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THE DEVELOPMENT AND TESTING OF SOIL WETTING AGENTS

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ABSTRACT

Water repellent (non wetting) soils in Western Australia affect pasture and crop establishment and growth, the erosion of particular land classes, and water use and turf health in urban areas. Experimental materials were synthesised to give a range of properties, some of which should optimise the performance as soil wetting agents. The soil wetting and rewetting properties of the experimental and many commerically available wetting agents were evaluated on a coarse, water repellent Bassendean sand using plastic ring infiltrometers.

A rainfall simulator was used to study effective rates of the various materials for improving the penetration of rainfall into the soil. Large differences between wetting agents were observed in both studies.

Four of the experimental materials had superior wetting and rewetting properties to all other wetting agents tested. The properties of some of the successful materials are discussed.

INTRODUCTION

Surfactants or wetting agents have been extensively used in programmes assessing the adverse effects of water repellent soils. (Letey et al, 1975) By using wetting agents runoff from water repellent slopes has been reduced (Osborne et al, 1964), seedling germination has been improved (Osborne et al, 1967) and the effects of dry patch in turf have been diminished. However, while wetting agents have proved effective in several applications they have been considered unsuitable for other than intensive applications and their use has largely been restricted to turf, horticulture and urban applications. Expense has removed any consideration of their use in broad-acre agriculture (King, 1974).

Few, if any, of the wetting agents marketed for the purpose of overcoming soil water repellency have been developed particularly for that use. Generally, their recommendation for use in overcoming dry patch in turf is an extension of more general uses as spray additives for wetting plant surfaces.

Weil et al (1979) tested a very extensive range of poly ethoxylate chemicals for their effectiveness in wetting a water repellent soil. They found that wetting agents which appeared to show outstanding soil wetting properties had several characteristics including the confirmation that the wetting agents functioned best at HLB values near their solubility limit (HLB 7-9). Best wetting was accomplished with fatty acids and alcohols having an alkyl chain of 9-10 carbon atoms with two or three oxyethylene groups attached and the terminal hydroxyl group left intact.

Many of the surfactants presently available in Australia as soil wetting agents have properties which do not match those given above. Many are comprised largely of Terric GN8 and GN9 chemicals with HLB values of greater than 12. An attempt was made to synthesise wetting agents satisfying at least some of the above criteria to see whether they might be more effective soil wetting agents. These were compared with a large range of surfactants, some of which were recommended for use as soil wetting agents and others, such as dishwashing liquids, were not.

A successful soil wetting agent should guarantee rapid, even and deep penetration of water when applied as a solution and if applied to a dry soil surface should enhance the penetration of following rainfall or irrigation into the soil. Ideally the wetting agents should also remain effective should the soil dry, guaranteeing excellent rewet properties of the soil. Lastly, to defray the high costs of such chemicals the wetting agent should persist in the soil for many wetting and drying cycles, retaining its effectiveness through these. Ideally, in our Mediterranean type climate, with long dry summers,and the requirement for rewetting each winter the wetting agents should survive for more than twelve months so the initial cost could be discounted, against subsequent benefits.

MATERIALS AND METHODS

Representative wetting agents and detergents, and, where possible, details of their chemical properties were collected from a number of manufacturers. Eighteen experimental surfactants with a range of structures were mixed by W.A. Chemical Manufacturers (Product A, B, etc) and Klen Chemicals (Klen RP 61, 62, etc). Where possible the HLB of the mixtures was obtained as this was considered an important property related to the usefulness of the materials as soil wetting agents (Table).

Ring Infiltrometer Tests

Plastic tubes 100mm in diameter and 200mm long were pushed into a bare, raked coarse Bassendean sand with a soil water contact angle (Emerson and Bond 1963) of > 100 degrees. The soil inside and outside the tubes was lightly tamped to prevent leakage from the ring and 200ml of solutions of 1.0%, 0.5%, 0.1% and in some cases 0.01% of wetting agent in water were poured carefully onto the soil surface, using a plastic sieve to disperse the energy of the poured water. For each of three replicates of each concentration and many control infiltrometers the time from completion of pouring until disappearance of all water was recorded.

