Management options for dry saline soils on Upper Yorke Peninsula

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Key Findings

- Application of sand and straw improved lentil growth and grain yield in the first year. Sand rates above 650 t/ha and straw rates above 6.6 t/ha resulted in lentil grain yields of 0.45 t/ha – 0.57 t/ha compared to the control 0.12 t/ha.
- Oats were the highest yielding species at 0.9 t/ha, followed by safflower, barley and peas. Canola also performed well but was not harvested due to bird damage. Wheat, triticale, lentil and vetch were the lowest yielding species trialed.

Introduction

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 include 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 up take 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 species and varieties with improved salt tolerance.

Methodology

Site selection and rainfall

Two trials were established at Tickera, SA (-33.8466, 137.6844) – a soil amelioration trial and a crop species/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 species/variety trial was a split plot design where crop type (monocot/dicot) was the whole plot and crop species/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. Long-term (1969-2022) average growing season rainfall for Tickera is 252 mm.

Soil properties

Soil samples were collected on April 29, 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 with no replicates per depth.

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.

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).

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

Stubble cover score	**Sample depth** (cm)	**pH 1:5** (water)	**Chloride** (mg/kg)	**Salinity EC1:5** (soil:water) (dS/m)	**ECe** (estimated) (dS/m)	**Boron** (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	-

Sand, gypsum and straw amelioration trial

Sand and gypsum treatments were spread on the soil surface May 3, 2022. Straw treatments (from baled wheat) were applied post seeding on May 27, 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. 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 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.

The trial was sown with Hurricane XT lentils on May 26, 2022, at a rate of 50 kg/ha. Fertiliser at seeding was applied as MAP 1% Zn at 60 kg/ha. The trial was managed with the application of pesticides to ensure a weed, insect and disease-free canopy.

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 trial was sown on the May 26, 2022. Boxer Gold® @ 2.5 L/ha was applied to all wheat, barley and triticale plots for ryegrass control, making oats the only cereal with no pre-emergent grass control. The site was treated with bifenthrin after Mandalotus weevil were observed damaging the canola.

Table 2. Crop types and varieties selected for salinity management trial Tickera, SA 2022.

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#	-
Wheat	Glad_V26*	180#	-
Wheat	Glad_V3*	180#	-
Wheat	Gladius	180	7.5
Wheat	Scepter	180	7.5
Lentil	Bolt	120	-
Lentil	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. Plant establishment was scored for each plot on June 21, 2022, ranging from 0 (no plant emergence) – 10 (full plant emergence). A Greenseeker was used to measure NDVI on July 12, 2022. Prior to harvest a score of crop cover was made on all plots where 100 = 100% crop cover and 0 = no crop cover. Grain harvest for all species, excluding Safflower and Canola, was completed on November 17, 2022 using a plot header. Safflower was harvested on Jan 6, 2023 due to delayed maturity compared to other crops using a plot harvester. Canola was not harvested due to severe bird damage at the end of the season.

Results

Sand, gypsum and straw amelioration trial

Lentil crop cover assessments at harvest show sand applied at 650 t/ha and 1300 t/ha had the highest level of crop cover (70-90%). This also translated to improved grain yields of 0.45 t/ha and 0.57 t/ha compared with the control 0.12 t/ha (Table 2). These results indicate the higher sand rate treatments provided a non-saline layer for crops to establish well and yield more in year one.

Crop cover for the two highest rates of straw were not as high (38% and 40%) compared to the sand treatments, however, had similarly high grain yields at 0.52 t/ha and 0.46 t/ha (Table 2). These results suggest the higher rates of straw may have been able to retain more soil moisture for the crop by reducing evaporation.

The lower rates of straw 3.3 t/ha and sand 130 t/ha produced plant cover and grain yields similar to the high rates, but they were also no different to the control (Table 2). In future years the longevity of the various sand and straw rates will continue to be measured.

Gypsum applied at 10 t/ha did not improve plant cover or grain yield compared to the control. A lack of crop response is not uncommon from many soil amendments in year one. For example, 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.

Table 2. Crop cover (% plot) and grain yield (t/ha) for sand, straw and gypsum treatments at Tickera, SA.

