Management options for dry saline soils on Upper Yorke Peninsula: The second season

Sam Trengove, Stuart Sherriff, Jordan Bruce, Declan Anderson and Sarah Noack
Trengove Consulting

Key messages

- In season one lentil grain yields were generally low (0.16 t/ha – 0.62 t/ha) in the sand, straw and gypsum amelioration trial. The high sand application rate (1300 t/ha) was the only treatment to improve lentil grain yield compared to the control.
- This season larger differences among the sand and straw rates are emerging. Sand rates above 650 t/ha and straw rates above 6.6 t/ha resulted in wheat grain yields of 1.95 t/ha – 2.42 t/ha compared to the control 0.67 t/ha.
- Wheat yields following various crop type/varieties sown in 2022 to manage salinity ranged from 0.51 – 0.99 t/ha. Wheat yields following canola and field pea were higher compared to wheat following wheat, triticale or barley.
- There was a link between wheat grain yield this season and plant cover from the various crop types/varieties at harvest last year. Crop types which had <40% plant cover at harvest resulted in lower wheat yields the following season.

Why do the trial?

Dry saline soils are a type of land salinity that occurs in soils with high levels of naturally occurring salt (but is not associated with a shallow water table). In mild situations, dry saline land can also be referred to as transient salinity, where salts are trapped within the soil profile (e.g., due to low permeability clay subsoil) and salts move up and down depending on seasonal conditions. Situations which lead to higher evaporation of moisture e.g., long hot summers, periods of drought and the loss of surface plant/stubble cover increase the presence and severity of saline soils patches. Poor plant growth and yields are commonly observed on impacted areas due to the difficulties for crops to take up water in saline soils and the toxic effects of high salt in the plant.

This research aims to trial and demonstrate different management practices which could be used by growers to ameliorate saline soil patches:

1) Amending soil with sand, straw or gypsum - application of amendments to the soil surface can improve crop emergence by reducing evaporation leading to more soil moisture, or by reducing the moisture required to germinate a seed by increasing the sand content of the soil surface. Gypsum was also included to increase the amount of calcium relative to the level of sodium (salt) and address sodicity in the longer-term.
2) Selecting crop types/varieties – to investigate the differences in crop performance on saline soils between crop types and varieties with improved salt tolerance.

How was it done?

Site selection and rainfall

Two trials were established at Tickera, SA (-33.8466, 137.6844) in 2022 – a soil amelioration trial and a crop type/variety trial. The saline area was selected based on historical crop performance and soil test results (Table 1). The amelioration trial was a randomised complete block design and the crop type/variety trial was a split plot design where crop type (monocot/dicot) was the whole plot and crop type/variety was the sub plot. Both trials had four replicates and the individual treatments are described below. All plots were scored prior to seeding for stubble cover (barley) to assess the variation in salinity level across the site. Stubble cover was measured visually by scoring each plot from 1 (low stubble cover = more saline) to 5 (high stubble cover = less saline).

Growing season (April – October) rainfall at Tickera was 250 mm in 2022 and 219 mm in 2023. Long-term (1969-2022) average growing season rainfall for Tickera is 252 mm.

Soil properties

Soil samples were collected on 29th April 2022 by sampling the surface 0-10 cm in all five stubble cover scores (Table 1). Deeper cores were sampled in areas with scores 1 and 4 and segmented as follows, 0-10 cm, 10-20 cm, 20-40 cm and 40-60 cm, these were not replicated.

The Tickera site is a moderate to strongly alkaline (pH >8.0) clay loam with salinity issues (Table 1). Salinity was measured using chloride and an electrical conductivity estimated (ECe) which uses a texture conversion factor (9.5 for sandy loam) from the EC1:5. Chloride levels in the surface and subsurface ranged from 520 – 4800 mg/kg. The critical level for chloride in clay soils is 300 mg/kg (Hughes 2020). Above this critical value salinity damage is likely to occur depending on crop tolerance. The ECe across the site was 5.4 – 37. In general, it is expected at ECe 4-8 yields of many crops will be affected and 8-16 only crops with tolerance will yield well (Hughes 2020). Beyond 32 is generally considered too salty for most broadacre crops to grow.

Table 1. Soil properties for samples collected at salinity management trial Tickera, SA 2022.

