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TITLE: Improved pasture establishment and production on water repellent soils'.

SHORT TITLE: **Pasture establishment on water repellent soils**

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Improved pasture establishment and production on water repellent soils

ABSTRACT

Pasture establishment and production is reduced by water repellent soils. Two field experiments were conducted on water repellent soils to investigate (i) the improvement in emergence of pasture species with furrow sowing and the use of a press wheel and banded wetting agent and (ii) the residual effectiveness (applied 2 years previously) of a wetting agent on pasture growth and composition. In the first experiment, conventional level sowing (flat planting) was compared with furrow sowing using press wheels. Five pasture species were included and the furrow-sown treatments involved a banded wetting agent applied at four rates. Furrow sowing with a planter having press wheels increased the average emergence at 14 days after sowing by 133% relative to the conventional treatment and emergence was further increased 44% by banding 4 L ha^{-1} of wetting agent in the furrows. There was a large (up to a six-fold) increase in early pasture production (330 to 2,010 kg ha^{-1}) and a large effect on pasture composition due to the residual effect of a wetting agent applied 2 years previously. The proportion of subterranean clover (*Trifolium subterraneum*) in the sward increased from 6 to 33% due to the use of a wetting agent.

Pasture establishment on water repellent soils is affected by non-uniform infiltration of water into soil. Farmers commonly report large reductions in emergence for pasture sown into water repellent soils with conventional level sowing practices. Conventionally sown seeds in dry soil may not germinate despite adequate rainfall, resulting in patches of bare soil between emerged plants and an overall poor pasture establishment. Natural re-establishment is similarly poor.

Surface soil compaction can improve plant emergence under these circumstances (Stout et al., 1961; Pathak et al., 1976; Crabtree and Gilkes, 1998). Earlier work has shown that using a combination of a wetting agent, furrow sowing, and press wheels, increased soil water content around seeds, which increased emergence and grain yield of barley (*Hordeum vulgare* L.) (Crabtree and Gilkes, 1998). These treatments are likely to have similar beneficial effects for pasture species, which is the principle hypothesis examined in this research.

Pasture composition is adversely affected by water repellence (King, 1985). Some pasture species, including subterranean clover, generate a near random placement of seed over a soil surface and are disadvantaged compared to airborne weed seeds that accumulate in hollows where water ponds after rainfall. These low lying areas of microrelief on water repellent soils may become wet with little rain as they act as water basins or sumps in which soil becomes wet and can support weed growth. Subsequently, the weeds in these vegetated patches can support insects that attack desirable seedlings as they emerge later. Thus heterogeneity in wetting soil and consequent plant growth is undesirable and should be avoided.

While it is clear that pasture production may be adversely affected by water repellence there are no published data providing details of the magnitude of lost production and its economic value. The hypotheses tested here for water repellent soils are that: (i) furrow sowing with press wheels and banded wetting agents will improve emergence of five pasture species and (ii) early pasture growth and the composition of pastures are severely restricted by the water repellent nature of these soils. This research included consideration of the residual effectiveness of a wetting agent.

MATERIALS AND METHODS

Sites

The pasture establishment site was at north Gibson, 40 km north of Esperance, Western Australia. The soil was a grey sand overlaying lateritic gravelly loamy sand at 25-35 cm and a heavy textured horizon starting at 80-90 cm (duplex soil: Dy 4.82, Northcote, 1979). The topsoil (0-10 cm) had a pH of 4.8 (1:5 0.01 M $CaCl_2$), contained 10 g kg^{-1} clay and 11 g kg^{-1} organic carbon. The measured water repellence was 3.6 MED (molarity of ethanol drop test, King, 1981). The site has an average annual rainfall of 425 mm, most of which falls during the winter growing season from May to October.

The site chosen to investigate the residual effect of a wetting agent was at Wellstead, 80 km north east of Albany, Western Australia, and is a red/brown gravelly sand overlying clay at 45 cm (Duplex soil type: Dy 4.83, Northcote, 1979). The topsoil had a pH of 5.0 (1:5 0.01 M $CaCl_2$), with a gravel content of 220 g kg^{-1}, a clay content of 40 g kg^{-1}, organic carbon of 12 g kg^{-1}, and a water repellence value of 3.9 MED. This site had been sown to barley 2 years earlier (in 1987) (Crabtree and Gilkes, 1998) with various rates of a wetting agent (0-75 L ha^{-1}) applied at the time of sowing. The site receives an average 440 mm annual rainfall but received 600 mm in 1988, which probably leached some of the 1987 applied wetting agent to below the surface soil.

The design for the 1987 experimental was a completely randomized block with three replicates. The wetting agent (Aquasoil®) applied in

1987 at 0, 5, 10, 20, 50, or 75 L ha^{-1} in a 2 cm wide band while sowing barley with press wheels trailing. A boom was mounted behind the press wheels with nozzles at 18 cm spacings and adjusted to spray water and wetting agent in the bottom of the furrows directly above the seed. Two years after these treatments, when pasture measurements were taken (1989) for this paper the site had been levelled out by sheep traffic.