Treatment	**Crop cover at harvest 2022** (%)	**Grain yield** (t/ha)
Control	18^{a}	0.12^{b}
Gypsum at 10 t/ha	30^{a}	0.19^{b}
Sand at 130 t/ha	45^{ab}	0.34^{ab}
Sand at 650 t/ha	70^{bc}	0.45^{a}
Sand at 1300 t/ha	90^{c}	0.57^{a}
Straw at 3.3 t/ha	45^{ab}	0.35^{ab}
Straw at 6.6 t/ha	40^{a}	0.52^{a}
Straw at 10 t/ha	38^{a}	0.46^{a}
Pr(>F)	**<0.001**	**0.01**
LSD (P≤0.05)	**28**	**0.24**

Grain yield response to the various sand rates applied (Figure 1) shows grain yield stabilises after approximately 200 t/ha. That is, application of sand rates beyond this point did not result in large yield gains in lentils in 2022. For straw application rates the response appears to plateau after 5 t/ha.

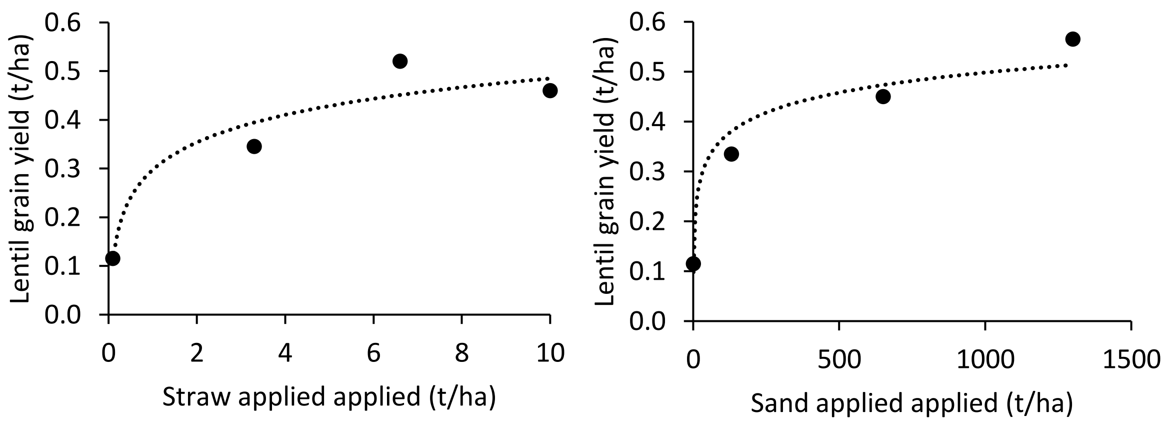

Figure 1. Lentil grain yield response in relation to straw (left, y = 0.0816ln(x) + 2.972, R^2 = 0.918) and sand (right, y = 0.0579ln(x) + 0.0983, R^2 = 0.9501) rates applied in salinity management trial Tickera, SA.

Crop type and variety trial

There were differences between crop species but there was no significant difference between varieties, within crop species (wheat and lentil), for any of the crop assessments. The Pr(>F) values for variety for the measurements were; emergence = 0.958, NDVI = 0.625, plant cover at harvest = 0.314 and grain yield = 0.614 (data not shown). The near isogenic wheat lines derived from Gladius (V3, V13, V36) had previously shown they can accumulate more salt however, in this trial they were not able to perform better than the parent variety Gladius.

Emergence scores for all crop types ranged from 4.9 for safflower up and average of 8.5 for all wheat varieties. The results show that all cereal crops (barley, oats, triticale and wheat) established better than the pulses (lentils, vetch and peas) and canola and safflower had the poorest establishment.

Across the trial NDVI values were low at the end of July (< 0.22). In general, the cereals and canola had the best plant cover (measured by NDVI) where lentils, field pea and safflower measured values similar to bare soil (0.11-0.14). The low NDVI values recorded in July across the trial were not reflective of the large differences in crop biomass observed in the field later in the season (Photo 1). The low NDVI for safflower in late July was not surprising given it was sown at the same time as all the other treatments. Safflower is slower developing and requires warmer conditions compared with the cereal, pulse and canola crops.

Despite low emergence early in the season, canola and safflower measured high crop cover (75% and 83%, respectively) at harvest (Table 3). Other treatments with high crop cover at harvest were oats (82%), lentil (57%) and vetch (57%). The lower crop cover in the cereals can be attributed to low rainfall from mid-June through July which caused crop damage / death in the more saline patches.