Stubble cover score	Sample depth	pH 1:5 water	Chloride	Salinity EC1:5 (soil:water)	ECe (estimated)	Boron
	cm		mg/kg	dS/m	dS/m	mg/kg
1 (Low stubble / more saline)	0-10	8.1	4800	3.9	37	-
	10-20	8.6	1500	1.5	14	18
	20-40	8.9	1400	1.4	13	29
	40-60	9.1	1400	1.5	14	32
2	0-10	8.2	1800	1.6	15	-
3	0-10	8.2	1300	1.2	11	-
4 (High stubble / less saline)	0-10	8.0	1600	1.4	13	-
	10-20	8.8	520	0.62	5.9	8
	20-40	9.1	770	0.97	9.2	25
	40-60	9.1	1400	1.5	14	38
5	0-10	8.2	720	0.71	6.7	-

Boron levels across the site and soil depths ranged from 8 – 38 mg/kg. Boron toxicity for sensitive crop generally occurs at levels > 5 mg/kg and at levels > 15 mg/kg it is considered toxic for dryland cereals (Hughes 2020).

Sand, gypsum and straw amelioration trial

Sand and gypsum treatments were spread on the soil surface 3rd May 2022. Straw treatments (from baled wheat) were applied post seeding on 27th May 2022. Treatments included; control, gypsum 10 t/ha, straw 3.3 t/ha, straw 6.6 t/ha, straw 10 t/ha, sand 130 t/ha, sand 650 t/ha and sand 1300 t/ha (Photo 1). Sand rates were calculated on applying a sand layer of 1 cm (130 t/ha) 5 cm (650 t/ha) and 10 cm (1300 t/ha) covering the surface. The sand was sourced from a sand pit 15 km northeast of the trial site at Alford and applied using a front-end loader and shovel. The gypsum used in the trial had a purity of 69% making it a grade 3 product.

In the first season, the trial was sown with Hurricane XT lentils on 26th May 2022 at a rate of 50 kg/ha. Fertiliser at seeding was applied as MAP 1%Zn at 60 kg/ha. The trial was sown to Chief CL Plus wheat on 11th May 2023 at a rate of 80 kg/ha. Fertiliser at seeding was applied as MAP 65 kg/ha plus urea 42 kg/ha. The trial was managed with the application of pesticides to ensure a weed, insect and disease-free canopy.

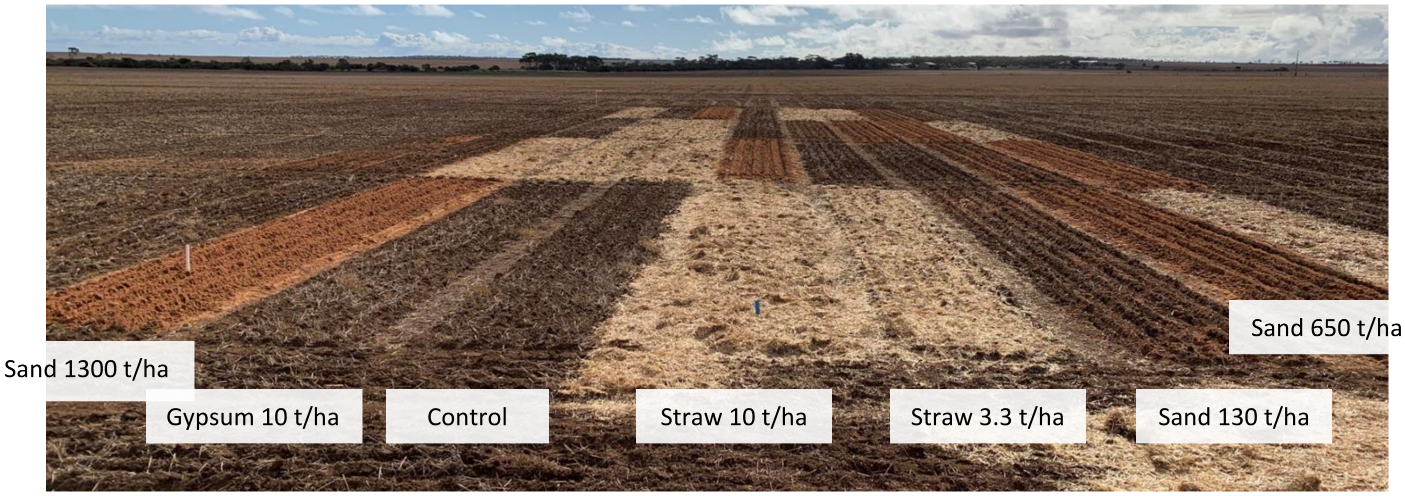

Photo 1. Sand, gypsum and straw amelioration treatments post seeding at salinity management trial Tickera, SA (taken 27th May 2022).

