Effect of row spacing, deep ripping, gypsum, water harvesting furrow and mulching crops grown on hard setting sodic soils

Shahab Pathan, David Hall and Glen Riethmuller Department of Primary Industries and Regional Development, WA

Key messages

- Depth of sowing is critical and difficult to control on deep ripped/cultivated heavy-textured soils.
- Crop establishment was negatively affected by the deep ripping treatments, mainly due to cloddy seedbeds and furrow infill.
- Wide row spacing (60 cm) has no yield benefits over narrow row spacing (30 cm), and treatments effects depend on seasonal variability.

Aims

Heavy-textured soils in the eastern grainbelt are subject to a range of constraints including sodicity, compaction and transient salinity. Each of these reduces plant growth by restricting water infiltration, water storage, crop emergence and root growth. Petersen (2016) estimates that sodicity alone results in $580 million in lost production in WA. Strategies to improve water storage and availability to plants include combinations of deep tillage, gypsum, wide row spacing, furrow forming wheels and stubble mulching. This paper reports on a four-year trial aimed at developing and assessing improved management systems to increase water storage in hard-setting sodic soils.

Method

The field trial site was located at Merredin Research Station (MRS) in paddock 3c (S31.505, E118.2126). The soil at the trial site is classified as a calcareous loamy earth (Schocknecht and Pathan, 2013) with multiple constraints, which include hardsetting, subsoil compaction and sodicity. There was considerable variation in physical and chemical properties at different depths (Table 1). Top soil was comprised primarily of sandy clay particles (clay 34-44%) and subsoil medium clay (clay 46-52%). A hard setting surface, poorly drained and few lime fragments (pedogenic carbonates) have been observed at >30 cm. Subsoils are highly compacted with soil resistance more than 3.5MPa within 20-25cm.The topsoil (0-20 cm) is moderately neutral, non-saline, with low soil organic carbon. The subsoil (20-80 cm) is alkaline, moderately saline (EC>0.45 mS/m) and highly sodic (ESP>15%) at depth (Table 1).

Table 1: Selected soil chemical properties of the trial site (MRS paddock 3c) at different depths and samples were taken prior to applying treatments.

Soil depth (cm)	pH ($CaCl_2$)	EC 1:5 (mS/m)	Total CEC (meq/100g)	OC (%)	Boron (mg/kg)	Sulphur (mg/kg)	ESP	Ca/Mg
0-10	5.1	5.1	11.81	0.77	2.6	13.9	4.5	1.91
10-20	6.8	10.3	24.11	0.54	7.7	12.8	9.1	1.34
20-40	7.9	44.9	27.55	0.30	16.3	125.3	17.5	1.18
40-80	8.2	63.3	26.60	0.12	30.6	140.8	31.8	0.86

The deep ripping (~40 cm) treatment (four 26 tines spaced 445 mm apart with five leading tines100 mm shallower and 223 mm off line) was completed in April 2015. Gypsum (2.5 t/ha; 84% purity) was applied on the surface by hand prior to deep ripping in 2015 and reapplied in April 2018. Furrow (5.0 cm height and 23.1-degree angle) was made using especially deigned wheels (23.5 cm wide and 5.0 cm deep) attached behind the tractor for harvesting water in the row. Following the 2015 growing season, each field plot (45 m) was split with half the plot across the entire area receiving a mulch of wheat straw (5 t/ha) and half without mulch. The narrow (30 cm) and wide row (60 cm) spacing can be combined with the five major treatments, and mulching effect can be evaluated within these treatments (Figure 1). Ten treatments were laid out in a factorial randomised block design with three replicates.

Crops were sown using knifepoints, press wheels and standard agronomic practices for the region. The wheat straw mulch was applied using hand immediately after seeding. The mineral nutrient analysis of the wheat straw mulch used in this trial are given below (Table 2). Necessary fertilise (such as K-Till Extra, Agras, AgStarter 50-60kg/ha) and herbicide was applied as standard regional practice for specific crops. Measurements made during the growing season included germination counts, crop growth/vigour (NDVI), shoot dry matter, grain yield and quality (Table 3).

Table 2: Mineral nutrient analysis of the wheat straw mulch used in the trial.

