open pollinated.
- Sowing too deep (>30mm) reduced yield.

BACKGROUND

Dry sowing is a common occurrence in Mallee and Wimmera cropping systems however, without a reliable forecast this can be a gamble for good establishment, particularly on a small seeded crop like canola.

2021 saw a lot of dry sowing in the Mallee and Wimmera and with little summer rain and unreliable forecasts some growers made the decision to drop canola out of the rotation for the season.

Where it remained in rotation, establishment quality around the region was varied.

A responsive trial was established at Watchupga to investigate the impacts of different factors on canola establishment under marginal moisture conditions.

AIM

To investigate the effect of variety selection, sowing rate and sowing depth on canola establishment in marginal soil moisture conditions in the Southern Mallee.

PADDOCK DETAILS

Location:	Watchupga
Crop year rainfall (Nov-Oct):	234mm
GSR (Apr-Oct):	172mm
Soil type:	Sandy Clay
Paddock history:	Vetch hay

TRIAL DETAILS

Crop type:	Canola
Treatments:	Refer to table 1
Target plant density:	Refer to table 1
Seeding equipment:	Knife points, press wheels, 30cm row spacing
Sowing date:	19 April
Replicates:	Four
Harvest date:	6 December
Trial average yield:	1.4t/ha

TRIAL INPUTS

Fertiliser:	Granulock®Z @ 60kg/ha at sowing (below seed), Urea @100kg/ha July 9 and Urea @ 80kg/ha August 11
Herbicide:	Managed as per best practice
Insecticide:	Alpha-cypermethrin @ 400mL/ha October 6, Sulfoxaflor @ 50g/ha and Alpha-cypermethrin @ 400mL/ha October 26
Fungicide:	Prosaro® @ 450mL/ha July 21, Aviator Xpro® @ 400mL/ha 6 October
Seed treatment:	Jockey® @ 2000mL/100kg and imidacloprid @ 400mL/100kg

METHOD

A replicated field trial was established as a split plot design with sowing depth as the whole plot and variety and sowing rate as subplots. Assessments included establishment rate counts, final establishment counts, seedling depth assessment, flowering biomass, grain yield and quality assessments.

Table 1. Trial treatment outline.

Variety	Sowing depth target	Sowing rate (equivalent kg/ha rate ATR stingray/Hyola 350TT)
ATR Stingray (OP)	Shallow (~10mm)	50 plants/m ² (2.4kg/5.1 kg)
Hyola 350TT (hybrid)	Normal (~20mm)	60 plants/m ² (2.9kg/6.1kg)
	Deep (~35mm)	

From November 2020 through to March 2021 the site received 44mm of rain. There was very little stored moisture. In April, there was only one rainfall event of 1.2mm received.

RESULTS AND INTERPRETATION

SEEDLING DEPTH

Prior to sowing, three different depths were set for the seeder, targeting a shallow, normal and deep sowing for canola. Measurements were taken following emergence and found no statistical difference in the depth of shallow and normal seedlings however, deep sown treatments were significantly deeper (Table 2). While the measurements suggest limited differences between treatments, it is important to remember that measurements were taken on established seedlings and there may have been seeds at different depths (potentially very close to the surface) that did not establish.

Table 2. Average seedling depth (mm) achieved at different depth targets across the trial.

Sowing depth target	Established seedling depth (mm)
Shallow	21 ^a
Normal	23 ^a
Deep	35 ^b
Sig. diff.	<0.001
LSD (P=0.05)	2.4
CV%	18.5

RAINFALL AND ESTABLISHMENT

Emergence did not begin to occur until a month following sowing, after the receipt of a 4.6mm rainfall event. Three previous rainfall events of 1–1.4mm did not trigger germination. Not all treatments began to emerge at this time, however. The majority of plants emerging following this event were Hyola 350TT at the shallow and normal depth. Emergence rate data found that the hybrid was able to establish higher numbers at a faster rate on less rainfall and is less sensitive to sowing depth than the open pollinated, small seeded ATR Stingray (Figure 1).

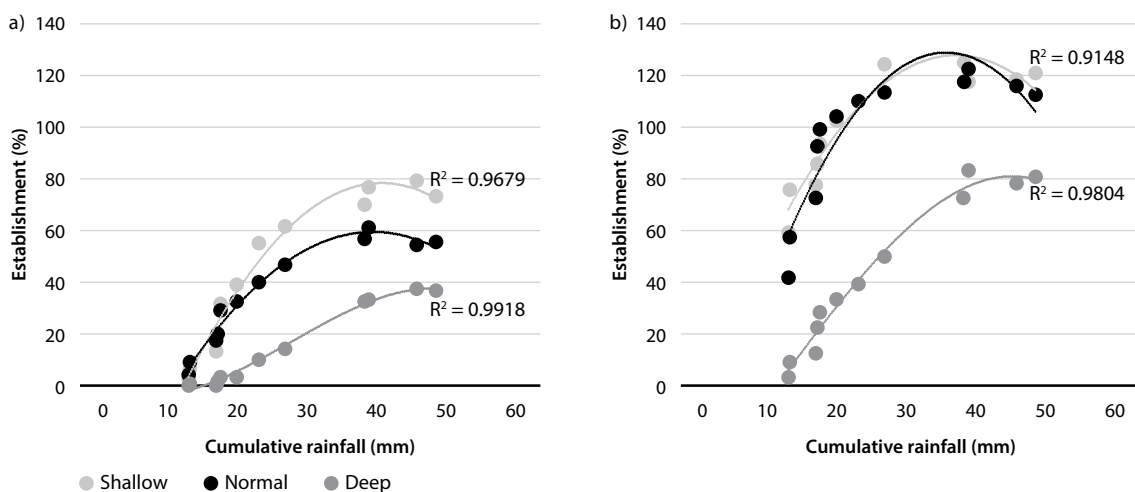


Figure 1. a) ATR Stingray establishment (%) at 50 plants/m² sowing rate and b) Hyola350TT establishment (%) at 50 plants/m² sowing rate against cumulative rainfall (mm). Data collected between 29 and 79 days following sowing.

Final establishment was somewhat patchy. It was not affected by sowing rate but was reduced from sowing deep (Figure 2).

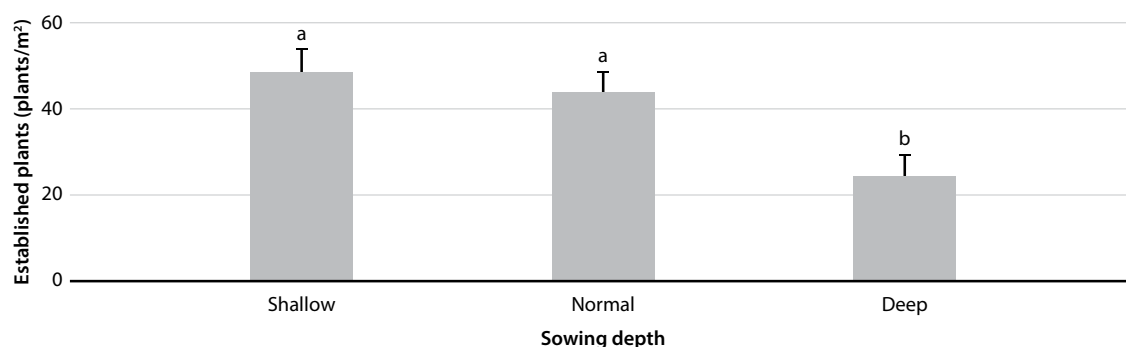


Figure 2. Average establishment (plants/m²) across sowing depths. $P < 0.001$, LSD= 5 plants, CV= 25.2%

Hyola 350TT established more plants than ATR stingray however neither reached full targeted establishment (Table 3).

Table 3 Average establishment (plants/m² and %) of varieties.

Variety	Average established plants (plants/m ²)	Average establishment (%)
Hyola_350TT	46.4 ^a	85
ATR_Stingray	31.5 ^b	58
	Sig. diff.	$P < 0.001$
	LSD (P=0.05)	5.8
	CV%	25.02

BIOMASS

Hyola 350TT had higher biomass at flowering than ATR Stingray with an average of 2.2 t/ha and 1.0 t/ha respectively ($P < 0.001$). In both varieties flowering biomass was reduced by placing seed too deep which was reflected in final yield (Figure 3).

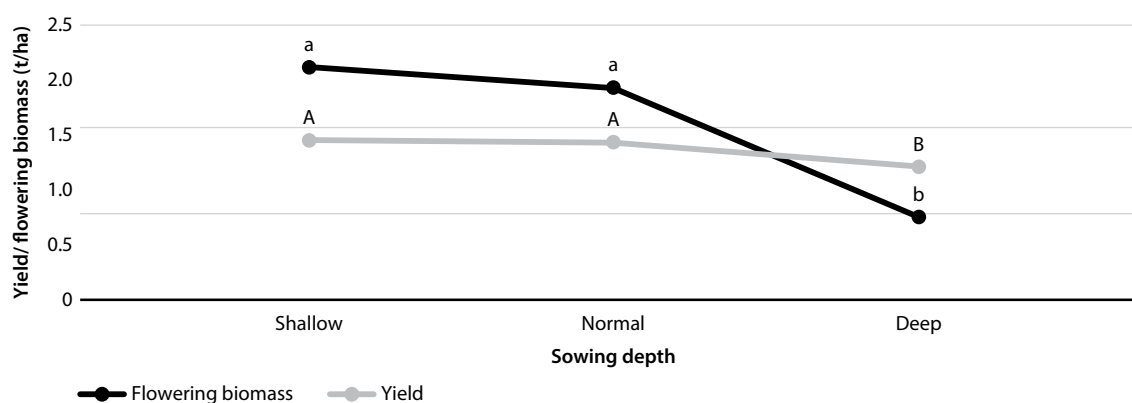


Figure 3. Average flowering biomass (t/ha) and yield (t/ha) for different sowing depths. Biomass: $P < 0.001$, LSD= 0.47t/ha, CV% 37.8 Yield: $P = 0.005$, LSD= 0.12t/ha, CV% 7.4

YIELD

Depth sowing rate and variety both had an impact on yield. There was an interaction between variety and sowing depth. Hyola 350TT yielded higher than ATR Stingray however at depth yields were lower for both varieties (Table 4).

Table 4. Average yield (t/ha) of varieties at different sowing depths.

Sowing depth	Variety yield (t/ha)	
	Hyola 350TT	ATR Stingray
Shallow	1.46 ^{ab}	1.45 ^{ab}
Normal	1.49 ^a	1.38 ^{bc}
Deep	1.32 ^c	1.11 ^d
	Sig. diff. LSD (P=0.05) CV%	P= 0.038 0.13 7.3

A trend of lower yield with deeper sowing was seen however when comparing the two varieties, Hyola 350TT yield was less sensitive to depth (Figure 4). The effect of sowing depth reflects the influence of depth on established plant numbers (Figure 5).

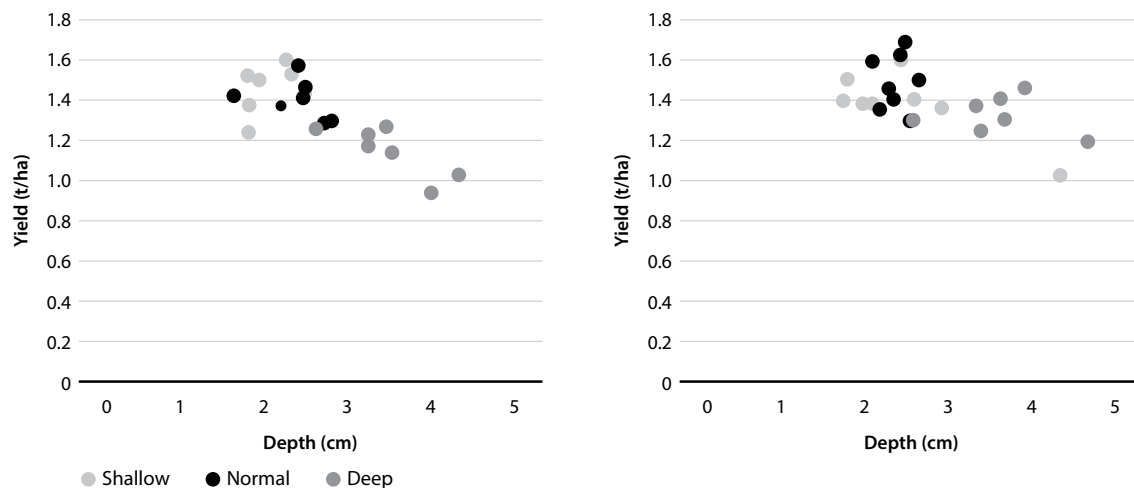


Figure 4. Yield (t/ha) for different seedling depths (cm) for ATR Stingray (left) and Hyola 350TT (right).

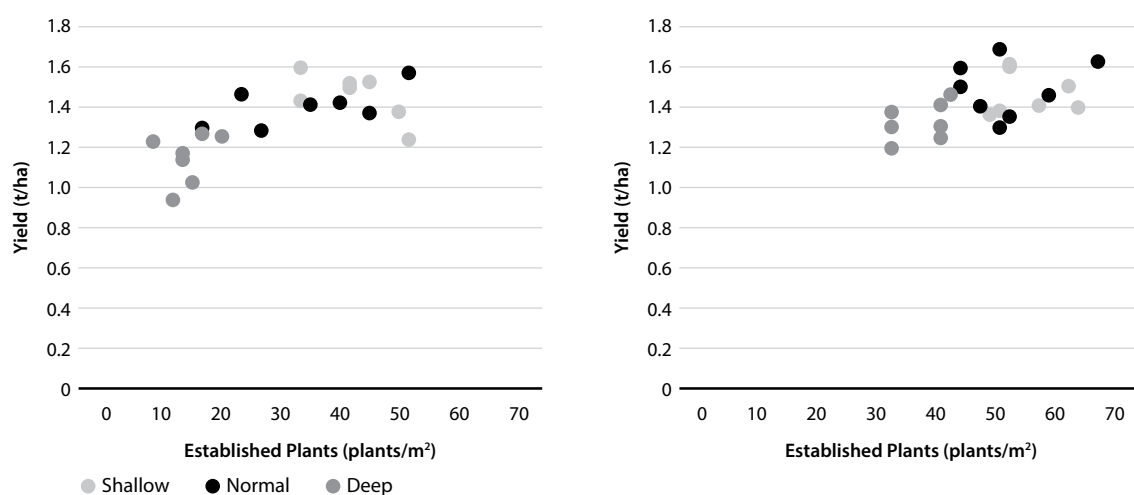


Figure 5. Yield (t/ha) for number of established plants (plants/m²) at different sowing depths for ATR Stingray (left) and Hyola 350TT (right).