Crop type and variety trial

A range of crop types and varieties were selected for the trial based on their expected relative tolerance to soil salinity (Table 2). The crop type/variety treatments were sown in 2022. The residual effects of these treatments were assessed in 2023 with all plots sown to a Chief CL Plus wheat as described above on 11th May.

Table 2. Crop types and varieties sown in the first season (2022) of the salinity management trial Tickera, SA.

Crop type	Variety	Target plant density (plants/m^2)	Expected tolerance to soil salinity level (ECe)
Barley	Compass	150	10
Oats	Mulgara	240	5.4
Triticale	Yowie	200	8
Wheat	Glad_V13*	180#	-
	Glad_V26*	180#	-
	Glad_V3*	180#	-
	Gladius	180	7.5
	Scepter	180	7.5
Lentil	Bolt	120	-
	Highland	120	-
Field Pea	Butler	50	3
Vetch	Timok	50	4
Canola	44Y94	50	8
Safflower	Conventional	40	6

**Near isogenic lines of Gladius wheat (able to accumulate 10x more sodium than current wheat varieties) was sourced from The University of Adelaide. Only two replicates of these varieties were included due to seed availability. #Seeding rates of near isogenic lines ranged from 50 - 80 kg/ha due to limited seed source.*

Crop assessments

The same crop assessments were conducted in both trials in 2023. Plant emergence was scored for each plot on 29th May 2023, ranging from 0% (no plant emergence) – 100% (full plant emergence). A Greenseeker was used to measure NDVI on 29th June and 28th July 2023. Grain harvest was completed on 2nd November 2023 using a plot header. Grain quality assessments included protein, test weight and screenings.

Statistical analysis

Analysis of this experiment was conducted using linear mixed models with restricted maximum likelihood using ASReml-R (Butler, 2022) and the R Core Team (2022) package biometryassist (Nielsen et al. 2022). Where there is significance evidence from the model that the explanatory variable means differ, Tukey's multiple comparison test was used to determine which of the means are different at a significance level of 5%.

What happened?

Sand, gypsum and straw amelioration trial

In season one lentil grain yields were generally low (0.16 t/ha – 0.62 t/ha) across the trial. The high sand application rate (1300 t/ha) was the only treatment to improve lentil grain yield compared to the control.

This season sand applied at 650 t/ha and 1300 t/ha improved wheat grain yields to 1.97 t/ha and 2.26 t/ha, respectively compared to the control at 0.61 t/ha (Table 2). Both treatments can clearly be identified (high plant cover) in an aerial image of the trial (Photo 2). These results indicate the higher sand rates are providing one or both of the following, a mulching effect disrupting the evaporation from the soil surface retaining more moisture and reducing surface salinity and a layer of soil with lighter texture for crops to establish well and therefore yield significantly more. In general grain quality in the sand treatments was similar compared to the control, meeting H2 receival standard. However, test weight was borderline (minimum for maximum grade >76 kg/hL) for the sand rates and in one case reduced the delivery grade to AUH2. This reflects below average growing season rainfall impacting grain fill in the sand treatments which had higher yield potential.

A similar result was observed for the straw rates trialled. The 6.6 t/ha and 10 t/ha treatments had high wheat grain yields of 1.95 t/ha and 2.42 t/ha, respectively (Table 2). As for the sand treatments these results suggest the higher rates of straw had a mulching effect and were able to retain more soil moisture (summer and in-season) for the crop by reducing evaporation and surface salinity and improving emergence and yield. Grain quality for these two treatments was lower compared with the sand, gypsum and control. Grain protein was less than 11.5% resulting in a maximum delivery grade of APW1. It is not surprising that nitrogen supply may be lower in these treatments given the large volume of straw applied, where soil microbial biomass ties up nitrogen as the straw decomposes.

The lower rates of straw 3.3 t/ha and sand 130 t/ha produced wheat grain yields that were no different to the control (Table 2).

Table 2. Lentil and wheat grain yields (t/ha) and wheat grain quality for sand, straw and gypsum treatments at Tickera, SA.

