Water harvesting in low rainfall areas significantly improves yield on sodic soils

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Key messages

- Water harvesting increased cereal yield in low rainfall environments by up to 140%, however water harvesting did not always result in a yield benefit.
- The effectiveness of water harvesting was most evident in years with below average growing season rainfall.
- The responsiveness of sodic soil to water harvesting depends on specific soil properties such as electrical conductivity and exchangeable sodium percentage, and the major constraints limiting production.

Aims

Sodic soil, often called heavy red or Morrel soil, typically perform well in higher rainfall years (>200 mm April – September rainfall) but perform poorly in lower rainfall years (E Barrett-Lennard 2019, pers. Comm.). Alleviating constraints associated with sodic soil, and improving productivity is essential for economic viablity. Trials investigating water harvesting on sodic soil in the low rainfall zone of WA (<200 mm growing season rainfall) were conducted in 2016, 2017 and 2018.

The aim of this research was to determine whether water harvesting on sodic soil could significantly reduce constraints associated with sodic soil and improve yield in low rainfall areas (growing season rainfall less than 200 mm). This paper outlines the major findings from three years of trials.

Method

Over the three years of the experiments, trial sites with sodic soil in the low rainfall agricultural zone of Western Australia, were selected based on grower knowledge, EM38 readings, soil pH and soil electrical conductivity (EC) readings (Table 1). Each trial was conducted on a new site except for Bonnie Rock in 2017, which was a repeat of the trial conducted in 2016. Trials were sown with either barley or wheat.

Surface pH_{H2O}(0-10 cm) ranged from 5.8 at Beacon to 8.5 at Moorine Rock, and at depth (30-50 cm) from 8.6 at Merredin 2017 to 9.4 at Hines Hill (Table 1). At most sites the electrical conductivity ($EC_{1:5}$) increased with depth, except for Hines Hill and Burracoppin which had higher $EC_{1:5}$ at the surface. All sites were sodic (Exchangeable Sodium Percentage (ESP) > 6) at depth (30-50cm), with the majority of sites being sodic from 10 cm downwards in the soil profile.

Trials in 2016 and 2017 included a number of proof-of-concept treatments (Mulvany et al, 2018), however based on the results from 2016 and 2017 the treatments in 2018 were limited to conventional tillage (no water harvesting) and tillage in combination with water harvesting (‘blue-sky’ approach) on 460 mm row spacings at a farrow angle of 26°.

The ‘conventional’ treatment was seeded as per grower practice and had no manipulation of the soil surface to harvest water (Figure 1a). The soil surface of the inter-row in the water harvesting treatment was manipulated at seeding to form two faces which then had clear plastic placed over them immediately after seeding to maximise rainfall runoff into the furrow (Figure 1b). This treatment is referred to as the ‘2-hat’ treatment in subsequent sections of this paper as it had runoff from two faces of the plastic. Results presented below will focus on just the conventional and 2-hat treatments from all three years of trials.