Two or three days later when the soil within the tubes had dried (the tests were carried out in January and February 1981, mean maximum temperatures 27.8 degrees C and 27.7 decrees C) the disappearance time for 200ml of water was recorded. This is known as the rewet time. Once all water had disappeared, the plastic rings were removed and a cross section of the wetting pattern exposed using a spade. This was rated for effectiveness of wetting on a 1 to 5 scale with 1 being fully wet and 5 representing only a small proportion of the soil wet.

On the basis of the wetting (W) and rewetting (R) times, the wetting agents were grouped into four categories with the main criteria for catefory 1 being W < 60s and R < 120s at all concentrations.

Sprinkling Infiltrometer Tests

The rainfall simulator developed by Marsh (1974) was used to develop a variable intensity rainfall event which delivered a total of 25mm in 10 minutes. The event was recorded and replayed in every test of wetting agents applied to 2m x 1m plots on a Bassendean sand with a contact angle of >100 degrees. Wetting agents were applied at rates of 100 and 50 l/ha of active ingredient for all materials and also at 20 and 10 l/ha for selected and effective treatments. Plots were allowed to dry before the rainfall event was applied and the excess of rainfall minus infiltration was collected using a suction apparatus from within each of four (approximately 0.1 sq m) metal plot borders, placed regularly in the spray pattern. A measuring cylinder was used as a rain guage to ensure that rainfall varied by < ±10% for each event.

The time from rainfall commencement to runoff initiation was recorded and after each test a cross section of the infiltration pattern was cut using a spade and the mean depth of water penetration recorded.

RESULTS AND DISCUSSION

For each wetting agent the mean time of infiltration was plotted against wetting agent solution concentrations, and on the basis of the results obtained wetting agents were divided into four different categories (figures 1 to 4). Each wetting agent was placed in one of these categories. Although there were some wetting agents on the borderline between categories 2, 3 and 4, the differences between these and the category 1 with excellent wetting and rewetting properties were outstanding (Table 1).

TABLE 1: Categorisation of wetting agents according to infiltration versus time plot.

CATEGORY			
1	2	3	4
Product H *	Product K	Product B	Product A
Product I	Empigen BB	Product C	Empilam F D
Product L	BS 100	Product E	Gardiquat
Klen RP 68*	Aqua Gro	Product F	Dishwashing-Woolworths
	Klen RP 66	Product G	Dishwashing-Hunters
	Pro-Am	Product M	Dishwashing-Trix
	David Grays Wetting Agent	Nansa HS 80	Medina Soil Activator
	Wetting Agent A	Nonion G04	Soilife
		Terrawet 100	Klen RP 65
		Nufarm	Agral 60
		Nonidet WK	
		Dishwashing-Fab	
		Dishwashing-Sunlight	
		Dishwashing-Palmolive	
		Klen RP 64	
		Klen RP 61	
		Klen RP 62	
		Klen RP 63	
		Klen RP 67	
		Plus 50	

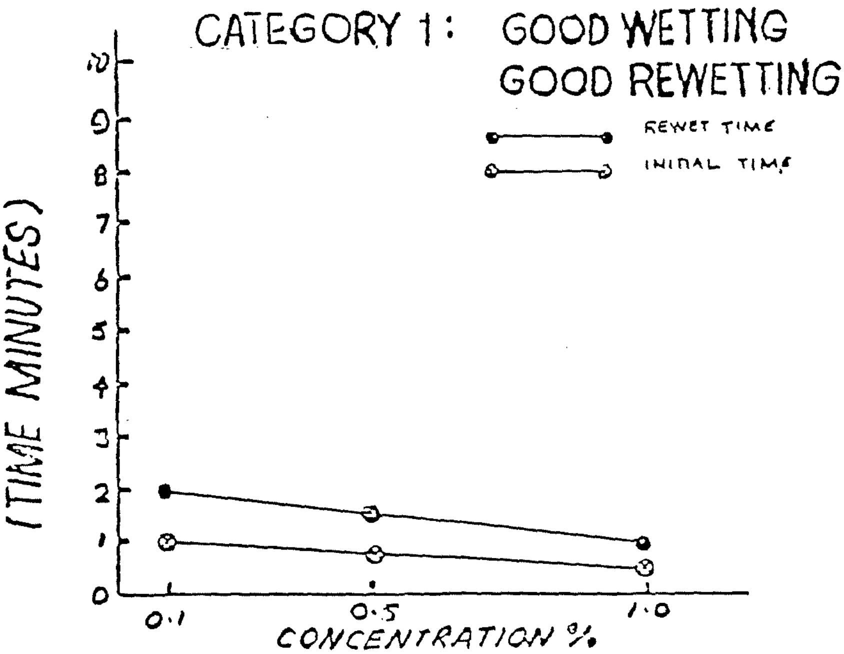
* Note: All Wetting agents with Product (A, etc) or Klen names were experimental