Treatment	2022	2023		
	Lentil grain yield (t/ha)	Wheat grain yield (t/ha)	Protein (%)	Test weight (kg/hL)
Control	0.23 b	0.67 c	11.8 bc	78.1 abc
Gypsum at 10 t/ha	0.16 b	1.26 c	11.8 bc	77.7 bcd
Sand at 130 t/ha	0.25 ab	1.26 bc	11.9 abc	76.3 cde
Sand at 650 t/ha	0.40 ab	1.97 ab	12.1 ab	76.1 de
Sand at 1300 t/ha	0.62 a	2.26 a	12.6 a	75.4 e
Straw at 3.3 t/ha	0.40 ab	1.19 c	11.5 bcd	78.4 ab
Straw at 6.6 t/ha	0.46 ab	1.95 ab	11.3 cd	78.9 ab
Straw at 10 t/ha	0.46 ab	2.42 a	11.0 d	79.8 a
Pr(>F)	0.001	<0.001	0.007	0.001

Gypsum applied at 10 t/ha has not improved grain yield compared to the control in either season. A lack of crop response is not uncommon from many soil amendments in the first few years after application. The surface-applied gypsum will gradually move through the soil profile with rainfall, but this can take many years. Long-term monitoring of this site will be required to understand the full soil, crop and economic returns from these treatments.

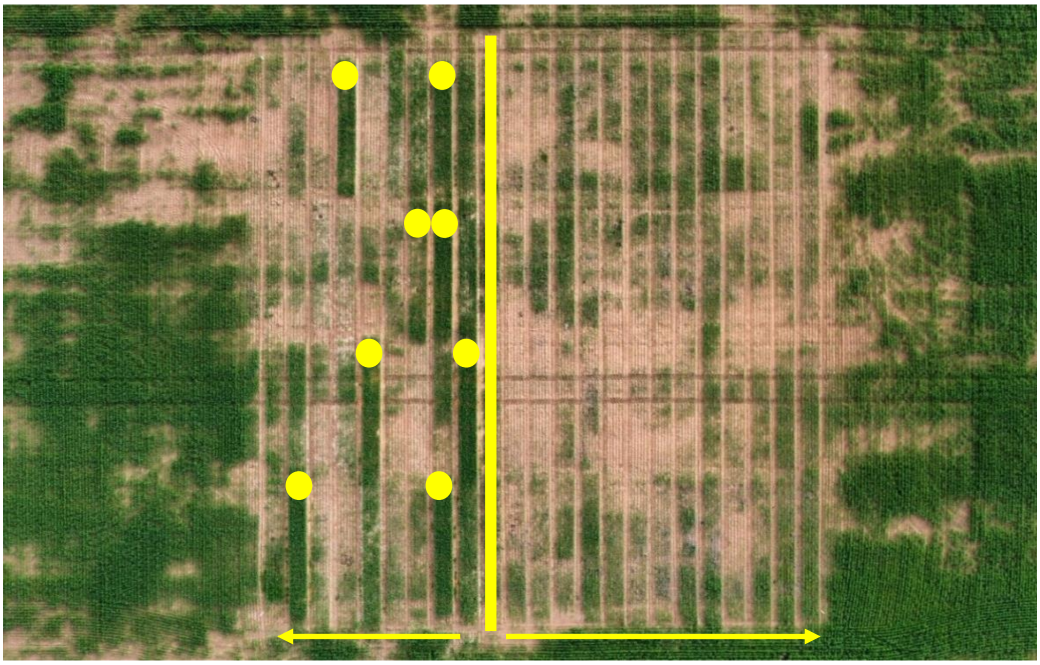

Photo 2. Aerial photo of the salinity management trials at Tickera, SA on July 28, 2023. Line shows the buffer with the sand, gypsum and straw trial on the left and crop type/variety trial on the right. Dots indicate the 650 t/ha and 1300 t/ha sand rate plots applied in 2022.

Cumulative grain yield response to the various sand rates applied (Figure 1) shows grain yield stabilises after approximately 650 t/ha. That is, application of sand rates beyond this point did not result in large yield gains. This sand rate is higher compared to 2022 results in isolation, which suggested rates above 200 t/ha were sufficient to achieve high lentil grain yields.

For the straw rates there is a liner response in cumulative grain yield (Figure 1). This suggests the straw rates trialled have not maximised grain yield and further gains may be achieved from rates above 10 t/ha.

As multiple seasons of data and crop types are evaluated a better understanding of optimal sand and straw rates at Tickera will be determined. It is also unknown how long these treatments will have effect on crop growth and production.