Pasture establishment experiment

The five pasture species, subterranean clover, dryland lucerne (*Medicago sativa*), tagasaste (*Chamaecytisus palmensis*), phalaris (*Phalaris sp.*), and perennial ryegrass (*Lolium perenne*) were sown at 18 cm row spacings either in the furrow with wetting agent applied (at 0, 0.5, 1, and 4 L ha^{-1}) or into level soil without wetting agent (control). Heavy (33 kg) press wheels were trailed behind the seeder and this improved furrow definition (Crabtree and Gilkes, 1998). Each treatment was replicated three times in the randomized complete block design experiment.

Weeds were sprayed with a 1:1 mix of paraquat and diquat at 2 L ha^{-1} 7 days before cultivating the plots and seeding on 9 June 1988. Cultivation was done with a full-cut cultivator at 8 km hr^{-1} and at 8 cm deep across the plots. Species in all plots were sown with a cone seeder at 4 km hr^{-1}, except for the conventional treatment plots, which were sown at 8 km hr^{-1}. Plots were 20 m long and 1.4 m wide.

The seeder had four rows of tines (hoes); the front for cultivating, the middle two for sowing and the rear for seed covering. Each row of tines was spaced at 36 cm and had 12 cm wide points attached.

Sowing at the bottom of the furrow was achieved by lifting the rear covering tines and trailing press wheels. The control treatment plots were level sown with trailing harrows.

Wetta Soil® wetting agent was applied in the bottom of the furrows through solid stream nozzles, which were mounted to the rear of the press wheels. A 3 mm solid stream of wetting agent (at various concentrations) was applied, with the mix making a total spray volume of 30 L ha^{-1} for all treatments at a spraying pressure of 150 kPa. Because of the low volumes of water applied, a water only control treatment was not considered necessary. The wetting agent is a nonyl-phenyl-ethoxeate, a molecule with a hydrophobic and a hydrophillic end and has been specifically developed as a soil wetting agent (Carnell, 1984).

Seeds were sown at 5 kg ha^{-1}, 0-10 mm deep, with an 80 mm wide spread (see Figure 1) and with 13 kg ha^{-1} of phosphorus as superphosphate. Plant counts were made in each plot at six 1-m row sections at 14 and 28 days after sowing. Since this pasture site already contained sub-clover and ryegrass, which germinated at the same time as the experimental plant species, we did background plant counts on neighbouring plots not sown to these species. This helped us to calculate the treatment effect for the seeds sown. However, the background plants probably contributed to increased variability in data for these two species.

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Insects attacked the plants between 14 and 28 days after seeding, reducing plant populations of some species. This was despite chlorpyrifos insecticide being applied at 2 L ha^{-1} 9 and 22 days after seeding to kill redlegged earth mite (*Halotydeus destructor*), cutworm (*Agrotis* spp.) and vegetable weevil (*Listroderes difficilis*) larvae.

Effect of residual wetting agent on pasture

The residual effects of Aquasoil® wetting agent were determined by measuring effects on volunteer pasture growth and composition. This was two years after barley was furrow sown with press wheels and six rates of wetting agent in June 1987 (from 0-75 L ha^{-1}). The subterranean clover-rich annual-pasture had regenerated the previous year providing an adequate seedbank for regeneration in 1989. Three replicates were taken from a randomised complete block design.

Three pasture dry matter (DM) samples were cut from 0.25 m^2 of each plot on 3 July 1989, two years after the wetting agent had been applied. The samples were oven dried at 50^{o}C for 48 hours, weighed and separated into subterranean clover, grasses (*Bromus diandrus* and *Hordeum leporinum*) and capeweed (*Arctotheca calendula*) components.

RESULTS

Pasture establishment experiment

Furrow sowing with press wheels increased emergence (plants m^{-2}) of all five species by an overall species average of 230% at 14 DAS relative to the value for the level sowing treatment (Table 1). By 28 DAS the increase in emergence was much less (40%) but still represented a significant and agronomically important improvement in emergence. Based on 14 DAS data there was a further 47% average improvement in emergence by applying 4 L ha^{-1} of wetting agent compared with the furrow sown with press wheels and no wetting agent. The lowest rate of wetting agent (0.5 L ha^{-1}) actually decreased plant emergence for 3 species at 14 DAS by an average of 15%, although not significantly.

Continued insect attack and damage may have affected responses at 28 DAS compared with 14 DAS, and was particularly severe for the broad-leaved species. The insecticide was applied twice, although with limited success, because the trial area was surrounded by older pasture which resulted in re-invasion by insects. Lucerne was completely absent from the trial by 28 DAS.

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The residual effect of wetting agent on pasture growth

Pasture DM yields in July were increased 6-fold by wetting agent applied two years earlier to a barley crop (Table 2). Production of subterranean clover was increased by 1.7 t ha^{-1} for the highest rate of applied wetting agent. The pasture composition improved with proportionally more subterranean clover and less grass and capeweed in the sward. Photographs of this pasture for 0 and 50 L ha^{-1} plots clearly show the contrast between the treatments. Visual inspection of the plots at the end of the season (early October), showed that the plots treated with wetting agent maintained their superior pasture production.