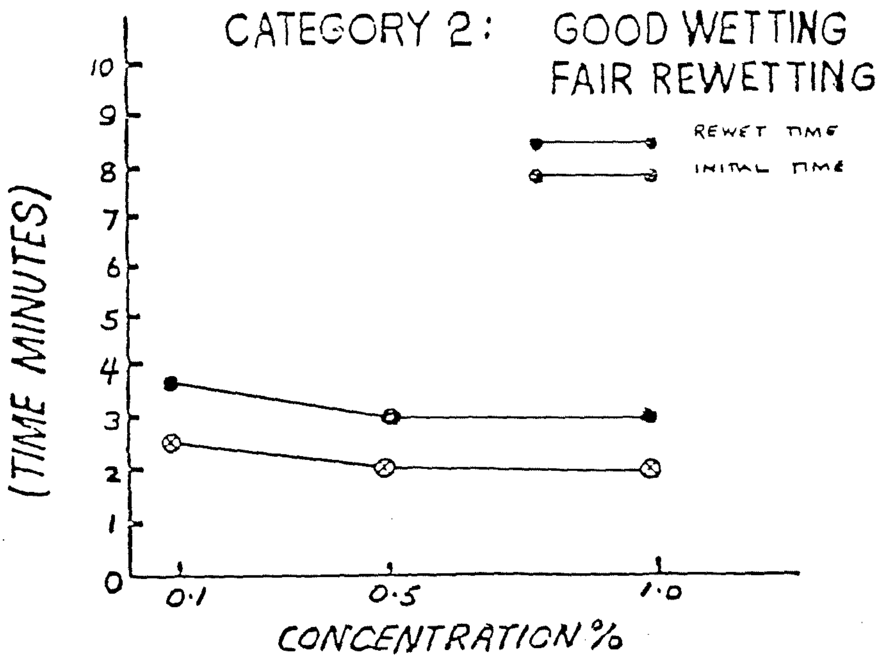
FIGURES 1 to 4

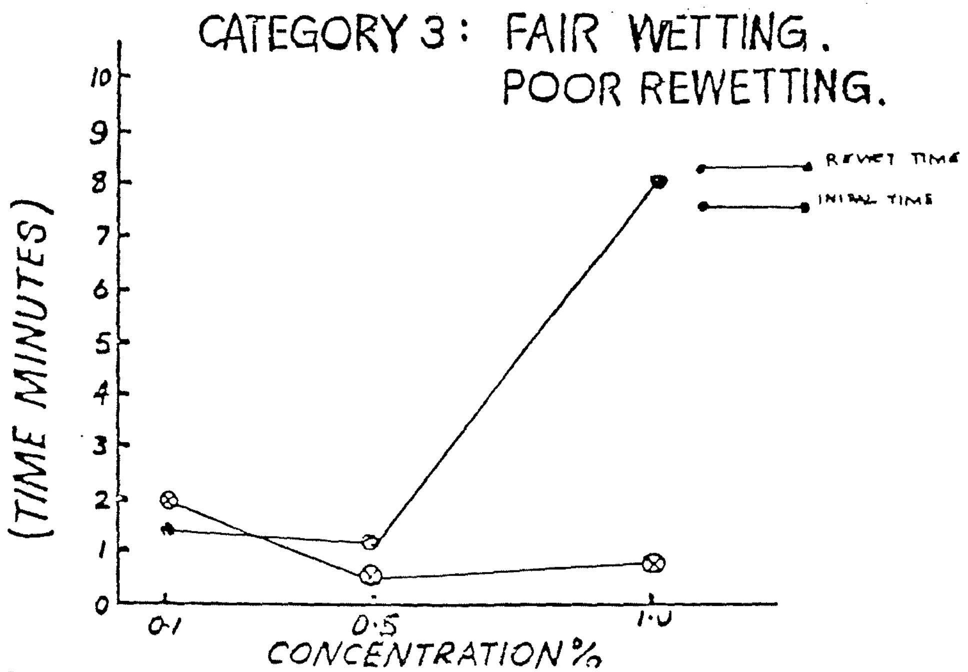
showing concentration versus

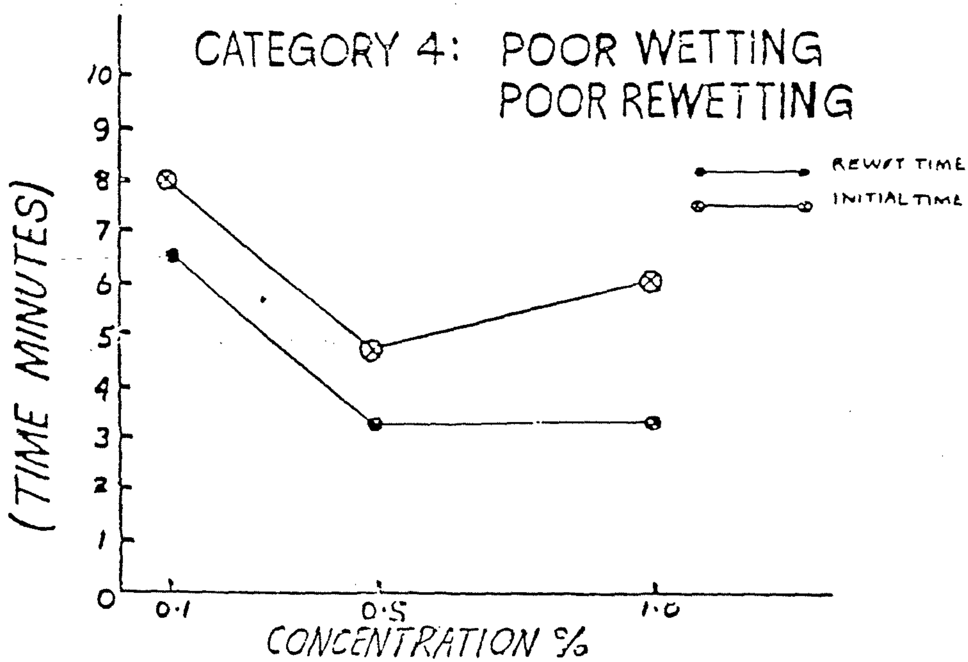
disappearance time plots for

Category 1 to 4 wetting agents.


CATEGORY 1: GOOD WETTING
GOOD REWETTING
REWET TIME
INIDAL TIME
(TIME MINUTES)
0
1
2
3
4
5
6
7
8
9
10
0·1
0·5
1·0
CONCENTRATION %


CATEGORY 2: GOOD WETTING
FAIR REWETTING
REWET TIME
INITIAL TIME
(TIME MINUTES)
0
1
2
3
4
5
6
7
8
9
10
0·1
0·5
1·0
CONCENTRATION %


CATEGORY 3: FAIR WETTING.
POOR REWETTING.
REWET TIME
INITIAL TIME
(TIME MINUTES)
0
1
2
3
4
5
6
7
8
9
10
0·1
0·5
1·0
CONCENTRATION %


CATEGORY 4: POOR WETTING
POOR REWETTING
REWET TIME
INITIAL TIME
(TIME MINUTES)
0
1
2
3
4
5
6
7
8
9
10
0·1
0·5
1·0
CONCENTRATION %

The ring infiltrometers suggested that four of the experimental wetting agents were superior soil wetting agents to the commercial and other experimental lines. However, the ring infiltrometers could only be considered comparative and gave no indication of necessary actual application rates. Deep penetration of water with even wetting was only obtained with category 1 wetting agents although Product K performed nearly as well.

Tests using the sprinkling infiltrometer provided more useful indications of necessary applicaiton rates. The total 'rainfall' application per 0.1 sq m plot was nearly 2.5 l and mean runoff from control plots was 1342 ml. Only four wetting agents prevented runoff with the standard event (Table 2) and of these only product K was not from the earlier category 1. Product I had by this stage been discarded as too difficult to use in tank mixtures, particularly in cold conditions. None of the other category 2 wetting agents prevented runoff, and, if at all effective, did not function well until applied at a rate of 100 l/ha of active ingreadient.