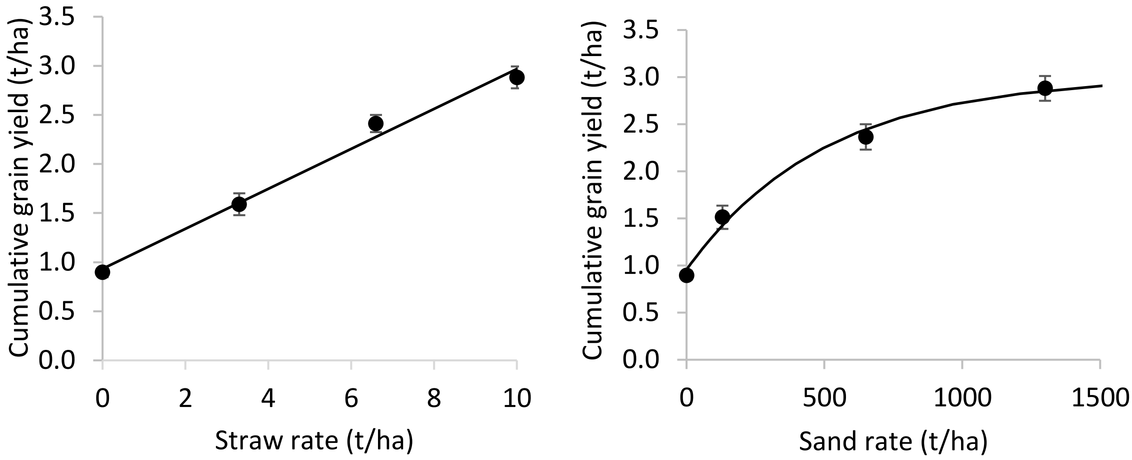

Figure 1. Cumulative (2022 lentil + 2023 wheat) grain yield response in relation to straw (left, R^2 = 0.988) and sand (right, R^2 = 0.978) rates applied in salinity management trial Tickera, SA.

Crop type and variety trial

Summary of 2022 crop performance

Canola and safflower had the highest crop cover (75% and 83%, respectively) at harvest in 2022. Other treatments with high crop cover at harvest were oats (82%), lentil (57%) and vetch (57%). The lower crop cover in the cereals was attributed to low rainfall from mid-June through July which limited tillering and caused crop damage/death in the more saline patches.

Grain yield was variable across the site, however there were differences between crop type with oats (0.9 t/ha) being the highest yielding. Barley, peas, and safflower had intermediate performance averaging 0.53 t/ha. Wheat, triticale, lentil and vetch were the lowest yielding. Grain yield of canola was not recorded due to severe bird damage prior to harvest.

Carryover effects in the 2023 wheat crop

Wheat plant emergence scores 18 days after sowing were low and varied between 11 – 44% across the crop types (Table 3). Despite variation in emergence there were only minor differences among treatments at the end of the season. The high variability in plant emergence is related to the natural variability of soil salinity levels across the trial (Photo 2). In some cases, crop production and stubble cover from 2022 may have also contributed this variation however there was not a strong correlation (Figure 2).

Grain yields across the trial were similar to the control treatments in the adjacent amelioration trial discussed above. They ranged from 0.51 t/ha – 0.99 t/ha and this highlights that these strategies are relatively ineffective at treating dry saline soils. Despite this, Greenseeker NDVI and grain yield data showed there were minor differences between crop type this season although there was no variety effect (Table 3). Both crop assessments showed wheat following canola and field pea were generally higher compared to wheat following wheat, triticale or barley.

There was a moderate relationship (R^2=0.62) between wheat grain yield this season and plant cover from the various crops/varieties at harvest in 2022 (Figure 2). Crop types with more crop cover at harvest had more residue cover over summer, with implications for soil evaporation, salt accumulation, and the establishment and growth of the following crop. In general canola, safflower, oats, and the pulses had moderate to high (>45 – 70%) plant cover which corresponded to the higher yielding treatments. The plant cover from wheat, triticale and barley in 2022 was low (<40%) and similarly wheat grain yields were lower following these crops.

There were no differences in grain quality among the treatments with all samples meeting H2 receival standard. On average grain protein was 12.1%, test weight 76.7 kg/hL and screenings 4.0% (data not shown).

Table 3. Wheat plant establishment, Greenseeker NDVI and grain yield (t/ha) averaged across variety for the crop type and variety salinity management trial Tickera, SA 2023.

