Estimation of crop losses associated with soil water repellency in horticultural crops

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Abstract
Soil water repellency (SWR) reduces soil affinity to water and affects an array of hydrological and geomorphological processes including infiltration, overland flow, accelerated soil erosion, uneven wetting, the development of preferential flow, and accelerated leaching of agrichemicals (Doerr *et al.* 2000) – all influencing irrigation efficiency, water conservation, and agricultural productivity (Blackwell 2000; Cooley *et al.* 2007; Robinson 1999).

Globally, the sustainability of crop and biomass production is being impacted by water scarcity and deteriorating water quality, however few studies exist that have assessed the potential influence of SWR on crop productivity. Previous studies have estimated losses in potatoes, lupin, and barley (Blackwell 2000; Cooley *et al.* 2007; Robinson 1999). The objective of this study was to utilize surfactant treatments to modify soil hydrological properties under precision irrigation as a means of estimating potential crop losses to SWR in three high value horticultural crops - grapes (*Vitis vinifera* L.), apples (*Malus domestica* Borkh.) and oranges (*Citrus sinensis*). Results indicate that the use of a novel surfactant maximizes water use efficiency and significantly increases yields.

Key Words
Yield loss, irrigation efficiency, hydrophobicity

Methods
Three trials were conducted on each apples and grapes and one on oranges in Victoria, Australia on clay loam, loam soils, or sandy loam soils, respectively. Apple varieties included 'Pink Lady' and 'Gala' Grape trials included table grapes ('Black Muscat') or wine grapes ('Shiraz'). Orange variety studied was the 'Navel'. The test design was a randomized complete block with each treatment replicated 4-6 times. Plot size varied by crop. SWR was mitigated by applying surfactant [a blend of alkylpolyglycoside (APG) and ethylene oxide/propylene oxide (EO/PO) block copolymer surfactants (Kostka and Bially 2005)] at initial rates of 0 or 5 L/ha in the spring, then at 0 or 2.5 L/ha respectively monthly for up to five months. Plots were irrigated either by drip irrigation, micro-jet sprinklers or mini sprinklers and received the same irrigation volumes and management practices. Soil volumetric water content (VWC) was monitored at a depth of 10 cm using a Theta probe (Delta-T Devices, Cambridge, UK). At harvest, fruit weights were measured and used for crop yield estimations.

Results and Discussion
In each test location, VWC was significantly lower ($p = 0.05$) in control soils than in the surfactant treatments on each measurement date regardless of soil type or irrigation method (Figure 1). Surfactant treatment resulted in higher VWC in the upper region of the soil profile. Soil VWC was not systematically monitored deeper in the rootzone at each location however where measured, a deeper wetting front and higher VWC at 20-25 cm were encountered (data not presented).