Mineral nutrient	**Old wheat straw mulch** (3 year old)	**Fresh wheat straw mulch** (1 year old)
Total carbon (%)	36.93	43.17
Total nitrogen (%)	0.63	0.31
Phosphorus (%)	0.04	0.02
Potassium (%)	0.26	0.65
Calcium (%)	0.34	0.12
Sulphur (%)	0.06	0.05
Magnesium (%)	0.12	0.07
Zinc (mg/kg)	7.45	4.24
Copper (mg/kg)	4.45	1.8
Manganese (mg/kg)	139.12	77.78
Boron (mg/kg)	17.58	7.34

Table 3: A summary of the trial site major activities during last four years (2015-2018).

Activities	**2015**	**2016**	**2017**	**2018**
Gypsum (2.5 t/ha)	24 April			17 April
Deep ripping (~40 cm)	25 April			
Crop	Wheat	Wheat	Barley	Chickpea
Variety	Emu Rock	Mace	Latrobe	Striker
Sowing date	21 May	5 May	29 May	29 May
Seeding rate (kg/ha)	50	60	60	120
Plant biomass cut	30 September	24 August	5 October	10 October
Crop harvest	4 December	24 November	28 November	13 November
Growing season rainfall (mm)	211	210	188	229
Annual rainfall (mm)	345	462	322	319

Results

Crop establishment (plants/m^2) was negatively affected by the deep ripping treatments resulting in reduced plant numbers, irrespective of row spacing and mulching for the years 2015 to 2017 (Table 4). For example, in 2016 growing season, 61-76 plants/m^2 were established in the un-ripped treatment, compared with 44-61 plants/m^2 in the deep ripped treated plots, irrespective of mulching. This is mainly due to the seed being sown too deep (>5 cm) in the soft soils and exacerbated by large clods and furrow infill. Deep ripping can also reduce soil water content in the surface layers by disturbing and exposing the soil to evaporation, which can reduce crop establishment and grain yield in drier season. Depth of sowing is critical and difficult to control on ameliorated/cultivated soils were also observed other trials in south Western Australia (Blackwell et al, 2016).

Table 4: Effect of treatments on crop establishment (plant/m^2) during last four years (2015-2018), irrespective of mulching.

Treatments	Crop establishment (plants/m^2)			
	2015 Wheat	2016 Wheat	2017 Barley	2018 Chickpea
1. Untreated control at 30 cm row spacing	64	72	92	27
2. Untreated control at 60 cm row spacing	55	61	79	29
3. Gypsum at 30 cm row spacing	69	76	90	27
4. Gypsum at 60 cm row spacing	54	70	71	25
5. Deep ripping at 30 cm row spacing	38	59	75	28
6. Deep ripping at 60 cm row spacing	28	45	61	26
7. Deep ripping + gypsum at 30 cm row spacing	37	56	77	25
8. Deep ripping + gypsum at 60 cm row spacing	31	44	68	26
9. Deep ripping + gypsum + Furrow at 30 cm row spacing	43	61	83	28
10. Deep ripping + gypsum + Furrow at 60 cm row spacing	33	47	69	28
Lsd of means (5% level)	11 (p<0.001)	10 (p<0.001)	16 (p=0.006)	7 (p=0.96)

Despite poorer crop establishment, plant shoot dry matter and vigour (NDVI) were not significantly affected by the deep ripping treatments, irrespective of row spacing and mulching. Significant growth and shoot dry matter was observed in the year of lowest rainfall (319-322 mm) during 2017 and 2018 growing season under mulch comparer to no mulch regardless treatments (data not shown).