Table 1: Soil characteristics and trial details

	pH $_{(H_2O)}$ (depth cm)	EC (mS/cm) (depth cm)	ESP (%) (depth cm)	Crop type	Sowing date	Growing season rainfall (mm)	Fertiliser
Bonnie Rock2016/2017	5.9 (0-10) to 8.9 (30-50)	0.13 (0-10) 0.54 (30-50)	NA	Scope(D) barley (2016 and 2017) at 50 kg/ha	12 May 2016 and 21 April 2017	184 (2016) and 95 (2017)	At Seeding: 50 kg/ha AgYield Topup: 50 kg/ha Urea + 100 kg/ha Agras
Kalannie2016	6.4 (0-10) 9.0 (30-50)	0.15 (0-10) 0.54 (30-50)	NA	Mace wheat at 50 kg/ha	2 June 2016	244	At Seeding: 50 kg/ha AgYield Topup: 50 kg/ha Urea + 100 kg/ha Agras
Merredin2017	8.5 (0-25) 8.6 (25-50)	0.08 (0-25) 0.13(25-50)	NA	Scope(D) barley at 50 kg/ha	31 July 2017	157	At Seeding: 50 kg/ha AgYield
Beacon2018	5.8 (0-10) 8.7 (30-50)	0.12 (0-10) 0.46 (30-50)	7 (0-10) 22 (30-50)	Spartacus barley at 70 kg/ha	9 May 2018	184	At seeding: 35 kg/ha Agstar Extra and 20 kg/ha Urea Topup: 44 kg/ha Urea
Burracoppin2018	6.2 (0-10) 9.0 (30-50)	1.06 (0-10) 0.44 (30-50)	5 (0-10) 16 (30-50)	Spartacus barley at 50 kg/ha	23 April 2018	120	At seeding: 25 kg/ha MAPte Topup: 44 kg/ha Urea
Hines Hill2018	8.4 (0-10) 9.4 (30-50)	2.54 (0-10) 1.16 (30-50)	5 (0-10) 9 (30-50)	Mace wheat at 70 kg/ha	13 June 2018	147	At seeding: Agras Extra 65 kg/ha Topup: 44 kg/ha Urea
Kalannie2018	7.4 (0-10) 9.1 (30-50)	0.37 (0-10) 0.69 (30-50)	3 (0-10) to 17 (30-50)	Spartacus barley at 70 kg/ha	8 May 2018	189	At seeding: 25 kg/ha Urea + 35 kg/ha AgFlow extra Topup: 44 kg/ha Urea
Merredin2018	7.2 (0-10) 9.0 (30-50)	0.10 (0-10) 0.16 (30-50)	3 (0-10) 7 (30-50)	Scepter wheat at 70 kg/ha	1 May 2018	186	At seeding: 50 kg/ha AgYield Topup: 44 kg/ha Urea
Moorine Rock2018	8.5 (0-10) 9.3 (30-50)	0.46 (0-10) 0.85 (30-50)	2 (0-10) 13 (30-50)	Mace wheat at 70 kg/ha	12 June 2018	131	At seeding: 60 kg/ha AgFlow Topup: 44 kg/ha Urea

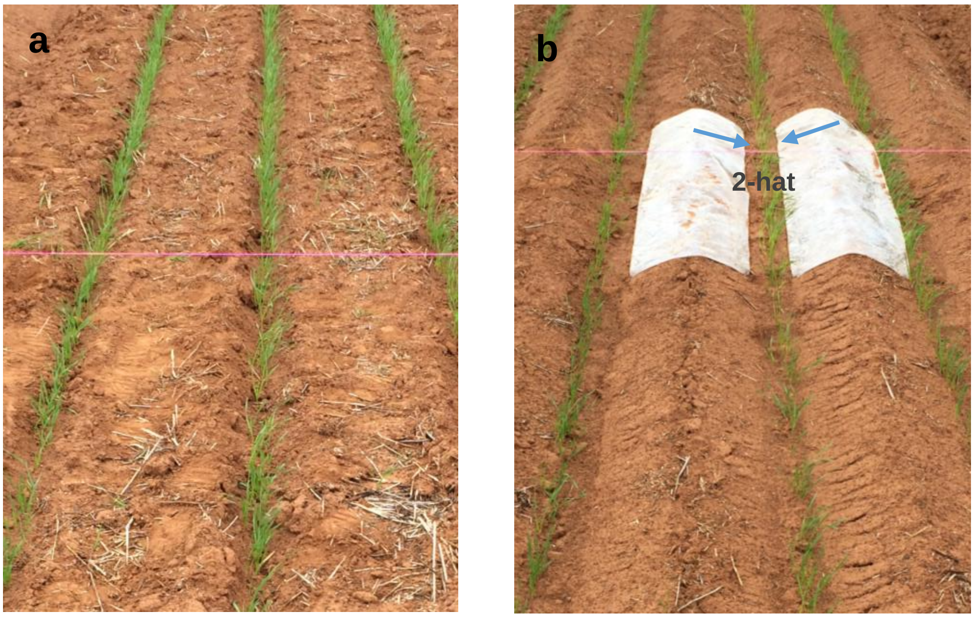

Figure 1: Image of two main tillage treatments, a – conventional tillage treatment and b – inter-row mounding with plastic 'hats'.