Increased sowing rate increased yields by 8% (Table 5).

Table 5. Average yield (t/ha) of different sowing rates (plants/m²).

Sowing rate (plants/m ² target)	Yield (t/ha)
50	1.3 ^a
60	1.4 ^b
Sig. diff.	0.023
LSD (P-0.05)	0.06
CV%	7.4

COMMERCIAL PRACTICE AND ON-FARM PROFITABILITY

Canola can be successfully sown into dry soil and establish well. A few key factors need to come into play for this success. The soil must be dry enough to avoid premature germination and sufficient germinating rains, ~10mm of cumulative rainfall within a week depending on soil type and variety, must fall for even establishment to occur.

Research undertaken as part of the broader plant establishment project investigated how soil moisture can affect canola germination over time. Seed germination and emergence is sensitive to the availability of soil moisture. At low soil moisture, germination rates decline and the time to establishment is delayed. An example is given in Figure 6 for a sandy loam soil. Seed of hybrid canola was sown at 15mm depth in soil at different moisture contents. Emergence after three weeks fell from 100% in soil near field capacity (10–12% moisture content) to 20% in soil at 7% moisture content. There was no establishment in soil at 5% moisture content.

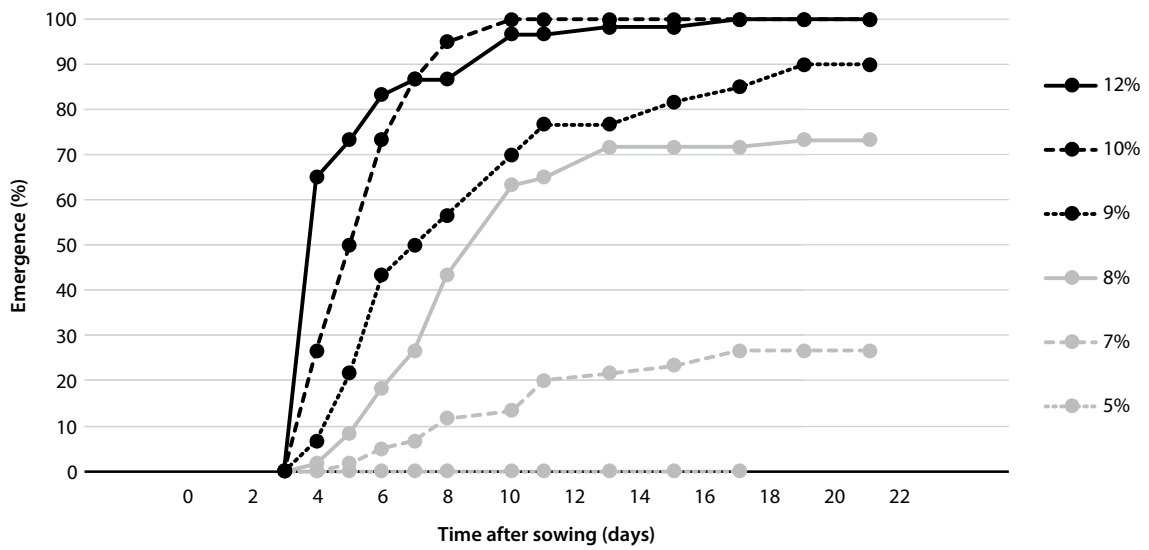


Figure 6. Changes in emergence time of canola sown into soil at moisture contents between 5% and 12%

The effect of moisture content on final emergence in canola and wheat after three weeks is shown in Figure 7 and shows how quickly emergence can decline in dry soil. In canola emergence declined from approximately 100% to 70% by a 2% decline in the soil moisture and a further decline of 1–2% in soil moisture reduced emergence to approximately 30%. Wheat showed a greater tolerance and its emergence did not start to decline until about 7%. Similar trends will be seen in other soils although the actual soil moisture values will be different depending on soil texture.

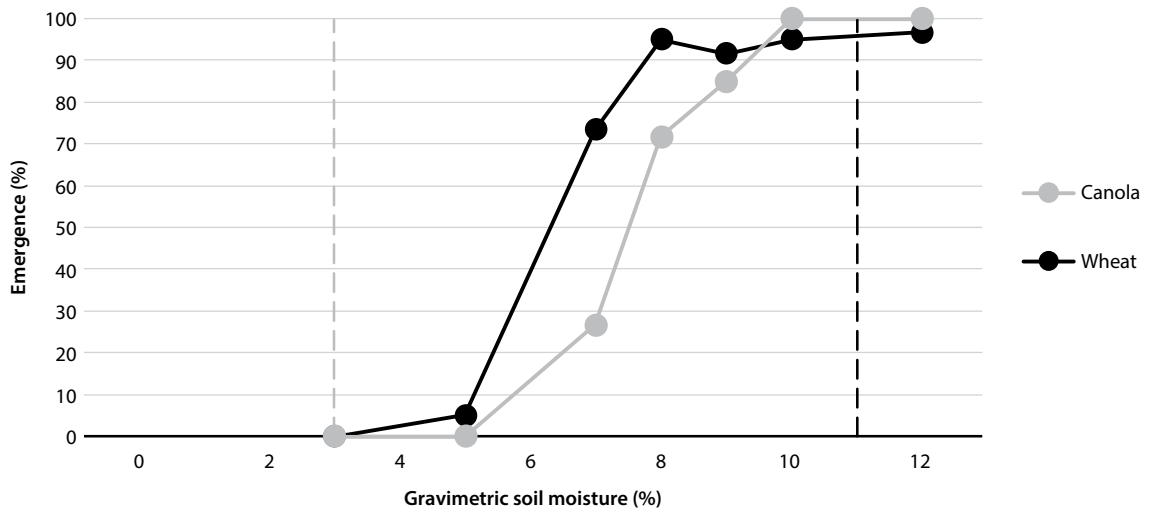


Figure 7. The effect of different soil moisture contents on the emergence of hybrid canola and wheat. The vertical dotted lines represent the soil water content at field capacity (black) and permanent wilting (grey).

Patchy establishment was found in this trial with small rainfall events following sowing resulting in established plant numbers significantly below targets in some plots, particularly deep sown ATR Stingray. Variety selection, with factors such as large seed size and hybrid vigour contributed to faster and better plant establishment on small rainfall events. Selecting a hybrid variety over an open pollinated will provide a stronger choice for establishment due to the significantly greater early vigour of these varieties.

Canola has the ability to branch and compensate for low plant numbers to some degree. If a crop has achieved patchy establishment it is important to assess established plant numbers and consider the potential of lower plant numbers compared to a better established but later sown crop. Research by BCG in the last few years as part of this project has shown that yield can be optimised in canola with plant numbers as low as 23 plants/m² (Clarke and McDonald 2020).

Traditionally, the recommended sowing depth for canola is between 1.5cm and 3cm however in some seasons seed can successfully be placed deeper (5cm) and successfully establish with access to moisture further down the soil profile (GRDC 2018). Results from this research and others consistently suggest that the risk of low emergence when sowing at a depth greater than 30mm is high and targeting a depth <30mm is recommended (GRDC 2019). Unless you are sowing into moist soil, targeting a deep sowing depth with canola will result in no advantage. Targeting a shallower depth will take advantage of smaller rain events for germination and will be more successful across most seasons in the Mallee environment. Sowing deeper, particularly on heavier soils when dry, can bring up clods and reduced seed to soil contact required for good establishment. Soil type should be considered when selecting sowing depth.

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ACKNOWLEDGEMENTS

This research was funded by the GRDC as part of the *Optimising plant establishment, density and spacings to maximise crop yield and profit in the southern and western regions* project (9176134) in collaboration with the University of Adelaide.

LONG-TERM RESPONSES TO SOIL AMELIORATION IN THE WIMMERA

James Taylor (BCG)

TAKE HOME MESSAGES

- Deep ripping can increase yields where compaction is the limiting factor. Crop establishment is still affected three years later.
- Poultry manures are a valuable soil ameliorant, increasing crop yields at both Lubeck and Netherby. Matched synthetic fertiliser rates performed similar to manure at Netherby in 2021.
- The yield increase from claying in small plot trials is not as large as in commercial practice. This highlights that the right equipment should be used for claying.

BACKGROUND

There are generally parts of the paddock that underperform. This can be for a range of reasons, including soil constants such as compaction, non-wetting sands, nutrition, toxicities and sodicity.

The best soil amelioration options address the specific constraints in a paddock. Not every technique is appropriate, and some can be damaging. In some cases, reducing soil constraints can provide a rewarding return on investment despite the initial investment cost.

BCG continued three long-term soil amelioration trials in the Wimmera during the 2021 growing season. This adds an additional year of data to results reported in *2020 BCG Season Research Results* (BCG 2021).

Netherby deep ripping by soil ameliorant

The Netherby site is a typical west Wimmera sand over clay (Agriculture Victoria, 2020). The topsoil has non-wetting characteristics, owing to its high sand and low clay content. A severe compaction layer is present at 15cm depth.

This trial was established in 2020 with a wheat crop. Yield improvements were found from deep ripping when combined with duck manure or fertiliser. Claying significantly decreased yields.

This season, barley was sown across the trial to quantify the ongoing effects of deep ripping and soil amelioration.

Netherby deep ripping for pulses

Research on Mallee sands has demonstrated yield increases for pulses (Moodie et al, 2020). This trial was established as a BCG Members' trial in 2020 to determine if pulses responded to deep ripping on sand over clay duplex soils in the west Wimmera. It showed deep ripping significantly increased the yield of chickpeas, while no yield response was observed in lentils. This year, wheat was sown across the trial to quantify the impact of deep ripping in 2020.

Lubeck deep ripping by soil ameliorant

This trial in the southern Wimmera looks at techniques to boost yields on a sandy gravel at Lubeck.

It was established in 2019 to investigate whether deep ripping and a range of ameliorants improved crop performance.

Results from both 2019 and 2020 showed chicken manure significantly increased yield. Deep ripping reduced crop establishment and claying significantly decreased crop yield.

This season, barley was sown across the trial to quantify the ongoing effects of deep ripping and soil amelioration.

AIM

To investigate the effects on yield of crop rotation, deep ripping, spreading manure and claying on constrained soils in the Wimmera over multiple years.

PADDOCK DETAILS

Location:	Netherby
Crop year rainfall (Nov–Oct):	310mm in 2021 and 345mm in 2020
GSR (Apr–Oct):	230mm in 2021 and 241mm in 2020
Soil type:	Sand over clay
Location:	Lubeck
Crop year rainfall (Nov–Oct):	494mm in 2021 and 410mm in 2020
GSR (Apr–Oct):	282mm in 2021 and 283mm in 2020
Soil type:	Sandy gravel

TRIAL DETAILS

Trial name	Netherby deep ripping by soil ameliorant	Netherby deep ripping for pulses	Lubeck deep ripping by soil ameliorant
Crop types/s	Barley cv. Spartacus CL	Wheat cv. Razor CL Plus	Barley cv. Spartacus CL
Paddock history	2020 wheat, 2019 vetch hay	2020 chickpea and lentil, 2019 vetch hay	2020 chickpea, 2019 wheat
Harvest date	8 December 2021	8 December 2021	17 December 2021
Trial average yield	3.8t/ha	3.5t/ha	5.5t/ha

Sowing date:	1 June 2021, all sites
Target plant density:	130 plants/m ²
Treatments:	Refer to Table 1, Table 2 and Table 3.
Seeding equipment:	Knife points, press wheels, 30cm row spacing
Replicates:	Four

TRIAL INPUTS

Fertiliser: Granulock® Supreme Z @ 60kg/ha + Flutriafol (200mL/100kg) at sowing.
120kg/ha urea applied as split application at GS13 and GS31 at Netherby.
160kg/ha urea applied as split application at GS13 and GS31 at Lubeck.

Trial managed as per best practice for weeds, pests and diseases.

METHOD

Netherby deep ripping by soil ameliorant

The trial was established on a sand over clay soil with a shallow hard layer where the 2019 vetch crop was less productive than the rest of the paddock. A replicated split-plot trial was sown with the main plot for ripping and the subplot being randomised for soil amendment treatments (Table 1). The deep ripping treatments were imposed in early April 2020. The clay and manure was spread on 14 April 2020 and cultivated into the soil on the same day. The site was cultivated again on 5 May 2020 after a rain event to further incorporate the clay. The manure was analysed for nutrient content and matched synthetic fertiliser treatments of nitrogen and phosphorous were applied (Table 2). The fertiliser treatments were broadcast and incorporated by sowing with Scepter wheat on 25 May 2020.

Assessments in both 2020 and 2021 included crop establishment counts, NDVI and biomass cuts at flowering. The plots were also harvested for grain yield and analysed for protein, test weight and screenings each year.

Table 1. Treatment outline for Netherby deep ripping by soil ameliorant, 2021.