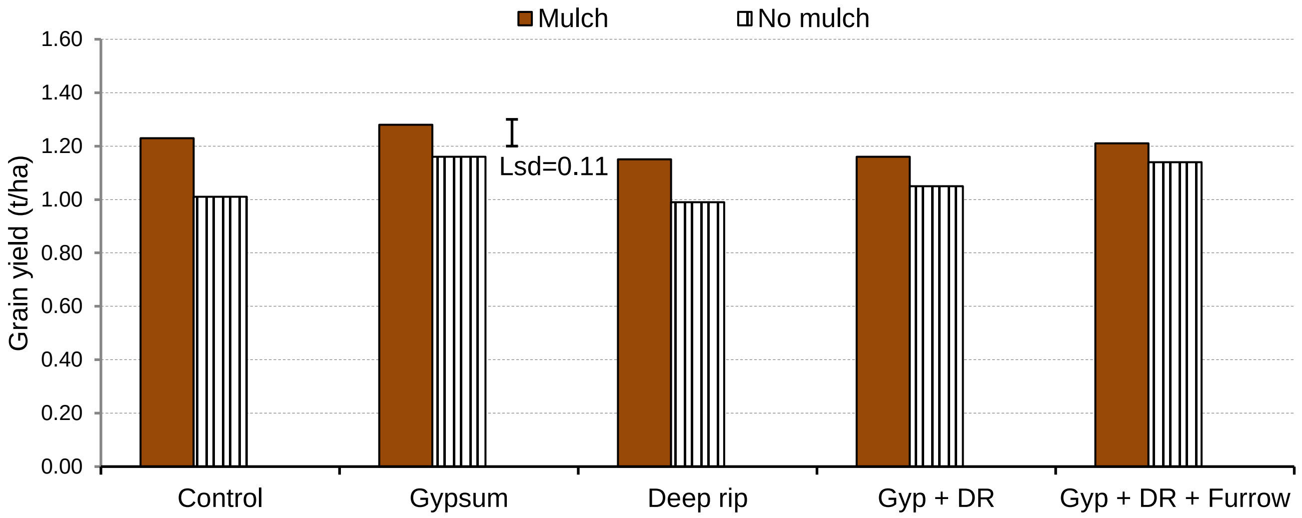
Table 5: Effect of various treatments on grain yields (t/ha) during last four years (201-2018), irrespective of mulching.

Treatments	Grain yield (t/ha)			
	2015 Wheat	2016 Wheat	2017 Barley	2018 Chickpea
1. Untreated control at 30 cm row spacing	2.01	3.50	1.14	1.45
2. Untreated control at 60 cm row spacing	1.78	2.81	1.10	1.47
3. Gypsum at 30cm row spacing	2.02	3.22	1.29	1.51
4. Gypsum at 60cm row spacing	1.74	2.87	1.15	1.41
5. Deep ripping at 30 cm row spacing	1.63	3.73	1.12	1.40
6. Deep ripping at 60 cm row spacing	1.49	3.15	1.02	1.43
7. Deep ripping + gypsum at 30 cm row spacing	1.65	3.56	1.14	1.49
8. Deep ripping + gypsum at 60cm row spacing	1.54	2.99	1.08	1.52
9. Deep ripping + gypsum + Furrow at 30 cm row spacing	1.84	3.52	1.22	1.52
10. Deep ripping + gypsum + Furrow at 60 cm row spacing	1.68	3.01	1.13	1.34
Lsd of means (5% level)	0.13 (p<0.001)	0.25 (p<0.001)	0.10 (p=0.002)	0.13 (p=0.14)

