AGRONOMY JOURNAL

TITLE: Banded wetting agent and compaction improve barley production on a water repellent sand

SHORT TITLE: **Barley establishment on water repellent sand**

Bill L. Crabtree[A] and Robert J. Gilkes[B]

[A] Western Australian No-Tillage Farmers Association, 12 Fermoy Ave, Northam, W.A. 6401

[B] Soil Science and Plant Nutrition, Faculty of Agriculture, University of Western Australia, Nedlands, W.A. 6009, Australia.

ACKNOWLEDGMENTS

Peter King for inspiring this research. Bruce Radford, Craig Henderson, Anne Hamblin, Mike Bolland, John Hamblin, Mike Perry, Malcolm Oades and David Smith for comments and discussions. Ian Mickel for the loan of his press wheels. John Moore, Gary Dean, Max Crowhurst, and Mike Clarke for technical assistance, and Leon Slattery for the use of his land.

Banded wetting agent and compaction improve barley production on a water repellent sand

ABSTRACT

Large areas of cropland in Western Australia exhibit severe annual water repellency. Crop establishment is frustrated by the staggard emergence of plants, despite significant amounts of rain falling prior to the desired time of seeding. Three techniques were used to investigate improvements in barley (*Hordeum vulgare* L.) establishment on a water repellent sand: (i) spraying various rates of banded (2 cm wide) wetting agent while furrow seeding with press wheels, (ii) seed placement either in a furrow or in the side of a ridge, and (iii) compaction with press wheels or a Flexi-Coil® land packer. The application of wetting agent increased seedling emergence from 110 to 170 plants m^{-2}, dry matter production from 4.2 to 6.0 t ha^{-1} and grain yield from 1.96 to 2.60 t ha^{-1}, despite more weeds occurring with increasing rate of banded wetting agent. Use of press wheels, which also resulted in a furrow sowing condition, increased seedling emergence from 72 to 101 plants m^{-2} and grain yield from 1.70 to 2.13 t ha^{-1}. Furrow sowing, at 18 cm row spacings with full soil disturbance, in the absence of heavy press wheel compaction, had no effect on seedling emergence or grain yield. The application of wetting agent increased topsoil wetting and decreased spatial variability of emergence. Increased soil wetting may have increased plant nutrient availability (from fertilizer and soil), reduced evaporation and possibly reduced water loss to subsoil on this duplex soil. The optimum degree of compaction required on water repellent soils is not known and needs further research.

Water repellent soils resist wetting and, in a Mediterranean climate, the topsoil (10 cm) may take months to wet uniformly, despite the top 5-

10 mm wetting readily. Reduced and non-uniform topsoil wetting causes patchy weed emergence that results in crops being sown later, thereby reducing yield (King, 1981). Water repellent soils wet in a fingering pattern of patches below which water ponds in depressions (Dekker and Ritsema, 1995). Once these patches become wet in late autumn or early winter they usually remain wet throughout the growing season and will harvest water to support weed growth, even in dry seasons.

Water repellence is typically caused by a relatively high amount of organic matter occurring in soils with low clay contents (McGhie, 1980; Summers, 1987). Sandy soils throughout the world commonly experience water repellence (DeBano, 1981), especially if they are dry for part of the year. There are at least one million hectares of sandy soil affected by water repellence in the south coast region of Western Australia (Summers, 1987). This area is expected to increase due to an increasing soil organic matter content as legume production and reduced tillage systems increase.

Several soil conservation factors are adversely affected by water repellence. The risk of water and wind erosion is increased (Wetherby, 1984). With wettable soils and direct seeding, weeds proliferate and provide root materials that promote clod formation, and protect the soil from erosion at seeding time (Crabtree, 1990). In water repellent soils, dry patches may remain throughout the season and are prone to erosion. Preferred pathways for water infiltration in some soils may increase recharge to the watertable: thus plants are unable to use water that bypasses the root zone.

