Seeder-based approaches to mitigate the effects of sandy-soil constraints

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Abstract
Solutions to mitigate the impacts of soil constraints, such as annual interventions at seeding, offer lower cost alternatives to full profile amelioration options. The concept of a fertility strip over a permanent seed row zone has been investigated since 2017 at a low fertility sandy site, using a range of mineral (clay, fertiliser) and organic (composted manure, biochar) inputs into the furrow at sowing. 0.5 t/ha grain yield responses to edge-row sowing with a further 0.4-0.6 t/ha in yield responses to 200 mm deep-furrow till have been achieved. An evaluation of 13 different soil wetter treatments at a severely water-repellent site showed the potential to more than double wheat establishment and generate up to 21% (or 0.22 t/ha) grain yield response, as a result. The data also suggest specific soil wetter chemistries may promote later season effects associated with specific yield gains. Discrete Element Method computer simulations of soil/tool interactions are also being investigated to guide the modifications of furrow openers and seed banding attachments to better control furrow backfill in water-repellent soil environments and secure seed placement into underlying moisture.

Key Words
Edge-row sowing, permanent fertility strips, deep furrow till, soil wetters, DEM modelling

Introduction
The presence of unused soil water at harvest on deep sands is an indicator of a constraint restricting water extraction, which may include non-wetting topsoil-layer leading to poor crop establishment, soil pH (both acidity and alkalinity), poor nutrient supply and sublayer compaction. It is proposed that the constraints to water use require improved diagnosis and management, and that some of the more cost-effective and lower risk solutions might come from seeder-based strategies. Edge-row sowing, where sowing occurs as close as practical (e.g. 3-4cm) to the previous crop row, is known to offer benefits for crop establishment in water repellent sands due to the role of furrows and root systems under existing stubble rows for facilitating water infiltration and storage in surface layers (Roper et al. 2015), and creating potential grain yield benefit (Davies et al. 2019).
A higher fertility strip is an expected outcome of cumulative edge-row sowing managed within a permanent row zone, whereby the seed row shifts in turn from a centre position to alternating sides over a cycle of 3 years, which are repeated. The concept can also use additional inputs of organic matter, clay and other amendments to boost the fertility of the zone in which the crop is sown and potentially increase the extent of any biomass and grain yield benefits, while contrasting with a gradually depleting inter-row zone, less favourable to competitive weed development. In non-wetting sands, banding of soil wetter chemistries on either the furrow surface and near the seeds are common recommendations. However, extensive work in WA suggests soil type and moisture condition at seeding have a major influence on crop response to soil wetters (Davies et al. 2019). Their work showed that applying soil wetters while dry seeding achieved 11% average grain yield increase (10 trials) in repellent sands, vs 18% in repellent forest gravels (6 trials). When seeding after a reasonable rainfall, these grain yield responses became non-significant (7 trials) and reduced to 5% (3 trials), respectively. There is a need to develop the same level of guidance for Southern Australian water-repellent sands. This article reports on two field trials conducted in SA during 2017 and 2018, focussing on lower-cost approaches to increase crop productivity on South Australian water-repellent deep sands.

Methods
Lameroo- Edge-row sowing in permanent fertility strips (2-year evaluation to date)
The Lameroo site is situated in the SA Mallee (S35.24562, E140.39749) in a 269 mm growing season rainfall (GSR) zone. The deep sand site was classified as repellent (MED 2.5 at 0-5cm). In addition to mineral nutrition in the furrow (Table 1), some amendments (compost, clay or biochar) were also applied annually to a range of fertility strip treatments, one of which includes placement at 20 cm depth, in contrast to the baseline 10 cm furrow depth. Control plots were inter-row sown under both base and high nutrient inputs. All plots were sown at 0.28 m row spacing.

