Seed coatings with various surfactants and glues to improve crop establishment on water repellent soils.

Geoff Anderson, DPIRD, **Todd Erickson**, UWA/BGPA, **Steve Davies,** DPIRD, **Glenn McDonald,** DPIRD, **Tom Edwards,** DPIRD

Key messages

- In a decile one seasonal condition which occurred in 2017 there was a large expression of poor crop establishment by to water repellency and substantial benefit from the use of seeds coated and banded surfactants (Anderson *et al*. 2018). In contrast, in a decile three seasonal conditions which occurred in 2018 were less conducive to repellence expression and apart from some improvement in canola establishment no benefits were measured
- There was some evidence of reduced wheat establishment from one surfactant coating, however this did not impact on final grain yield and there was no evidence of toxic effects from any of the other surfactants used.
- Project experimental results to date have demonstrated that coating grain with surfactants for crops grown on repellent soils can be beneficial but that this will depend on season and will likely have more value for earlier sowing on more strongly repellent soils.

Aims

This paper aims to examine two aspects of coating surfactants onto seeds to improve crop establishment and production on water repellent soils. First to examine if commercially available surfactants and glues can be coated onto seeds to improve crop establishment of crops on water repellent soil. Second to examine if these seed coatings have a toxic effect on the seeds resulting in reduced crop establishment.

Water-repellent soils affect about 10 M ha of arable sandy soils which are used for agricultural production in southern Australia (Roper *et al*. 2015). Often crop establishment on these soils can be poor resulting in reduced weed competition and lower grain yield. Currently, banding of wetter on top of and in the furrow is one of the techniques used to improve crop establishment on water repellent soils in WA (Crabtree and Henderson 1999, Davies *et al*. 2016, Sherriff 2016). Anderson *et al*. (2018) illustrated coating seeds with surfactants increased cereal germination and production under poor seasonal conditions (ie. a decile one rainfall year).

When seeds are coated with a surfactant and are placed on or near the soil surface the initial germinating rainfall event washes the surfactant off the seeds. Hence, mitigation the water repellence around and below the seeds resulting in increased germination (Madsen *et al*. 2016). Because the surfactant is washed off the seeds before germination it is unlikely to have a toxic effect on seeds germination. Nevertheless, it is important to test for any toxic effect of the surfactant seed coatings. Also, it may be possible to use other commercially available surfactants and glues and compare with the non-ionic alkyl ended block copolymer surfactants used by Madsen *et al*. (2016).

Method

In 2018, we conducted three randomised complete block design field experiments with three replicates. One experiment was on grey sand with a molarity of ethanol droplet (MED) test of 2.0 (moderate repellence) located 7 km northeast of Badgingarra. The other two experiments were on sandy gravel with a MED test of 5.0 (very severe repellence) located 18 km south of Darkan. In the 0-10 cm soil layer the organic carbon content of the Badgingarra grey sand was 1.1%, and the Darkan sandy gravel was 3.6%. While the soil particle size analysis of the < 2mm soil fraction for the Badgingarra was 96% of sand and 4% of clay, and for the Darkan sandy gravel was 85% of sand, 9% of silt and 6% of clay. Finally, the gravel content of the Darkan sandy gravel was 48% in the 0-10 cm soil layer.

The Badgingarra experiment used wheat (cultivar Scepter) while the Darkan experiments used canola (cultivar Stingray) and barley (cultivar Spactarus CL). Scepter wheat was coated with Vibrance® and

Gaucho®, Spactacus CL was coated with Evergol® and Stingray was coated with Cruiser Opit[C] and Maxim XL® before applying the surfactants treatment.

In the canola and wheat experiments seeds were coated with either SET-4001 (Madsen *et al*. 2016) and modified Alkylated Polyol (surfactant 1) and Polyethylene Glycol / Ethoxylated Alcohol mixture (surfactant 2) (Table 1). In the case of SET-4001 and surfactant 2, PVA glue 1 (Madsen *et al*. 2016) was used to stick the wetter onto the seeds. The SET-4001 and surfactant 2 were coated onto the seeds at four rates of 0, 0.5, 1.0 and 2.0 L/t of seeds. While surfactant 1, was coated at higher rates of 0, 5, 10 and 20 L/t without using glue. Barley and wheat was seeded at a rate of 65 kg seed/ha which gives SET-4001 and surfactant 2 rates of 0.032, 0.065 and 0.130 L/ha. While canola was seeded at a rate of 3 kg/ha which gives SET-4001 and surfactant 2 rates of 0.0015, 0.003 and 0.006 L/ha. The surfactants seed coating treatments were compared to banding surfactant 2, placed on top of the furrow or in-furrow near the sown seeds at rates of 0, 1, 2 and 5 L/ha.