Weed control is frustrated by staggered weed emergence associated with water repellent soils. Weeds that germinate in hollows from a ‘false break’ rainfall, which occurs after a typical summer drought in south Western Australia, grow vigorously and rarely experience drought before crops are planted. After an adequate rainfall, or ‘true break’, occurs for planting crops, higher than normal rates of herbicides are needed to control these older weeds, thus increasing a farmer’s herbicide cost. In addition, sowing is often delayed to ensure that most weeds germinate before applying knockdown herbicides. Soil applied herbicides, such as simazine or atrazine, are commonly used in growing *Lupinus angustifolius* L., may be ineffective because to be fully effective they require even soil wetting.

Several techniques have been used to reduce the impact of water repellence in southern Australia. Cultivating in the rain physically mixes the surface 0-10 mm soil, which readily wets, with the remaining dry topsoil (100 mm). However, this technique relies on extended rainfall events, so that farmers can cultivate large areas while the surface soil is wet or while rain is falling. Cultivation also increases the risk of wind erosion (Wetherby, 1984). The addition of clay to topsoil eliminates water repellence at application rates of 70-200 t ha^{-1} (Ward and Oades, 1993) but may not be economical if appropriate clay is not found close to the site of application.

Furrow sowing has been tested with some success in improving crop emergence for water repellent soils (Bond, 1972; King, 1985). Increasing the depth of ponded water, which increases the hydraulic head, can improve water entry into repellent soil (Emerson and Bond, 1963). Bond (1972) found improvements in both emergence and grain yield in small plots on water repellent sand when barley was sown in the bottom of the furrow compared to sowing in the ridge.

Using press wheels, while furrow sowing, on water repellent soil has not been investigated in Australia. This is surprising as press wheels are known to reduce average pore size and increase seed-soil contact (Hyder et al., 1955) giving better movement of soil water to the seed (Stout et al., 1961). Many farmers in southern Australia have used Flexi-Coil® land packers (a herringbone pressing pattern) at seeding to increase cereal establishment on sandy soils with some improvements in emergence (Crabtree, 1990). In the early 1990's many farmers in the south coast region of Western Australia adopted press wheels, furrow sowing, and no-tillage sowing to improve emergence and limit wind erosion on these water repellent soils.

The value of wetting agents in improving water infiltration on water repellent sands has been known for years (Pelishek et al., 1962). McGhie (1983) and Carnell (1984) improved the formulation and effectiveness of wetting agents, and McGhie (1983) banded them over the seed, at an application rate of 10 L ha^{-1}. However, the wetting agent was not placed in the furrow, press wheels were not used, and there was no economic improvement in grain yield. King (1974, 1985) also experimented with wetting agents and concluded that they were too expensive for agricultural use.

This study, with barley grown on a water repellent sand, examines the effects of (i) different rates of wetting agent (ii) seed placement (furrow and side of a ridge), and (iii) compaction (press wheels and Flexi-Coil® land packer) treatments on plant growth.

MATERIALS AND METHODS

Two experiments were conducted at Beaumont, South Stirlings, near the south coast of Western Australia (33°S, 118°E). The soil was a red/brown gravelly sand overlying clay at 45 cm (duplex soil: Dy 4.83, Northcote, 1979). The topsoil (10 cm) had a pH of 5.0 (1:5 0.01 M $CaCl_2$), with a gravel content of 225 g kg^{-1}, a clay content of 30-60 g kg^{-1}, organic carbon of 10-12 g kg^{-1} and a water repellence value of 3.3 to 4.5 MED (molarity of ethanol drop test, as per King, 1981).

The soil was cultivated with a tined implement in April 1987 in a dry state to a depth of 10 cm. Plots were 1.44 m (8 rows) wide and 20 m long. All treatments were replicated four times. Barley (*Hordeum vulgare* L. cv. Stirling) was sown at a 2-3 cm depth on 29 June 1987 into dry soil at 80 kg ha^{-1} with 21 kg ha^{-1} nitrogen and 9.1 kg ha^{-1} phosphorus using a cone seeder with four rows of tines.