Table 1: Seeding agronomy summary for fertility strip treatments at the Lameroo site

	2017	2018
Crop (seed rate)	Trojan wheat (64 kg/ha)	Compass barley (61 kg/ha)
Base input (nutrient kg/ha)	9N+11P+5S shallow banded below seeds	10P+3S with seeds (19N+3S deep banded at furrow depth)
High input (nutrient kg/ha)	Additional 34N deep banded	Additional 26N+6S deep banded
Other base inputs	Complementary seed treatments, SE14 soil wetter 4L/ha, trace element Chelate mix 4Zn+3Mn+1Cu at 2.5L/ha, Rhizoctonia+take all protection by fungicides in-furrow	

Murlong- Wetter chemistry and placement

The Murlong site is situated on Eyre Peninsula (S33.69129, E135.94405) in a 249 mm GSR zone. The soil was classified as severely repellent (MED 2.8 at 0-5cm and 3.0 at 5-10cm). The impacts of 13 different wetting agents (both surfactants and humectants) in single and dual placement configurations were tested, with product costs between $12 and $41 per ha. The wetter treatments were pre-tested on the Murlong soil under laboratory conditions showing a de-ionised water control penetration time of >120 min, whereby the various soil wetters in solutions at recommended rates reduced the penetration time down to 2-3s at best and 82 min at worst. This initial ranking indicated a variable ability of soil wetter products to act as surfactants. The soil wetter chemistries included pure surfactants, surfactant/humectant blends, and enriched blends with organics/nutrients. Split applications included single products applied at 50:50 rate or combined products applied at full rate in their recommended locations. All suppliers were consulted to ascertain the recommended application rates and furrow delivery locations for each product.

Plots were set at 0.28m row spacing and sown on 21-23 June 2018 after a delayed and poor season opening. Wheat CL Razor was sown at 63 kg/ha targeting 155 plants/m^2 at 80% establishment. Nutrients (kg/ha) were split applied as follows: 20N+4S deep banded at full furrow depth (100 mm), while 6N+11P+2S+0.5Zn was shallow banded 20 mm below seeding depth. Seeding included in-furrow fungicides and foliar trace elements (Zn, Cu, Mn) during late tillering. Soil wetter treatments were applied in 100 L/ha volume with foam suppressant at 0.05% v/v, using a Teejet TPU1501 low angle flat fan nozzle behind press-wheels to produce a 25-30mm wide band spray on the furrow surface (FS), while seed zone (SZ) applications were obtained with a Keeton in-furrow seed firmer.

Results and Discussion

Lameroo- Edge-row sowing with permanent fertility strips

Uniform wheat crop establishment was achieved across all treatments in 2017 (Year 1 data not shown), while a 252 mm (decile 5) GSR resulted a 0.6 t/ha response (P<0.05) to the 20 cm deep furrow till treatment (3.90 t/ha), compared with its 10 cm reference (3.36 t/ha). In contrast, the variety of inputs in fertility strip treatments did not show any significant effect (average 3.50 t/ha).

Table 2. Crop responses to fertility strip treatments at Lameroo in 2018 (Year 2) – NB: 100kg/ha clay as Ca bentonite, 100kg/ha compost as TailorMade™ prills, 60kg/ha Cool Terra biochar - Note: 100 kg/ha rate in-furrow over 3 years has a similar local concentration to 14 t/ha mixed within a 0-10cm layer)

Treatments	Nutrient input	Plants/m^2 at 38DAS	Barley yield (t/ha)
Control (Inter-row sowing)	Base	50 bc	1.35 d
Base Fertility Strip BFS (edge-row sowing)		71 a	1.84 c
BFS + clay		69 a	1.84 c
BFS + compost		74 a	1.94 bc
BFS + (clay+compost)		63 a	1.83 c
BFS + 2x (clay+compost)		66 a	1.86 c
200mm deep BFS + (clay+compost)		71 a	2.20 a
Control (Inter-row sowing)	High	43 c	1.35 d
High Fertility strip HFS		49 bc	1.75 c
HFS + biochar		73 a	2.19 ab
Least significant difference at P=0.05		15	0.26

Edge-row vs inter-row sowing impacts were first assessed in 2018, where there was a 7 mm soil water advantage over the 0-40cm profile under existing stubble rows, accessible via edge-row sowing compared with the inter-row sowing alternative. This stored water advantage converted to a crop establishment benefit with up to +48 % (+24 plants/m^2) more barley plants established under fertility strip treatments (Table 2). Following a 125mm (decile 1) GSR, +0.5 t/ha gain was achieved from edge-row sowing relative to inter-row sowing (1.4 t/ha), with a further +0.3 t/ha gain (2.2 t/ha yield) for edge-row sowing combined with either deep furrow till to 20 cm depth or with combined high fertiliser and biochar inputs. A separate trial revealed that it was the physical disruption (including deep banded nutrition) rather than the addition of clay/compost amendments at depth driving this benefit. The deep-furrow till option is compatible with tine seeders having a press-wheel regulated seed banding boot, where furrow depth can be independently adjusted on the go without impacting seeding depth.

