# Quantifying Surfactant Interaction Effects on Soil Moisture and Turf Quality

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Department of Employment,
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# Quantifying Surfactant Interaction Effects on Soil Moisture and Turf Quality.

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**TU08034: Quantifying Surfactant Interaction Effects on Soil Moisture and Turf Quality.**


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## Media Summary

Soil water repellency occurs widely in horticultural and agricultural soils when very dry. The gradual accumulation and breakdown of surface organic matter over time produces wax-like organic acids, which coat soil particles preventing uniform entry of water into the soil.

Water repellency is usually managed by regular surfactant applications. Surfactants, literally, are surface active agents (SURFace ACTive AgeNTS). Their mode of action is to reduce the surface tension of water, allowing it to penetrate and wet the soil more easily and completely. This practice improves water use efficiency (by requiring less water to wet the soil and by capturing rainfall and irrigation more effectively and rapidly). It also reduces nutrient losses through run-off erosion or leaching. These nutrients have the potential to pollute the surrounding environment and water courses.

This project investigated potential improvements to standard practices (product combination and scheduling) for surfactant use to overcome localised dry spots on water repellent soils and thus improve turf quality and water use efficiency.

Weather conditions for the duration of the trial prevented the identification of improved practices in terms of combination and scheduling. However, the findings support previous research that the use of soil surfactants decreased the time for water to infiltrate dry soil samples taken from a previously severely hydrophobic site.

Data will be continually collected from this trial site on a private contractual basis, with the hope that improvements to standard practices will be observed during the drier winter months when moisture availability is a limiting factor for turfgrass growth and quality.

## Technical Summary

A water-repellent soil does not wet up spontaneously when a drop of water is placed upon the surface. In turf, this translates into “dry patches” or localised dry spots, irregular shaped areas where the grass or other plants suffer from drought because the repellent soil below does not wet up uniformly following rain or irrigation and much of the affected area remains dry between the “fingers” of higher infiltration.

In practice, water repellency in higher profile turf sites is usually managed by periodically applying surfactants to the affected areas to improve water penetration. We report here the results of an experiment in which potential improvements to standard practices (product combination and scheduling) for surfactant technology from Aquatrols Corporation in the US was investigated to ensure control of localised dry spots on water repellent soils could be achieved effectively and efficiently.

This project built on earlier work by the Redlands turf team, which showed positive interactions between two different surfactants. The aim was to investigate in more detail these synergistic effects between surfactants to determine their optimum combination and scheduling for turf use.

High rainfall and high intensity rainfall events during the data collection period reported here were such that conditions under which water repellency is a limiting factor were not reached.  The soil, in its dry state was extremely hydrophobic, however soil moisture contents did not approach the critical threshold level, a unique level for each and every soil, above which the repellency effect is temporarily eliminated and below which the soil returns to a hydrophobic condition (Poulter 2006).

The findings did support previous research that the use of soil surfactants decreased the time for water to infiltrate dry soil samples taken from a previously severely hydrophobic site. However, statistical differences were insufficient to clearly define improvements to standard practice at this stage.

The project will continue on a private contractual basis, with the hope that improvements to standard practices will be observed during the drier winter months when moisture availability is a limiting factor for turfgrass growth and quality. Further, focussed project development will be dependant upon findings from these continuing investigations.

## Introduction

Water conservation is a complex issue, such that savings in urban water use on turfed areas can be achieved through a range of different strategies. At the plant level, options include growing grasses that use (transpire) less water, or ones that are deeper rooted and therefore able to tap greater supplies of soil water than other grasses. At the soil level, better use can be made of available water by maximising infiltration, minimising runoff, and helping to retain water within the soil profile, thereby making it more available to the plants growing there.

The physical properties of the soil needed for efficient water capture, storage and use are compromised by the condition of soil water repellency at low moisture contents. This condition occurs in many horticultural and agricultural soils and is caused by the production of complex organic acids during organic matter decomposition. These wax-like substances form a coating over the soil particles, such that the ability of water to adhere to these particles (and hence move through the soil) is then impeded.

If infiltration is impeded, water and other applied chemicals (pesticides, herbicides and fertilisers) will either sit on the soil surface or run off to a non-target area. This can lead to lower than expected turf quality, and may potentially harm the surrounding environment including water ways.

A water-repellent soil is diagnosed by the fact that it does not wet-up spontaneously when a drop of water is placed upon the surface. Water may pool on the surface of dry repellent soil rather than wetting it up, or it may flow preferentially and rapidly through discreet paths in the profile without wetting the surrounding soil (fingered flow). Depending on the intensity of the rainfall or irrigation event, there is a potential for the water received to flow beyond the root zone with consequent loss to the plant of water and leached nutrients. Vertical leaching of nutrients is in the order of 3 times greater in these fingers of preferential flow.

In turf, this condition translates into “dry patches” or localised dry spots which are irregular shaped areas where the grasses and other plants are experiencing water and nutrient stress due to the non-uniform moisture distribution within the repellent soil, even after significant rainfall or irrigation. Much of the affected area remains dry between the “fingers” of higher infiltration. This results in areas of turf that are both non-uniform and of poor quality.

In practice, water repellency in higher profile turf sites (and other landscaped areas) is usually managed by applying surfactants periodically to the affected areas to improve water penetration. Surfactants, literally, are surface active agents (SURFace ACTive AgeNTS). Their mode of action is to reduce the surface tension of water, allowing it to penetrate and wet the soil more easily and completely. Surfactants are essentially long chain polymers of varying complexity with a hydrophilic end and a hydrophobic end. The hydrophobic end binds to the coating on the soil particle while the hydrophilic end extends into the pore space allowing water to adhere to it.

Water repellency is a common condition encountered in many turf situations due to the gradual accumulation and breakdown of organic matter on the surface over time. While soil surfactants will not change the infiltration and water retention properties of a non-hydrophobic soil, an effective surfactant can improve water entry and increase soil moisture content on a repellent soil (possibly through the wetting of finer pores previously ‘blocked’ by hydrophobic substances), hence the resultant improvement seen in turf quality. In the wider context, this will improve water use efficiency (by requiring less water to wet the soil and by capturing rainfall and irrigation more effectively and rapidly), nutrient use efficiency, and reduce the loss of mobile nutrients into the surrounding environment and water courses.

In recent work on proprietary surfactants (Poulter et al. 2006), interactions between chemicals with somewhat different properties were seen in terms of improved turf quality along plot edges where some overlap inevitably occurs while spraying. By comparison, no such improvement in turf quality was seen where increased rates of the same chemicals had been applied separately. Similar synergistic effects were subsequently noted by international researchers in Europe and USA (S. Kostka, personal communication 2006). One of the surfactants(Dispatch) under investigation in this project is based upon synergistic theories (Kostka and Bially 2005). The product is a mix of two types of surfactant technologies, a block copolymer blended with an alykyl polyglycoside. However, the research of Poulter and Loch (2006) suggested (through observation only) that the efficacy of this product was further enhanced when applied in combination with another block copolymer that incorporated methyl caps, enabling the product to better bind with the hydrophobic organic acid on the soil particle surface (Revolution).

The primary aim of this project was therefore to investigate further these potential synergistic effects between surfactants to determine the optimum combination and scheduling of these chemicals for turf use.

## Materials and Methods

The trial was located on a water-repellent sand-based golf green at Windaroo Lakes Golf Course (ladies green for the $16^{th}$ hole). This course is located half way between Brisbane and the Gold Coast near Mount Warren Park. The course comprises Kikuyu and couch fairways, Bermuda 328 greens and is fully watered from on site dams.

Experimental design consisted of a strip-plot with 4 replications (blocks) accommodating the application of 3 primary surfactant treatments to 3m X 1m strips in each direction in a criss-cross arrangement. The block and plot layout is illustrated in Figure 1 and Plates 1 and 2. The treatments applied in each direction, as per Figure 2 were:

A. Control (no surfactant, water only)

B. ACA 1848 (DispatchTM)

C. ACA 1820 (RevolutionTM)

This resulted in 9 treatments, which allowed all possible combinations of the 3 primary treatments above (i.e. 0X, 1X, 2X, and 1X+1X) and also looked at changing the order of application: a control plot receiving no surfactant, two plots each receiving single rates of ACA 1848 or ACA 1820, plots receiving double rates of ACA 1848 and double rates of ACA 1820, and two plots receiving a combination of ACA 1848 and ACA 1820 (one of these receiving ACA 1848 first and the other receiving ACA 1820 first). The final size of these combination plots was $1m^2$. Final treatment numbers were then:

**Table 1 Final treatments**

| Treatment number | Application 1 | Application 2 |
|---|---|---|
| 1 | Nil | Nil |
| 2 | Nil | Dispatch |
| 3 | Nil | Revolution |
| 4 | Dispatch | Nil |
| 5 | Dispatch | Dispatch |
| 6 | Dispatch | Revolution |
| 7 | Revolution | Nil |
| 8 | Revolution | Dispatch |
| 9 | Revolution | Revolution |