Measurements were taken throughout the growing season. Soil measurements included apparent EC with the EM38, soil moisture and salinity index measurements using a TDR 350 Fieldscout probe (down to 20 cm). There was also continuous soil moisture monitoring at 20-25 cm using Wildeye© soil moisture probes, and plant performance indicators included green canopy cover (Canopeo©), anthesis biomass, grain yield and, in 2018, plant tissue analysis.

Results

Seasonal overview

Seeding in 2016 occurred into soil moisture sufficient for germination (Figure 2a). In 2017, with dry conditions (April to July), the Bonnie Rock trial was dry-seeded (Table 1) with plants emerging about four weeks later, whereas the Merredin trial was seeded into sufficient moisture at the end of July followed by regular rainfall events after emergence and for most of the growing season (Figure 2b). In August 2017 rainfall became more regular, and the season had a relatively 'soft' finish with mild daily temperatures at both sites.

In 2018 conditions were dry up to the end of May so half of the sites were dry seeded. Hines Hill and Moorine Rock were the only sites to be sown into moisture sufficient for germination. Rainfall events throughout June, July and August meant that moisture was non-limiting for most of this time (Figure 2c and 2d). There was little to no rainfall in September, followed by numerous rainfall events in October.

Grain yield

In 2016 both sites had a positive water harvesting effect (Figure 3). Yield in the 2-hat treatment was 2.5 t/ha at Bonnie Rock and 3.0 t/ha at Kalannie, compared to 1.8 t/ha and 1.5 t/ha respectively in the conventional treatment. This corresponded to a yield increase of 36% at Bonnie Rock and 96% at Kalannie in the 2-hat treatment.

In 2017 Bonnie Rock had an even stronger water harvesting effect with 140% more yield in the 2-hat treatment, whereas Merredin did not have any difference between the treatments (Figure 3). It is likely that the latter trial had yield potential given that it had significantly more heads, but due to the late sowing this did not follow through to grain yield.

In 2018 there was no overall difference between the treatments across all of the sites, but there were significant differences at individual sites (Figure 3). Yield was 100% greater at Hines Hill and 33% greater at Kalannie in the 2-hat treatment. Yield in the 2-hat treatment was 1.6 t/ha at Hines Hill and 4.2 t/ha at Kalannie compared to 0.8 t/ha and 2.0 t/ha respectively in the conventional treatment.

Beacon was the only site in 2018 that had a yield penalty in the water harvesting treatment. The 2-hat treatment had a lower soil salinity index (the ratio of the bulk EC to the volumetric water content of the soil) and higher sodium in leaf samples taken at anthesis (data not presented). This site was highly sodic (ESP of 7.2% at 0-10 cm to 22% at 30-50 cm) so it is plausible that water availability in the 2-hat treatment was less due to dispersion and enhanced evaporation at the soil surface which would have prevented water from infiltrating to the root zone.