Table 1 Treatment summary for the canola and wheat experiments.

Treat.	Placement	Surfactants	Glue	Rates
1	Coated	SET-4001	PVA-1	0, 0.5, 1.0 and 2.0 L/t
2	Coated	Surfactant 1	No glue	0, 5, 10 and 20 L/t
3	Coated	Surfactant 2	PVA-1	0, 0.5, 1.0 and 2.0 L/t
4	On top of furrow	Surfactant 2	No glue	0, 1, 2 and 5 L/ha
5	Within furrow	Surfactant 2	No glue	0, 1, 2 and 5 L/ha

In the Darkan barley experiment, seeds were coated with either SET-4001 (Madsen *et al*. 2016), surfactant 1 and 2, Oxirane Methyl, Polymer with Oxirane and alcohols, C9-11, ethoxylated (surfactant 3) and polyether modified polysiloxane (surfactant 4) (Table 2). These surfactants were mixed with either PVA-1 or PVA-2 glue which is used to stick the surfactant onto the seeds. The exception was for the surfactant 1 were no glue was used. The surfactants SET-4001, surfactant 2-4 were coated at three rates of 0, 1.0 and 2.0 L/t of seeds. While surfactant 1, was coated at higher rates of 5, 10 and 20 L/kg without using glue. These treatments were compared to banding surfactant 2, placed on top of the furrow or in-furrow near the seeds at a rate of 5 L/ha.

Table 2 Treatment summary for the barley experiment.

Treatment	Placement	Surfactants	Glue	Rates
1	Coated	SET-4001	PVA-1	0, 1 and 2 L/t
2	Coated	SET-4001	PVA-2	0, 1 and 2 L/t
3	Coated	Surf. 1	No glue	0, 5, 10 and 20 L/t
4	Coated	Surf. 2	PVA-1	0, 1.0 and 2.0 L/t
5	Coated	Surf. 2	PVA-2	0, 1.0 and 2.0 L/t
6	Coated	Surf. 3	PVA-1	0, 1.0 and 2.0 L/t
7	Coated	Surf. 3	PVA-2	0, 1.0 and 2.0 L/t
8	Coated	Surf. 4	PVA-1	0, 1.0 and 2.0 L/t
9	Coated	Surf. 4	PVA-2	0, 1.0 and 2.0 L/t
11	On top of furrow	Surf. 2	No glue	0, 5 L/ha
12	Within furrow	Surf. 2	No glue	0, 5 L/ha

Seeds were coated using a 14–inch rotary seed coater (BraceWorks, Canada). Polyvinyl alcohol (PVA-1 or PVA-2) glue was the binding agent, and lime and talcum powder were the drying agents and to minimise seed to seed adhesion. We produced surfactants coated seeds by spraying a solution containing the surfactant and the glue onto the seeds by placing the solution on the central spinning disc of a seed coating machine (Madsen *et al*. 2016). The ratio of surfactant to glue was varied to give surfactant rates of 0.5, 1.0, 2.0 and 4.0 L/t for the application of 55 L/t of the surfactant/glue mixture. PVA-1 glue is supplied as a solid and was dissolved in water to make an 8% solution of PVA-1. The amount of lime and talcum powder required to minimise seeds adhesion increased with increasing surfactant rates. At the lowest surfactant rate 0.5 L/t used 6.12 kg lime/t of seeds and 0.02 kg talc power/t of seeds. While for the highest surfactant rate used 7.01 kg lime/t of seeds and 0.16 kg talc power/t of seeds.

The Badgingara experiment was sown dry to Scepter wheat on 22 May 2018. The Darkan experiments were sown dry to Spactarus CL barley and Stingray canola on 18 May 2018. Plant densities were measured (plant/m^2) on 29 June (38 DAS) at the Badgingarra site and 20 June 2018 (33 DAS) at the Darkan sites. Individual plots were harvested to determine grain yields (t/ha) on 21 November at the Badgingarra site and 28 November at the Darkan sites.

Results

Annual rainfall for Darkan was 494 mm and 375 mm for Badgingarra. The growing season started as a result of a strong cold front which passed over the wheat belt on 25 May (Table 1). Rainfall over the period from sowing to the measurement of plant density was 109 mm at the Badgingarra site and 92 mm at the Darkan site. Hence, both sites had decile three seasonal conditions up to 20 June at the time of crop establishment assessment.

Table 3 Monthly rainfall for the Darkan and Badgingarra sites for 2018.

Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Darkan	93	9	9	12	43	81	86	105	7	29	20	0	494
Badgingarra	46	0	5	3	58	54	145	24	4	35	0	0	375

In general, there was minimal expression of water repellency on crop establishment or treatment response to the surfactants placement treatments (Table 2). At the Badgingarra wheat experiment there was lower (P=0.10) wheat establishment when surfactant 1 was coated at relatively high rates of 0.5-2.0% but this was not reflected in differences in grain yield. At the Darkan canola experiment the seed-coated treatment SET-4001 and surfactant 2, and the furrow placement of surfactant 2 applied with seeds improved plant density from 40 plants/m^2 to 51-53 plant/m^2 or a 31-33% increase (significant at a P=0.10 level). However, this early response in plant density did not translate to higher canola grain yield. At the Darkan barley experiment only surfactant 2 banded with the seeds (5L/ha) increased grain yield by 12%.

Table 4 Plant density (plant/m^2) and grain yield (t/ha) for canola, barley and wheat experiments in 2018.

	Wheat (Badgingarra)		Canola (Darkan)		Barley (Darkan)		
Treatment	Plants /m^2	Grain yield (t/ha)	Plants /m^2	Grain yield (t/ha)	Treatment surfactants and glues	Plants /m^2	Grain yield (t/ha)
Control	72	1.76	40	1.27	Control	75	3.75
Surf. 1 0.5%	48	1.56	43	1.27	Surf. 1 0.5%	84	3.80
Surf. 1 1.0%	56	1.63	51	1.18	Surf. 1 1.0%	86	3.89
Surf. 1 2.0%	54	2.05	43	1.25	Surf. 1 2.0%	82	3.76
SET-4001 0.05%	63	1.57	48	1.31	Surf. 2 0.1% PVA-1	76	3.75
SET-4001 0.1%	80	2.16	57	1.19	Surf. 2 0.2% PVA-1	70	3.59
SET-4001 0.2%	73	1.93	49	1.20	Surf. 2 0.1% PVA-2	92	3.75
Surf. 2 0.05%	74	1.62	58	1.22	Surf. 2 0.2% PVA-2	93	3.49
Surf. 2 0.1%	84	1.52	54	1.32	Surf. 3 0.1% PVA-1	82	3.69
Surf. 2 0.2%	85	1.81	47	1.35	Surf. 3 0.2% PVA-1	91	3.87
Surf. 2 top of furrow 1L	73	1.51	56	1.11	Surf. 3 0.1% PVA-2	92	3.84
Surf. 2 top of furrow 2L	64	1.69	39	1.13	Surf. 3 0.2% PVA-2	84	4.03
Surf. 2 top of furrow 5L	86	2.03	37	1.15	Surf. 4 0.1% PVA-1	86	3.69
Surf. 2 with seeds 1L	88	1.73	53	1.32	Surf. 4 0.2% PVA-1	91	3.78
Surf. 2 with seeds 2L	84	1.75	53	1.35	Surf. 4 0.1% PVA-2	93	3.88
Surf. 2 with seeds 5L	79	1.90	49	1.17	Surf. 4 0.2% PVA-2	80	3.72
					Surf. 2 on top of furrow 5L/ha	82	3.64
					Surf. 2 with seeds 5L/ha	88	4.20
LSD P<0.05[A]	23	0.41	21	0.23		22	0.31
LSD P<0.10[B]	10	0.33	12	0.10		18	0.27

[A]treatment by rate interaction, [B]treatment main effect

Conclusion

Seasonal conditions appear to have a large effect on the expression of reducing crop establishment due to water repellency. In 2017, which was a decile one growing season there was a large response to the surfactants placement treatments (Anderson *et al*. 2018). In contrast, in 2018, which was a decile three growing seasons up to 20 June, there was no response to the wetter placement treatments (Table 1). In 2017, seed coating and furrow placement treatments increased wheat establishment by up to 109% and biomass production by 100% (Anderson *et al*. 2018). In contrast, in 2018 these same treatments had limited impact on crop performance. The exception was at Darkan for the canola experiment where both the seed coating and furrow placement improved established by 31-33% ($P<0.10$). However additional germination following these 20 June plant density measurements and compensational growth of canola resulted in no grain yield benefit.

Toxicity can be an issue when coating materials onto seeds. Surfactant 1 coated at the relatively high rate of 0.5-2.0% appeared to reduce wheat emergence at the Badgingarra experiment but this was not sufficient to reduce yield. Conversely the surfactant 1 seed coating did not affect canola and barley plant densities or grain yield at the Darkan experiments. Perhaps the reduction in the wheat establishment was caused by a combined effect of the surfactant and the fungicide seed coating, but further work is required to identify the cause. In general, when seeds are placed at, or near, the soil surface there is unlikely to be a toxic effect from the surfactant seed coating because the germinating rainfall will wash the surfactants off the seeds and into the soil. Also the fungicide and surfactant are applied in separate layers to reduce the risk of producing an interactive toxic effect. Previous work has shown mixing the surfactant and fungicide together and applying it as a single layer greatly reduced seeds germination (unpublished data).