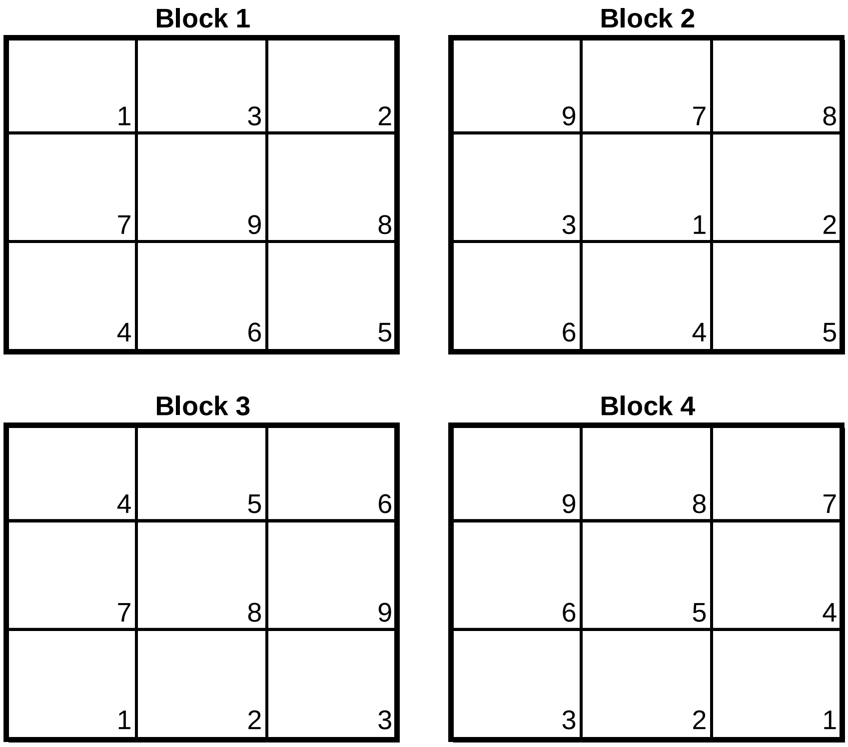



**Figure 1 Block layout of field trial, with treatment numbers for plots.**

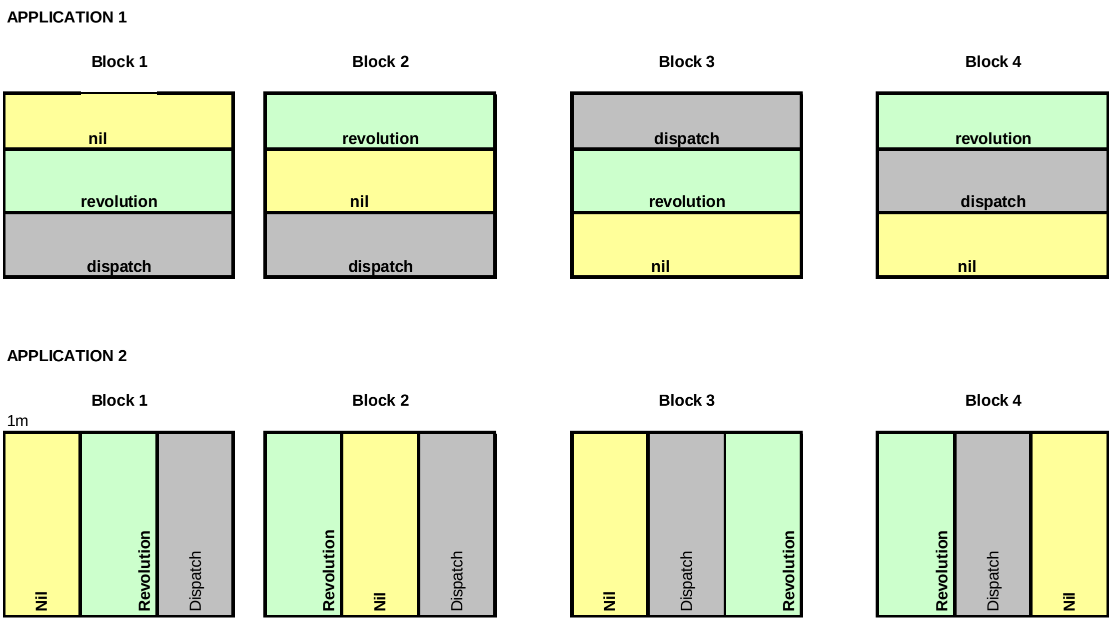



**Figure 2 Order and direction of treatment applications at field trial**

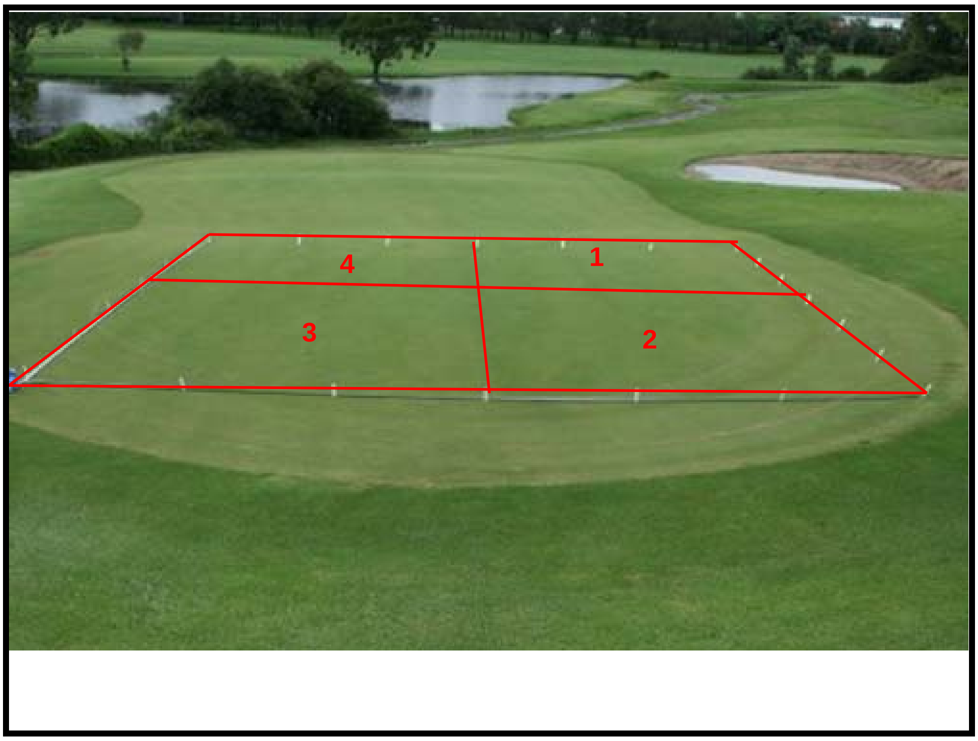
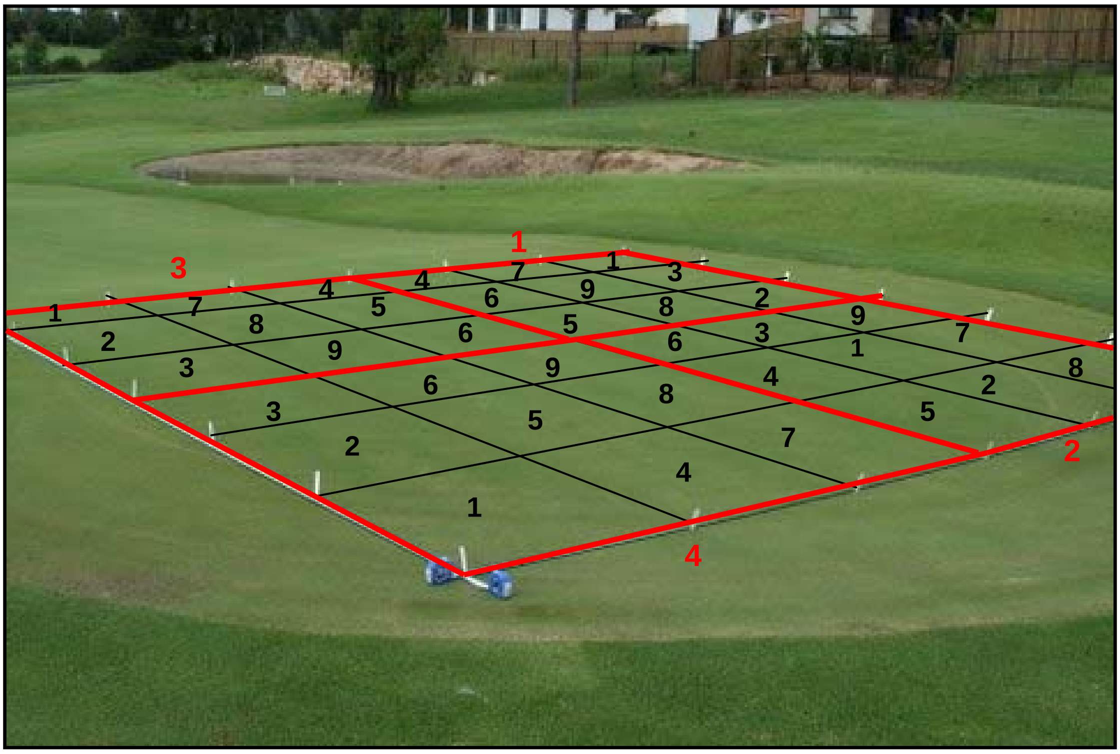



**Plate 1 Block layout of field trial**




**1-4**: Block numbers **1-9**: treatment numbers

**Plate 2 Block and treatment layout of field trial**

The green in question had previously been treated with Aquatrols surfactants, as a result it was decided to delay the first sample collection for one month to ensure the materials were no longer active. The trial was marked out in preparation for sampling and treatment application on the 22 October 2008. On 4 November 2008, the site was core sampled prior to the first treatment application.

The primary treatment strips were re-applied at 4-weekly intervals, with the last treatment application occurring on 5 May 2009 . Prior to every second monthly treatment application, three 2-cm-diameter soil cores per plot were collected randomly. After sampling, soil cores were placed individually into split polypipe holders taped together for transport to Redlands Research Station where the holders were opened and the soil cores (still intact) allowed to air dry in a glasshouse for two weeks. Following air-drying of the soil cores, standard water drop penetration tests were carried out to determine the level of soil water repellency at 1 cm intervals along the top 6 cm of each core sample, starting at the soil-thatch interface. Each test involved placing a 0.35 ml drop of water on the soil surface and recording the time taken for this to penetrate (or disappear into) the soil core, up to a maximum period of 10 minutes.

In conjunction with each monthly sampling and re-application of treatments, measurements of soil moisture were taken with an ICT International Pty Ltd Moisture Probe, MPM-160-B. Visual assessment ratings for quality for each plot by using a 1-9 scale (1 = worst, 9 = best) were made immediately prior to every second monthly re-application of surfactant treatments. This subjective assessment was replaced with turf colour readings using a Fieldscout TCM 500 NDVI Turf Colour meter (Spectrum technologies®). This instrument measures reflected light in the infrared (IR) and near infrared (NIR) bands, the ratio of which is the Normalised Difference Vegetation index (NDVI) which is an indication of plant health. Soil water infiltration was also assessed *in situ*. Rainfall data was available from the Bureau of Meteorology website from nearby weather stations (station numbers 0409733 and 040854).