Banded Wetting Agent Experiment

The experimental design was a completely randomized block with banded wetting agent (Aquasoil®; a non-ionic surfactant), which was applied behind trailing press wheels at 0, 5, 10, 20, 50, and 75 L ha^{-1}, and concentrated in a 2-cm-wide band while sowing. The cast iron press wheels were in a gang of eight. Each wheel weighed 28 kg, was 10.3 cm wide, was 38.2 cm in diameter and was 'V' shaped with an internal apex angle of 120°. Each wheel had a total loading of 31 kg (the extra 3 kg are for axle, frame, and bearings), which applied an average vertical force of 3.0 N mm^{-1}. The apices of the press wheels were placed directly over the seed.

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 (vertically) above the seed. The spraying pressure was 150 kPa and a total of 300 L ha^{-1} of water plus wetting agent was applied for all treatments. The amount of wetting agent and water applied is equivalent to 0.03 mm (or 0.27 mm in the 2 cm strip) of rainfall. This water evaporated within an hour of application on a dry, warm (18-21°C) and windy (10-20 km h^{-1}) day.

Seed Placement and Compaction Experiment

This experiment was a split plot design with seed placement treatments as mainplots and compaction treatments as the subplots with 4 replicates. The seeds were placed either half-way up the ridge (conventionally) or in the bottom of the furrow (Fig. 1).

INSERT FIGURE 1 NEAR HERE!

Conventional seed placement was achieved by using all four ranks of the cone seeders tines with 10 cm wide points; the front rank of tines for cultivating, the middle two ranks for sowing, and the rear rank for seed covering (which destroys furrow sowing). Furrow sowing was achieved similarly, but with the middle two ranks of tines having 5 cm wide points and the rear rank removed. The dry cultivation provided a fine structured seedbed prior to seeding.

Compaction treatments were achieved using a gang of eight press wheels or a Flexi-Coil® land packer, with no compaction as a control.

The Flexi-Coil® land packer was rolled over the plots immediately after seeding. It weighed 493 kg, was 1.83 m wide, and randomly covered 58% of the soil surface with an average force of 4.5 N mm^{-1}.

Measurements

Seventy-two soil core samples (0-10 cm) were taken on 16 October 1987 (109 days after seeding) on a 4 m square grid within the plots. The soil was then air dried for 72 hours, gently sieved with a screen having 2 mm openings and water repellence of the soil was measured. The MED test was used, which is the 'Molarity of an Ethanol Drop' that takes 10 seconds to be completely absorbed into the soil (King, 1981). The experimental soils had MED values ranging from 3.3 to 4.5 (severe repellence being >3.2; King, 1981) and the average MED for the sites of the two experiments being 4.0 (s.d. = 0.22) and 3.8 (s.d. = 0.22), for the compaction/placement and wetting agent experiments respectively.

Emergence was measured using ten 0.25 m^2 quadrats per plot, at 14 and 28 days after seeding (DAS). As a measure of spatial variability of plants, the lowest three quadrat counts in each plot were averaged, which demonstrate how poor emergence was on parts of some plots. Plants were cut from six random 0.25 m^2 quadrats per plot on 16 October to determine dry matter. Grain yields were measured by machine harvesting the crop from all eight rows of each plot on 20 November 1987. A one-way analysis of variance was conducted and then least significant differences (LSDs) were calculated at the 5% level.

RESULTS

The average annual rainfall is 415 mm, 270 mm during the growing season of May to October. At an adjacent site in 1987, the year of the experiments, only 240 mm of rain fell with 157 mm falling during the growing season. Rain falling after October was too late to influence grain yield (Table 1). In the 2 years before the experiments, the site supported a subterranean clover (*Trifolium subterraneum* L. cv. Dinninup) dominant pasture.

