

Soil Water Repellency – Influence on Irrigated Apple Productivity

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Abstract. Soil water repellency (SWR) deleteriously influences soil hydrological properties, yet few reports on consequences to crop yield and quality exist. With global concerns on drought and water availability and the projected impacts of climate change, development of novel strategies to optimize efficient rootzone delivery of water are required. It is the objective of this study to utilize surfactant treatment to increase soil water content and wetting front depth in a precision irrigated, Goulburn clay loam soil in Victoria, AU, as a means of estimating potential crop losses to SWR in *Malus domestica* Borkh. [cv. Pink Lady (2006/07 and 2007/08) and cv. Gala (2007/08)]. SWR was mitigated using an alkyl polyglycoside - block copolymer surfactant co-formulation applied initially at 0 or 5 L ha⁻¹ in November and followed by 3-4 monthly applications at 0 or 2.5 L ha⁻¹, respectively on mini-sprinkler irrigated *M. domestica* Borkh. Mitigation of SWR significantly increased soil volumetric water content at the 0-10 cm and 10-25 cm depths ($p = 0.05$) and increased fruit size by 17g – 41 g and total yield by 20% – 40% in the respective varieties ($p = 0.05$). The net difference in crop value was \$6,000 - \$9000 ha⁻¹ for Pink Lady and \$3,600 ha⁻¹ for Gala. This is the first study to demonstrate the impact of SWR on productivity in apples.

Keywords: water repellency, soil water content, surfactants, crop yield, apples, irrigation efficiency

Introduction

Soil water repellency (SWR) reduces a soil's affinity to water and affects an array of hydrological processes including infiltration, runoff, soil erosion, heterogeneous wetting, the development of preferential flow, and accelerated leaching of agrichemicals (Doerr et al., 2000 Dekker et al., 2001). Heterogeneous wetting and flow results in deprivation of a consistent water supply to plants, decreased rootzone storage of water, and non-uniform soil distribution of crop production and crop protection chemicals.

The phenomenon of SWR is attributed to the accumulation of hydrophobic organic compounds as coatings on soil particles and aggregates, as well as, physiochemical changes that occur in decomposing soil organic matter of plant or microbial origin (Miller and Williamson, 1977; Hallett et al., 2001; Hallett, 2008). In most soils, SWR is a transient phenomenon appearing

after the onset of dry periods with high evaporative demand. The impacts can vary widely and are highly influenced by environmental conditions and rainfall (Doer et al., 2000).

While it is recognized that SWR can influence irrigation efficiency, water conservation, and agricultural productivity, few studies have been published literature assessing the effects of SWR on productivity of agricultural and high value horticultural crops (Crabtree and Henderson, 1999; Robinson, 1999, Blackwell, 2000; Cooley et al., 2007).

Surfactants are commonly employed to ameliorate SWR in highly managed turf grass, improve infiltration, reduce runoff, and improve irrigation efficiency and turf performance (Cisar et al., 2000; Kostka, 2000; Park et al., 2005; Mitra et al., 2006). While this strategy is commonplace in turfgrass, application in agricultural crop production has been limited for two key reasons: the lack of recognition of SWR as a problem of agronomic significance and the lack of documentable evidence for surfactant enhancement of crop yields.

The sustainability of crop and biomass production is being impacted globally by depletion of water resources resulting in water scarcity and deteriorating water quality. As soil water repellency is now recognized as norm in agricultural soils rather than an exception, the use of surfactants may enable us to ascertain the potential impacts of this phenomenon on crop productivity. Hence, the objectives of this study were to utilize surfactant treatments to modify soil hydrological properties under precision irrigation as a means of estimating potential crop losses to SWR in a high value horticultural crop - apples (*Malus domestica* Borkh.).

Materials and Methods

Three trials were conducted in Victoria, AU on a clay loam soil with a history of poor wetting and water infiltration. Apple varieties included the cultivars Pink Lady planted at 1190 trees ha⁻¹ on a trellis system and Gala planted at 100 trees ha⁻¹ under a traditional central leader planting. The test design was a randomized complete block with each treatment replicated 5-6 times with each plot containing 5-6 trees, but varied by planting method (trellis versus single leader).