Data were analysed through GenStat Version 11.1.0.1575 (Eleventh edition, 2008 for Windows) using standard Analysis of Variance procedures and Repeated Measure Analysis, which also generated protected Least Significant Differences (LSDs) for comparison of treatment means. Variance and standard deviation were also determined using GenStat summary statistics for treatment means of soil moisture content on each sampling occasion.

# Results

## Water Drop Penetration tests

### Repeated Measure analysis

This method of statistical analysis allows for the likelihood of a greater correlation between observations of the same subject taken at different times, therefore given an overall analysis of variance for the duration of the experiment. The data entered for this analysis excluded measurements taken pre-treatment. Figure 3 below illustrates time averaged water drop penetration time for each treatment from repeated measure analysis. Different letters denote statistical differences at a 5% confidence interval. Results are also summarised in Table 2.

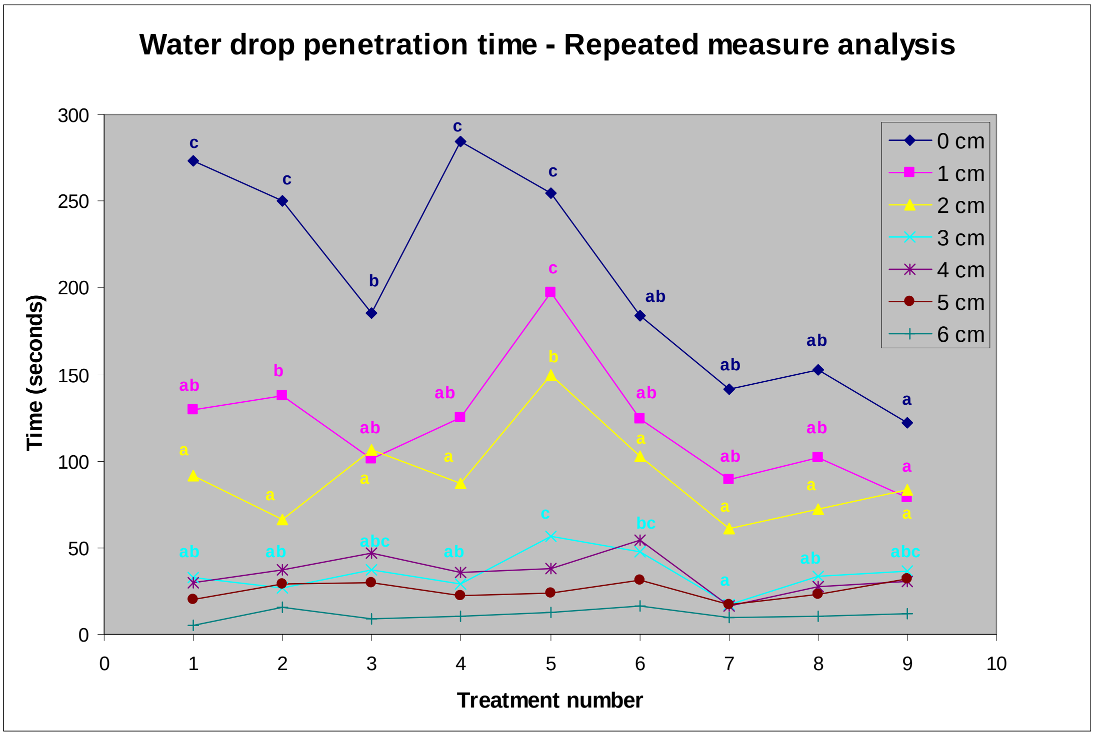



**Figure 3 Time averaged water drop penetration time for each treatment. Different letters denote statistical differences at 5% confidence interval (p<0.01).**

### Analysis of variance – individual sampling times

Water drop penetration (WDP) times for each treatment are shown progressively for each increment in depth from Figure 4 to Figure 10. Pre-treatment data is illustrated in bold. The equivalent tabulated data, including LSD’s, are presented in Table 3 to Table 9 with annotation denoting statistical differences at 5% the confidence interval.

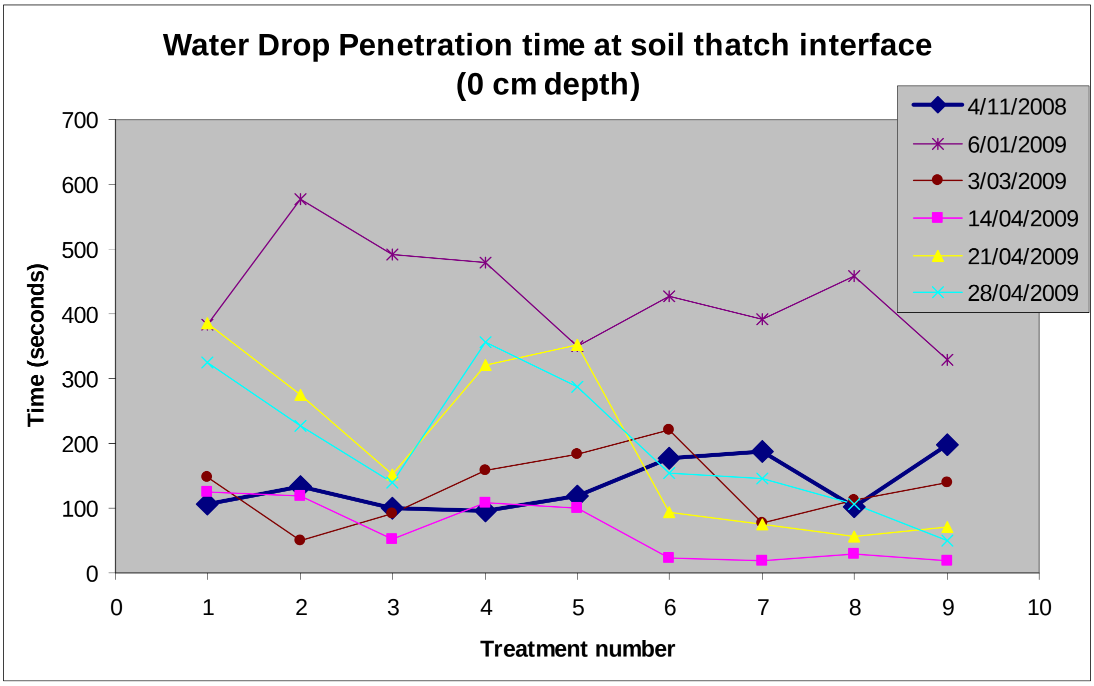



**Figure 4 Effect of repeated monthly applications of surfactants on mean water drop penetration time (seconds) at 0 cm depth (i.e. at the soil-thatch interface).**

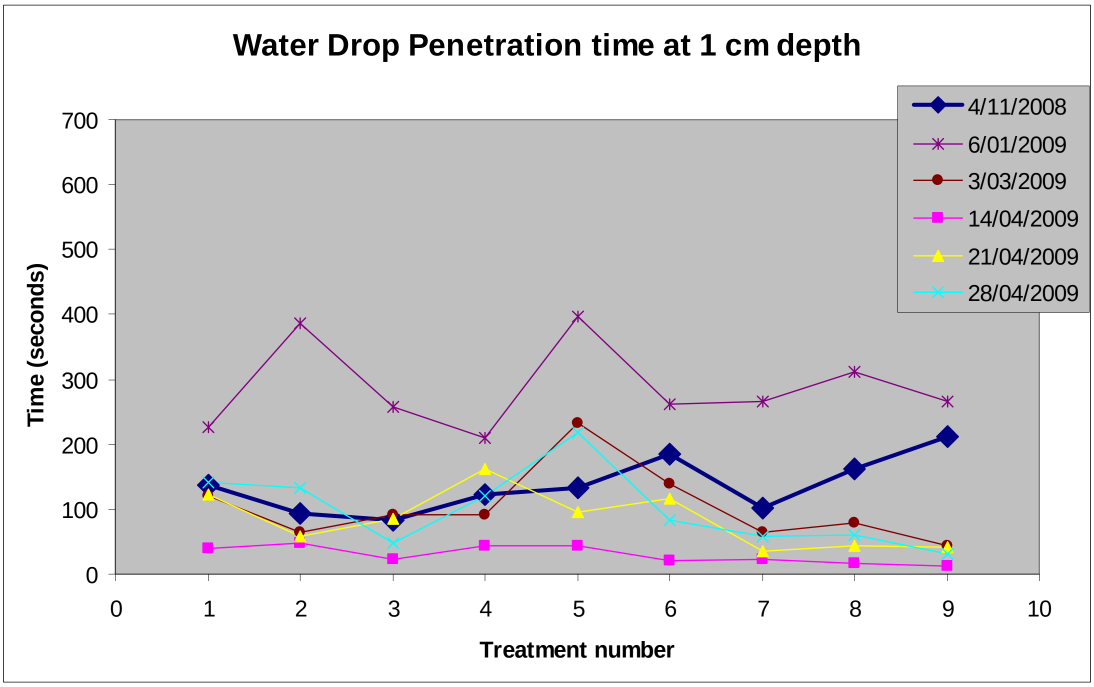



**Figure 5 Effect of repeated monthly applications of surfactants on mean water drop penetration time (seconds) at 1 cm depth.**