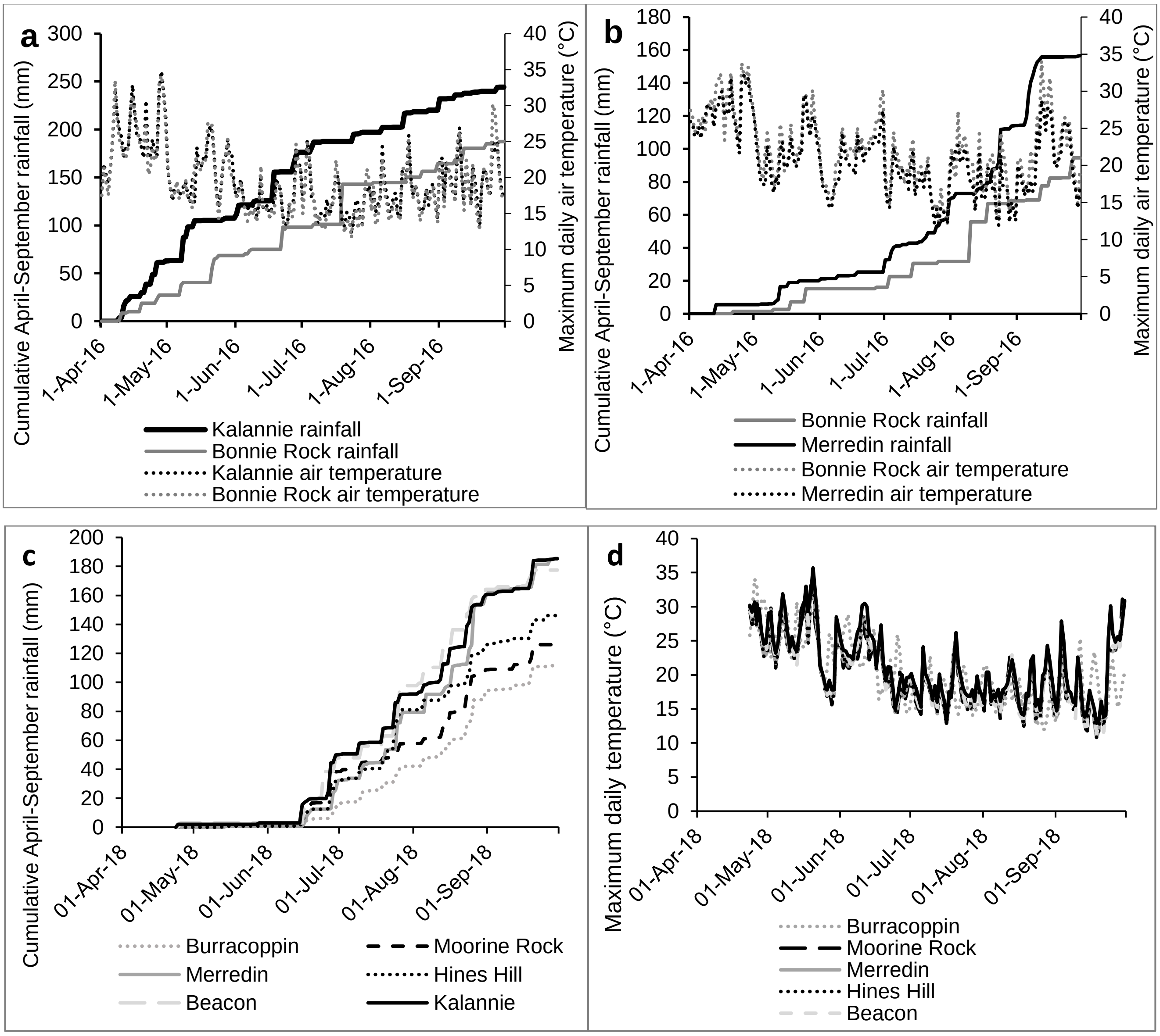

Figure 2: Cumulative growing season rainfall from April to September and maximum daily air temperature for all trials in 2016 (a), 2017 (b) and 2018 (c, d).