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⁻¹ in the spring as a 1 m band down the tree line. Applications thereafter were applied monthly at 0 or 2.5 L ha⁻¹, respectively for up to four months. Plots were irrigated by mini sprinklers and received the same irrigation volumes and management practices. Soil volumetric water content (VWC) was monitored at 0-10 cm and 10-25 cm using a Theta probe (Delta-T Devices, Cambridge, UK). At harvest, fruit weights were measured from selected individual trees and used for crop yield estimations.

Results and Discussion

At each of the three test locations differences in soil VWC were observed between the untreated control and soils where SWR was mitigated with surfactant treatments ($p = 0.05$).

Soil VWC was significantly lower in the untreated control than in soils where SWR was mitigated with surfactant treatments.

At Location 1, soil VWC was monitored at two depths (0-10 cm and 10-25 cm) throughout the test period. Statistically significant differences in VWC were observed between treatments, not only in the upper portions of the soil profile (0-10 cm) (Figure 1) but also deeper in the profile (10-25 cm) (Figure 2). On each measurement date, VWC was lower in the untreated control than in the SWR mitigated surfactant treatment. Water contents in the untreated controls were up to 25% lower than in soils where SWR was mitigated by surfactant treatments.

While not monitored systematically over the test period, statistically significant differences ($p = 0.05$) in soil VWC were observed between the untreated control and SWR surfactant mitigation treatment on each sampling date and depth at the remaining two locations (data not presented). Across all three test locations, surfactant mitigation of SWR resulted in higher VWC of the soil profile.

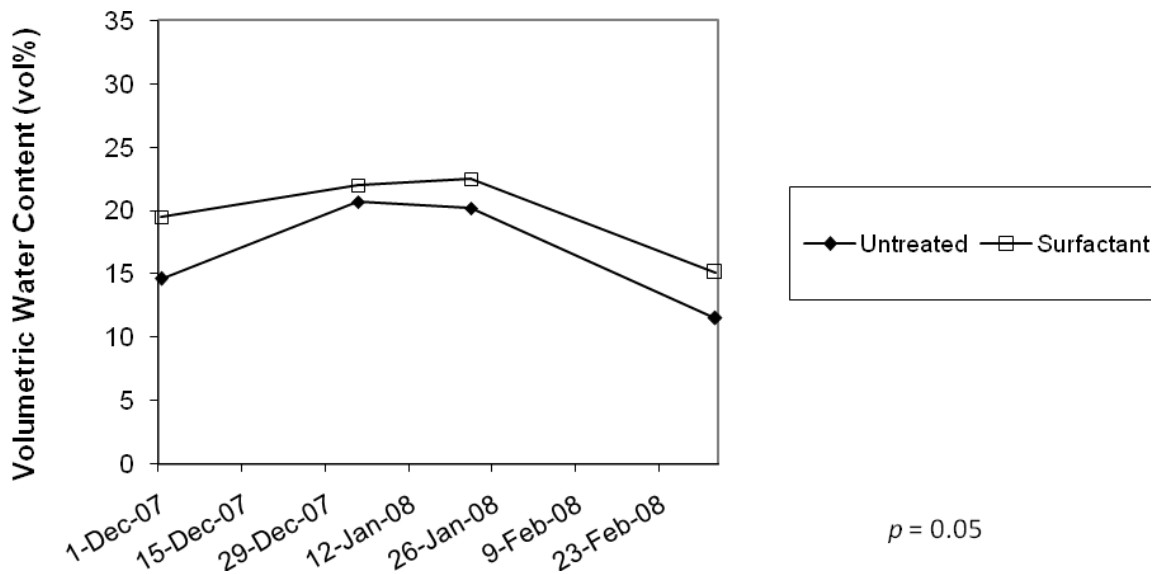


Figure 1. Soil volumetric water content (vol%) (10 cm depth) in untreated and surfactant-treated soils under precision irrigation in a clay loam soil.