Ripping	Soil amendment
Not ripped	Untreated control
Ripped to ~30cm	Clay @ 100t/ha
	Clay @ 200t/ha
	Duck manure Rate 1
	Duck manure Rate 2
	Duck manure Rate 3
	Fertiliser Rate 1
	Fertiliser Rate 2
	Fertiliser Rate 3

Table 2. Nutrients applied in Netherby deep ripping by soil ameliorant, 2021.

Treatment rate	Nutrition provided	Manure applied	Fertiliser applied	Clay applied
Rate 1	13kg/ha N + 23kg/ha P	4.6t/ha duck manure with wood shaving base	49kg/ha triple super and 28kg/ha urea	-
Rate 2	28kg/ha N + 49kg/ha P	9.9t/ha duck manure with wood shaving base	106kg/ha triple super and 60kg/ha urea	-
Rate 3	55kg/ha N + 97kg/ha P	19.8t/ha duck manure with wood shaving base	211kg/ha triple super and 120kg/ha urea	-
100t/ha	3.6kg/ha N + 0kg/ha P	-	-	100t/ha
200t/ha	7.2kg/ha N + 0kg/ha P	-	-	200t/ha

Netherby deep ripping for pulses

A replicated split-plot trial was sown on 25 May 2020. The site was ripped in early April 2020 with a tyne depth of 65cm and a tyne spacing of 30cm. Chickpeas and lentils were sown to investigate the impacts of deep ripping on pulses. In 2021, the trial site was sown to wheat and assessments were undertaken for establishment, NDVI, biomass at flowering, yield and grain quality.

Lubeck deep ripping by soil ameliorant

A replicated split-plot trial was sown with the main plot for ripping and the subplot randomised for soil amendment treatment (Table 3). The trial was ripped to a depth of 30cm on 26 March 2019. The chicken manure and clay were spread on 6 June 2019, the day before sowing. Each year, in-season assessments included crop establishment counts, NDVI and biomass. The plots were harvested to assess yield and grain quality parameters. In 2021, the site was sown to barley.

Table 3. Treatment outline for Lubeck deep ripping by soil ameliorant, 2021.

Ripping	Amendment
Ripped to ~30cm Not ripped	Control (no amendment) Chicken manure with rice hull base @ 20t/ha Clay @ 200t/ha Clay @ 300t/ha

RESULTS AND INTERPRETATION

DEEP RIPPING BY SOIL AMELIORANT

Netherby

Wheat establishment averaged 97 plants/m², which was lower than the targeted 130 plants/m². The late season break may have contributed. The average crop establishment for deep ripped treatments was lower at 89 plants/m² compared with not ripped treatments at 105 plants/m² ($P < 0.001$, LSD 7.8 plants/m², CV 17.15%). There were no differences in plant establishment for ameliorants. Establishment was not correlated to yield ($r^2 = 0.02$).

Soil ameliorant had a significant impact on biomass (Figure 1). The duck manure rate 3, duck manure rate 2, fertiliser rate 3 and fertiliser rate 1 had significantly increased biomass compared with the control. There was no significant difference in biomass between both clay treatments and the control. The source of nutrients did not affect biomass, with each duck manure rate and its respective fertiliser treatments not significantly different. Deep ripping did not impact on biomass in 2021.

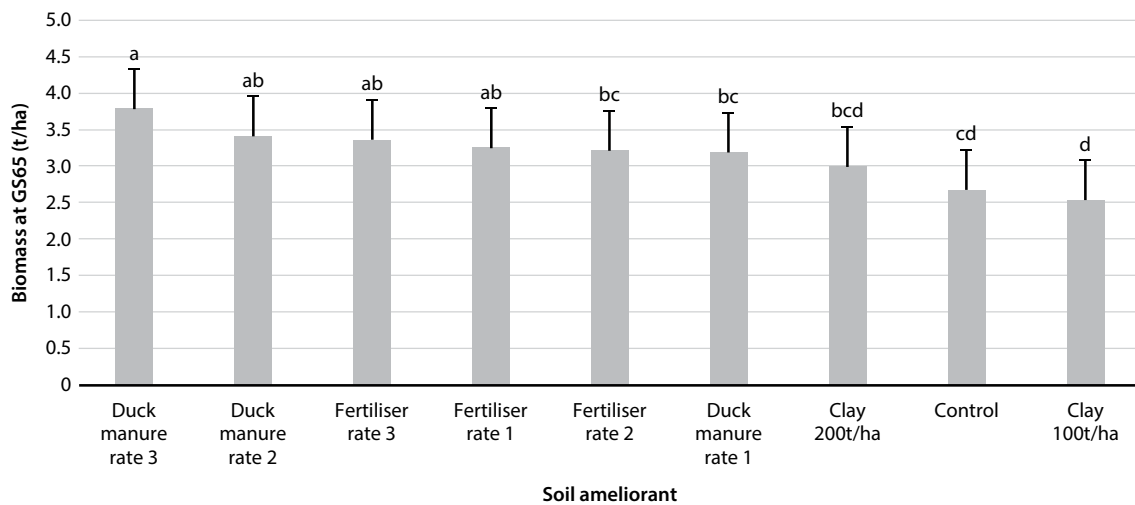


Figure 1. Biomass response to soil ameliorant, Netherby 2021. Stats: $P=0.001$, LSD 0.6t/ha, CV 17.8%.

Grain yield across the trial averaged 3.8t/ha. The deep ripped treatments yielded 4t/ha which was significantly higher than the not ripped treatment at 3.7t/ha ($P<0.001$, LSD 0.12t/ha, CV 7.5%).

There were significant responses to soil ameliorant observed, with duck manure rate 3, fertiliser rate 3 and fertiliser rate 2 yielding more than the control (Figure 2) ($P<0.001$, LSD 0.3t/ha, CV 7.1%).

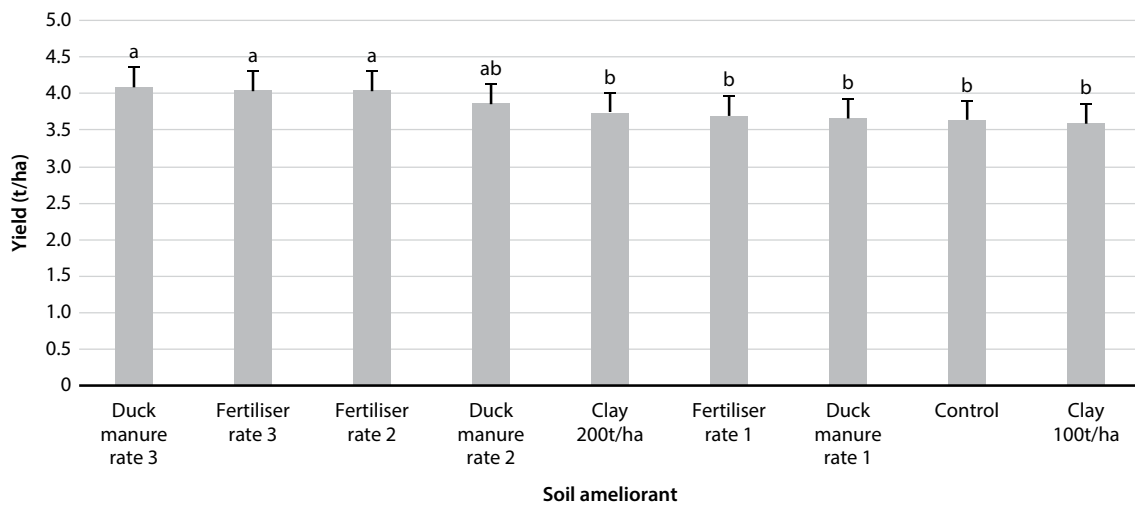


Figure 2. Yield response to soil ameliorant, Netherby 2021. Stats: $P<0.001$, LSD 0.3t/ha, CV 7.1%.

Ripping had no significant impact on grain protein which averaged 12.1 per cent (%). The soil ameliorant treatments with higher protein than the control were: clay 200t/ha, clay 100t/ha, fertiliser rate 1 and fertiliser rate 3. This is likely because of the additional nitrogen available in fertiliser rate 3 and the relationship with lower yields in clay treatments and fertiliser rate 1. All treatments in this trial graded FED2, with protein and high screenings the reason for downgrades. There were no significant differences in screenings because of ameliorant or deep ripping.

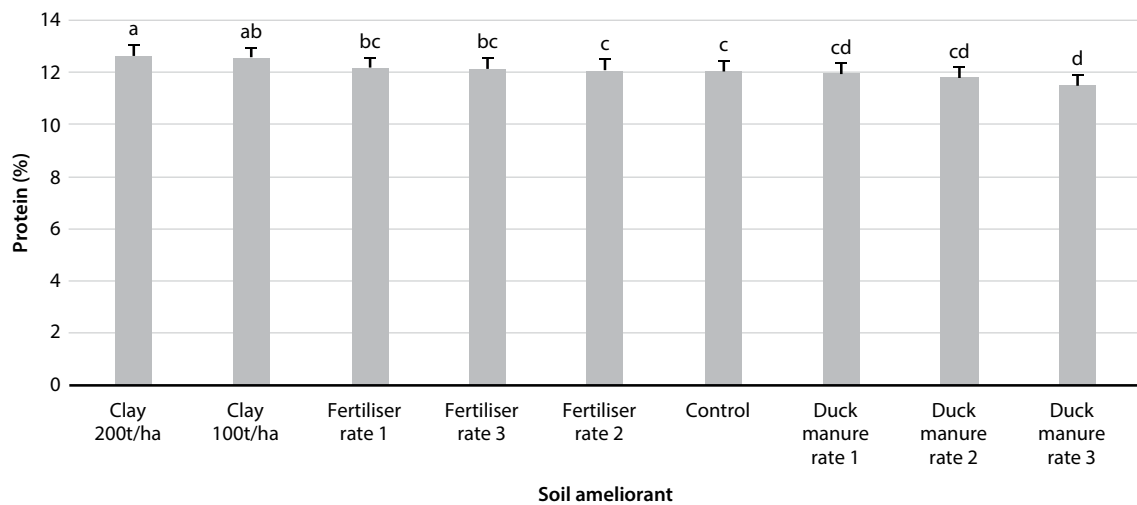


Figure 3. Grain protein response to soil ameliorant, Netherby 2021. Stats: $P < 0.001$, LSD 0.5%, CV 3.76%.

Lubeck

Crop establishment averaged 76 plants/m² across the trial, which was lower than the targeted 130 plants/m². Establishment was still reduced on the deep ripped treatments. The average crop establishment for deep ripped treatments was 61 plants/m² and for not ripped treatments it was 90 plants/m² ($P < 0.001$, LSD 13 plants/m², CV 25.6%).

The average biomass at late flowering was 8t/ha. There was a significant response to soil ameliorant with chicken manure significantly increasing biomass compared with the control (Figure 4). Deep ripping did not have a significant effect on biomass.

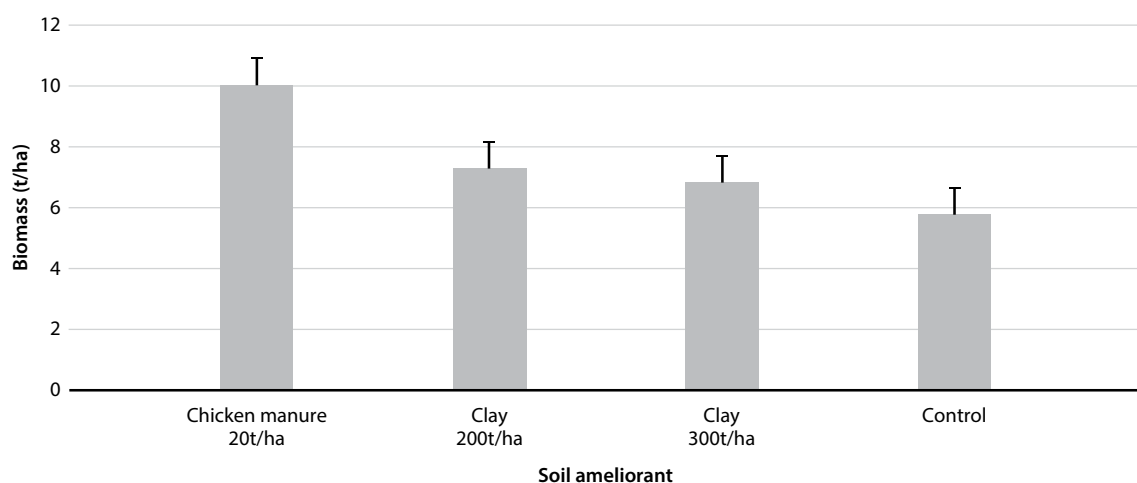


Figure 4. Biomass response to soil ameliorant, Lubeck 2021. Stats: $P < 0.001$, LSD 0.9t/ha, CV 18.2%.

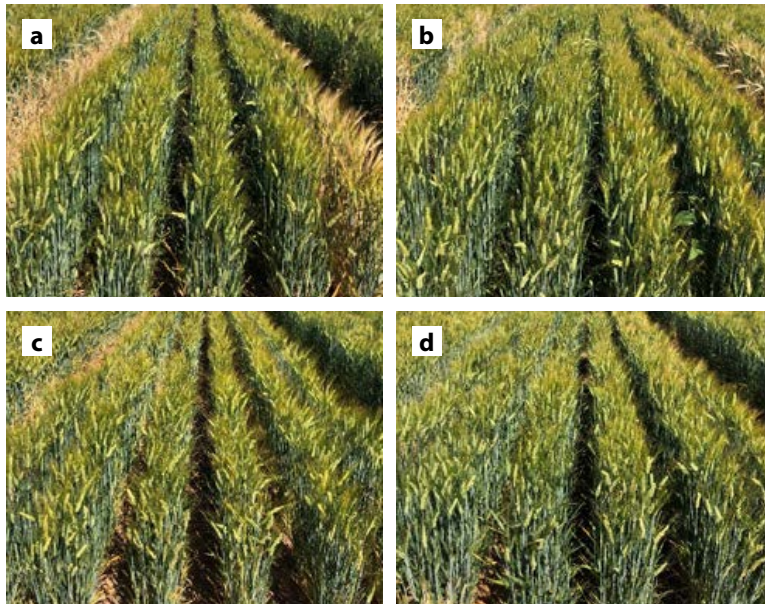


Figure 5. Unripped control (a) and unripped chicken manure 20t/ha (b) vs. ripped control (c) and ripped with chicken manure 20t/ha (d), Lubeck 2021.