INSERT TABLE 1 NEAR HERE

Applied Banded Wetting Agent

Increasing the rate of applied wetting agent increased emergence, decreased plant spatial variability, and increased DM production and grain yield (Table 2). The following equation gives the best fit for the grain yield data ($P < 0.001$, $n=4$, $r^2 = 0.98$)

$$\text{Grain yield (t ha}^{-1}) = 1.96 + 0.31\ [\text{wetting agent rate (L ha}^{-1})]^{0.16}$$

There was vigorous growth of the subterranean clover (*Trifolium subterraneum*) weed in plots where the wetting agent, was applied at the higher rates, while the clover was sparse in the control plots. It is estimated that this amount of clover would have decreased barley grain yield by at least 25% (M. Ewing, *pers comm*).

Soil wetting was improved by addition of the wetting agent. On 16 October 1987, 7 hours after 9 mm of rain, the untreated soil was mostly wet to a depth of only 1 cm. While where 50 L ha^{-1} of wetting agent had been applied, the topsoil was wet evenly along the furrow to a depth of 10 cm. This topsoil had 10-50% of this soil volume wet, and the water had moved out from the furrow to an increasing distance with increasing rates of banded wetting agent. For the control treatment the soil was mostly dry at depth in the furrow and usually only wet in the top 1 cm.

INSERT TABLE 2 NEAR HERE

Placement and Compaction Experiment

Placement of the seed in the side of the ridge (conventional sowing), but with the use of a press wheel, increased emergence ($P<0.05$) by 40% and grain yield by 25% and greatly reduced spatial variability (data not shown). No other treatment significantly increased emergence or grain yield (Table 3).

The quadrats with least plants in each plot, which provide an indication of spatial variability, had three times more plants where the seed was conventionally sown with press wheels compared to sowing without compaction (56 versus 19 plants m^{-2} at 28 DAS).

There was no relationship between the severity of repellence and DM production in this experiment. However, water repellence in these experiments was above 3.2 MED in all cases, which indicates severe repellence.

INSERT TABLE 3 NEAR HERE

Unintentionally, the conventional seed placement (seed located in the side of the ridge) was lost when press wheels were applied and became a furrow sowing treatment (Table 3). The soil near the seed with this treatment received more than the intended 3.0 N mm^{-1} compaction. Furthermore, for the furrow sown treatment, soil around the seed was compressed to a lesser extent than intended, as the sides of the press wheels compressed the sides of the 'already furrowed' soil surface. It is therefore likely that the only treatment that resulted in effective compaction and furrow placement was the conventional plus press wheel treatment, which resulted in the greatest yield.

DISCUSSION

The application of a banded wetting agent in this experiment proved effective and is likely to be profitable for southern Australian farmers. By using the curve of best fit, and the costs and prices for Australian farmers, a rate of 1 L/ha of banded wetting agent (at A$5-10/L) would have returned about 200% on monies invested for most years since 1987. Benefits of the wetting agent in this study would have been greater if subterranean clover had been killed. Changing the row spacing, degree of tillage, and furrow shape and size are now considered important refinements to this system.

This narrow band of wetting agent, in conjunction with furrow sowing, ensured good soil wetting in the immediate vicinity of the seed. Both Bond (1972) and McGhie (1983) speculated that economic returns might occur with banded wetting agents and these results show that increased soil wetting has improved emergence, growth, and grain yield of barley.

The better soil wetting with applied wetting agent was both along and across the width of the furrow, thus decreasing spatial variability of plant growth. Once wet, the soil remained wettable throughout the growing season. Some topsoil in the plots without applied wetting agent remained dry and unimbibed, and viable seed was excavated from these patches at harvest time.

Wetting agents give several benefits to the plant-soil system. Better soil wetting releases applied fertilizers to the soil solution and increases mineralization of organic matter. Uniform wetting along the furrows improved water infiltration and decreased surface ponding, thereby decreasing evaporation and increasing water use efficiency of the crop.