During blossoming, plant growth regulators (thinners) were applied to manage fruit set resulting in statistically equivalent fruit numbers on a per tree basis. However, yields in the untreated controls were significantly lower ($p = 0.05$) on a hectare basis than with the SWR mitigation surfactant treatment (Table 1). The yield component most affected by SWR was mean fruit size - a difference of 24-32 g in the cv. Pink Lady and 43 g in the cv. Gala ($p=0.05$).

When examining the yield differences on a hectare basis, yield depressions of 3.7 – 6.1 Mg ha⁻¹ (16-23% difference) solely attributable to WR were encountered in the two varieties tested. Mitigation of SWR resulted in increased net return of \$6,000 - \$9000 ha⁻¹ for Pink Lady and \$3,600 ha⁻¹ for Gala. This study is the first to provide an insight on potential crop losses in apples growing in a water repellent soil.

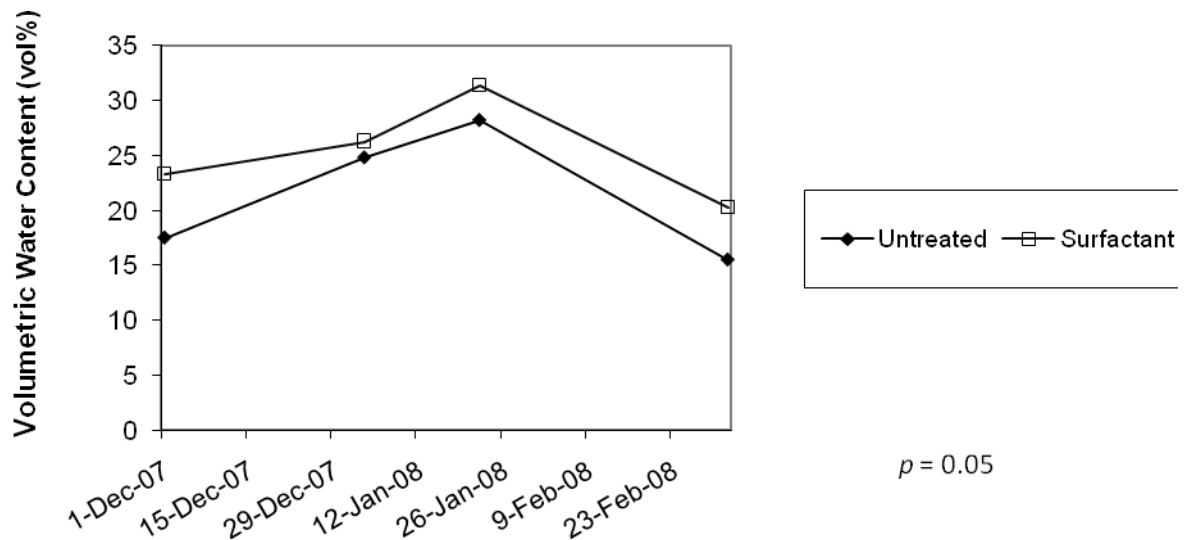


Figure 2. Soil volumetric water content (vol%) (25 cm depth) in untreated and surfactant-treated soils under precision irrigation in a clay loam soil.

Table 1. Effect of SWR on fruit size and yield in control and SWR-mitigated (surfactant treated) irrigated apples (*Malus domestica* Borkh.) in Victoria, AU.

Location	Variety	Fruit Size (g)		Yield (Mg ha ⁻¹)	
		Control	Surfactant	Control	Surfactant
1	Pink Lady	142.5 b ^a	175.3 a	29.3 b	34.9 a
2	Gala	81.3 b	124.3 a	7.9 b	11.8 a
3	Pink Lady	125 b	149 a	30.2 b	36.3 a

^aPaired comparisons followed by the same letter are not significantly different, LSD (0.05).

Conclusions

The results from these studies provide evidence that SWR deleteriously impacts soil hydrological status resulting in reduced productivity, yield, and quality in apples (*Malus domestica* Borkh.), a high value horticultural crop. While irrigation practices and volumes were identical, water use efficiency was higher in the surfactant treatments and resulted in increased fruit size and yield increases in the apple cultivars Pink Lady and Gala.

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. Research is continuing to confirm these results in other high value horticultural crops.

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