In Madsen *et al*. (2016) studies have used a non-ionic alkyl ended block copolymer surfactant glued onto the seeds using PAV-1 glue. In the barley experiment we have tested if alternative surfactants and PVA-2 glue can be used. Madsen *et al*. (2016) use a non-ionic alkyl ended block copolymer for seed coating because it can provide a beneficial effect on tissue growth and cell viability in plant tissue culture media (Lowe *et al*. 2001). Non-ionic alkyl ended block copolymer surfactant have an amphiphilic structure consisting of polar hydrophilic heads and non-polar hydrophobic tails. In water-repellent soil, the non-polar tails attach onto non-polar hydrophobic surfaces, and subsequently increase the overall soil wettability by facing the polar heads toward the by-passing water (Dekker *et al*. 2005). However, they can degrade over time and require repeated application to maintain the effect on water repellent soil (Song *et al*. 2014). While, the seasonal condition did not provide a water repellence limitation at the experimental sites, the alternative surfactants and glues combinations had no negative impact on barley plant densities or grain yield (Table 1). Ideally, this experiment should be repeated in less favourable seasonal conditions or under controlled conditions provided by a rain-out shelter and/or irrigation treatments to examine if surfactants and glues treatments can provide a positive response.

The surfactant seed coating method uses two separate steps and requires specialised commercial seed coating machine. Canola seeds is very expensive and is sown at low rates. Hence, the cost of coating canola seeds using a commercial seed coating machine is likely to be a very small cost per hectare making it very economical. In contrast, wheat seeds cost is much less but sown at much greater rates making uneconomical to be done in commercial seed coating machines. Thus cheaper on-farm seeds treatments need to be developed to reduce the cost of treating the seeds. In this paper, we have presented the method currently used to coat surfactants onto the seeds and provided some alternative surfactants and glues options which could be used in developing an on-farm seeds treatment procedures.

Keywords

Water repellent soil, surfactant, seed coating and furrow.

Acknowledgements

DPIRD Project Number: FFPJ04 and GRDC project DAW00244. The management of the experimental sites by the DPIRD research support units is greatly appreciated.

References

Anderson G, Erickson T, Davies S, McDonald G 2018, Seeds coated with wetters improved cereal germination on water repellent soils. In “2018 Grains Research Updates”, 26-27 February 2018, Perth, Western Australia. www.giwa.org.au/2018researchupdates

Davies S, McDonald G, Anderson G, Harte L, Poulish G, Devlin R, Jenkinson R 2016, New opportunities for soil wetting agents on repellent soils. In “2016 Grains Research Updates”, 29 February-1 March 2016, Perth, Western Australia. http://www.giwa.org.au/2016researchupdates.

Dekker LW, Oostindie K, Kostka SJ, Ritsema CJ 2005, Effects of surfactant treatments on the wettability of a water repellent grass-covered dune sand. Australian Journal of Soil Research 43, 383–395.

Crabtree WL, Henderson CWL 1999, Furrows, press wheels and wetting agents improve crop emergence and yield on water repellent soils. *Plant and Soil* 214, 1–8.

Erickson TE, Rojas MM, Kildisheva OA, Stokes BA, White SA, Heyes JL, Dalziell EL, Lewandrowski W, James JJ, Madsen MD, Turner SR, Merritt DJ 2017, Benefits of adopting seed-based technologies for rehabilitation in the mining sector: a Pilbara perspective. *Australian Journal of Botany* Published online 30 November 2017.

Lowe KC, Anthony P, Davey MR, Power JB 2001, Beneficial effects of Pluronic F-68 and artificial oxygen carriers of the post-thaw recovery of cryopreserved plant cells. Artif. Cells Blood Substit. Immobil. Biotechnol. 29, 297– 316.

Madsen MD, Fidanza MA, Barney NS, Kostka SJ, Badrakh T, McMillan MF 2016, Low-dose Application of non-ionic alkyl-terminated block copolymer surfactant enhances turfgrass seed germination and plant growth. *HortTechnology* 26, 379-385.

Roper MM, Davies SL, Blackwell PS, Hall DJM, Bakker DM, Jongepier R, Ward PR 2015, Management solutions for water repellent ("non-wetting) soils in Australian agriculture - a review. *Soil Research* 53, 786–806.

Sherriff M 2016, Improving crop establishment with in-furrow liquids. In “2016, Grains Research Updates”, 29 February-1 March 2016, Perth, Western Australia. http://www.giwa.org.au/2016researchupdates.

Song E, Schneider JG, Anderson SH, Goyne KW, Xiong X. 2014, Wetting agent influence on water infiltration into hydrophobic sand: I. Rewettability. Agronomy Journal 106, 1873–1878.