Use of the press wheel increased emergence and grain yield with conventional sowing (which effectively became a form of furrow sowing) but not with the designated furrow sowing. This is thought to be due to better compaction of soil around the seed. The improvements are not due to furrow sowing alone as furrow sowing, even with press wheels, gave no improvements. Hence a combination of compaction plus furrow sowing increased emergence and grain yield. In contrast, Bond (1972) found that furrow sowing alone gave better emergence and grain yield. Perhaps the extremely low rainfall for this experiment is the reason for the difference. Flexi-Coil® land packing was of no benefit, possibly because it did not create a furrow-sowing-effect and compaction was random.

Compaction requirements of water repellent soils need defining. Dry sand does not compact well and water repellent soils are usually mostly dry at the desired time of sowing. In this work an average pressure of 3 N mm^{-1} was not adequate to provide optimal barley emergence. Other studies have shown that compaction increases cereal emergence for a range of soil types both in Australia and elsewhere (Radford and Wildermuth, 1987), including sandy soils (Pathak et al., 1976). Increased emergence is usually attributed to better seed-soil contact, which was not directly measured in this study. Because of the dry nature of water repellent soils, the compaction mechanics may be different than in wettable soils.

Press wheels had not previously been used in Western Australia, mostly because they had not been tested and proved beneficial and their rolling motion is hindered by tree stumps. However, this experiment demonstrates that increased grain yields can be obtained with press wheel use. The Flexi-Coil® land packer has given increased grain yields on a wettable soil (Crabtree, 1990) although that did not occur in this experiment.

More testing of these systems is needed. Variables such as furrow shape and size, compaction requirements, and rates and types of banded wetting agent need to be further researched in a range of conditions. Attention should also be given to the wind erosion risk and herbicide techniques due to the staggered emergence of weeds and because herbicides require uniform soil-water conditions. Numerous farmers in southern Australia have adopted elements of this management package with considerable success.

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FIGURES AND TABLES

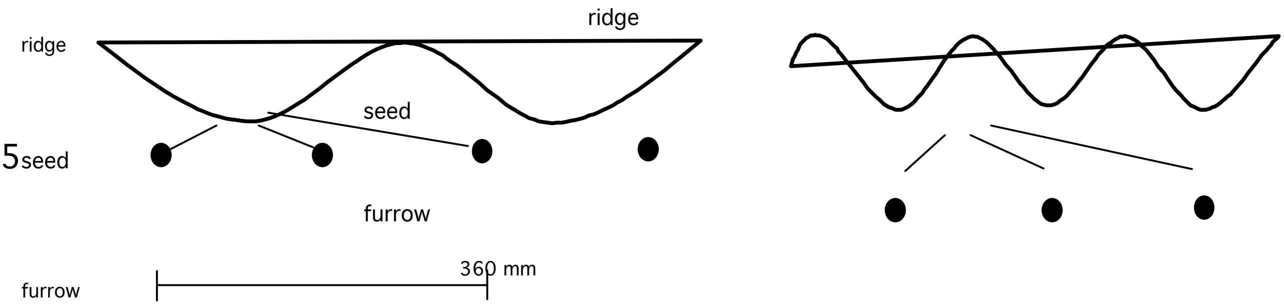

Figure 1: Conventional sowing, or side of the ridge sowing, versus furrow sowing for seeding in the bottom of the furrow.

Table 1. 1987 rainfall (mm) at a neighbouring site (Swain's farm).

Month	Jan-April	May			June			July			Aug.	Sep.	Oct.
Part of month†	all	E	M	L	E	M	L	E	M	L	all	all	all
Rainfall (mm)	23	31	2	2	3	11	9	5	10	18	30	21	15

† all, E, M and L is the whole month or early, middle and late third of the month.

Table 2. Barley emergence, dry matter production at anthesis and grain yield, with applied wetting agent.