Biomass at late flowering averaged 8t/ha across the site. The chicken manure at 20t/ha had a biomass at flowering of 9.7t/ha compared with non-manure treatments at an average of 6.7t/ha (Figure 5) ($P < 0.001$, LSD 0.9t/ha, CV 22%).

Grain yield across the trial averaged 5.7t/ha. Deep ripping did not have a significant impact on yield. There were significant responses to soil ameliorant observed (Figure 6). Chicken manure and chicken manure with clay were the highest yielding. Both clay treatments yielded better than the control.



Figure 6. Yield response to soil amelioration treatments at Lubeck, 2021. Stats: $P < 0.001$, LSD 0.5t/ha, CV 8.7%.

Grain protein across the trial averaged 12.56%. Deep ripping did not have a significant impact, but soil ameliorant did. The soil ameliorant treatments with higher proteins than the control were chicken manure 20t/ha and clay 200t/ha, chicken manure 20t/ha and clay 300t/ha (Figure 8). All treatments in this trial graded FED2, with protein and high screenings the reason for downgrades. There were no significant differences in screenings because of ameliorant or deep ripping.

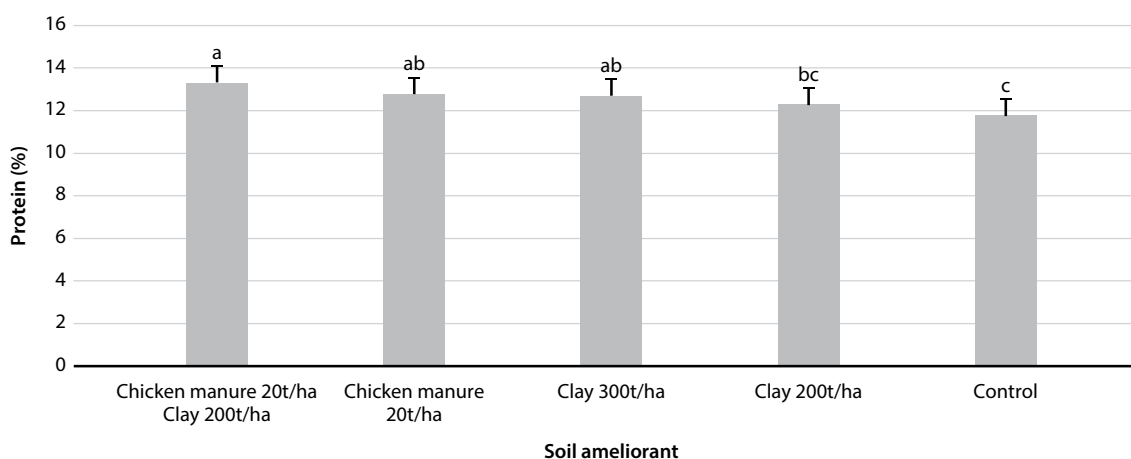


Figure 7. Barley protein response to soil ameliorant, Lubeck 2021. Stats: $P < 0.01$, LSD 0.7%, CV 6.6%.

DEEP RIPPING FOR PULSES

Netherby

Crop establishment averaged 102 plants/m² across the trial, which was lower than the targeted 130 plants/m², however there were no differences in establishment between treatments ($P=0.23$). Biomass at flowering had a significant response to the previous crop type with wheat sown following chickpeas averaging 3.3t/ha while wheat sown after lentils averaged 3.8t/ha ($P=0.001$, LSD 0.3t/ha, CV 8.1%). These differences in biomass at flowering led to a yield response, with the lentil stubble treatments yielding 3.6t/ha, significantly higher than the chickpea stubble treatments at 3.4t/ha ($P < 0.001$, LSD 0.5t/ha, CV 1.8%). Deep ripping treatments averaged 3.6t/ha compared with not ripped treatments that averaged 3.4t/ha ($P < 0.001$, LSD 0.54t/ha, CV 1.8%). No differences in grain quality were observed.

COMMERCIAL PRACTICE AND ON-FARM PROFITABILITY

IMPORTANCE OF UNDERSTANDING SOIL TYPE AND CONSTRAINTS

Before undertaking expensive soil amelioration techniques, it is important to understand the soil constraint that is limiting production.

Manure

Manure can be a valuable soil ameliorant and fertiliser. A question that arose in 2020 was, 'why are manure treatments yielding more than the matched fertiliser?' Soil samples from the trial showed phosphorous levels were a major difference between chicken manure and synthetic fertiliser. The soil tests could not verify if micronutrients such as zinc were different. In 2021 there were no differences in yield between the equivalent rates of manure and synthetic fertiliser.

It is important to have manure tested at a lab before spreading it on your paddock to ensure it does not contain anything harmful, such as high salt or boron content. Interpreting the amount of P, K and S the crop will get from manure is difficult. This is because the lab result will include the total amount of P, K or S and not necessarily the amount that is available to plants. Conventional synthetic fertiliser at sowing may still be needed to ensure crop demands are met. Test for nitrate and ammonium in the manure which are the types of nitrogen used by plants. There will be other forms of nitrogen in the manure as organic compounds (some will be released, some will not) and testing for total N will help show this. Carefully manage nitrogen inputs in the first season to ensure the crop doesn't "hay off" from excess nitrogen.

Keep records of test results, manure application rates and yield to allow comparison of the benefits and costs against synthetic fertiliser.

The main limitations for widespread adoption of litter spreading are availability and cost. Transport and application cost can be high compared with synthetic fertiliser. The low nutrient density of manure means its economical application is limited to paddocks located close to poultry sheds or a feedlot.

For more information about poultry litter as a fertiliser, including budgeting, refer to GRDC, 2015, *Chicken litter as fertiliser for broadacre grain crops*. <<https://grdc.com.au/resources-and-publications/grdc-update-papers/tab-content/grdc-update-papers/2015/08/chicken-litter-as-fertiliser-for-broadacre-grain-crops>>

Deep ripping

Deep ripping removes compaction in the soil by physically breaking up hard layers. At the Netherby site there has been an ongoing response to deep ripping. Penetrometer testing was performed to confirm that a compaction layer existed and the ripping had alleviated the constraint.

Identifying compaction as the cause of reduced yield is important. The Lubeck site highlights this with deep ripping not converting to yield benefits across three years. Reduced crop establishment is a negative aspect of deep ripping. The effect has been observed in the third year at Lubeck and second year at Netherby. It may affect which crop species can successfully be established on the paddock as seen at Lubeck where canola failed to establish. Weeds may be more challenging to manage with less crop competition.

Getting a crop response in the first year is critical for making soil amelioration worthwhile. At Netherby, chickpeas were a sound option to sow on ripped soils because the benefits were converted into extra income that covered the cost of ripping. Lentils did not respond to deep ripping in 2020, but in the second year wheat on lentils yielded 3.6t/ha of H1 generating an extra \$103/ha of income compared with the wheat on chickpeas yielding 3.4t/ha of H2.

Deep ripping can bring up subsoil with unwanted characteristics. Both Lubeck and Netherby have relatively benign subsoils but it is important to test the soil to at least 1m in increments to check for underlying issues such as sodicity, salinity, boron or unfavourable pH.

Claying

Non-wetting sands are present in patches in the West Wimmera. Compared with the control, yield significantly decreased after clay spreading at both 100t/ha (0.18t/ha) and 200t/ha rates (0.29t/ha) at Netherby in 2021. This was unexpected, as claying performed elsewhere on sand in the west Wimmera increased yields. The yield drop is probably due to difficulties in incorporating clay at a plot scale. The clay was incorporated using the narrow tyne of the plot seeder. Growers who have success with claying often use wide points or off-set discs combined with smudge bars.

Clay applied at 300t/ha and 200t/ha started to show increased yield at Lubeck in the third year, 2021. This may be because of the poor incorporation of clay in small plot trials in early years compared with commercial practice. When clay was initially spread it raised the plot height substantially, making sowing depth hard to manage but with time and weather the clay has dispersed more into the topsoil.

For more information about clay spreading, including case studies in the West Wimmera region, refer to *Spread, delve, spade, invert: a best practice guide to the addition of clay to sandy soils*. <https://grdc.com.au/___data/assets/pdf_file/0035/75698/grdcspreaddelvespadeinvertpdf.pdf>

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ACKNOWLEDGEMENTS

Lubeck and Netherby deep ripping by soil amelioration trials were funded through the Australian Government's National Landcare Program, with support from the Wimmera Catchment Management Authority.

Netherby deep ripping for pulses trial was funded by BCG members through their membership.

We thank RobCo, of Rainbow, and the Taylors for hosting the trials.

INVESTIGATING THE BENEFITS AND SHORTCOMINGS OF MULTISPECIES COVER CROPS IN A LOW RAINFALL BROADACRE MIXED FARMING SYSTEM

Terry Rose (SCU), Tom Draffen (BCG), Tariq Gerardi (BCG)

TAKE HOME MESSAGES

- The benefit of planting multispecies cover crops in a low-rainfall environment is unclear and planting them adds additional complexities.
- Agronomically issues such as the carryover of crop disease, weed pressures, sowing logistics, seed source and cost of seed have all been identified as challenges in the first year of the project.
- Termination research highlighted that when there is variability in flowering time in mixed species crops it will inevitably cause issues when using a mechanical method of termination.
- Alongside this is the complex problem of terminating a range of species with different herbicide tolerances and maturity timings which to date has been difficult to manage.

BACKGROUND

The use of multispecies cover crops is a new practice which has increased in popularity in Australian farming systems in the past decade. The foundations of multispecies cover cropping are based on an ecological theory that a more diverse root system will increase soil microbial levels and soil carbon.

Cover crops are not harvested directly for an economic return and are instead planted to provide the benefits that ground cover and diverse root systems generate.

The general practice of planting cover species is not new to the Wimmera and Mallee regions. Single species vetch covers are a common option as they fix atmospheric nitrogen while providing a weed and disease break. These benefits give a good return on the moisture used by the crop which would otherwise have been used for the next year's cereal crop in a long fallow rotation.

The benefit of planting multispecies cover crops in the low-rainfall broadacre farming regions of Victoria is unclear, and planting them adds complexities associated with weed management and termination of species that mature at different rates (Wortman et al. 2012).

In environments where water is not a limiting factor, multispecies cover crops have been grown with some success. Where long fallowing is practiced in northern NSW/southern Qld, spring cover crops have been shown to have no negative impact on soil water balances and subsequent crop yields when cover crops are removed sufficiently early in the fallow to allow re-filling of profile water with following rainfall (Whish et al. 2009). The extra groundcover typically aids water infiltration into the soil in intense summer storms, which can offset the water transpired by cover crops (Whish et al. 2009). While rainfall infiltration rates into soils may not be an issue in the Wimmera and Mallee, it is possible that cover crop residues may reduce evaporation of soil moisture, which may partially offset water use by the cover crops.

In non-irrigated, low rainfall areas however, cover crops are more of a risk where consistent rainfall cannot be guaranteed (Wortman et al. 2012). The main risk is a reduction in the subsequent crop yields due to water use by cover crops, a phenomenon often observed in semi-arid environments (Nielsen et al. 2015).

In 2021, with funding from the Department of Agriculture, Water and Environment, Southern Cross University and BCG began a two-year trial to investigate the possible benefits of multispecies cover cropping.

*Note: This is a two-year systems trial; this article is a trial progress update and should not be treated as a results piece. Results and trial outcomes will be published in the *2022 BCG Season Research Results* manual.

AIM

To identify and validate the benefits from multispecies cover crops and methods of cover crop termination (eg. crimping) which retain residue on the soil surface while maintaining or increasing system productivity in a low rainfall broadacre farming system.

PADDOCK DETAILS

Location:	Watchupga South
Crop year rainfall (Nov–Oct):	234mm
GSR (Apr–Oct):	172mm
Soil type:	Sandy loam
Paddock history:	2020 Barley

TRIAL DETAILS

Treatments:	Refer to Table 1
Target plant density:	Refer to Table 1
Seeding equipment:	Knife points, press wheels, 30cm row spacing
Sowing date:	7 April (vetch and cover mixes), 7 May (grain crops), 4 October 2021 (summer cover crop)
Replicates:	Three

TRIAL INPUTS

Fertiliser: Granulock® Supreme Z + Flutriafol (400mL/100kg) @ 60kg/ha at sowing, Urea spread at 80kg/ha on wheat treatment 5 August

The trial is managed for weeds, pests and disease as per best practice.

Table 1. Treatment outline and sowing rates.

Treatment description	Crop type	Variety	Sowing rate (kg/Ha)
4 species mix (farm-ready mix)	Barley	Leabrook	17
	Oats	Mulgara	20
	Field peas	PBA Wharton	18
	Vetch	Volga	19
7 species mix (nitrogen focus)	Wheat	DS Bennett	10
	Faba beans	PBA Amberley	30
	Lentils	PBA Jumbo 2	5
	Chickpeas	PBA Royal	10
	Field peas	PBA Butler	20
	Purple vetch	Benetas	20
	Fodder rape	SF Greenland	0.5
13 species mix	Wheat	DS Bennett	3
	Barley	RGT Planet	4
	Oats	Forester	10

METHOD

This project aims to provide quantifiable background information on the efficacy and possible benefits of planting multispecies cover crops in low rainfall cropping zones where long fallows are used.