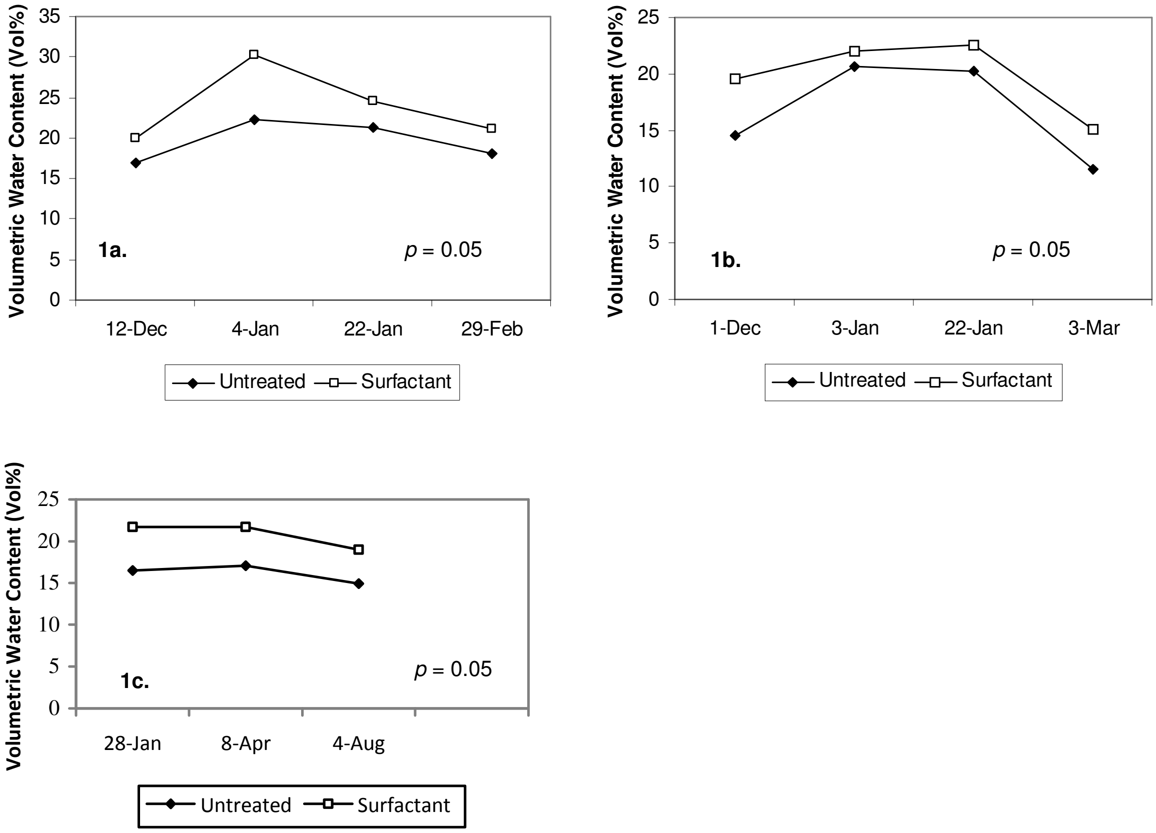

Figure 1. Soil volumetric water content in selected untreated and surfactant-treated soils under precision irrigation: a) loam soil in a vineyard and b) clay loam soil in an apple orchard and c) sandy loam soil in a citrus grove.

Yields in each of the untreated controls were significantly lower ($p = 0.05$) than in the surfactant treatment (Table 1, Table 2 and Table 3). Total yield differences of 2.4–2.6 Mg/ha (14-45% increase) were observed between the two treatments in grapes (Table 1). In apples, yield differences between treatments ranged between 3.9-6.1 Mg/ha (19-49% increase). While in oranges the yield difference was 7 Mg/ha (24% increase). Total yield differences across all trials and crops is 4.3 Mg/ha (27% increase) were observed between the control and surfactant treatments. Due to thinning, there were no differences in fruit or bunch number in apples or grapes, respectively, however, fruit size and bunch weights were significantly lower in the untreated controls (data not presented).

Table 1. Yield effects in untreated control and surfactant treatments in precision irrigated grapes (*Vitis vinifera* L.) on different soil types in Victoria, AU.

			Yield (Mg/ha)	
Location	Soil Type	Variety	Control	Surfactant
G-1	Clay Loam	Shiraz	5.6 b[a]	8.1 a
G-2	Loam	Shiraz	16.6 b	19.0 a
G-3	Loam	Muscat	15.9 b	18.5 a

[a]Numbers in rows followed by the same letter are not significantly different. LSD (0.05).

Table 2. Yield effects in untreated control and surfactant treatments in precision irrigated apples (*Malus domestica* Borkh.)on different soil types in Victoria, AU.

			Yield (Mg/ha)	
Location	Soil Type	Variety	Control	Surfactant
A-1	Clay Loam	Pink Lady	29.3 b[a]	34.9 a
A-2	Clay Loam	Gala	7.9 b	11.8 a
A-3	Clay Loam	Pink Lady	30.2 b	36.3 a

[a]Numbers in rows followed by the same letter are not significantly different. LSD (0.05).

Table 3. Yield effects in untreated control and surfactant treatments in irrigated citrus (*Citrus sinensis*) on different soil types in Victoria, AU.

Location	Soil Type	Variety	Yield (Mg/ha) Control	Surfactant
1	Clay Loam	Navel Oranges	28.8 b[a]	35.8 a

[a]Numbers in rows followed by the same letter are not significantly different. LSD (0.05).

Conclusion

The results from these studies provide evidence that SWR deleteriously impacts soil hydrological status resulting in reduced productivity, yield, and quality in high value horticultural crops. Irrigation practices and rates were identical in both the control and surfactant treatments. While irrigation volumes were identical, water use efficiency was higher in the surfactant treatments and resulted in significant yield increases. At a cost of $100 AUS per hectare and an application rate of 10-12L/ha over the season, the net return was on average $4500 AUS, $3500 AUS and $5000 AUS for apples, grapes and oranges, respectively.

In light of the severity of drought conditions experienced by growers in the Murray-Darling River Basin and projections that due to climate change such precipitation deficit conditions are becoming the norm, simple innovative management strategies such as the incorporation of surface active agents in irrigation programs can have profound effects on soil hydrological status, crop yield, and water use efficiency.

Additional research is underway to determine if the surfactant treatment solely influenced hydrological status or if other plant stress defense mechanisms were impacted. Assessment of fruit quality and chemistry is the subject of ongoing research, particularly in wine grapes.

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