Banded wetting agent rate ($L\ ha^{-1}$)	Emergence 28 DAS (plants m^{-2}) weak areas†	Emergence 28 DAS (plants m^{-2}) average	Top DW at anthesis ($t\ ha^{-1}$)	Grain yield ($t\ ha^{-1}$)
0	69	110	4.29	1.96
5	97	134	5.31	2.36
10	108	145	5.62	2.44
25	119	149	5.49	2.44
50	122	161	6.01	2.54
75	132	170	6.02	2.60
LSD (0.05)	11	16	0.54	0.24

† average for the 3 quadrants with lowest emergence values per plot, as an indication of spatial variability when compared with average data.

Table 3. Emergence, dry matter at anthesis and grain yield, for barley sown either conventionally or in a furrow with different compaction treatments. Treatment effect on placing the seed in a furrow and compaction pressure on the soil above the seeds, as rated by eye.

Seed placement	Type of compaction	Emergence† (plants m^{-2}) 28 days post sowing	Anthesis dry wt ($t\ ha^{-1}$)	Grain yield ($t\ ha^{-1}$)	Treatment effect on furrow placement	Treatment effect on compaction over seed
Conventional	Nil – control	72	4.44	1.70	negative	negative
Conventional	Flexi-Coil®	73	4.99	1.82	negative	positive
Conventional	**Press wheel**	**101**	**5.04**	**2.13**	**positive**	**positive**
Furrow	Nil	62	4.68	1.69	positive	negative
Furrow	Flexi-Coil®	57	4.27	1.70	negative	negative

Furrow	Press wheel	74	4.09	1.79	positive	negative
LSD (0.05)		17	0.75	0.19		

† 200 plants m^{-2} would be equivalent to 100% emergence.

Dr Steve R. Evett
Associate Editor – Agronomy Journal
P.O. Drawer 10
Bushland, TEXAS 79012
USA

Dear Steve,

RE: TWO WATER REPELLENT PAPERS

Thanks for the letter on 5th August and prompt fax on 28th September, both regarding the two manuscripts I submitted to Agronomy Journal earlier this year. The titles for which are “Banded wetting agent and compaction improve barley production on a water repellent sand” (A98-18) and “Improved pasture establishment and production on water repellent soils” (A98-19). Thank you for posting me the Publications Handbook and photos.

I am thankful to you and the referees for the work done to improve the articles. In particular referee one, who has done such a thorough job – he/she obviously knows the Journals style very well and has a keen eye for constructive and thorough comments.

I believe that I have addressed all the concerns raised. In most cases I have adopted the changes suggested. Occasionally I have changed the text, and rarely I have suggested the changes are not necessary – with my reasons. As you have suggested I have gone through each issue with each referee one paragraph at a time. Please note the attached pages.

Thank you for clarification on the cost of photographs. Yes, I agree! They are probably not all that necessary (not at that price anyway! also $A1.00 = $US0.57). And I will not be requesting that they be included.

I have attached a diskette with the documents in Word Perfect as requested.

Sincerely.

Bill Crabtree
(WANTFA's Scientific Officer)
30th September 1998

Comments by Author (Bill Crabtree) on Agronomy Journal Reviews of the following paper

Banded wetting agent and compaction improve barley production on a water repellent sand (A98-18)

Reviewer #1

Para #1 Yes, I am sure this is true – "the results would have been different in wetter seasons". In fact, subsequent work with much lower rates (0.5-16 L/ha) of narrower (5 mm wide) banded wetting agent showed that less responses to amelioration occurred at wetter sites. This work has been submitted to Plant and Soil this year.

Para #2 I have reworded all sentences that are awkward and I have used the American spelling.

Para #3 I have attempted to closely follow the ASA style by making the numerous changes suggested.

Para #4 The Abstract now has "purpose and objective" statements included as the first two sentences, they read; "Large areas of cropland in Western Australia exhibit severe annual water repellency. Crop establishment is frustrated by the staggard emergence of plants, despite significant amounts of rain falling prior to the desired time of seeding."

Para #5 OK!

Para #6 My preference was to remove the letters a,b,c etc and keep the LSD's – I hope this is OK.

Para #7 The tables have been modified to fit with Journal standard (hopefully).

Para #8 OK!