The project will support establishment and operation of two trial sites to demonstrate soil management practices for improved soil health.

A two-year replicated, complete randomised block design trial was established in the Victorian Southern Mallee. Wheat, lentil, and vetch crops were managed as per best practice with an economic perspective being considered. Management of multispecies cover crops were minimal due to the complexity of the species within the mixtures.

In the first year, in-season assessments included emergence counts, biomass cuts (cover crops only) and grain yield/ quality parameters (lentils and wheat only).

Soil sampling

The soil sampling regime included soil samples being taken from each plot at sowing, termination, and every two months post-termination. Soil measurements included total carbon and nitrogen, hot water-extractable carbon, microbial biomass carbon, CO₂ respiration, citrate-extractable protein and six soil enzyme assays. Taken together, these measurements give an indication of overall soil health and will provide a comparative data set for assessing the impact of multispecies cover-cropping as a soil improvement option.

Mix selection

When developing the species mix for the trial, thought went into the selection of each crop variety to try to align the flowering time for all species within the mix. Each multispecies mix has a particular focus and decision process.

The four species mix was developed as a 'farm-ready' mix made up of crop types likely to be available to growers through seed retention from previous years. The seven species mix was developed with a focus on N fixation, and the 13 species mix focused on root diversity and biomass.

Termination

Investigating different termination methods is also part of this trial. Alternative termination methods such as green manuring are reported to provide benefits from enhancing soil fertility and organic carbon, as well as providing good summer cover, which will prevent soil moisture and top-soil loss.

Termination methods under investigation include the use of a specialised crimper roller, traditional green manuring using offset discs, chemical application or brown manure, and mixtures of brown manure and crimper rolling.

In the 2021 growing season the termination trial was sown using the 13 species mix as listed above. Although thought went into the selection of each crop variety in the mix there was still variability in flowering time for each plot, which inevitably caused issues when using a mechanical method of termination.

Findings to-date

Selecting species mixes which provide the appropriate function as a cover crop i.e nitrogen fixation, or high feed value and similar termination windows has been a problem. Each mix in the trial has had positives and negatives, as explained below.

High nitrogen fixing mixes can be beneficial for a following year's cash crop (especially if urea prices stay high) but will require the cover mix to have a high percentage of legumes and will then have a low degree of diversity.

Selecting cover mixes with a large range of species (ie. 13-way mix) is anecdotally, the best method for improving soil health metrics, soil structure and biological function in the soil. However, agronomically issues such as the carryover of crop disease, weed pressures, sowing logistics, seed source and cost of seed have all been identified as challenges in the first year of the project. Alongside this is the complex problem of terminating a range of species with different herbicide tolerances and maturity timings which to date has been difficult to manage.

Choosing cover mixes that produce high biomass and that provide the highest levels of ground cover and leave good levels of top-soil moisture and soil carbon for the following crop is a key requirement for the project. However, higher biomass varieties can access sub-soil moisture lower in the profile which would otherwise be utilised by a cash crop in the following season.

The second year of this trial will reveal what, if any, impact multispecies cover crops and differing termination methods have on the yield of a wheat cash crop which will be sown over the current plots.

It is hoped continued research will establish whether multispecies cover cropping can be economically viable when compared to long fallows and single species cover crops already adopted in the Wimmera and Mallee regions.

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ACKNOWLEDGEMENTS

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SOIL CARBON RESEARCH PROGRAM EXPLORES CHANGES IN SOIL ORGANIC CARBON ACROSS THE MALLEE REGION OF VICTORIA: PART 1

Tom Draffen (BCG) and Dr Mitchell Kirby (Southern Cross University)

TAKE HOME MESSAGES

- Preliminary results indicate that during the past decade the stock of SOC has increased by 27% from an average of 24.5t/ha to 33.7t/ha.
- Soil type was confirmed to have a statistically significant effect on SOC levels.
- The increase in bulk density was less than that of SOC, this highlights potential that the increase in SOC is a function of management practices.

BACKGROUND

The Soil Carbon Research Program (SCaRP) was a nationally coordinated program of soil carbon research that brought together researchers from the CSIRO, universities and state government agencies. The project began in April 2009 and concluded in June 2012, coordinating 13 soil carbon research projects. The SCaRP project was the largest and most extensive soil sampling and analysis program undertaken in Australia to measure stocks of soil carbon. More than 20,000 samples were taken from a wide range of soil types and farming operations across more than 4000 different locations in selected farming regions across Australia.

One of the key SCaRP projects was *Soil carbon in cropping and pasture systems of Victoria*. This project sampled 615 sites across Victoria. This involved compiling soil characteristics, soil carbon and land management data for 10 years before sampling. The management practice data included: crop type, crop yield, tillage type and frequency, stubble management, fallowing, pasture type, animal type, grazing regime, cutting for hay, irrigation, and application of fertilisers and other soil amendments. This dataset found management practices across the preceding decade (2000–2010) were not significantly linked to soil organic carbon (SOC) levels. As a function of changes in technology and management philosophy (whereby farmers are now actively managing SOC), it is reasonable to expect a different result for the most recent decade (2010–2020).

There is a wide range of benefits from improving SOC levels. They include both on-farm benefits (eg. lower input costs, water retention and sustained yields across variable climates) and societal benefits (eg. mitigating greenhouse gas emissions). We expect an update of the SCaRP project will provide Australian farmers with evidence to build confidence in their ability to increase SOC in agricultural soils.

AIM

To identify farm management practices in the Mallee region of Victoria that have a positive influence on soil organic carbon (SOC). The project also aims to identify strategies that may help build drought resilience across the region.

SAMPLING AND DATA COLLECTION METHODS

BCG revisited 15 sites that were originally tested in the SCaRP project. Each of the 15 sites occupy similar climatic conditions. Soil sampling was undertaken as close as possible to the locations sampled in the original SCaRP project. The sampling procedure followed that developed in the 2009–2012 SCaRP project.

At each site (paddock), 10 soil samples were taken at three different depths (0–10cm, 10–20cm, and 20–30cm). The location of these samples was randomly determined from 36 potential points across a 25m x 25m grid. The grid was orientated to sample a random distribution of row/inter-row soil. Samples were taken from the beginning of the soil surface and did not include any of the organic layer.

To obtain land management data, landholders at each site were surveyed to provide a 10-year management history. This survey was closely modelled after the previous SCaRP project and collected information on factors such as crop type, yield, tillage, stubble management, irrigation, fertilisers and other amendments/soil conditioners, fallows, cuts for hay, pasture type, pasture yield or stocking density and grazing management.

ANALYTICAL APPROACH

Soil carbon was measured both by mid-infrared (MIR) spectroscopy and LECO combustion (here the results are based only on LECO combustion or total organic carbon). To remove inorganic carbon, calcareous samples were pre-treated with sulphurous acid. Bulk density was calculated from the dry mass of the soil samples and divided by the volume of the soil cores. The SOC stock (expressed as t/ha) was calculated as

$$\text{SOC Stock} = h \times C \times \text{BD} \times (1 - G)$$

Where h is the thickness of soil layer (cm), C is the concentration of SOC in the fine earth (%), BD is bulk density (g/cm³), and G is the proportion of gravel in the soil sample (g/g). SOC Stock was calculated on a depth of 0–30cm.

Statistical analyses were conducted within the R software package to determine differences between the years and soil class. This consisted of a two-way ANOVA and Tukey's HSD post-hoc test.

PRELIMINARY RESULTS AND INTERPRETATION

Preliminary results indicate that during the past decade the stock of SOC has increased by 27% from an average of 24.5t/ha to 33.7t/ha. Similarly, bulk density (BD) has increased by 14%. Statistical analysis using a two-way ANOVA confirms the difference in SOC between 2010 and 2021 was statistically significant ($p < 0.05$) (Appendix 1).

Interestingly, the increase in bulk density was less than that of SOC. This suggests the increase in SOC is a function of management practices, which we hope to pursue in future analyses.

Table 1. Comparison of mean SOC and Bulk Density values from the 15 sites between 2010 and 2021.

	2010		2021		Difference
	Mean	Std dev	Mean	Std dev	
SOC Stock (t/ha)	24.5	7.4	33.7	11.4	27%
Bulk Density (g/cm ³)	1.4	0.1	1.6	0.2	14%

Figure 1 provides a comparison of the 2010 values and the 2021 values for individual sites segmented by soil type. It shows on all but three occasions the stock of SOC has increased. Soil type was also confirmed to have a statistically significant effect on SOC (Table 2) (Figure 1) (Appendix 1), which supports the consensus in literature.

Post-hoc tests reveal the primary cause for this difference is between Tenosol and the other three classifications (Appendix 2). We note the limitations of only having one replicate for the Tenosol, but it is interesting to see the substantial improvement in SOC between 2010 and 2021. This would be worthy of further investigation.

Table 2. Summary of SOC Stock by soil type (ASC) from the 15 sites between 2010 and 2021.

SOC Stock (t/ha)	2010		2021	
ASC	Mean	Std dev	Mean	Std dev
Calcarosol	27.75465967	2.8888715	37.060029	7.4463681
Sodosol	25.38608802	7.3115379	32.697089	13.312274
Tenosol	6.292021459	0	35.118853	4.6208729
Vertosol	25.08155967	0.8216725	32.701207	10.252105
Total	24.52595891	7.4142869	33.731952	11.386269

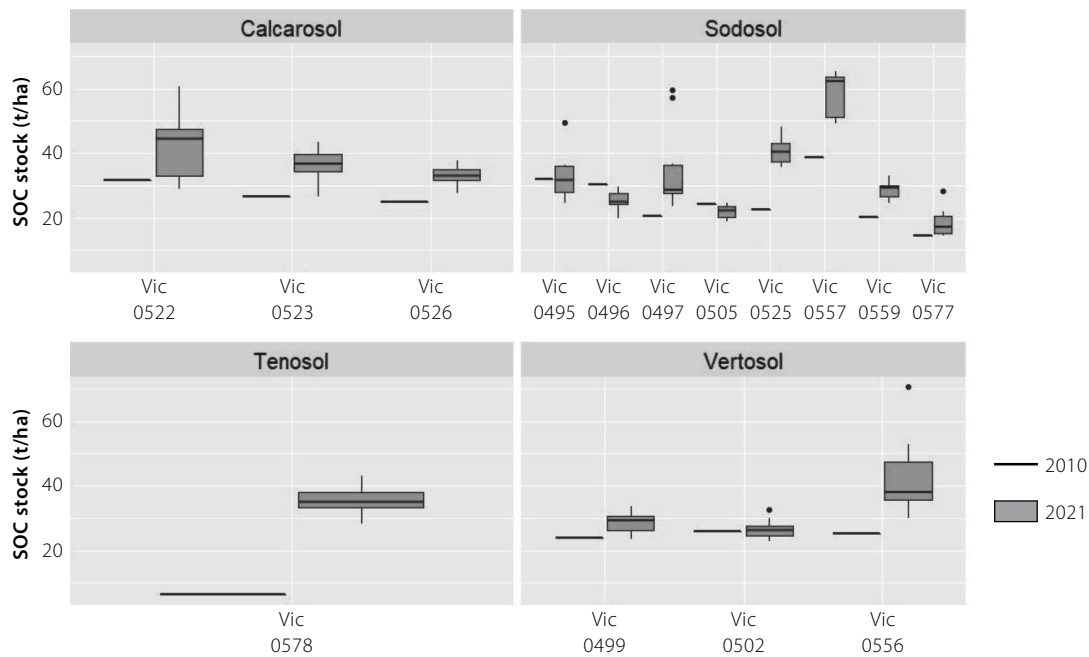


Figure 1. Change in SOC Stock between 2010 and 2021, across different sites and soil type (note: 2010 shows only the average and appears as a black line to the left of 2021 data).

COMMERCIAL PRACTICE AND ON-FARM PROFITABILITY

The next stages of this project will further explore the effects of other factors on SOC levels, specifically on-farm management practices. It is hoped through this investigation that the primary drivers of the changes in SOC and the contribution of farm management practices can be identified.

We expect the results of the next stage of analyses will provide valuable information to landholders with an interest in managing and improving SOC on their properties.

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APPENDICES

Appendix 1: Two-way ANOVA for SOC Stock, by year and soil classification (ASC).

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Year	1	6356	6356	73.708	5.29e-16 ***
ASC	3	2069	690	7.996	3.85e-05 ***
Residuals	295	25440	86		

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Appendix 2: Results from post-hoc test, Tukey'sHSD.

Tukey multiple comparisons of means
95% family-wise confidence level

Fit: aov(formula = C.Stock ~ Year + ASC, data = df3.a2)

\$Year

diff	lwr	upr	p adj
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2021-2010	9.205993	7.095679	11.31631	0
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\$ASC

diff	lwr	upr	p adj
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Sodosol-Calcarosol	-3.3657555	-6.997939	0.2664276	0.0803961
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Tenosol-Calcarosol	-11.7019067	-17.896979	-5.5068343	0.0000103
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Vertosol-Calcarosol	-3.5159607	-7.896538	0.8646170	0.1641313
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Tenosol-Sodosol	-8.3361512	-14.026689	-2.6456138	0.0010639
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Vertosol-Sodosol	-0.1502052	-3.782388	3.4819780	0.9995627
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Vertosol-Tenosol	8.1859460	1.990874	14.3810184	0.0040467
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ATTITUDES TO THE TERMINOLOGY 'REGEN AG' IN THE LOW-RAINFALL WIMMERA, MALLEE AND NORTH CENTRAL REGIONS OF VICTORIA

By Tom Draffen (BCG), Tom Leslie (QMR) and Kim Taylor (QMR)

TAKE HOME MESSAGES

- The terminology 'regenerative agriculture' or 'regen ag' is not engaging to farmers of the Wimmera, Mallee, and North Central regions.
- When presented with examples or descriptions of practices associated with the system, the farmers surveyed are confident large parts of what is considered 'regen ag' are already being implemented.
- The farmers surveyed seek local/anecdotal evidence of return on investment from the adoption of any new practice.
- The farmers surveyed will not buy in to a definition of 'regen ag' that excludes existing practices.