Murlong- Soil wetter chemistry and placement (2018 data)
The results are presented without labelling the chemistries until the full effects of treatments are better understood. Crop establishment averaged 24% of seeding rate (48 plants/m^2) for the two controls indicating very unfavourable conditions at seeding in this severely non-wetting sand (NB: 27 mm fell post-sowing in 11 events over 5 weeks). No differences were measured between the two controls (Figure 1) sown at the beginning and end of a 40-hour trial sowing period. Soil wetters increased crop establishment by 25 plants/m^2 on average, with a response range of 0 to 58 plants/m^2. Four subgroups of responses were defined, namely:

1. A top-level subgroup with four treatments more than doubled plant density, including two humectant chemistries (T1 and T4) applied in the seed zone.
2. Two other treatments (T10-T11) achieved an intermediate performance generating 70-80% crop establishment increase, both being applied at 50:50 split rate between furrow surface and seed zone.
3. A low response subgroup with three other products generating a 20-40% increase.
4. A no response subgroup with four treatments, which did not produce any significant impact on early plant establishment.

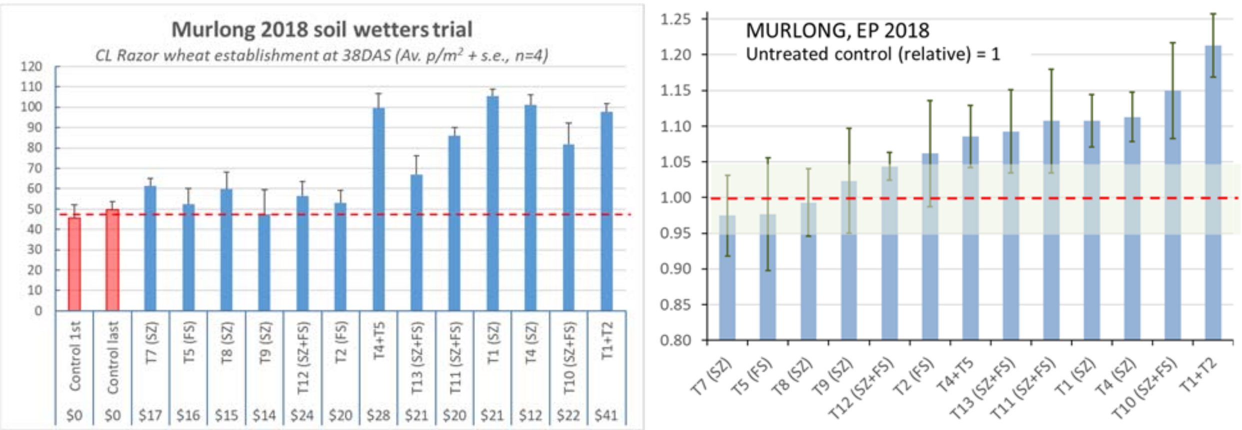

Figure 1. (left) Wheat crop establishment (plants/m^2) at 38DAS with respective product cost per ha; (right) corresponding wheat grain yield data, relative to control - Error bars/band are ±1 std error of the mean

Controls averaged a wheat grain yield of 1.02t/ha. Treatment grain yield responses ranged from 0 to 21 %, with a maximum response of 0.22t/ha ($P<0.01$). There was a significant positive correlation ($r = +0.76$) between grain yield and plant density at 38DAS, whereby the better-established treatments tended to achieve higher grain yields. This first year of trial data shows encouraging results on the ability of some soil wetter chemistries to improve seed germination in a highly water-repellent sand. The data also suggest some soil wetter chemistries, at similar initial impact on crop establishment, may additionally produce some in-season effects leading to yield gains. The potential for product synergies in split-application is also suggested. More work is being planned over the 2019-20 seasons to better understand the role that the different chemistries might have over a range of season types and some validation across different water-repellent sands will also be required.