The times to runoff initiation, and depth of water penetration were related to effectiveness in preventing runoff. Only when very low runoff figures were recorded, and initiation of runoff was slow, did water penetrate to 20mm or deeper in the test interval. Apart from the four wetting agents which prevented runoff only X 77 gave water penetration of 20mm and this was at a rate of application of 300 l/ha of product (37% active).

TABLE 2: Sprinkling infiltrometer assessment of wetting agents - runoff, time to runoff and depth of water penetration

Wetting Agent	Rate (l/ha)	Runoff (ml)	Time to Runoff (s)	Depth of Rainfall Penetration (mm)
Water (Control)	-	1342.2	27.0	3.0
Product L	10	137.5	240	15.0
(Aquasoil Wetter)	20	177.5	240	15.0
	50	2.5	570	20.0
	100	0	-	20.0
Product H	10	837.5	180	10.0
	20	260.0	270	15.0
	50	0	-	8.0
	100	0		12.0
Product K	10	165.0	240	12.0
	20	362.5	210	12.0
	50	0	-	10.0
	100	0	-	30.0
Klen RP 68	10	722.5	180	15.0
(Wetta Soil)	20	220.0	240	15.0
	50	0	-	25.0
	100	0	-	25.0
Detergent	50	1122.5	60	5.0
(20% active)	100	1217.5	90	8.0
	250	802.5	90	5.0
	500	597.5	180	8.0
Aqua Gro	10	1357.5	60	5.0
	20	1217.5	60	10.0
	50	720.0	150	8.0
	100	485.0	207	10.0

Note: This table summarises the range of results for the twenty nine wetting agents tested. Details for other wetting agents are available from the authors.

As in the ring infiltrometer testing, some of the experimental wetting agents appeared to be more effective on non-wetting soil when applied at rates of 10 to 100 l/ha of active ingredient. Such a range of application rates includes normal recommended rates for the commercial materials used for soil wetting. From the two tests reported here it appeared that products H, L and K and Klen RP 68 were superior soil wetting agents for use on water repellent sands.

Soil water repellency is normally a property of sandy soils (Roberts and Carbon 1971) and the cause of the repellency is always organic material although the source may vary from plants to fungi or an association between the two (McGhie and Posner, 1981). The nature of the organic material is uncertain but it has been categorised as humic acid (Roberts and Carbon, 1972), and lignified material (McGhie, 1980). It should not prove surprising if wetting agents which are successful on one water repellent soil also work on others as the organic materials could be of similar gross structure. The wetting agents developed in this programme have been used successfully to wet sands and enhance crop and pasture growth at several locations in Western Australia (McGhie and Tipping, unpublished data).

Properties of Soil Wetting Agents

Most common surfactants used as household detergents fall in the HLB range from 13-15 (ICI technical literature). Only five of the experimental materials were effective soil wetting agents and one of these (Product I) has been discarded. Three of the five were characterised by HLB values falling within the normal wetting agent range (HLB 7-9) (Table 3).

TABLE 3: HLB values of some of the experimental wetting agents

Product Name		HLB Value	Value as Soil Wetting Agent
Product	A	7.8	Poor
"	B	9.8	Poor
"	C	11.6	Poor
"	E	9.0	Poor
"	F	8.8	Poor
"	G	9.7	Poor
"	H	8.35	Good
"	I	8.4	Good
"	K	8.5	Good
"	L	Unknown	Good
"	M	10.0	Poor
Klen RP	61	Unknown	Poor
"	62	Unknown	Poor
"	63	15.0	Poor
"	64	12.5	Poor
"	65	15.0	Poor
"	66	12.5	Reasonable
"	67	13.0	Poor
"	68	4.0	Good

Obviously the association between wetting agent effectiveness and HLB values in the 8-9 range is not reliable as several of the experimental materials with values in that range were totally ineffective (Products A, E and F).

Further examination of the components of the successful wetting agents has shown the polypropylene-glycol ethoxylates (Teric PE series) to be the main active ingredient. Both the PE 61 and PE 62 are effect soil wetters with good rewetting properties, although the effectiveness of both can be enhanced by adding other nonionic and anionic surfactants (Carnell,personal communication).