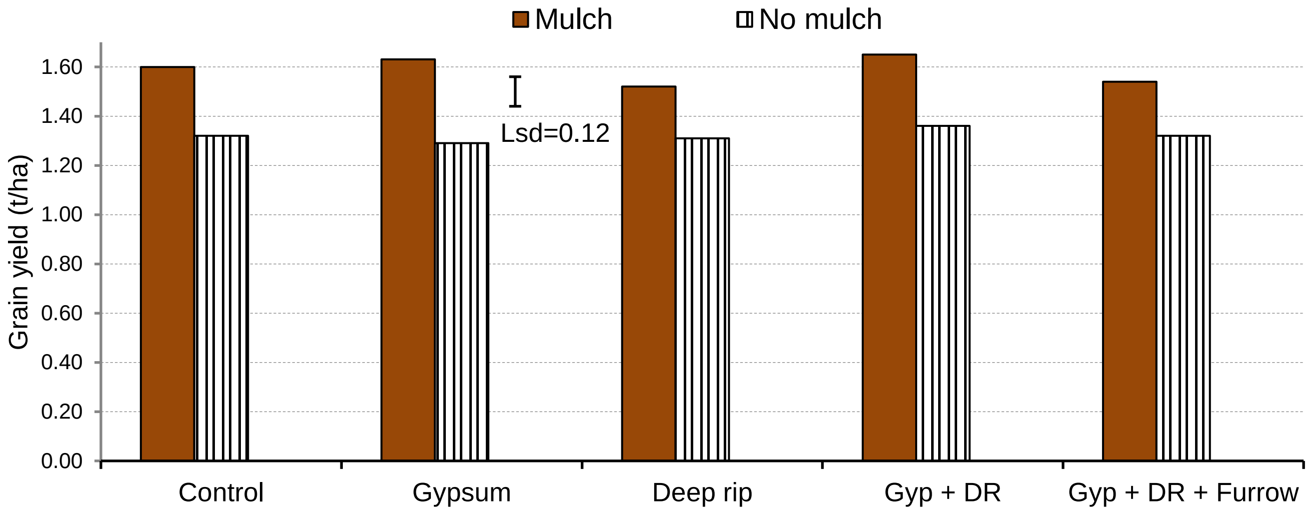
Grain yield responses to deep ripping were temporally and seasonally variable (Table 5). Deep ripping reduced crop yields (Table 5) in the initial year of the experiment due to cloddy seedbed conditions that reduced crop establishments (Table 4). There was no response to the deep ripping treatments in either the 2017 or 2018 growing season which received the lowest rainfall (319-322 mm). However, in 2016 growing season in the year of highest rainfall (462 mm) the highest grain yield occurred with one of the deep ripping treatments (3.15-3.73 t/ha), irrespective of row spacing (Table 5). This response of deep ripping in wet years is consistent with the findings of Wong and Asseng (2007).

Cereal (wheat and barley) grain yield in 2015, 2016 and 2017 were significantly ($p<0.001$) higher on narrow row spacing (30 cm) compared to wide row spacing (60 cm), average over mulching and irrespective of treatments (Table 5). For example, in 2016 higher grain yield was observed on narrow row spacing (3.5 t/ha) compare to wide row spacing (2.97 t/ha), average over treatments. This was mainly due to a low number of plants number in wide row spacing compare to narrow row spacing (Table 4). Nevertheless, in 2018 chickpea grain yield has no significant differences in between narrow and wide row spacing, average over treatments.

Grain yield increased in response to gypsum and mulching in the years of lowest rainfall (2017 and 2018, 322 and 319 mm respectively) while no response occurred in the year of highest rainfall (2016, 462 mm). For example, during 2017 and 2018 higher grain yield was found from gypsum treated plots compare to without gypsum, irrespective of mulching (Table 5). However, there was a greater increase in yield in response to gypsum without mulch than with mulch. For example, in 2017 without mulch barley grain yield was increased about 15% and with mulch 4% compared to untreated control, irrespective of row spacing (Figure 1a). This was mainly due to improved soil water infiltration, reduced soil sodicity (ESP), and improved soil Ca:Mg in response to the gypsum.



(a) Barley grain yield 2017



(b) Chickpea grain yield 2018

Figure 1: Effect of mulching on grain yields during 2017 (barley) and 2018 (chickpea), average over row spacing.

On the other hand, during 2017 and 2018 in the years of lowest rainfall (319-322 mm), significant ($p<0.001$) increases in grain yield were achieved with mulching, irrespective of treatments (Figure 1). For example, in 2018 growing season highest grain yield was found under mulch (1.60 t/ha) than without mulch (1.32 t/ha), average over treatments. This was may be due to the mulching maintained higher soil moisture and reduce surface crusting (Daniells, 2012).

Conclusion

Improvement of crop production on heavy-textured soils with subsoil sodicity is difficult since responses are highly variable from year to year. The results show that narrow row spacing (30 cm) has significant yield benefits over wide row spacing (60 cm), while applying gypsum, deep tillage, mulching and water harvest furrow had some positive impact, but responses were highly variable and depended on seasonal conditions, particularly rainfall. Positive responses to deep ripping were observed in the wetter year but not the drier years. On the other hand, gypsum and mulching responses were observed in the drier year but not the wetter years. Further research is needed to determine the reasons for variable responses of each subsoil constraint and to provide economic evaluation of different ameliorative techniques or combinations of these techniques for soils within each rainfall zone.

Key words

Subsoil sodicity, compaction, deep ripping, gypsum, mulch

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