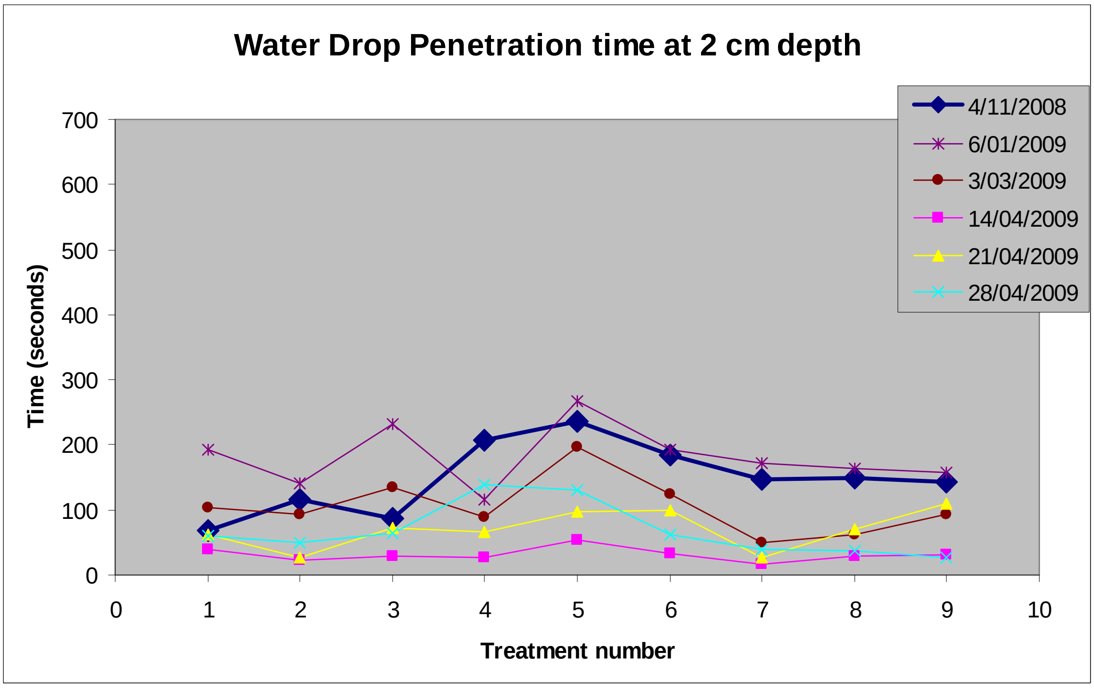



**Figure 6 Effect of repeated monthly applications of surfactants on mean water drop penetration time (seconds) at 2 cm depth.**

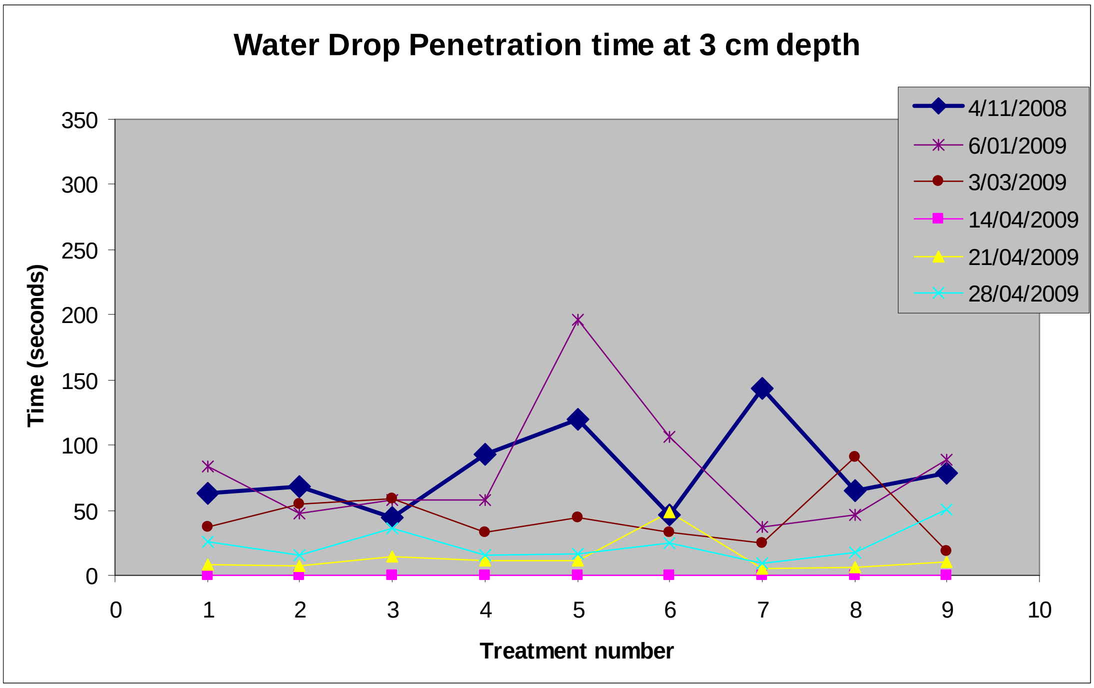



**Figure 7 Effect of repeated monthly applications of surfactants on mean water drop penetration time (seconds) at 3 cm depth.**

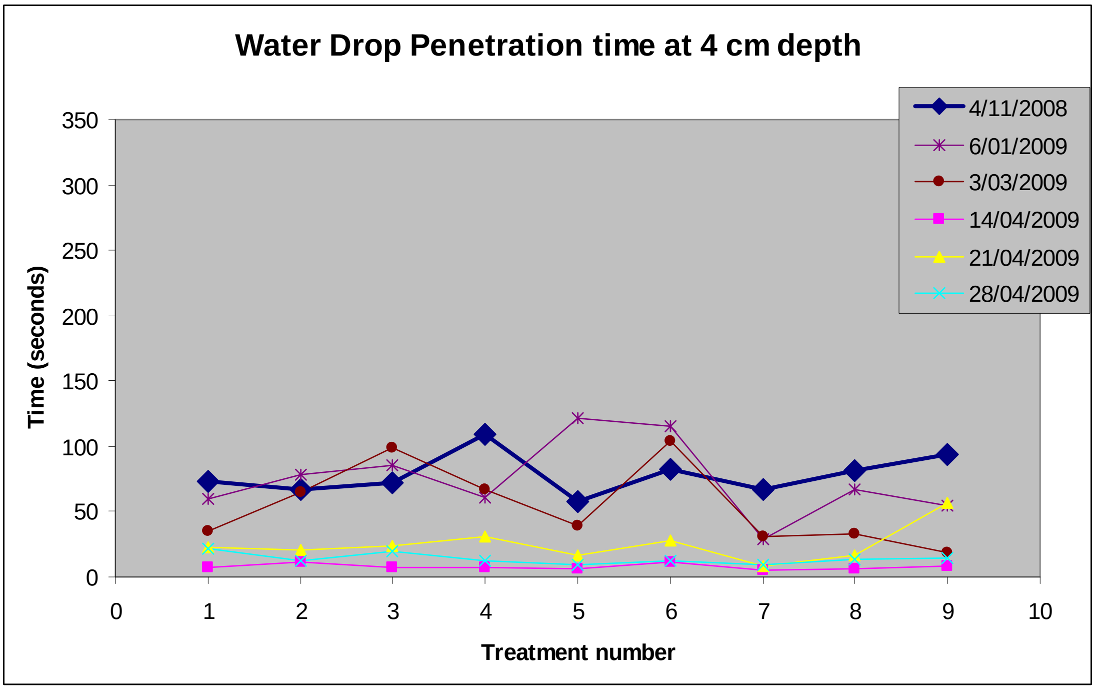



**Figure 8 Effect of repeated monthly applications of surfactants on mean water drop penetration time (seconds) at 4 cm depth.**

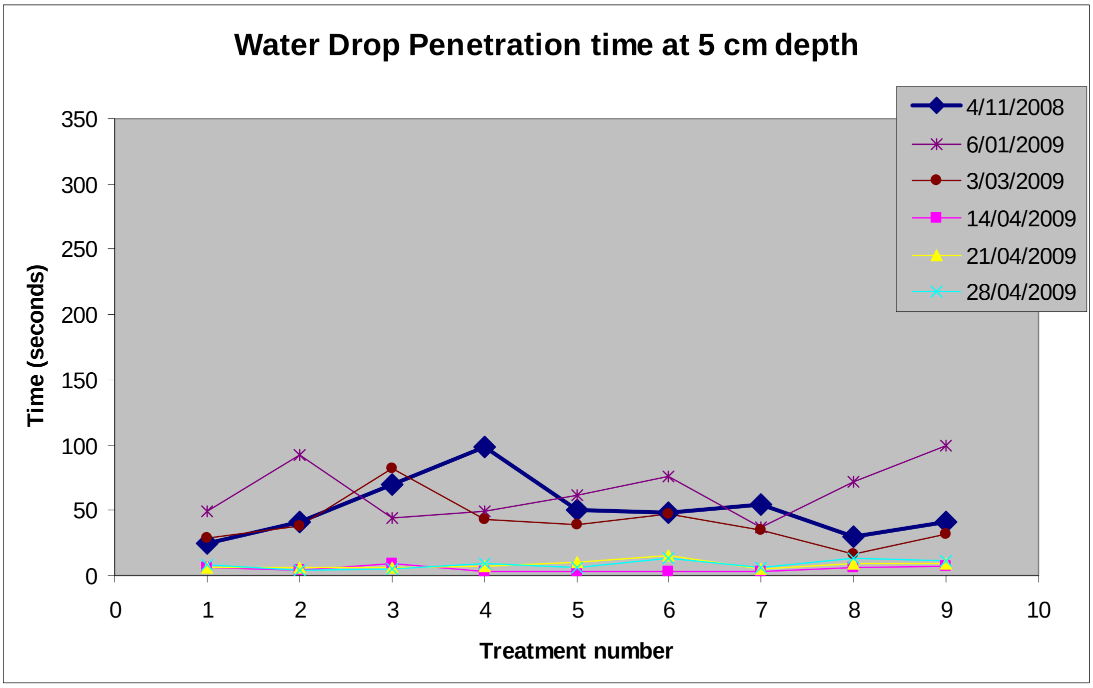



**Figure 9 Effect of repeated monthly applications of surfactants on mean water drop penetration time (seconds) at 5 cm depth.**