Para #9 Repeat of Para #4 suggestion! – done!

Specific Comments 1-3 are in covering letter, the remainder were in the text:

1. Dy 4.83 = this is referring to the standard Australian reference on soil classification (Northcote) which every Australian soil scientist uses in our Journals. Specifically, this code refers to the soil as a duplex (sand over clay) with a certain hue and pH acid trend with depth. I have modified the wording to make it clearer to non-Australians by saying; "(duplex soil: Dy 4.83, Northcote, 1979)." I hope this is adequate.
2. I have reworded the MED sentence to say; "The MED test was used, which is the 'Molarity of an Ethanol Drop' that takes 10 seconds to be completely absorbed into the soil (King, 1981)."

3. I have reworded the 'Six... quadrants were cut" to "Plants were cut from six random 0.25 m^2 quadrats per plot..." I have checked for others that the referee has observed and have changed them appropriately – I hope they have all been found!
4. Page 4, line 8: The state is Western Australia, so changed to; "in south Western Australia".
5. Page 4, line 15: Simazine and Atrazine are the chemical names!
6. Page 5, line 11: the seeds were not sown on the ridge but rather in the side of the ridge.
7. Page 6, line 20: Traditionally nothing grows in our agriculture during our November-April summers – except eucalypts. So I think I can leave as is – unless you suggest otherwise.
8. Page 9, line 1-3: Figure is not meant to have lines across the soil surface – computor glitch.
9. Page 11, line 15-16: I have re-worded to read; "There was vigorous growth of the subterranean clover (*Trifolium subterraneum*) weed in plots where the wetting agent, was applied at the higher rates, while the clover was sparse in the control plots." And likewise page 12, line 1-9 now reads; "On 16 October 1987, 7 hours after 9 mm of rain, the untreated soil was mostly wet to a depth of only 1 cm. While where 50 L ha^{-1} of wetting agent had been applied, the topsoil was wet evenly along the furrow to a depth of 10 cm. This topsoil had 10-50% of this soil volume wet, and the water had moved out from the furrow to an increasing distance with increasing rates of banded wetting agent. For the control treatment the soil was mostly dry at depth in the furrow and usually only wet in the top 1 cm."
10. Page 14, line 7-9: Is now reworded to say; "Unintentionally, the conventional seed placement (seed located in the side of the ridge) was lost when press wheels were applied and became a furrow sowing treatment (Table 3)."
11. I have put the figures on a separate page.
12. Dozens of other minor changes were made as the reviewer suggested – see the manuscript.

Reviewer #2

Para #1 Like yourself Steve, I would rather leave the manuscripts as two distinct papers.

Para #2 I agree that the photos are not needed.

Para #3 The figures and tables are now presented in Agronomy style – at the end.

Para #4 Rainfall distribution was not available for the actual site. The months May-July are the most critical for crop establishment and rainfall before this time was minimal and rainfall after this time was too late to greatly provide treatments effects and was also low (poor).

Para #5 I disagree strongly – the data in table one provides important detail to those who wish to look at mechanisms or modelling.

Para #6 No! the soil was wettable after the wetting agent – hence the improvement in growth.

Para #7 I am happy to do this if it adds value to the paper, but have not yet done so.

Para #8 I have previously presented the data as figures and I was advised to present them as tables as this provides the reader with the real numbers and overcomes the need to have 3 different y axis. The grain yield data has been analysed differently as shown on page 11, line 14 and I have now included an R^2 value. A different analysis would not affect the conclusions.

Para #9 Are not some of the greatest discovers made from “unintentional results”, I can’t see how this would affect the validity of the results – does this need follow-up?

Para #10 I believe a more specific analysis would not be productive as commodity prices change so much through time and this is only one years result (a very dry one) on banded wetting agents. I have included a likely price range for the wetting agent of A$5-10/L to allow the readers to make their own assumptions if they desire. I say the most economical rate would have been the 1 L/ha rate based on the power curve calculated on page 11, line 14. The reference to $800/ha was based on the 75 L/ha rate that gave a residual value two years later in a pasture – these are quite different issues.