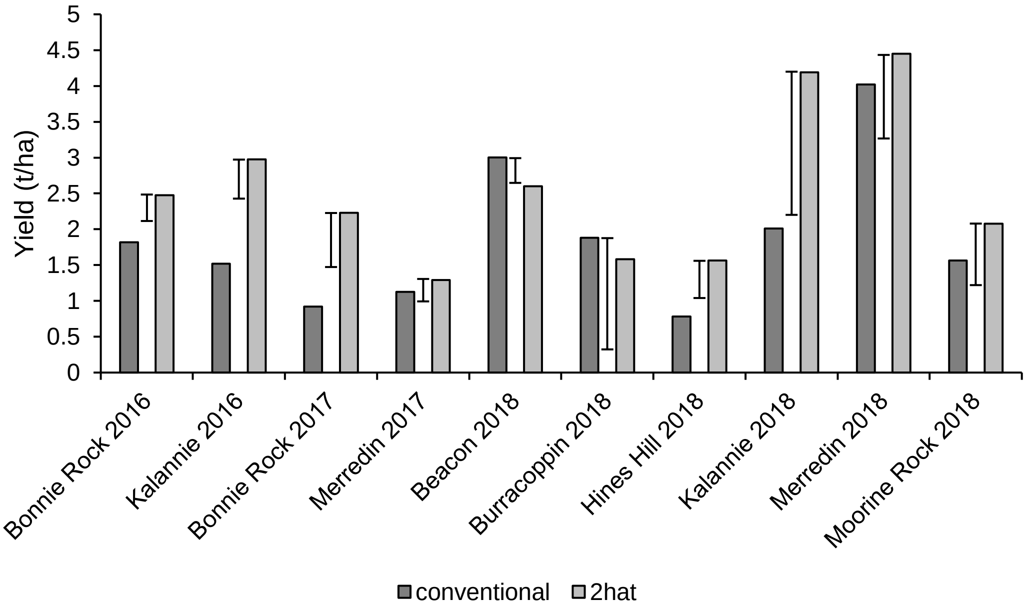

Figure 3: Average grain yield (t/ha) at trials in 2016, 2017 and 2018, with the least significant difference (LSD) at the 5% level as indicated by error bars. Crop species are reported in Table 1.

Conclusion

Our research has shown that water harvesting can significantly increase cereal yield on sodic soil, but this varies according to the season. The same trial was conducted at Bonnie Rock in 2016 and 2017. The benefit of water harvesting on yield was greatest in 2017 when the growing season rainfall was about half that of the rainfall in 2016. The benefit of water harvesting on sodic soil is likely to be most evident in drier seasons where plants would otherwise be stressed and water limited.

The responsiveness of a sodic soil to water harvesting is also dependent on the soil properties. Sodic soil can be highly variable with differing factors constraining production. Some sites have high alkalinity (Moorine Rock), whereas others have high surface EC (Hines Hill), high exchangeable sodium percentage (Beacon), or a combination of these factors. Results at the Beacon site show that water harvesting does not always work on sodic soil as there was a yield penalty of 15%. Although highly sodic in terms of exchangeable sodium percentage, it is likely that low EC at this site resulted in enhanced dispersion with the water harvesting treatment. Dispersion at the soil surface would have reduced water infiltration, leading to evaporation from the soil surface and less water available to infiltrate to the root zone. Unless sodic soil with low EC is treated with gypsum also, then water harvesting is unlikely to have a yield benefit. This highlights the importance in assessing the chemical and physical properties of a sodic soil to determine whether water harvesting will likely result in a yield benefit.

Although water harvesting does not always pay off, the upside is that when it does, yield can more than double. This has major implications in terms of future economics. At the ten sites over three years, water harvesting had significantly beneficial effects on yield at half of the sites, equating to a mean yield benefit of 97% and a median yield benefit of 100%. The unequal number of trial sites in each year meant that 60% of the sites reported here were in a relatively ‘soft’ year (2018). Even under these conditions, more often than not, water harvesting had a benefit. We would expect the beneficial effects of water harvesting to occur even more often than found here if the trials had been spread more evenly across a typical range of seasons.

This research is in the early stages, but it is clear that water harvesting and its effect on transient salinity on these sodic soil in low rainfall environments can have a role in lowering the risk of cropping such soil. Across all of the sites soil moisture was greatest with the 2-hat treatment, and in many instances the salinity index (indicator of the salinity of the soil solution) was lower. Greater hydration of the soil allowed for salts in the soil solution to become more diluted. Plants would have been able to respond to these periods of more favourable soil conditions.

We recognise that this work is still ‘blue-sky’ and the application of plastic sheeting will not currently be cost effective at a larger scale. However, our work shows that the benefits of water-harvesting are substantial. The challenge is now to find means of achieving this more cost effectively and on a broader scale. Further research is also warranted in exploring the potential for combining water harvesting with soil ameliorants. Currently water harvesting has a role in improving crop production on heavy-textured, sodic soil on the fringes of the wheatbelt where growing season rainfall is limited. However, as climate change continues and seasons become drier and more pinched at the end of the season the potential for water harvesting in drought-proofing sodic soil will expand to a wider geographic area.

References

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Key words

Sodic soil, water harvesting, sodicity, low rainfall

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