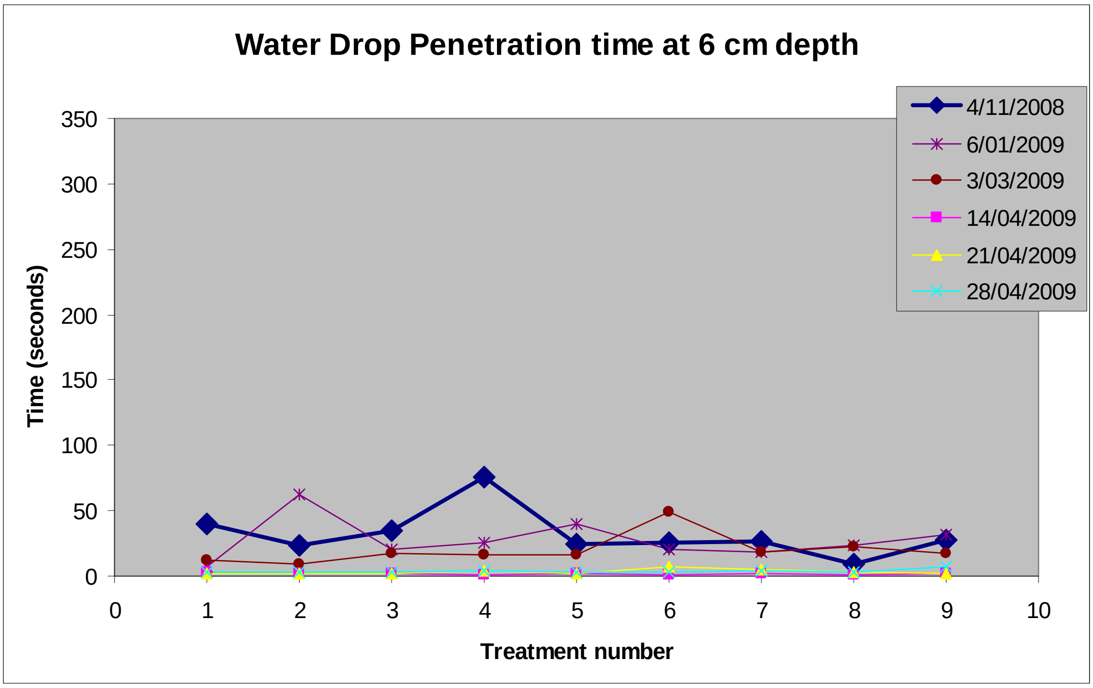



**Figure 10 Effect of repeated monthly applications of surfactants on mean water drop penetration time (seconds) at 6 cm depth.**

**Table 2 Time averaged water drop penetration time for each treatment using repeated measure analysis (GenStat version 11)**

| Treatment | | | Water drop penetration time – repeated measure analysis | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Treatment number** | **Application 1** | **Application 2** | **0 cm** | **1 cm** | **2 cm** | **3 cm** | **4 cm** | **5 cm** | **6 cm** |
| 1 | Nil | Nil | 273.3$^{c}$ | 129.9$^{ab}$ | 91.7$^{a}$ | 33.1$^{ab}$ | 29.5 | 19.8 | 5.32 |
| 2 | Nil | Dispatch | 250.1$^{c}$ | 137.4$^{b}$ | 66.3$^{a}$ | 27$^{ab}$ | 37.3 | 28.9 | 15.63 |
| 3 | Nil | Revolution | 185.1$^{b}$ | 101.6$^{ab}$ | 106.5$^{a}$ | 37.3$^{abc}$ | 47.1 | 29.6 | 8.85 |
| 4 | Dispatch | Nil | 284.6$^{c}$ | 125.4$^{ab}$ | 87.4$^{a}$ | 28.7$^{ab}$ | 35.6 | 22.3 | 10.33 |
| 5 | Dispatch | Dispatch | 254.9$^{c}$ | 197.3$^{c}$ | 149.4$^{b}$ | 56.3$^{c}$ | 38.3 | 24.1 | 12.75 |
| 6 | Dispatch | Revolution | 183.7$^{ab}$ | 124.3$^{ab}$ | 102.5$^{a}$ | 47.4b$^{c}$ | 54.2 | 30.9 | 16.22 |
| 7 | Revolution | Nil | 141.1$^{ab}$ | 89.4$^{ab}$ | 60.9$^{a}$ | 17.2$^{a}$ | 16.3 | 17.2 | 9.55 |
| 8 | Revolution | Dispatch | 152.4$^{ab}$ | 102.1$^{ab}$ | 72.5$^{a}$ | 33.8$^{ab}$ | 27.2 | 23.4 | 10.73 |
| 9 | Revolution | Revolution | 122$^{a}$ | 78.7$^{a}$ | 83.3$^{a}$ | 36.3$^{abc}$ | 30.4 | 31.9 | 12.12 |
| LSD | | | 61.21 | 51.72 | 42.7 | 21.76 | 18.5 | 12.4 | 7.58 |

**Table 3 Water drop penetration time, averaged for all depths.**

| **Treatment** | | | **Water drop penetration time all depths combined** | | | | | |
|---|---|---|---|---|---|---|---|---|
| Application 1 | Application 2 | Treament Number | Sampled 4/11/08 | Sampled 6/1/09 | Sampled 3/3/09 | Sampled 14/4/09 | Sampled 21/4/09 | Sampled 28/4/09 |
| Nil | Nil | 1 | 73.3 | 143.4 | 69.2b$^{cd}$ | 32.6$^{a}$ | 89.7$^{a}$ | 81.1$^{ab}$ |
| Nil | Dispatch | 2 | 77.3 | 197.8 | 53.3$^{cd}$ | 30.3$^{a}$ | 57.7$^{ab}$ | 62.8$^{bc}$ |
| Nil | Revolution | 3 | 70.3 | 169.7 | 82.2$^{abc}$ | 19.6$^{ab}$ | 54.3$^{ab}$ | 42.9$^{cd}$ |
| Dispatch | Nil | 4 | 114.7 | 142.7 | 71.1$^{bcd}$ | 28.9$^{a}$ | 86.5$^{a}$ | 95.3$^{a}$ |
| Dispatch | Dispatch | 5 | 105.7 | 204.8 | 107.5$^{a}$ | 31.6$^{a}$ | 84.4$^{a}$ | 95.3$^{a}$ |
| Dispatch | Revolution | 6 | 106. 8 | 171.2 | 102.5$^{ab}$ | 20.1$^{ab}$ | 55.1$^{ab}$ | 50.5$^{cd}$ |
| Revolution | Nil | 7 | 103.9 | 135.7 | 42.9$^{d}$ | 10.6$^{b}$ | 23.4$^{b}$ | 38.6$^{cd}$ |
| Revolution | Dispatch | 8 | 85.4 | 163.3 | 59.5$^{cd}$ | 13.4$^{b}$ | 30.7$^{b}$ | 34.6$^{cd}$ |
| Revolution | Revolution | 9 | 113.1 | 146.6 | 51.6$^{cd}$ | 13.1$^{b}$ | 48.5a$^{b}$ | 22$^{d}$ |
| | | L.S.D. | 56.74 | 76.98 | 34.55 | 13.66 | 43.67 | 30.59 |

**Table 4 Water drop penetration times at 0cm (soil thatch interface)**

| **Treatment** | | | **Water drop penetration time – 0 cm** | | | | | |
|---|---|---|---|---|---|---|---|---|
| Application 1 | Application 2 | Treament Number | Sampled 4/11/08 | Sampled 6/1/09 | Sampled 3/3/09 | Sampled 14/4/09 | Sampled 21/4/09 | Sampled 28/4/09 |
| Nil | Nil | 1 | 106 | 384 | 147 | 124.7$^{a}$ | 386$^{a}$ | 325$^{ab}$ |
| Nil | Dispatch | 2 | 134 | 578 | 50 | 118.7$^{ab}$ | 276$^{a}$ | 227$^{bc}$ |
| Nil | Revolution | 3 | 101 | 491 | 91 | 51.3$^{ab}$ | 152$^{a}$ | 140$^{cde}$ |
| Dispatch | Nil | 4 | 96 | 480 | 159 | 108.1$^{ab}$ | 320$^{a}$ | 356$^{a}$ |
| Dispatch | Dispatch | 5 | 118 | 350 | 184 | 99.7$^{bc}$ | 353$^{b}$ | 287$^{ab}$ |
| Dispatch | Revolution | 6 | 177 | 427 | 221 | 22.1$^{c}$ | 94$^{b}$ | 154$^{cd}$ |
| Revolution | Nil | 7 | 187 | 391 | 77 | 18.8$^{c}$ | 74$^{b}$ | 145$^{cde}$ |
| Revolution | Dispatch | 8 | 102 | 459 | 112 | 29.1$^{c}$ | 56$^{b}$ | 106$^{de}$ |
| Revolution | Revolution | 9 | 197 | 330 | 139 | 19.3$^{c}$ | 71$^{b}$ | 50$^{e}$ |
| | | L.S.D. | 105.2 | 166.2 | 152.7 | 67.97 | 115.9 | 102.6 |

**Table 5 Water drop penetration times at 1 cm**

| Treatment | | | Water drop penetration time – 1 cm | | | | | |
|---|---|---|---|---|---|---|---|---|
| Application 1 | Application 2 | Treament Number | Sampled 4/11/08 | Sampled 6/1/09 | Sampled 3/3/09 | Sampled 14/4/09 | Sampled 21/4/09 | Sampled 28/4/09 |
| Nil | Nil | 1 | 138 | 226 | 120 | 39.3abc | 123 | 140.6b |
| Nil | Dispatch | 2 | 93 | 386 | 64 | 47.3a | 58 | 132.9b |
| Nil | Revolution | 3 | 83 | 258 | 92 | 23.8bcd | 86 | 48.6cd |
| Dispatch | Nil | 4 | 123 | 210 | 91 | 44.1ab | 162 | 120.2bc |
| Dispatch | Dispatch | 5 | 132 | 396 | 232 | 43.8ab | 95 | 218.6a |
| Dispatch | Revolution | 6 | 185 | 262 | 140 | 20.8bcd | 116 | 82.7bcd |
| Revolution | Nil | 7 | 102 | 265 | 65 | 23.7bcd | 35 | 58.6cd |
| Revolution | Dispatch | 8 | 163 | 312 | 78 | 16.7cd | 44 | 60.7cd |
| Revolution | Revolution | 9 | 211 | 265 | 43 | 12.9d | 42 | 31.9d |
| | | L.S.D. | 115.1 | 167.3 | 112.8 | 23.32 | 87.2 | 71.99 |