2022 Crop	Plant emergence (%) 29th May	NDVI 28th July	Grain yield (t/ha)
Barley	15 bc	0.306 abc	0.64 bc
Oats	44 a	0.391 a	0.91 a
Triticale	11 c	0.303 abc	0.78 abc
Wheat	32 abc	0.299 bc	0.7 abc
Lentil	30 abc	0.375 ab	0.88 ab
Peas	30 abc	0.361 abc	0.66 abc
Vetch	26 abc	0.292 bc	0.6 c
Canola	40 ab	0.352 abc	0.83 abc
Safflower	16 abc	0.285 c	0.58 c
Pr (>F)	0.040	0.022	0.020
LSD (0.05)	27.5	0.089	0.26

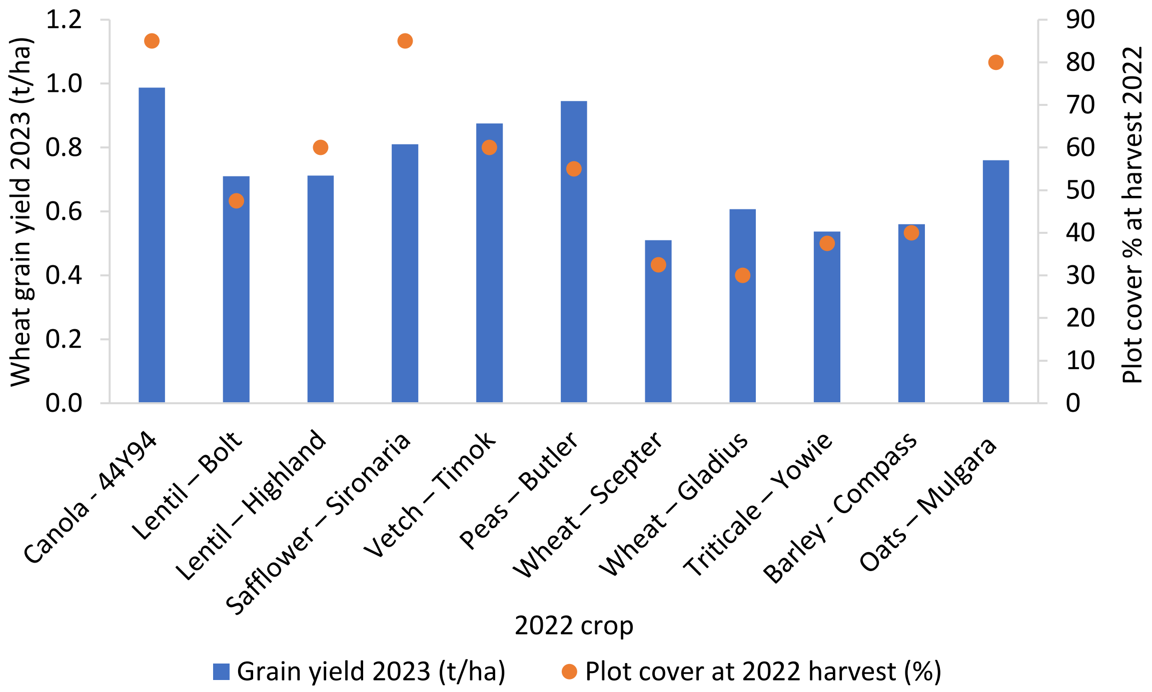

Figure 2. Wheat grain yield for the various crop types / varieties sown in 2022 and their respective plot cover % at harvest for salinity management trial at Tickera, SA.

What does this mean?

Application of at least 650 t/ha of sand or 6.6 t/ha of straw improved wheat grain yields this season compared to the control. The application of sand at that rate is logistically difficult unless a source is located nearby. However, if there is a source close by, this level of application is achievable over large areas, such as in the scenario of spreading clay on sands to alleviate non wetting properties. Where sand is not readily available it is likely to be unviable and application of straw at a minimum of 6.6 t/ha would be more achievable. The longevity of response is important for these amelioration treatments due to high cost and needs further investigation.

Crop type and variety selection had minor influence on wheat NDVI and grain yield in season two of the trial. Both crop assessments showed wheat following canola and field pea were generally higher compared to wheat following wheat, triticale or barley. There were few differences among the remaining crop types/varieties. However, there was a moderate relationship between plant cover at harvest in season one and wheat grain yield in 2023. Crop/variety treatments which had higher plant cover at harvest in 2022 generally had higher grain yields compared to those with low (<40%) plant cover.

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