BACKGROUND

Regenerative agriculture or 'regen ag' is a term which has been adopted by some farmers, advocates, and academics to describe farming practices that take a 'holistic' approach to land management. The term describes a farming system which takes a conservation and rehabilitation approach to food and farming systems. It focuses on topsoil regeneration, increasing biodiversity, improving the water cycle, enhancing ecosystem services increasing resilience to climate change and strengthening the health and vitality of farm soil.

Anecdotally, farmers who describe themselves as regenerative operate in high rainfall agricultural areas with rich soils where livestock or mixed-farming operations are the primary economic driver.

Farmers in the low rainfall broadacre cropping region of Victoria operate under dramatically different conditions and have been early adopters of a no-till or minimum-till farming system, which focuses on soil management, water retention, plant diversity and ground cover.

Farmers in the low rainfall broadacre cropping regions of Australia implement a system of high production and high input farming that is both profitable and sustainable.

These systems improve farming landscapes by replacing beneficial natural elements in the soil, such as the primary macronutrients (N, P and K), and using topsoil conservation techniques that include stubble retention, no till or minimum-till farming, diverse crop rotations, long fallows and integrated pest and weed management strategies encompassing multiple methods of pest and weed control.

Sustainable broadacre farmers have adopted practices using advanced technology to match inputs to yield potential and increase soil function through applied science. These systems are designed and implemented across multiple years, taking a long-term approach to best practice farm management.

In low rainfall broadacre cropping environments, farming systems groups such as BCG have provided farmers with information about applied scientific research and commercial practices that has advanced farming in the region.

A key element for farmers in the low rainfall broadacre cropping region is soil health, most importantly topsoil health, and undertaking practices which sustain and enhance the productivity of agricultural soils. Farmers in the Wimmera, Mallee and North Central have implemented strategies that include diverse crop rotations, improving agricultural soils through better water holding capacity and water cycling, replacing nutrients removed through agricultural production, maintaining sustainable stocking rates, and attempting to sequester carbon in the soil.

Farmers undertaking these practices in the low rainfall agricultural region have been adopting and implementing new and innovative practices and strategies over the past 20 to 30 years. Applied scientific research and extension has provided farmers with the knowledge and confidence to make profitable decisions. Farmers have also made significant investment in operational assets and equipment, such as no-till seeders and harvest weed seed control mechanisms.

AIM

To collect qualitative data to understand how the principles and practices of regenerative agriculture are being interpreted by farmers of the Wimmera, Mallee and North Central regions.

METHODOLOGY & SAMPLE SELECTION

BCG engaged the services of Quantum Market Research (QMR) to design and undertake a targeted survey of a sample of the BCG membership to better understand localised farmers' perception and attitudes toward the term 'regen ag'.

Specifically:

- Current awareness, knowledge and implementation of 'regen ag' farming practices.
- Defining 'regen ag' from the perspective of farmers.
- What consideration has been given, and what is inhibiting further consideration?
- What are perceived to be the potential benefits and barriers?
- What practices from 'regen ag' are 'low hanging fruit' for adoption, and which are contradictory to current thinking?
- Perceptions of current evidence and where gaps exist for low–medium rainfall farming systems.

- Prioritising evidence gaps which, if addressed, can promote consideration/adoption.
- What research farmers believe they need to realise the aspirations of 'regen ag'.
- What else can promote more productive consideration of 'regen ag' principles and practices.

The research was designed to be qualitative rather than quantitative which involves collecting and analysing non-numerical data (e.g., text, video, or audio) to understand concepts, opinions, or experiences.

BCG provided QMR with a list of 100 BCG members from which the sample for surveying was randomly selected. The selection of 40 farmers was screened by QMR to ensure the sample was representative of the farming region. During the screening process 27 BCG members were contacted: four members weren't recruited because they didn't meet the required criteria and eight either directly or indirectly declined. Once the sample size of 15 had been recruited, the remaining 13 members of the random selection were dismissed.

This is considered a very high degree of success in recruitment. It indicated BCG members were willing to support research into this topic and trust the organisation.

The sample is drawn from a relatively small total audience, from within a limited geographic area. Consistency of feedback provides confidence that the sample reflects the views of the audience. This sample is a representative cross-section of:

- Different geographies within the regions.
- Mix of farm size/scales (from smaller-scale 'husband and wife teams' up to those with 10+ employees).
- Those who self-identify as earlier adopters versus slower to adapt and change.
- Those who self-identify as having relatively more versus less existing understanding of 'regen ag'.

There is no indication that findings would differ if the sample size was increased as the findings were so consistent. It's reasonable to assume that another 15 people would continue to say similar things to the 15 who preceded them.

The sample of 15 farmers randomly selected from the BCG membership can be broken down as follows:

- Eight broadacre + livestock (mixed farmers)
- Seven broadacre only
- One agronomist.

The sample was selected to provide a representative cross-section of different geographies within the regions. Mix of farm size/scales (from smaller scale 'husband and wife teams' up to those with 10 or more employees), those who self-identify as earlier adopters versus slower to adapt and change, and those who self-identify as having relatively more versus less existing understanding of 'regen ag'.

QMR was given background information from various sources to develop an understanding of the key themes, principles and practices associated with 'regen ag' and develop the discussion guide used to drive conversations with the growers. The discussion guide was designed to provide an impartial, non-judgemental platform for conversation which was deliberately undertaken by a researcher from outside of BCG and independent of agriculture.

Interviews were conducted during October 2021 via video conference and recorded. Each interview was approximately 60 minutes.

The project was carried out in line with the Market Research International Standard, AS ISO 20252.

EXECUTIVE SUMMARY

The term 'regen ag' does not engage the farmers surveyed in the Wimmera, Mallee and North Central regions, who have an incomplete awareness and comprehension of the term.

It is perceived to be a passing buzzword rather than a meaningful practice or system. The farmers surveyed associate the term 'regen ag' with hard boundaries, niche enterprises and environmental fundamentalism and do not consider it to be a field of innovation that is relevant to their operation.

The farmers surveyed assessed innovative practices on their individual merits. In comparison to a practice such as no-till which has a practical association (avoiding cultivation), the term 'regen ag' is an intangible category-level term considered too vague to be engaging.

When presented with examples or descriptions of practices associated with 'regen ag', the farmers surveyed were confident many of them were already being implemented and were not new or novel practices developed through the 'regen ag' movement.

Principles of no-till farming, stubble retention, integrating enterprises, controlled traffic and cell grazing are all practices implemented in viable farming systems in low to medium rainfall regions.

The open-ended nature of some of the principles of 'regen ag', for example 'encouraging natural biological cycles', led the farmers surveyed to presume they only partially conformed to the definition.

The farmers surveyed assumed only partially conforming to the definition or practices associated with 'regen ag' left them excluded from being considered a practitioner. However, the concept or possibility of further untapped potential in already proven fields is motivating for them.

The farmers surveyed were reluctant to buy-in to any system that is exclusionary of other existing practices, as they believed there were exceptions to any best practice. For example: the most ardent supporters of no-till may employ cultivation or burning of stubbles in some circumstances.

Furthermore, the farmers surveyed support their peers in other districts who may face different growing conditions so what is considered best practice varies from place to place.

When a system of farming makes an exclusionary judgement, for example where it requires the elimination of synthetic inputs or prohibits burn-offs, it was dismissed by the farmers surveyed as being ideology-driven and lacking understanding of the diverse agricultural environment and farming practices in the low and medium rainfall zones.

The farmers surveyed all indicated they sought local/anecdotal evidence of return on investment from the adoption of any new practice. It was considered that only the most commercially successful farmers, with the resources and interests to pursue innovation, would implement new practices without seeing first-hand how what works elsewhere might translate into their own growing conditions.

R&D must support these early-adopters and support the trickle-down effect of mainstream farmers learning from them. Notably for the field of 'regen ag', the surveyed farmers perceived little value in how practices may be proven at smaller/niche scale or in other growing conditions.

RESULTS AND INTERPRETATION

There was a general sense from the farmers surveyed that 'regenerative agriculture' meant practicing farming that was supportive of soil health.

All farmers surveyed believed the current generation of improvements in farming practices were effective and sustainable in relation to soil health. However, they fell short of self-identifying as 'regen ag' farmers, believing the term had associations with practices that were not implemented in their farming operations.

Pushed to describe what they thought was intended by 'regen ag', it was common for the farmers surveyed to assume it was a field of niche farming methods applicable to smallholders, lifestyle farmers, or those that followed organic or environmental principles that weren't commercial in scale.

Some of the farmers surveyed with this opinion went on to describe how such smallholders co-opted terms, creating tension with mainstream or 'conventional' farmers who felt unfairly judged by those without a complete understanding of what was commercially realistic or profitable for their enterprises.

The farmers surveyed listed a range of current practices they thought might fit the definition however they ultimately believed the term referred to a standard or set of inflexible principles which they did not, or could not, completely adhere to. Like organic labelling, they think of 'regen ag' as a specific sub-set of farming.

The farmers surveyed perceived 'regen ag' as having an association with 'Greenies' and ideological approaches to farming. There was a sense that the term referred to a farming practice beyond the boundaries of commercial-scale production systems.

Importantly, the term was not directly associated with controversy, rather wariness. As the farmers surveyed have only peripheral understanding of the term, there is no embedded concept of a debate about the definition. Concerns were driven simply by terminology as the word 'regenerative' implies an environmental focus, rather than an agricultural one.

Methods which can be shown to work 'in principle', or at small scale, may not be applicable at commercial scale or within the agro ecosystem of the Wimmera, Mallee and North Central regions. The farmers surveyed remain interested in new and innovative approaches to farming systems but were wary they may be forced to defend the retention of necessary practices within their farming systems under scrutiny from idealistic outsiders. They feel pressure for change and that as such the term 'regen ag' is symptomatic of a broader issue which presents as a conflict between science, productivity, profitability, and environmental ideology in modern agriculture.

The surveyed farmers' perception of hard boundaries that were not flexible to context-dependent circumstances around the definition was further alienating. Without a clear understanding of what those boundaries might be, most of the farmers surveyed rejected that any principle was universally best practice. Even cultivation still has some application, although it is more scarcely undertaken in modern cropping systems.

Whilst they don't reject or feel outright defensive, the mainstream farmers surveyed dismissed the term 'regen ag' as irrelevant. Many of the farmers surveyed felt the term referred to a theoretical field, rather than an objective practice.

Some of the farmers surveyed were wary that the term might be used to push an agenda (eg. the banning of glyphosate) which would dramatically alter their ability to remain productive and profitable farmers in a low to medium rainfall environment.

COMMERCIAL PRACTICE AND ON-FARM PROFITABILITY

The in-depth survey highlighted that the farmers surveyed in the Wimmera, Mallee and North Central regions of Victoria were reluctant to adopt any label to define their system of production. But when presented with three definitions of 'regen ag' which were synthesised through conversations with advocates and adopters of the term, most were able to draw comparisons between their farming practices and the principles of 'regen ag'.

The definitions presented to the sample were:

1. Regenerative Agriculture techniques generally focus on integrated management of soil, water, vegetation, and biodiversity and becoming more efficient in the use of natural resources.
2. A system of farming principles and practices focused on improving soil health and farming ecosystems.
3. Whilst sustainable systems maintain productivity, regenerative systems go a step further in restoring what has been lost and improving what is currently there.

When introduced to these three definitions, the farmers surveyed noted a focus on soil health, sustainability, and improvement of agricultural ecosystems. All felt their production systems were aligned with these practices. Improving soil structure, water retention properties, improved soil fertility and nutrient availability is central to the principles and practices of Wimmera, Mallee and North Central farming systems.

The farmers surveyed drew a straight line of comprehension between industry developments in the past 20 years and improvements in soil health. Secondary to this, the farmers surveyed are searching for and implementing practices intended to inhibit weed pressure and herbicide resistance, reducing their reliance on and minimising the use of herbicides, with practices such as harvest weed seed control, livestock incorporation, weed identification and activation spray technology and crop competition. Based on these conclusions, the surveyed farmers readily identified a suite of innovations they'd adopted which qualify as regenerative. No-till, disc seeding, stubble retention, inter-row sowing and planting more resilient varieties are all focused on soil health and working with nature to improve farming practices.

The issue of 'restoring what has been lost', central to one of the definitions of 'regen ag', was challenging for the farmers surveyed. They clearly agreed the ambition of this generation of farmers was to repair damage and leave soils better than they inherited them.

The farmers surveyed identified the Wimmera, Mallee and North Central regions as an example of where excessive clearing and over-cultivation has damaged soils, negatively affecting the capacity of the land.

Reflecting on their livelihood and their legacy, it was common for the farmers surveyed to commit to leaving the soil health improved for the next generation.

However, they expressed concern that a definition focused on restoration (without greater explanation) was inhibitive to their current farming practice.

There is a concern that this refers to a hands-off approach, allowing nature to take its course. Working with natural systems, under a farmer's control was approachable, but allowing natural systems to take precedence with no intervention or management was seen as undermining the industry. This was inferred to be an example of focusing on environmental rather than productivity benefits, irrespective of commercial application. As such it was seen as a threat to profitability and livelihood.

The farmers surveyed considered the economics of productivity make it possible to care for the land. If you're not productive, you won't have the resources to make investments that can further support improved soil health.