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DISCUSSION

Furrow sowing with press wheels doubled plant emergence, for all species, compared with the conventional level sowing practice. The benefits were most evident during early plant establishment. These improvements due to press wheels are much greater than those that have been measured for barley on similar water repellent soils (Bond, 1972; Crabtree and Gilkes, 1998).

The application of banded wetting agent gave further improvements in pasture emergence (47%) over the use of press wheels alone. A similar, although less spectacular, response was observed for barley (Crabtree and Gilkes, 1998). Interestingly the larger sized seeds responded better to these ameliorative measures. This work clearly indicates that pasture establishment on water repellent soils in southern Australia are likely to benefit from furrow sowing, press wheel use and low rates of banded wetting agent.

An important observation is that at 0.5 L ha^{-1} of applied wetting agent the rain water was channelled into a narrow band (typically 10 mm wide) at the bottom of the furrow (Figure 1). Without wetting agent the water repellent soils usually wet to 10 mm depth evenly across the flat part of the furrow (perhaps 60 mm wide). The wider spread of water that occurred in the soil without the banded wetting agent therefore ensured that more of the shallow placed seeds came in contact with water and emerged compared to the seeds from the 0.5 L ha^{-1} rate of banded wetting agent where a thinner and deeper soil volume was wetted . However, as a result of deep drainage and surface drying of the water repellent soil, the emergence was not translated to more pasture growth and more seedlings died in the furrow for the treatment without wetting agent than when wetting agent was used.

In the second experiment the residual effect of wetting agent greatly improved pasture quantity and quality. One year after application, in 1988, which was a very wet year, there were no visible differences in pasture regeneration across treatments, indicating even wetting of all plots. However, in 1989 even with the early rainfall being 50% higher than the average value, differences in early (July) pasture production between treatments were marked.

There was up to a 6-fold increase in early pasture production where a wetting agent had been applied 2 years earlier. With a cost of up to \$800 ha^{-1} the rates of wetting agent used in this experiment are uneconomic. However, these data clearly demonstrate that early pasture production is reduced on water repellent soils and can be improved by the use of wetting agents. In Mediterranean climates this limited early winter production occurs at a critical time for stock management and is of much greater value to farmers than pasture produced later in the season.

This work also clearly demonstrates that water repellence reduces pasture quality and quantity. These effects have major implications for subsequent pasture dynamics, including effects of insects and composition for legume soil nitrogen accumulated for following crops and pastures.

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FIGURES AND TABLES

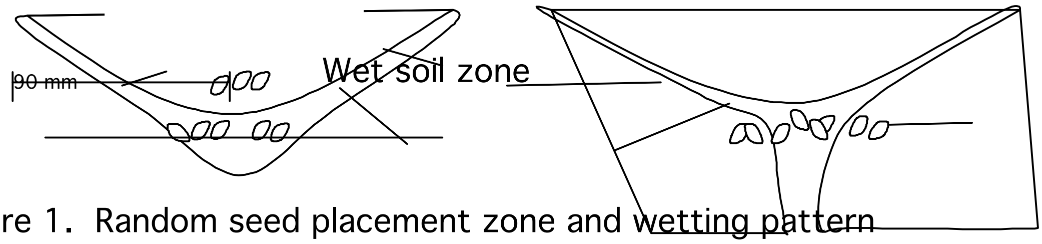

Figure 1. Random seed placement zone and wetting pattern observed after rain without wetting agent (left) and with 0.5 L ha^{-1} of wetting agent (right).

Table 1. Pasture species emergence (plant m^{-2}) at 14 and 28 days after seeding (DAS).

Treatment †	Clover 14 DAS	Clover 28 DAS	Lucerne‡ 14 DAS	Lucerne‡ 28 DAS	Tagasaste 14 DAS	Tagasaste 28 DAS	Phalaris 14 DAS	Phalaris 28 DAS	Ryegrass 14 DAS	Ryegrass 28 DAS
Level	**39**	63	**18**	na	**6**	44	**63**	78	**70**	117
F, 0.0	**107**	77	**50**	na	**14**	63	**111**	128	**141**	156
F, 0.5	**99**	91	**40**	na	**23**	68	**134**	126	**119**	139
F, 1.0	**110**	98	**46**	na	**21**	72	**125**	142	**144**	160
F, 4.0	**127**	95	**67**	na	**24**	73	**197**	157	**189**	156
LSD (0.05)	**36**	Ns	**26**	-	**9**	14	**53**	53	**65**	ns

† Treatment where Level is level sown, F is furrow sown and values are the rate of banded wetting agent in (L ha^{-1}).

‡ na is not assessed (as plants were eaten by insects and affected by disease).

Table 2: Pasture dry matter (DM) on 3 July 1989, two years after application of banded wetting agent.

Banded wetting agent (L ha^{-1})	Total DM (kg ha^{-1})	Partitioned DM (% of total) clover	capeweed	grasses
0	330	6	4	90
5	520	10	22	67
10	840	25	18	57
20	1,490	44	7	50
50	1,810	42	25	33
75	2,010	52	12	36
LSD (0.05)	120			