**Table 6 Water drop penetration times at 2 cm**

| Treatment | | | Water drop penetration time – 2 cm | | | | | |
|---|---|---|---|---|---|---|---|---|
| Application 1 | Application 2 | Treament Number | Sampled 4/11/08 | Sampled 6/1/09 | Sampled 3/3/09 | Sampled 14/4/09 | Sampled 21/4/09 | Sampled 28/4/09 |
| Nil | Nil | 1 | 68 | 193 | $104^{b}$ | 40.2 | 61.3 | $59.6^{c}$ |
| Nil | Dispatch | 2 | 115 | 140 | $93^{ab}$ | 22.1 | 26.7 | $49.8^{c}$ |
| Nil | Revolution | 3 | 88 | 231 | $134^{ab}$ | 28.9 | 73.2 | $65^{bc}$ |
| Dispatch | Nil | 4 | 208 | 116 | $89^{b}$ | 27.5 | 66.5 | $138.2^{a}$ |
| Dispatch | Dispatch | 5 | 237 | 268 | $197^{b}$ | 54.8 | 96.9 | $129.8^{ab}$ |
| Dispatch | Revolution | 6 | 184 | 192 | $124^{b}$ | 33.5 | 100.2 | $62.6^{c}$ |
| Revolution | Nil | 7 | 147 | 172 | $49^{b}$ | 15.8 | 27.8 | $39.2^{c}$ |
| Revolution | Dispatch | 8 | 149 | 164 | $63^{a}$ | 28.3 | 70.3 | $37.2^{c}$ |
| Revolution | Revolution | 9 | 143 | 157 | $93^{b}$ | 31.3 | 108.8 | $26.3^{c}$ |
| | | L.S.D. | 127.9 | 152.1 | 100.9 | 25.92 | 72.47 | 66.54 |

**Table 7 Water drop penetration times at 3 cm**

| Treatment | | | Water drop penetration time – 3 cm | | | | | |
|---|---|---|---|---|---|---|---|---|
| Application 1 | Application 2 | Treament Number | Sampled 4/11/08 | Sampled 6/1/09 | Sampled 3/3/09 | Sampled 14/4/09 | Sampled 21/4/09 | Sampled 28/4/09 |
| Nil | Nil | 1 | 63 | 84 | $36.9^{b}$ | 8.5 | 25.8 | 10.8 |
| Nil | Dispatch | 2 | 68 | 48 | $54.8^{ab}$ | 6.8 | 16 | 9.8 |
| Nil | Revolution | 3 | 44 | 58 | $58.8^{ab}$ | 14.4 | 36.1 | 19.2 |
| Dispatch | Nil | 4 | 93 | 58 | $32.8^{b}$ | 11.2 | 15.1 | 26.5 |
| Dispatch | Dispatch | 5 | 120 | 196 | $44.2^{b}$ | 11.7 | 16.5 | 13.8 |
| Dispatch | Revolution | 6 | 46 | 106 | $32.7^{b}$ | 48.2 | 25.2 | 25.5 |
| Revolution | Nil | 7 | 144 | 37 | $24.9^{b}$ | 5.5 | 9.4 | 9.3 |
| Revolution | Dispatch | 8 | 65 | 46 | $90.8^{a}$ | 6.3 | 17.3 | 8.5 |
| Revolution | Revolution | 9 | 78 | 89 | $19^{b}$ | 10.8 | 50.1 | 13 |
| | | L.S.D. | 91.7 | 90.7 | 40.75 | 37.69 | 33.39 | 17.34 |

**Table 8 Water drop penetration times at 4 cm**

| Treatment | | | Water drop penetration time – 4 cm | | | | | |
|---|---|---|---|---|---|---|---|---|
| Application 1 | Application 2 | Treament Number | Sampled 4/11/08 | Sampled 6/1/09 | Sampled 3/3/09 | Sampled 14/4/09 | Sampled 21/4/09 | Sampled 28/4/09 |
| Nil | Nil | 1 | 72.6 | 60.2 | 35.1[b] | 7.08 | 23.1 | 21.8 |
| Nil | Dispatch | 2 | 67.1 | 78 | 64.6[ab] | 11.17 | 20.1 | 12.8 |
| Nil | Revolution | 3 | 72.2 | 85.7 | 98.8[a] | 7.67 | 23.8 | 19.4 |
| Dispatch | Nil | 4 | 109.2 | 60.3 | 67.2[ab] | 6.83 | 30.9 | 12.8 |
| Dispatch | Dispatch | 5 | 58 | 121.3 | 39.2[b] | 5.67 | 16.4 | 8.8 |
| Dispatch | Revolution | 6 | 82.4 | 115 | 103.6[a] | 11.58 | 28.3 | 12.3 |
| Revolution | Nil | 7 | 66.6 | 28.4 | 31[b] | 5.5 | 7.8 | 9 |
| Revolution | Dispatch | 8 | 80.9 | 67.3 | 33.1[b] | 5.75 | 16.1 | 13.7 |
| Revolution | Revolution | 9 | 93.2 | 54.7 | 18.7[b] | 8.33 | 56.3 | 13.9 |
| | | L.S.D. | 84.14 | 60.06 | 58.08 | 7.856 | 37.41 | 13.92 |

**Table 9 Water drop penetration times at 5 cm**

| Treatment | | | Water drop penetration time – 5 cm | | | | | |
|---|---|---|---|---|---|---|---|---|
| Application 1 | Application 2 | Treament Number | Sampled 4/11/08 | Sampled 6/1/09 | Sampled 3/3/09 | Sampled 14/4/09 | Sampled 21/4/09 | Sampled 28/4/09 |
| Nil | Nil | 1 | 24.6 | 49.7 | 29.1[b] | 5.83 | 6.5 | 8 |
| Nil | Dispatch | 2 | 41.3 | 92.3 | 38.4[b] | 3.92 | 5.67 | 4.17 |
| Nil | Revolution | 3 | 69.8 | 44.5 | 82.2[a] | 9.08 | 6.67 | 5.5 |
| Dispatch | Nil | 4 | 98.2 | 49 | 42.8[b] | 3.33 | 6.83 | 9.75 |
| Dispatch | Dispatch | 5 | 50.6 | 61.6 | 39[b] | 3.5 | 10.42 | 5.92 |
| Dispatch | Revolution | 6 | 48.3 | 75.6 | 46.9[b] | 3.25 | 15.75 | 13.08 |
| Revolution | Nil | 7 | 54.7 | 36.9 | 35.3[b] | 2.58 | 5.58 | 5.75 |
| Revolution | Dispatch | 8 | 29.7 | 71.9 | 16.9[b] | 6.42 | 8.92 | 13 |
| Revolution | Revolution | 9 | 41.1 | 99.3 | 32[b] | 7.42 | 9 | 11.5 |
| | | L.S.D. | 58.51 | 48.13 | 30.57 | 4.801 | 6.436 | 7.454 |

**Table 10 Water drop penetration times at 6 cm**

| Treatment | | | Water drop penetration time – 6 cm | | | | | |
|---|---|---|---|---|---|---|---|---|
| Application 1 | Application 2 | Treament Number | Sampled 4/11/08 | Sampled 6/1/09 | Sampled 3/3/09 | Sampled 14/4/09 | Sampled 21/4/09 | Sampled 28/4/09 |
| Nil | Nil | 1 | 40.3 | 7.2 | 12.3[b] | 2.83 | 1.67 | 2.58 |
| Nil | Dispatch | 2 | 23.3 | 62.6 | 9.2[b] | 2.08 | 1.58 | 2.75 |
| Nil | Revolution | 3 | 34.7 | 20.2 | 17.9[b] | 1.75 | 1.83 | 2.58 |
| Dispatch | Nil | 4 | 75.3 | 25.9 | 16.2[b] | 1.5 | 3.92 | 4.08 |
| Dispatch | Dispatch | 5 | 24.4 | 40.4 | 16.2[b] | 1.92 | 1.83 | 3.42 |
| Dispatch | Revolution | 6 | 25.6 | 20.2 | 49.5[a] | 1.33 | 6.92 | 3.08 |
| Revolution | Nil | 7 | 26.3 | 18.7 | 18[b] | 2.42 | 4.75 | 3.92 |
| Revolution | Dispatch | 8 | 8.7 | 23.2 | 22.9[b] | 1.33 | 2.83 | 3.42 |
| Revolution | Revolution | 9 | 27.9 | 31.4 | 17.3[b] | 1.92 | 2.25 | 7.67 |
| | | L.S.D. | 53.33 | 30.18 | 20.31 | 1.605 | 3.435 | 4.068 |

### Soil moisture content

Volumetric soil moisture content was measured on eight occasions using a moisture probe meter which averages moisture content over a 5 cm depth range. Consequently soil moisture reading presented here are of the depth range 0 to 5 cm. Figure 11 shows moisture content at each occasion thus illustrating changes through time. Figure 12 shows only the data from occasions for which statistical differences were apparent at 5% confidence interval. This data is also tabularised in Table 12.