The farmers surveyed universally buy-in to the principles of no-till farming and associate these practices with improvement. They have clear comprehension and agreement on the benefits however, they also appreciate that no-till is reliant on the use of agricultural herbicides to be profitable in a low to medium rainfall environment.

Stubble retention is increasingly considered best-practice in most settings, with increased water holding capacity and reducing potential for erosion top-of-mind for all the farmers surveyed. Stubble retention is made possible by technology innovations through convergence of design and engineering in seeding equipment, GPS systems and the use of agricultural herbicides. Stubble retention is a case study for why a one-size-fits-all or exclusionary definition for 'regen ag' cannot work in practice. Despite near complete agreement with retaining stubble, it's thought there will always be circumstances when burning off or strategic tillage is appropriate.

The mixed farmers surveyed believe in the synergies of livestock within their operations. Mixed farming systems are regarded as delivering a range of benefits, including a secondary source of income, especially when input costs are offset by feed production as part of a cropping operation. Similarly, livestock incorporation addresses some of the challenges present with grain operations (primarily weed and pest control).

However, prevailing thinking about the benefits and use of sheep has shifted over time and there is not thought to be 'one right answer'. The farmers surveyed were mindful of trade-offs, which affects adoption, such as the understanding that sheep compact soil.

Those with mixed operations were respectful that peers might take an alternative perspective in believing the trade-off of sheep was not worthwhile. It is a further example of why an exclusionary definition would alienate farmers from adopting the terminology 'regen ag'.

The farmers surveyed have a love-hate relationship with synthetic inputs and are conflicted about reducing usage. The farmers surveyed don't like using large quantities of chemical because it's expensive, unpleasant to handle and controversial. Unanimously within the sample of the farmers surveyed, there was a desire to avoid over-reliance on chemical use within their systems, not only due to the cost and management issues but also to combat weed resistance and protect beneficial insect species.

The underlying sentiment from those surveyed was that chemicals are essential to their productivity and make broadacre farming in low-rainfall regions viable/sustainable. Chemicals enables no-till farming and innovations such as stubble-retention, improves water availability during the growing season and protects against crop damage from pests.

The farmers surveyed cannot conceive of a future in which chemical inputs are no longer central to their operation. They use chemicals because they work and object to ruling out man-made interventions as a part of the suite of industry innovations. Without caveat, blunt reference to reducing or ceasing chemical input, while desirable, was dismissed by the farmers surveyed as ideology driven.

CONCLUSION

Widespread adoption of innovation is ultimately dependent on local and scientific evidence. The perception of farmers surveyed was that those with capital to invest led the adoption of new practices in their region.

After R&D organisations trial new practices and validate research in paddock, larger scale and commercially successful farmers, seeking growth through innovation, take the early adoption risk/trial and error in introducing these practices onto commercial farms. From there, innovations trickle down as more farmers are convinced and buy-in.

Most farmers surveyed indicated consideration of new practices was dependent on feasibility according to their own specific micro-climate, growing conditions and other variables.

The farmers surveyed were not confident of inferring how innovations trialled in other districts would translate to their operation. They commonly ascribe to a 'wait and see' approach, preferring to wait until the innovation is proven on a farm like theirs, which in turn means systems or innovations must be validated in proximity to their holdings.

Similarly, most farmers surveyed sought reassurance that returns were proven at commercial scale like their own. For all but the earliest of adopters, it is not sufficient for the returns on innovations to be proven in controlled trials.

In reference to 'regen ag' specifically, the farmers surveyed perceived the proof-points provided by advocates were derived from smaller-scale/niche operations or lifestyle businesses and weren't a useful reference point for what's applicable to them.

The surveyed farmers rely on R&D groups, consultants, particularly agronomists, and local peers to filter, comprehend and demonstrate how evidence should affect them.

As hands-on people, farmers adopt new practices by learning from others, and assessing demonstrations rather than from trial data itself. As such, localised trial days, field days, showcases and paddock walk-throughs where farmers can communicate with one another, are the most highly valued channels from which to understand how novel thinking translates into practical application.

The farmers surveyed were driven to improve profitability, efficiency and consistency. Improved efficacy in terms of profitability, efficiency and consistency are benefits they engage with and these improvements tend to be the starting point for changes in practice.

The farmers surveyed were averse to changes that would be detrimental to the environment but were not actively seeking out changes on this front. Environmental benefits were a 'nice to have' and there was a tendency to assume new ideas would be neutral or positive for the environment.

Mental health benefits were seen as linked to profitability, rather than any one practice. The farmers surveyed expressed a degree of cynicism towards a claim about any practice or approach having a direct connection to mental health.

Benefits were associated with the practices, rather than principles and any benefits were associated with individual practices rather than 'regen ag' as a system or field. Moreover, the believability of benefits like improved profitability hangs on proven practices such as no-till, which has a strong evidence base including local results and widespread adoption.

Claims of benefits seen as indirectly linked to an idea or approach were met with caution from the farmers surveyed. Proven improvements to profitability were the basis of most changes and this was the key benefit sought.

While there is movement behind the term 'regen ag' it has been coined in areas of higher annual rainfall which have predominantly been intensive livestock regions. Some of the key practices such as maintaining a living root system are not applicable, while other regenerative practices have already been adopted and are considered best practice.

This research has shown that the farmers surveyed believe they are already doing many of the practices but feel the term 'regen ag' is too inflexible and as such creates feeling of tension and alienation of such farmers who have been quietly undertaking soil health innovations for the past 30 years and are not inspired by theoretical goal setting or ideology, but rather by the specific, measurable outcomes of individual practices.

ACKNOWLEDGEMENTS

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OATEN HAY AGRONOMY – WIMMERA 2021

Alison Frischke and Genevieve Clarke (BCG)

TAKE HOME MESSAGES

- Hay yield was highest for longer season varieties Vasse and Wintaroo in response to above average spring rainfall in the Wimmera in 2021.
- Delaying sowing from 30 April to 11 June had no effect on hay yield, due to the dry autumn delaying emergence.
- Across nine varieties, hay yield increased by 0.3t/ha as nitrogen rate increased from 30 to 60kg N/ha but yielded the same at 90kg N/ha. There was no variety response to nitrogen.
- Comparing increasing nitrogen rates up to 150kg N/ha for Mulgara, Wintaroo and Yallara, yields plateaued at 90kg N/ha.
- Height was influenced by variety and N rate for some varieties. Variety affected greenness, as did N rate but was not variety specific. Stem diameter responded to variety and time of sowing for some varieties.

BACKGROUND

Hay exporters take both a subjective and objective approach to determining hay quality. Each exporter has a different set of quality parameters and uses different testing standards depending on the international market destination and feed type (hay or pellets). Visual indicators are used in the paddock, such as hay colour, stem thickness, texture and smell. Feed testing measures levels of metabolisable energy, water soluble carbohydrates (WSC), protein, fibre (NDF and ADF) and digestibility. These are combined to determine palatability, animal intake and performance. Generally, exporters are seeking thin stemmed, soft textured hay, with high WSC and low in fibre (require $NDF \leq 50 - 57\%$ and $ADF \leq 27 - 35\%$).

The National Hay Agronomy project is a four-year investment by the AgriFutures Export Fodder Program, led by DPIRD with BCG, Agriculture Victoria, NSW DPI and SARDI. The project, now in its third—and final—season, aims to improve the understanding of how agronomic practices affect export oaten hay yield and quality.

From the national research, guidelines will be developed to help growers better manage oaten hay crops to meet export market specifications for a competitive advantage in our export fodder markets. Here are the initial results from 2021.

AIM

To evaluate hay yield and quality of oat varieties at different times of sowing and under different nitrogen (N) nutrition strategies.

PADDOCK DETAILS

Location:	Wallup
Crop year rainfall (Nov–Oct):	256mm
GSR (Apr–Oct):	198mm
Soil type:	Clay
Paddock history:	2020 chickpeas

TRIAL DETAILS

Crop type/s:	Oats
Treatments:	Refer to Table 1
Target plant density:	320 plants/m ²
Seeding equipment:	Knife points + splitter boot (70mm split), press wheels, 30cm row spacing
Sowing dates:	Refer to Table 1
Replicates:	Three
Trial average hay yield:	6.8t/ha

Table 1. Treatment outline: Oat varieties, time of sowing and N rate, Wallup 2021

Variety	Variety Characteristics			Time of Sowing	N rate** (kg N/ha)
	End Use	Height	Maturity		
Brusher	Hay/grazing/feed grain	Tall	Quick	(30 April)*	10***
Carrolup	Milling/hay	Mod tall	Quick	27 May – TOS1	30
Durack	Milling/hay	Mod tall	Very quick	11 June – TOS2	60
Koorabup	Hay	Mod tall	Mid – quick		90
Mulgara	Hay/feed	Tall	Quick		120***
Vasse	Hay	Mod tall	Mid-slow		150***
Williams	Milling/hay	Short – tall	Quick		
Wintaroo	Hay/grazing	Tall	Mid		
Yallara	Milling/hay	Mod tall	Quick		

* Treatment sown 30 April, emerged 27 May due to dry sowing conditions

** Nitrogen applied as two thirds at sowing and one third at six weeks post sowing

*** Mulgara, Wintaroo and Yallara only.

TRIAL INPUTS

Fertiliser: All treatments received Granulock® Supreme Z + Flutriafol (200mL/100kg) @ 60kg/ha, plus additional N applied as urea to make treatment rate targets (Table 1)

Seed treatment: EverGol® @ 260mL/100kg and Gaucho® @ 240mL/100kg

Trial managed as per best practice for herbicides, insecticides and fungicides.

METHOD

A replicated field trial was sown with a split plot trial design. Treatments from the 2019 Oaten Hay Agronomy trial were repeated for the third time, except for the variety Forester (very slow maturity) which was replaced by Vasse in 2020: a mid-slow variety more suited to the Wimmera.

Assessments included soil analysis and moisture, plant establishment, NDVI, hay biomass at GS71, plant height, lodging, leaf greenness (SPAD chlorophyll measure) and stem diameter. NIR (including DairyOne calibration) was being analysed at the time of writing and will be reported once national results have been collated.

RESULTS AND INTERPRETATION

Measured in March, plant available water was 56mm and soil N to 1m was 71kg N/ha.

Across 2019 to 2021, combinations of autumn, winter and spring conditions varied for the Oaten Hay Agronomy trials at Kalkee, Rupanyup and Wallup (Figure 1) affecting responses by varieties to time of sowing and N rate between years.

See 2019 and 2020 BCG Season Research Results for previous results.

In 2021, most of autumn was dry at Wallup (Figure 1(c)). The first time of sowing (TOS1) was dry sown on 30 April. A rain event of 6.6mm fell on 10 May but the next rain of 10.4mm was not until the 25 May, pushing emergence of TOS1 out to 27 May. The second time of sowing (TOS2) was sown on 11 June, separating sowing dates but keeping the later oaten hay sowing date practical. TOS2 plots emerged 7–10 days later, separating emergence dates between treatments by 3–3.5 weeks.

After the dry, slow start, crops established well and received regular winter rainfall until mid-August. The crop then finished with plentiful September rain, which continued into October when plots were cut for hay.

Across the trial, hay yields averaged 6.8t/ha.

Hay yield and quality parameters were generally influenced by variety selection and rate of applied nitrogen but not time of sowing. There was no three-way interaction between the factors but there was a two-way interaction between time of sowing and variety.