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Materials for testing were generously provided by:

W.A. Chemical Manufacturing Co,
6-10 Hodgson Way, KEWDALE, W.A. 6105

(Note: Product L is now marketed as AquaSoil Wetter)

Wetta Chem Products
Bourke Street, BUNBURY, W.A. 6230

(Note: Klen RP 68 is now marketed as WettaSoil)

Aquatrols Corporation of America
1432 Union Avenue, Pennsauken, NEW JERSEY, 08110, U.S.A.

Shell Chemicals
155 William Street, MELBOURNE, VIC. 3000

Albright and Wilson (Australia) Ltd
313 Middleborough Road, BOX HILL, VIC. 3128

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Western Australian Department of Agriculture

Agdex 511

Water repellent soils on farms

By D. A. McGhie, Plant Research Officer, Bunbury

Soils which after rain do not wet or have only a thin veneer of wet on top of dry soil are termed water repellent. The effect of such soils may show in many ways.

Patchy annual pastures. Early in the growing season only some areas of soil wet and patchy pastures result, with plants growing in the moist soil. This situation may improve later in the season if heavy continuous rain falls, but an even pasture is unlikely.

Early growth in depressions. Ponding of water in natural depressions or hoof marks increases germination and this effect is more noticeable in dry than in wet years.

Failure of crop to germinate. In conventionally seeded areas some seed may be placed in soil which remains dry and as a result germination is reduced.

Early growth in mulch rows. Grass may appear where straw has been deposited by headers before it appears in interlying areas.

Wetting pattern

The patchy germination of crops or pastures may be explained by examining a cross section of the soil underlying such areas. A typical patchy germination with its associated wetting pattern is shown in Figure 3.

Once the wetting channels are established they provide the easiest path for subsequent infiltrating water to follow and there may well be no change in the wetting pattern with time, particularly in a dry year.

Causes of water repellent soils

• Before clearing, the native vegetation adds leaf and stem litter to the surface of the soil and dead roots accumulate at greater depths. When broken down into fine particles by soil animals the residues of many of these materials are extremely water repellent. Incorporating small amounts of this material into soils, particularly sands, forms a water repellent mixture. Many native plants of Western Australia produce water repellent organic matter and form a water repellent surface soil in their leaf drop zone. This may serve to prevent competition from other plants and in some cases to conduct rainfall from within the leaf drip zone to a concentration of roots lying in wettable soil just outside this area.

• Annual pasture species, particularly clovers and medics, form water repellent organic residues. Under long pasture phases the amount of these materials present in the soil increases and with this the water repellence may rise. Once again, this effect is more noticeable on light than heavy soils and grey sands are more prone to water repellence than yellow sands. The severity of water repellence depends upon the length of time under pasture and also on the degree of repellence which was present before the pasture phase began, for example, whether or not the soil was wettable or was already extremely water repellent because of the native species present before clearing.

Fig. 1.—Pasture growth showing the effects of band-sprayed wetting agents. The bare (right) plot was seeded but not sprayed while the plot on the left was seeded and sprayed with bands of 20L/ha (within the bands) of WettaSoil®. The actual usage of wetting agent is 3 to 4 L/ha in this treatment.

Fig. 2.—Nozzles aligned with seeding discs to deliver a band spray over the seeding line. The fans are turned to spray along the seeding line.

• Perennial pasture species also cause severe water repellence although the reasons for this may vary. Lucerne, in association with fungi in the soil, has caused large areas of severe water repellence in South Australia. Where grown on deep grey sands in W.A. it could be anticipated to do the same. The water repellence is not necessarily a problem while the actively growing lucerne is able to tap sufficient water from deep sources. However, if the lucerne is killed, re-establishment of lucerne or any other plant species is extremely difficult as this must be done in the water repellent surface soil. While lucerne forms water repellent soils in association with fungi, perennial veldt grass has extremely water repellent organic matter and water repellence develops as explained for the native species and annual pastures.

continued overleaf

• Other sites of accumulation of plant residues such as animal camps or yards may also become water repellent as the most indigestible parts of the plant tend also to be the most water repellent.

If water repellence is a major factor affecting plant growth, then practices which improve growth or reduce water repellence should be used.