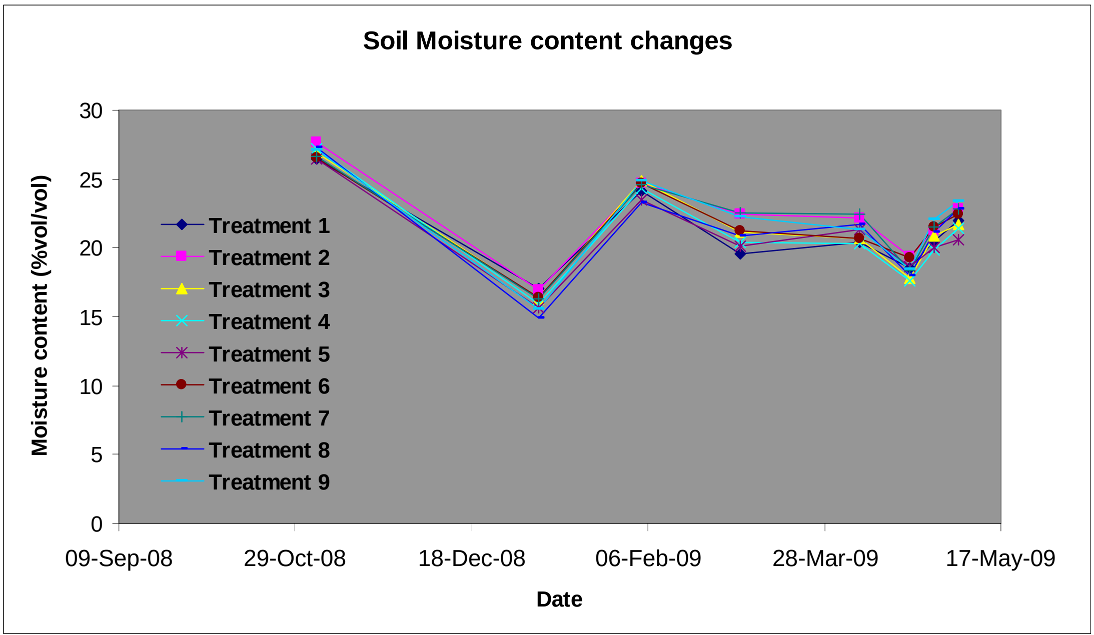



**Figure 11 Soil moisture content at each measurement occasion for each treatment**

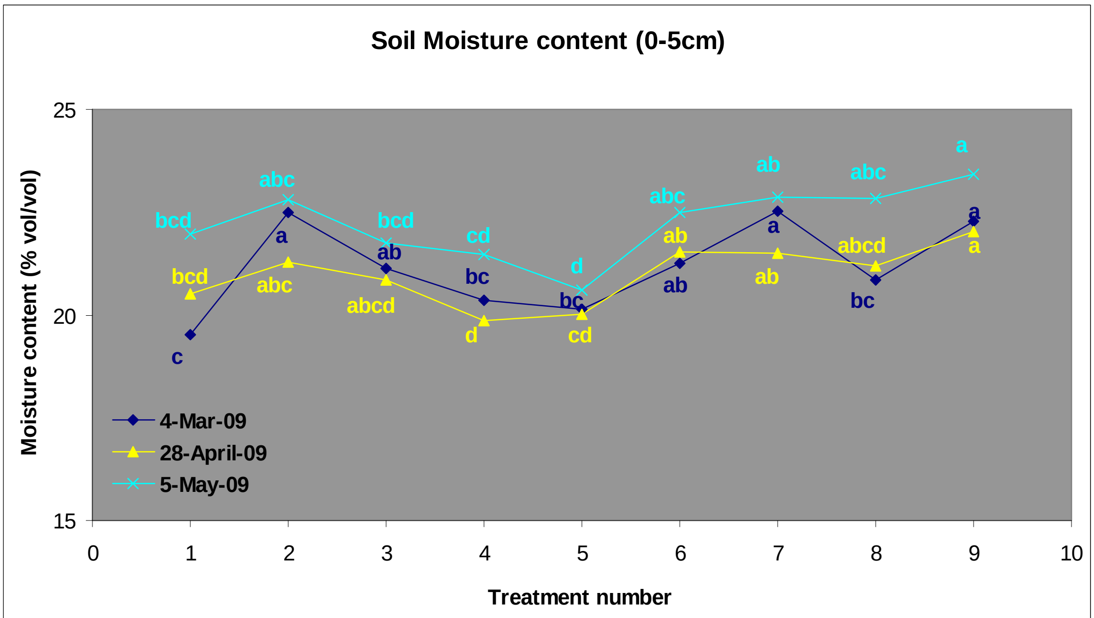



**Figure 12 Soil moisture content on the three occasions where statistical differences occurred. Different letters indicate a difference at a 5% confidence interval.**

### Turfgrass quality and colour

Turfgrass quality and colour ratings are shown in Table 13. The first occasion at which differences were visually apparent was 4 March 2009; hence data prior to this is not presented here.

### Climatic data

Weather data for the area was collated for two stations from the Bureau of Meteorology website (http://www.bom.gov.au/climate/dwo/index.shtml). Daily data was available for Logan City Water Treatment (station number 040854). This station is located at latitude 27° 41′02″ south, and longitude 153°12′41″ east. Data from a station closer to the site, Windaroo (station number 040973) at latitude 27°45′50″ south, and longitude 153°12′31″ east had incomplete monthly totals which are included as an indication of the likely variability in rainfall at the site. However, as shown in Table 14 there were minimal differences in rainfall between the two stations, therefore the daily data was assumed to be representative of the rainfall pattern to which the trial was exposed. Table 11 summarises the weekly rainfall occurring weekly for the 4 week period between each treatment application and subsequent sampling. This data sheds light on the lack of statistical differences between some of the treatments, which will be expanded upon in the discussion.

**Table 11 Weekly rainfall (RF) prior to each sampling occasion.**

| Application date | RF week 1 (mm) | RF week 2 (mm) | RF week 3 (mm) | RF week 4 (mm) | RF prior to sampling (< 7 days) (mm) |
|---|---|---|---|---|---|
| **2/12/2008** | 61 | 14.9 | 1.2 | 65.2 | 11.6[1] |
| **4/2/2009** | 0 | 117.3 | 52.4 | 1.2[2] | |
| **7/4/2009** | 43.8[3] | 1.7[4] | 0[5] | | |

[1] Sampled on 6/1/2009
[2] Sampled on 3/3/2009
[3] Sampled on 14/4/2009
[4] Sampled on 21/4/2009
[5] Sampled on 28/4/2009

**Table 12 Volumetric Soil Moisture content**

| Treatment | | | Soil Moisture content | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Application 1 | Application 2 | Treament Number | 4/11/08 | 6/1/09 | 4/2/09 | 3/3/09 | 7/4/09 | 21/4/09 | 28/04/09 | 5/5/09 |
| Nil | Nil | 1 | 26.43 | 17.02 | 24.09 | 19.52[c] | 20.4 | 18.54 | 20.52[bcd] | 21.96[bcd] |
| Nil | Dispatch | 2 | 27.63 | 16.96 | 24.68 | 22.49[a] | 22.18 | 19.38 | 21.27[abc] | 22.81[abc] |
| Nil | Revolution | 3 | 26.88 | 16.35 | 24.89 | 21.14[ab] | 20.65 | 17.84 | 20.85[abcd] | 21.75[bcd] |
| Dispatch | Nil | 4 | 27.17 | 15.93 | 24.3 | 20.36[bc] | 20.31 | 17.62 | 19.86[d] | 21.47[cd] |
| Dispatch | Dispatch | 5 | 26.45 | 15.64 | 23.46 | 20.15[bc] | 21.3 | 18.61 | 20.02[cd] | 20.61[d] |
| Dispatch | Revolution | 6 | 26.55 | 16.41 | 24.66 | 21.24[ab] | 20.71 | 19.27 | 21.53[ab] | 22.48[abc] |
| Revolution | Nil | 7 | 26.63 | 16.26 | 24.61 | 22.53[a] | 22.44 | 18.4 | 21.51[ab] | 22.86[ab] |
| Revolution | Dispatch | 8 | 27.32 | 14.87 | 23.28 | 20.85[bc] | 21.68 | 17.98 | 21.19[abcd] | 22.82[abc] |
| Revolution | Revolution | 9 | 27.07 | 15.59 | 24.92 | 22.28[a] | 21.3 | 18.48 | 22.04[a] | 23.41[a] |
| L.S.D. | | | 1.532 | 1.391 | 1.334 | 1.399 | 1.592 | 1.597 | 1.348 | 1.35 |

**Table 13 Turfgrass quality/colour ratings**

| Treatment | | | Visual rating | | Grass Index from NDVI reading | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Application 1 | Application 2 | Treament Number | 3/3/09 | 7/4/09 | 7/4/09 | 14/4/09 | 21/4/09 | 28/4/09 | 5/5/09 |
| Nil | Nil | 1 | 4.75 | 5.10 | 7.44 | 7.16 | 6.93 | 7.02 | 6.74 |
| Nil | Dispatch | 2 | 4.63 | 5.03 | 7.37 | 7.15 | 6.99 | 7.01 | 6.79 |
| Nil | Revolution | 3 | 4.88 | 5.25 | 7.42 | 7.22 | 6.92 | 7.10 | 6.82 |
| Dispatch | Nil | 4 | 5.13 | 5.08 | 7.38 | 7.14 | 6.96 | 7.11 | 6.91 |
| Dispatch | Dispatch | 5 | 5.25 | 5.05 | 7.42 | 7.17 | 6.97 | 7.18 | 6.74 |
| Dispatch | Revolution | 6 | 5.50 | 5.03 | 7.37 | 7.21 | 6.86 | 7.03 | 6.76 |
| Revolution | Nil | 7 | 5.00 | 4.95 | 7.42 | 7.17 | 6.93 | 7.07 | 6.77 |
| Revolution | Dispatch | 8 | 5.38 | 5.13 | 7.42 | 7.15 | 6.88 | 7.07 | 6.87 |
| Revolution | Revolution | 9 | 5.13 | 5.13 | 7.40 | 7.18 | 6.90 | 7.02 | 6.73 |
| L.S.D. | | | 0.46 | 0.45 | 0.10 | 0.08 | 0.16 | 0.14 | 0.21 |