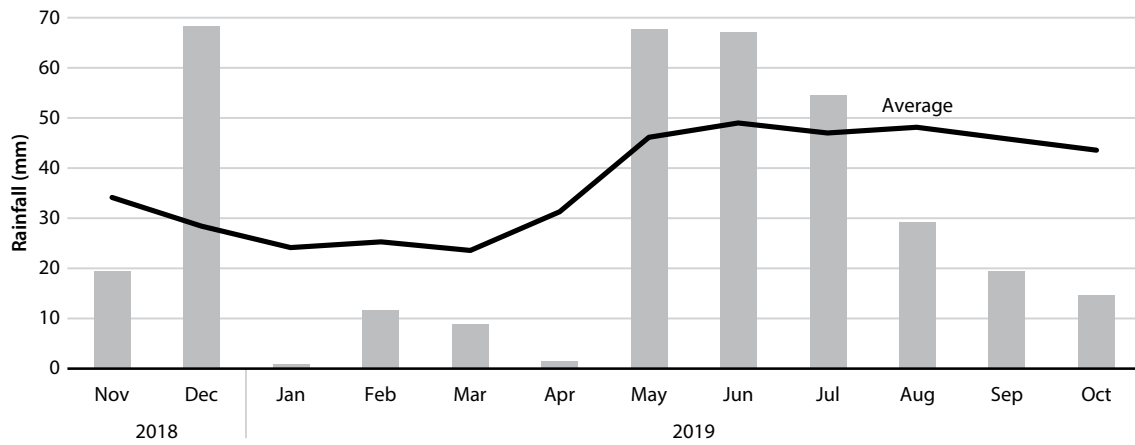
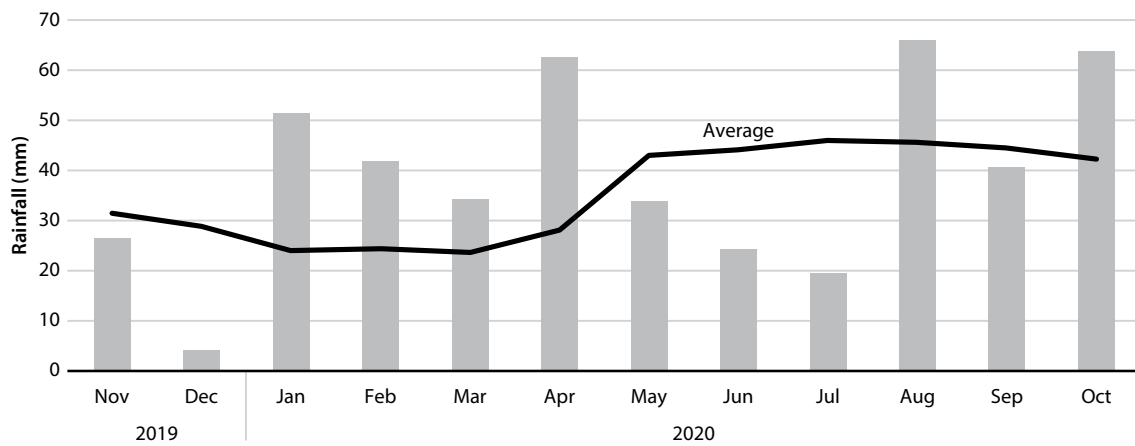
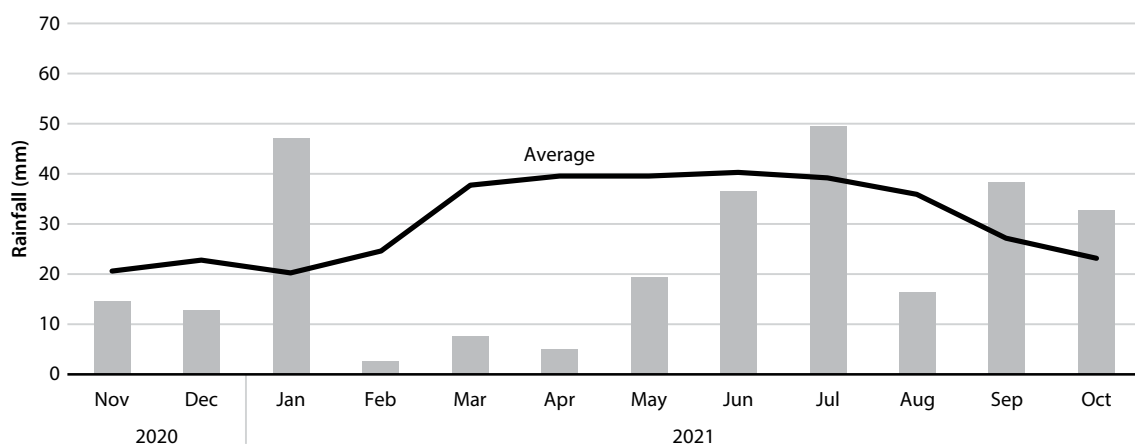
(a) Kalkee 2019**(b) Rupanyup 2020****(c) Wallup 2021**

Figure 1. Long term average rainfall and growing season rainfall, Oaten Hay Agronomy sites at (a) Kalkee 2019, (b) Rupanyup 2020 and (c) Wallup 2021.

Time of sowing

Across all varieties, time of sowing had no effect on hay yield in 2021, despite six weeks between sowing dates, and 3–3.5 weeks between emergence. Soil temperatures had begun to decline and, while crops emerged evenly, they lacked early vigour during June and into July as they struggled to establish roots and biomass.

On average, the highest hay yielding varieties were Vasse and Wintaroo (7.9t/ha), closely followed by Mulgara (7.2t/ha) ($P<0.001$).

A significant interaction between sowing date and variety occurred for three oat varieties ($P<0.001$). Mid-slow Vasse and mid-quick Durack benefited from earlier sowing and capitalised on the mild spring, with TOS1 outyielding TOS2 by 1.6t/ha and 1.1t/ha respectively. It is likely that the TOS2 date was too late for the faster-maturing variety to capitalise on the mild spring. Mid-quick Koorabup on the other hand yielded 1.7t/ha higher when sown later. All other varieties yielded similarly at both times of sowing.

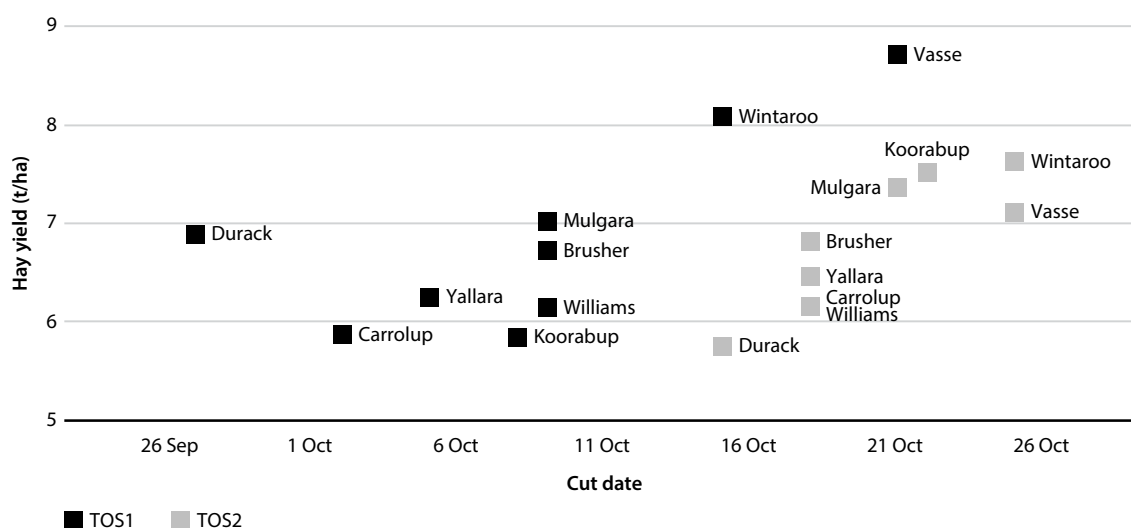


Figure 2. Oaten hay yield response to time of sowing with corresponding cut date, Wallup 2021. Stats TOS x Variety: $P<0.001$, $LSD=0.55t/ha$, $CV=7.2\%$.

For each time of sowing, the shortest season variety, mid-quick Durack was first to reach GS71, and longest season varieties—mid-maturing Wintaroo and mid-slow Vasse—were last to be cut for hay.

Nitrogen response

Across the nine varieties, hay yield increased by 0.26t/ha as N rate increased from 30 to 60N but there was no further response to 90N ($P<0.001$). The response to N rate did not differ between varieties.

There was a weak negative response ($P=0.094$) between TOS and N rate but only for the TOS2 30N treatment which yielded less (0.46t/ha) than other TOS and N combinations.

For varieties Mulgara, Wintaroo and Yallara that received six rates of N up to 150kg N/ha, there was again a general overall response to N rate ($P<0.001$), but no difference between varieties. Hay yields increased to 90N, then plateaued at higher rates (Figure 3).

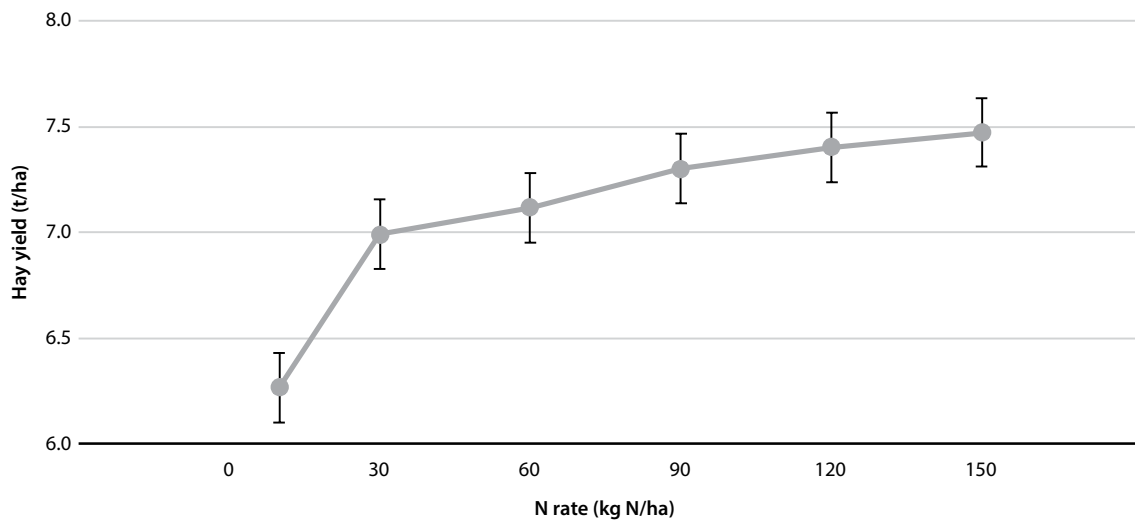


Figure 3. Oaten hay yield response to N rate across varieties, Wallup 2021. Stats: $P < 0.001$, $LSD = 0.33 \text{ t/ha}$, $CV = 6.9\%$.

Across the six N rates for Mulgara, Wintaroo and Yallara, there were no time of sowing and nitrogen rate interactions.

Hay quality

Plant height

Plant height averaged 76cm and was influenced by variety ($P < 0.001$) and N rate ($P < 0.001$), but not TOS.

Wintaroo was tallest at 89cm, followed by Brusher and Mulgara at 84cm and 83cm respectively ($P < 0.001$). While yielding highest, Vasse was one of the shortest varieties, averaging 69cm, with Durack at 70cm and Williams at 68cm. While TOS did not affect height on average across varieties, later TOS2 reduced already shorter Vasse plant height from 72cm to 67cm ($P = 0.001$).

Across varieties, increasing N rate from 30–60N to 90N increased plant height by 2cm from 75cm to 77cm ($P < 0.001$). By increasing N rate from 30 to 60N Vasse increased height by 5cm to 71cm, but height did not increase further when N was raised to 90kg N/ha ($P = 0.003$). Height increased for Brusher, Carrolup and Mulgara when N rate was raised from 60 to 90kg N/ha by 6cm, 3cm and 3cm respectively. N rate did not affect plant height for other varieties.

Lodging

No hay crops lodged in 2021.

Leaf greenness (SPAD chlorophyll measure)

Colour measurements or greenness of hay (SPAD) is a desired quality trait, indicating plant health and conditions for hay during curing and baling. SPAD averaged 50 units. It was affected by variety ($P = 0.001$) and N rate ($P < 0.001$) but not TOS across varieties.

Highest SPAD readings measured 50–52 for Mulgara, Brusher, Durack, Williams and Wintaroo, while Vasse measured lowest at 48; a contrast to the 2020 season when longer season Vasse was one of the greenest. TOS affected variety SPAD ($P = 0.038$) but only for Mulgara, which increased greenness by 4 units when later sown in July.

Increasing N rate from 30 to 60 to 90 increased SPAD from 47 to 51 and 52 respectively, but there was no SPAD response interaction between N rate with variety or TOS.

Stem thickness

Thinner stems (<6mm) with lower fibre and higher water-soluble carbohydrates make better quality hay. Stem diameter for all treatments met this quality target (Table 2). They averaged 4.5mm, ranging from 3.8mm to 5.1mm, driven by the high target plant density of 320 plants/m² (sowing rates ranged from 159 to 197kg/ha).

Table 2. Stem diameter of oaten hay varieties at two times of sowing, Wallup 2021.

TOS	Oaten hay variety								
	Brusher	Carrolup	Durack	Koorabup	Mulgara	Vasse	Williams	Wintaroo	Yallara
1	4.5 ^{abc}	4.4 ^{bcd}	4.9 ^a	3.8 ^e	4.7 ^{abc}	4.5 ^{abc}	4.6 ^{abc}	4.9 ^{ab}	4.3 ^{bcd}
2	4.4 ^{bcd}	4.2 ^{cde}	3.9 ^{de}	4.6 ^{abc}	4.6 ^{abc}	4.5 ^{abc}	4.4 ^{abc}	4.8 ^{ab}	4.4 ^{bcd}
	Sig. diff.				P=0.009				
	LSD(P=0.05)				0.3mm				
	CV%				11.9				

Stem diameter responded to TOS by variety (P=0.009). Durack responded strongest to later sowing with reduced stem thickness by 1.0mm, whereas Koorabup increased stem thickness by 0.8mm (Table 2). Durack TOS2 and both TOS for Wintaroo had the thickest stems but they were well under 6mm. There were no differences in stem diameter between sowing times for other varieties.

Although Vasse was below the industry standard of 6mm, it is not preferred by hay processors as the stems can be too thick when attention to seeding density is not taken.

Stem thickness did not respond to nitrogen rate in 2021.

COMMERCIAL PRACTICE AND ON-FARM PROFITABILITY

For the third season, the trial site received below average rainfall across the growing season. However, like in previous seasons, rainfall exceeded the average for particular months. In 2021 those months were July and September, during plant growth stages that would have set tillers and finished biomass.

Rainfall patterns from three different seasons in the Wimmera (Kalkee and Rupanyup) have produced different oaten hay yield and quality responses to agronomy treatments.

- In 2019, a drier spring meant crops sown earlier yielded higher, faster varieties generally did better, and crop yields were optimised at a lower nitrogen rate of 60kg/ha.
- 2020 had a favourable start and finish but a dry winter; delaying sowing until the end of May grew more hay, longer season varieties Vasse and Wintaroo performed better, and yields were optimised by higher N at 90kg/ha.
- In 2021, a very dry autumn meant time of sowing had less effect but good spring rain meant longer season varieties Vasse and Wintaroo again performed best and yields responded when N rates were increased to 90kg/ha.

The challenge is to make sowing decisions with regard to the season forecast that will favour hay production and then for that forecast to happen. Over the past three seasons, the spring forecast has eventuated, although nerves have been tested along the way. Time of sowing and variety decisions must be made at sowing and N rate should be decided and applied by GS25 (tillering) to GS31 (stem elongation), which is about six weeks after sowing.

Production and NIR quality results from similar trials nationally will be collated to produce guidelines for agronomy to optimise hay quality in different seasons and regions across Australia.

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