Techniques for handling water repellent soils

Water repellent soils have their major effect on crop and pasture growth at the break of the season as the water repellency slows the wetting of the soil and hence the germination of crops or pastures. Any methods which aim to reduce the effect of water repellency must improve the rate of wetting of the soil, either by lowering the level of water repellence in the soil or by "forcing" the rainfall or irrigation into the water repellent soil. At present, no completely successful technique is available although several promising methods have been developed and are being tested in Western Australia and South Australia.

Wetting agents

Two new wetting agents (WettaSoil©, Wetta Chem Products, Bunbury, and Aquasoil©, W.A. Chemical Manufacturers, Kewdale) have been developed jointly by the Department of Agriculture and the chemical companies. Soil wettability is always improved by applying these chemicals at rates of 50 litres per hectare. The effect of the wetting agents has been seen to persist for at least two to three years. Despite the residual effect broad-acre applications at the recommended rate are not economic, but a band-spraying technique in which from 10 to 20 per cent of the total paddock area is sprayed, has improved both crop and pasture establishment in some cases (Figure 1). Narrow bands of wetting agent are sprayed over the seeding lines. Machinery *modification is simple (Figure 2) and the technique* could easily be tested by farmers for its suitability on their water repellent soils. Within the sprayed band, application rates of wetting agent as low as 10L/ha have improved crop and pasture germination and chemical costs from $5 to $50 per hectare should prove economical for some farmers. Best results have been obtained on fine or better quality sands with the deep, coarse, water repellent sands giving the poorest results.

The new wetting agents are considered to offer the best potential for improving the early-season growth of crops and pastures. Farmers should experiment on their own land with Aquasoil© and WettaSoil© at the recommended rates, using a band-spraying application method to reduce the cost of the chemical. The effect of one application may persist for two to three years.

Although the band-spraying technique is still being developed it is considered to have excellent potential for improving germination on water repellent sands.

Deep ploughing and rotary hoeing

Although not successful in pasture or crop establishment, trials under local conditions of deep ploughing and rotary hoeing are favoured for establishing crops and pastures in South Australia. Soil wettability is improved by both of these treatments, which have the disadvantages of increasing the erodibility of the soil and diluting the "fertility" contained in the organic-rich surface soil. The adverse nutritional effect outweighed the benefits of improved soil wettability in several Western Australian trials.

Furrow seeding and cultivating in the rain

Furrow seeding and cultivating in the rain have been used in Western Australia and South Australia with little success. Furrow seeding aims to place all seed at the bottom of furrows by using trailing "furrow formers". Cultivating in the rain mixes dry soil with moisture and should improve the wetness of the soil. In crop and pasture trials these methods have proved disappointing.

Wettable residues

Cereal crops such as wheat, oats and barley have *relatively wettable residues and when added to a water* repellent soil in sufficient quantity, improve the soil wettability. Cropping with these cereals and incorporating or mulching residues will improve soil wettability, but other techniques might first be needed to grow a successful crop.

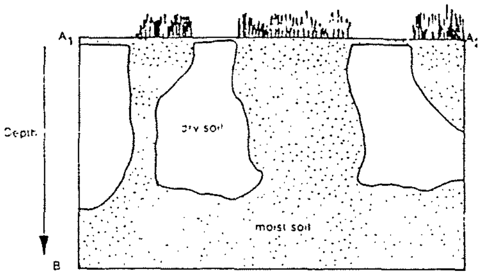

Fig. 3 — Patchy pasture on water repellent soil and the associated wetting pattern (Fig. 4)

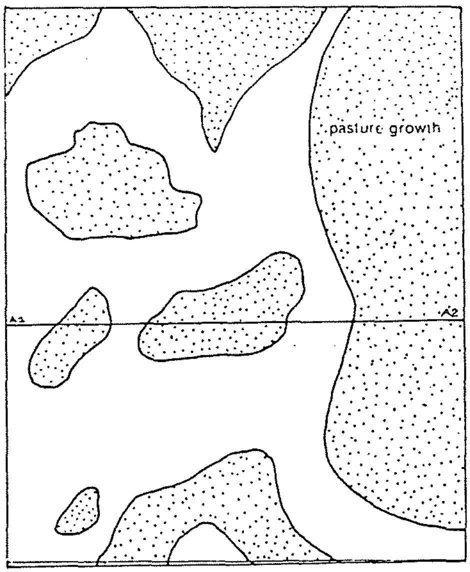

Fig. 4 — The associated wetting pattern in a water repellent soil

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