**Table 14 Daily rainfall (RF) and evaporation (E) for the duration of the trial with monthly totals included. *May 09 data was incomplete at the time of writing. Sampling dates are highlighted yellow, which also correspond to treatment applications except for the month of April where sampling occurred weekly after treatment application on 7 April. All other treatment application dates are highlighted orange.**

| | November 08 | | December 08 | | January 09 | | February 09 | | March 09 | | April 09 | | May 09* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Day** | **RF** | **E** | **RF** | **E** | **RF** | **E** | **RF** | **E** | **RF** | **E** | **RF** | **E** | **RF** | **E** |
| 1 | 0 | 6.4 | 0 | 10.2 | 0 | 7.6 | 0.6 | 4.6 | 0 | 8 | 0 | 2.1 | 0 | 4 |
| 2 | 0 | 8 | 0 | 6.4 | 0 | 7.2 | 1 | 3.8 | 0 | 4 | 16.9 | 7.5 | 0 | 2.8 |
| 3 | 0 | 3.2 | 0 | 8 | 6 | 2 | 1.4 | 4.6 | 0.8 | 6.4 | 118.6 | | 0 | 3 |
| 4 | 10.4 | 0.4 | 2.4 | 6.4 | 5.6 | 6.2 | 1 | 4.8 | 0 | 4 | 56 | 2.1 | 0 | 3.6 |
| 5 | 4 | 10.8 | 1.2 | 5.2 | 0 | 5.6 | 0 | 6.6 | 1.8 | 5.8 | 0.8 | 2 | 0 | 5.4 |
| 6 | 30.2 | 6 | 9.6 | 1.6 | 0 | 6.4 | 0 | 8 | 0 | 7.2 | 0.3 | 4.3 | 0 | 2.6 |
| 7 | 0 | 4 | 47.8 | 11.6 | 0 | 8 | 0 | 6.8 | 0 | 3.6 | 1 | 2.6 | 4 | 2.5 |
| 8 | 0 | 7.2 | 0 | 0 | 0 | 4 | 0 | 8 | 0 | 5.2 | 0.1 | 3.3 | 0 | 2.8 |
| 9 | 14.8 | 5.1 | 0 | 8.6 | 0.6 | 3.6 | 0 | 8 | 0 | 7.2 | 0 | 4 | 0 | 2.8 |
| 10 | 0 | 4 | 0 | 6.4 | 0 | 8 | 0 | 6.3 | 6.3 | 4.1 | 1.2 | 1.2 | 0 | 4 |
| 11 | 0 | 6 | 0 | 8 | 0 | 8 | 0 | 5.8 | 6.2 | 2.2 | 2.8 | 2.8 | 0 | 1.6 |
| 12 | 0.6 | 0.6 | 14.5 | 8.7 | 0 | 8 | 1 | 7.6 | 3.8 | 4.9 | 9.3 | 5.3 | 0 | 2 |
| 13 | 14.4 | 6.4 | 0.4 | 2 | 0.2 | 2.2 | 5 | 7.1 | 3.4 | 3.7 | 2.8 | 2.8 | 0 | 1.2 |
| 14 | 3.6 | 3.6 | 0 | 4 | 0 | 4 | 107.2 | 4.4 | 5.5 | 3.3 | 27.6 | 3.6 | 0 | 2 |
| 15 | 0 | 7.8 | 0 | 10.7 | 0 | | 0.7 | 1.3 | 0 | 3.4 | 0.1 | 3.3 | 0 | 1.8 |
| 16 | 0 | 4 | 0 | 8 | 0 | 8 | 0 | 8 | 0 | 6.8 | 0 | 4 | 0 | 3.2 |
| 17 | 21 | 12.8 | 0 | 4 | 0 | 4.6 | 0 | 7.4 | 20.4 | 8.2 | 0 | 4 | 0 | 3.6 |
| 18 | 12.4 | 2.2 | 0 | 6.2 | 0 | 4 | 3.4 | 1.1 | 0 | 7.8 | 0.4 | 3 | 0 | 2.8 |
| 19 | 41.4 | 2 | 1.2 | 9.2 | 0 | 8 | 0 | 8 | 0 | 5.4 | 0 | 5.7 | 85.6 | |
| 20 | 73.2 | | 0 | 9.2 | 0 | 8 | 16.6 | 2.4 | 0 | 1.8 | 0 | 4 | 79.3 | |
| 21 | 5.9 | 3.4 | 0 | 7.6 | 0 | 8 | 32.6 | 7.6 | 1.2 | 5.2 | 1.2 | 5 | | |
| 22 | 0.4 | 8 | 0 | 7 | 0 | 5.2 | 1.4 | 4.4 | 0.4 | 8.4 | 0 | 1.5 | 46.6 | |
| 23 | 0 | 8 | 0 | 4 | 34.9 | 2.9 | 1.8 | 4.5 | 0 | 4 | 0 | 0 | 12.2 | 4.2 |
| 24 | 0 | 8 | 0 | 8 | 0 | 8 | 0 | 8 | 0 | 8 | 0 | 5.8 | 17.6 | 3.4 |

| | November 08 | | December 08 | | January 09 | | February 09 | | March 09 | | April 09 | | May 09* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Day** | **RF** | **E** | **RF** | **E** | **RF** | **E** | **RF** | **E** | **RF** | **E** | **RF** | **E** | **RF** | **E** |
| 25 | 0 | 8 | 8 | 8 | 2.2 | 10.2 | 0 | 5 | 0 | 8 | 0 | 3.6 | 4 | 0 |
| 26 | 16.8 | 8 | 3.6 | 11.6 | 16.8 | 4.8 | 0 | 6.8 | 0 | 2.8 | 0 | 3.6 | | |
| 27 | 15.6 | 7.6 | 0 | 7.4 | 5 | 1.8 | 0.4 | 4.4 | 0 | 7 | 0 | 3.6 | | |
| 28 | 2.8 | 1.1 | 26.2 | 7.4 | 0.2 | 0.2 | 0 | 5.8 | 0 | 8 | 0 | 4.2 | | |
| 29 | 0 | 0 | 2.4 | 2.4 | 5.5 | 10.1 | | | 0.8 | 8.8 | 0 | 5.4 | | |
| 30 | 7.8 | 9.6 | 25 | 11.8 | 8 | 1.4 | | | 3 | 7 | 0 | 2 | | |
| 31 | | | 0 | 7.6 | 2 | 6.2 | | | 0.9 | 7.1 | | | | |
| Total | 275.3 | 162.2 | 142.3 | 217.2 | 87 | 172.2 | 174.1 | 161.1 | 54.5 | 177.3 | 239.1 | 102.3 | *249.3* | *59.3* |
| Windaroo | 249.7 | | 120 | | NA | | NA | | 54.5 | | 196 | | | |

## Discussion

The base (pre-treatment) water drop penetration times indicate the site was uniformly and severely hydrophobic, with no significant differences between blocks and plots.

Looking at the water drop penetration times post treatment, the top performers, overall, at the soil thatch interface were the treatments containing Revolution. That is, each of these treatments showed statistically lower water penetration times than other treatments not including this product. There were no statistical differences in the time averaged data, between the three Dispatch only treatments and the control. Similarly, from the time averaged data there were no significant differences between treatments with Revolution only and Revolution plus Dispatch. Again, at 1 cm depth the top performers were the treatments containing Revolution. At both depths the lack of differences between Dispatch only treatments and the control suggests that this product had either degraded or leached and any differences observed are merely an artefact of the base variation at site.

Beyond 2-3 cm there is no consistency in the differences between treatments, suggesting that the materials had not infiltrated beyond the surface. From this data it appears Dispatch has not had sufficient longevity to provide significant improvements to water infiltration time. The results from the repeated measure analysis suggested a detailed investigation of each depth increment and sampling time was justified.

The subsequent post treatment tests analysed individually also showed little significant difference between treatments in the early stages of the experiment. It was not until 14 April 09 that the first statistical differences were observed. This sampling occasion was one week after treatment application. At this time all treatments containing Revolution showed faster water drop penetration times at 0 and 1 cm depths. However, there were no differences apparent between treatments with a combination of Dispatch and Revolution. These differences remained in place for the following samplings (2 weeks and 3 weeks post treatment). However by the third week (28 April 09) there was greater overlap between treatments suggesting efficacy was deteriorating. Previously, sampling occurred 4 weeks after treatment, again supporting the theory that the longevity of the products was compromised at this site.

The climatic conditions at this site over the experimental period may well account for the loss in activity of the products. Table 11 summarises the rainfall immediately after treatment and prior to each of the sampling dates. In the four weeks between treatment application and the first sampling, there was a total rainfall of 153.9 mm, with 61 mm occurring in the first week and 65.2 mm in the week prior to sampling. Similarly the rainfall prior to the second sampling was 170.9 mm, including a high intensity event (117.3 mm) in the second week after treatment application. Rainfall of this magnitude would have leached well beyond the rootzone, potentially carrying any product not bound to soil particle surfaces. Where difference were observed (14 April) there was significantly less rainfall prior to each sampling event, although there was a 27.6 mm event on the morning of 14 April, again, prior to sampling.

Moisture content readings, soil water infiltration and turf quality ratings also show few statistical differences. The lack of treatment effects at the surface may have been due to the high rainfall discussed above. Given the high rainfall for the period of the study, soil moisture contents would have been maintained above the critical threshold level below which hydrophobicity is apparent for this soil type. Similarly, soil moisture was not a limiting factor for turfgrass quality and colour, hence no differences were apparent at this stage of the trial

No conclusions can be drawn without continued accumulation of data for each season. At this stage there is insufficient evidence to support any change to management practises from the current product label specifications. For this reason, there is no scientific justification in suggesting changes to application processes will result in better management of LDS.

An output of this project was to be the development of improved practices (product combination and scheduling) for surfactant use to overcome LDS. Lack of conclusive data has prevented the full achievement of this output. However, the results suggest that there may be value in altering the application schedule based on rainfall occurrences. This will be further investigated in the ongoing component of this project (being privately funded and conducted) before communication to the wider industry.

## Recommendations

The lack of statistical differences at this stage highlights the need to accumulate data over a longer time frame. The stop/go milestone for this project was based up continued funding from the Voluntary Contributor, Aquatrols Corporation, who have decided to privately fund continued data collection at this trial site.

Continuation of the project, on a private basis will allow data to be collected through the drier months where treatment differences are more likely to be observed, which is consistent with private research conducted from April 2005 to May 2006. During the dryer months, there will be a minor change to the project protocol. Treatment applications will continued monthly, however, sampling will be conducted every second month on the second week after treatment.

The decision to conduct a further, more focussed trial will be dependant upon the outcome from the continued data collection through the drier months.

## Technology Transfer

To date there have been no communication or extension activities associated with this project due to the lack of conclusive data pertaining to the effects of product combinations. The major reason for this is that no improvements to management practices have been identified that are different to the current product label specifications. Should further collection and analysis of data find supporting evidence of a beneficial effect this will be widely communicated to industry.

## Acknowledgments

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