There were no comments on the text from reviewer #2.

Reviewer #3

Para #1 OK!

Para #2 A one-way analysis of variance was conducted prior to the LSDs being calculated. I have now included such a comment in the text being the last statement before the Results section. Letter convention is now not relevant as I removed all letters.

Para #3 The objectives have been stated more clearly with the addition of two new leading sentences in the Abstract as Reviewer one suggested. I think the three objectives should be adequate, what do you think Steve? I agree that no press and wetting agents would have been a good option to explore and indeed this was done in about 15 subsequent mostly emergence trials. Therefore I believe these conclusions are sound.

Para #4 See specifics on manuscript below.

Para #5 I have addressed all (I think) of the format differences.

Para #6 I would rather leave the data in tables as discussed in response to Reviewer #2 above (see Para #8).

Para #7 I have corrected the data discrepancy in the abstract.

Para #8 To reword as suggested would, I think incorrectly change the meaning. It is the aptial variability of the plant population that is the important issue here – I think!

Specific Comments in the text:

Page 2, line 17: It should read decreased and not increased as the reviewer suggests.

Page 3, line 18: Sentence is recast as Reviewer one suggested.

Page 4, line 1: Sentence is now changed.

Page 6, lines 9-11 & 16: Also reworded.

Page 7, line 10: Row spacing can simply be calculated by dividing 1.44 m by 8. This is too simple and I think it would be silly to make the calculation.

Page 9, line 1-3: Lines are not meant to be there – it was a glitch in the computor.

Page 10, line 7: A good observation, I have reworded to say; "....being 4.0 (s.d. = 0.22) and 3.8 (s.d. = 0.22), for the compaction/placement and wetting agent experiments respectively."

Page 11, line 14: I have included r^2 value as suggested.

Page 12, lines 4-8: Have had major rewording, see Reviewer #1 (specific comment #9).

Page 13, line 4: I'm not sure what to do with this comment. I know that, as photos show; where no wetting agent was applied there were large areas where no crop emerged, however, with wetting agent there was uniform emergence in these types of otherwise would be dry areas.

Page 14, line 1-5: Positive and negative were casual observations – no data was collected. I have included a comment "as rated by eye" in the ending text in table 3.

Page 14, line 11-13: I have reworded the text which should hopefully alleviate the need for a diagram.

Page 15, line 8: There are too many cost/price issues and through time to make a robust economic conclusion. This is only one trial in one year. The 1.0 L/ha rate was calculated using a curve of best fit – which I understand to be valid (later work confirms this also).

Reviewer #4

Specific Comments in the text:

Many comments are made that have already been addressed by other Reviewers, sometimes more than once. Hence these I will not comment on these – I hope that is OK?

Page 2, line 10 & 14: The values 110 and 72 appear to be right to me (they are circled).

Page 3, line 10: "..will harvest water…" means that these ponds act as catchments throughout the year and water ponds here and infiltrates in this area (hence 'harvests'). Is there a better way to say it.

Page 9, line 19: N mm^{-1} is the standard to use so my engineering friends tell me.

Page 11, line 1-6: Plate 1 and 2 have been removed.

Page 13, line 4: Have included text in parenthesis saying "(data not shown)".

Page 16, line 4: "…decreased surface ponding, thereby decreasing evaporation…." This seems clear to me? As water ponds it is open to evaporational loss!

Page 17, line 10-15: I have reworded the whole paragraph to read "More testing of these systems is needed. Variables such as furrow shape and size, compaction requirements, and rates and types of banded wetting agent need to be further researched in a range of conditions. Attention should also be given to the wind erosion risk and herbicide techniques due to the staggered emergence of weeds and because herbicides require uniform soil-water conditions. Numerous farmers in southern Australia have adopted elements of this management package with considerable success."

Pages 17-21: I have shortened the references to fit with the standard and have put the figures and tables on a separate page.