Grain yield was variable across the site, however there were significant differences between crop type with oats (0.9 t/ha) being the highest yielding (Table 3). Previous research (Lyons 2016) similarly reported oats tested under salinity stress yielded more than wheat, triticale and barley. Mulgara and Wintaroo were also identified as oat varieties with promising tolerance (Lyons 2016). 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. No measurement was made to assess yield, however notes recorded at harvest, indicate that the canola yield was expected to be similar to the best treatments.

Crop types with more crop cover at harvest may be expected to have more residue cover over Summer, with implications for soil evaporation, salt accumulation, and the establishment and growth of the following crop. These legacy effects will be monitored and the whole site will be sown to wheat in 2023.

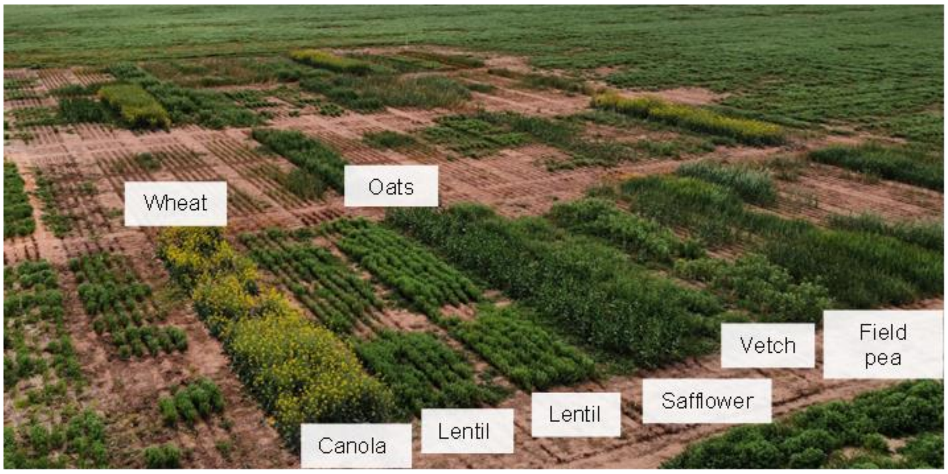

Photo 1. Crop type and variety treatments in the salinity management trial at Tickera, SA. Photo taken September 23, 2022.

Table 3. Plant emergence, Greenseeker NDVI, plant cover (%) and grain yield (t/ha) in crop type and variety salinity management trial Tickera, SA 2022.

Crop type	Emergence score (0-9)	NDVI 22nd July	Crop cover at harvest 2022 (%)	Grain yield (t/ha)
Oats	8.9^{a}	0.219^{a}	82^{d}	0.90^{a}
Barley	8.1^{ab}	0.200^{ab}	38^{ab}	0.53^{ab}
Triticale	8.7^{a}	0.211^{a}	43^{ab}	0.40^{b}
Wheat	8.5^{a}	0.193^{abc}	34^{a}	0.30^{b}
Lentil	7.1^{bc}	0.163^{cde}	57^{bc}	0.43^{b}
Vetch	6.7^{cd}	0.176^{bcd}	57^{bc}	0.45^{b}
Peas	5.8^{cde}	0.160^{de}	48^{ab}	0.49^{ab}
Safflower	4.9^{e}	0.143^{e}	75^{cd}	0.56^{ab}
Canola	5.6^{de}	0.215^{a}	83^{d}	-
Pr(>F)	**<0.001**	**<0.001**	**<0.001**	**0.011**
LSD (P≤0.05)	**1.36**	**0.032**	**22**	**0.42**

Conclusion

Application of at least 650 t/ha of sand or 6.6 t/ha of straw produced higher crop cover at harvest and grain yields compared to the untreated. The application of sand at that rate is logistically difficult unless a source is located nearby. However, if there is a source close by, it is achievable for this level of application, 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 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 had a bigger impact on crop performance compared to variety selection within this trial. It was expected that the near isogenic wheat lines would perform better than the standard varieties, Gladius and Scepter, as they have a greater capacity to accumulate salt. However, no crop or yield benefit was measured in this trial and more investigation is required to determine why this occurred.

Crop species performance did not rank in the order that was expected. Table 2 shows the expected ranking of crop tolerance to salinity with Barley > Canola > Triticale > Wheat > Safflower > Oats > Vetch > Field Peas. In this trial Mulgara oats produced the greatest grain yield of 0.9 t/ha closely followed by safflower, barley and field pea.

This trial will continue to be monitored in the 2023 season to observe any residual effects of applied sand and stubble and the effect of the different crop types.

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