Seeding system computer simulations to improve control over furrow backfill
Research in WA on water repellent sands has highlighted significant benefits from the use of inverted T openers, winged openers, and paired row seed boot attachments in improving crop establishment and grain yield (by up to 20%), relative to common centre banding knife point systems (Davies et al., 2019). The discrete element method (DEM) - a computer simulation technique - is being used to understand and optimise top-soil movement and furrow backfill during no-till seeding with tine openers. The DEM was used to model sowing into a drying soil profile (a high-risk scenario) using a range of seeding systems, over a range of speeds (see Figure 2). Knife point systems with closer plates were found to increase the risk of downward drag of potentially repellent top soil into the seed zone and below, in a process depending on

seeding speed. At low speed (5km/h), the top soil flows around the point and in front of the closer plate. The angled back inclination of the closer plate then forces top soil down to consistently contaminate the seed zone. As speed increases (8 km/h) the top soil begins to flow around the closer plate which becomes less effective. This causes intermittent patches of soil to flow below the seed zone. At high speed (12 km/h) the top soil mostly flows around the closer plate and its contamination in the seed zone is minimised, although intermittent patches still occur. In contrast, winged (paired row) openers upheave soil from depth which flows over the wing attachment and behind the point. They essentially block the ability of the top soil to backfill behind the opener into the seed zone. The reported benefits (Davies et al., 2019) of paired/winged seeders on crop establishment in repellent sands can likely be attributed to this feature. It should be noted that lateral soil throw from wing attachments increases significantly at higher speeds, which can increase the risk of ridging from top soil contamination reaching the neighbouring seed rows.

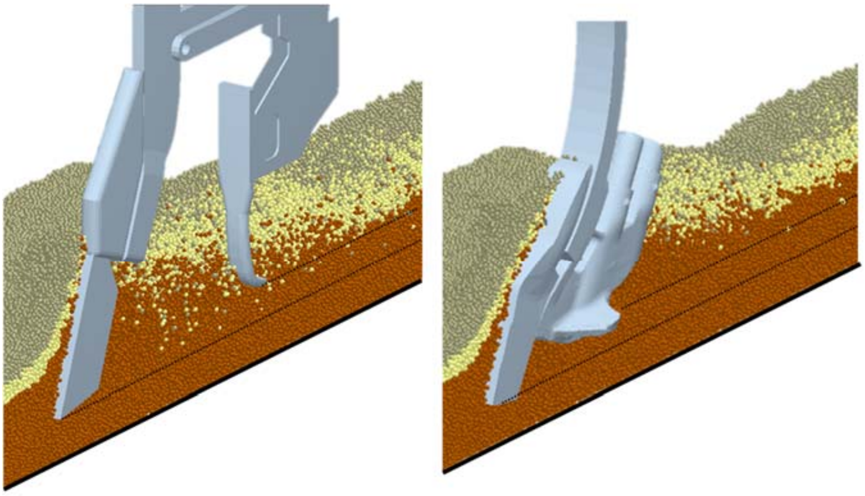

Figure 2. Cross sections during an 8km/h operation of centre banding (left) and paired row (right) seeding systems, contrasting the extent of seed zone contamination. (NB: The dry top soil is simulated in 2 distinct 25mm thick layers over a moist brown sandy base. The properties of each layer are calibrated using dedicated laboratory tests and actual field soil samples)

The simulation results can form the basis to improve seeding system performance in water repellent sands. A structured simulation programme is underway including targeted validation to provide confidence in the model prediction capabilities and enable a large-scale analysis, with the aim to develop recommendations for optimising of seeding system components.

Conclusions

Low-cost, low risk seeder-based strategies can offer tangible yield benefits in water repellent sands, particularly in below average rainfall seasons. Significant grain yield benefits of edge-row sowing and 200mm deep furrow till are shown in results to date, while the concept of fertility strip requires longer term data to demonstrate possible optimisation via inputs. Some wetter chemistries significantly increased crop establishment and yield on a severely repellent sand. This work is continuing and will integrate recommendations from DEM modelling on improved seeding systems.

Acknowledgements

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