SURFACTANT SEED COATING – A STRATEGY TO IMPROVE TURFGRASS ESTABLISHMENT ON WATER REPELLENT SOILS

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SUMMARY

Soil water repellency can be a formidable barrier to the successful establishment of new golf course greens and sports fields. Seed coating technology may provide a novel approach for delivering soil surfactants in these environments. Our purpose was to describe a more efficient approach for applying soil surfactants using seed coating technology. Within a laboratory grow-room study, we compared the response of uncoated seed to seed coated with an alkyl-terminated ethylene oxide-propylene oxide block copolymer surfactant. Three surfactant-coating rates were evaluated in the study, 60, 80, and 100% weight of product to weight of seed (w:w). Seeds were sown in a severely water repellent and a non-water repellent soil. In general, surfactant coatings responded similarly. In water repellent soil, surfactant coatings dramatically increased soil water content, turfgrass density, cover, and biomass. Slight improvements were also found in wettable soil for some response parameters.

Keywords: soil water repellency, seed coating, turfgrass, soil surfactant, wetting agent

INTRODUCTION

Soil water repellency dramatically reduces the ability of water molecules to infiltrate into the soil (Dekker *et al*. 2005). Precipitation or irrigation that encounters water repellent soil typically runs off or moves through preferential flow paths, which decreases moisture availability for seeds and seedlings in near-surface soil layers (Oostindie *et al*. 2011). To establish new turfgrass in water repellent soils, excess irrigation water may be needed to enable seed germination and plant establishment. For many arid regions of the world, the overuse of limited irrigation supplies is not a sustainable practice and is having negative ramifications on the quantity and quality of irrigation water (Tillman *et al*. 2002). In addition, over-watering can negatively affect the quality of new turfgrass by encouraging seedling diseases and causing seed and soil erosion.

An effective approach to managing soil water repellency is to apply soil surfactants. Nonionic soil surfactant formulations based on ethylene oxide-propylene oxide (EO/PO) block copolymers are commonly used to increase root-zone water reserves in water repellent soil (Dekker *et al*. 2005, Throssell 2005, Kostka 2007). Typically, irrigation water is used as a carrier in the application of the surfactant. While this approach is effective, it can be costly and difficult to apply in certain environments. Madsen *et al.* (2010) recently reported methods and materials for coating individual seeds with soil surfactants. This approach is believed to provide a more economical and efficient method of applying surfactant. The objectives of this study were to evaluate the effectiveness of surfactant seed coating (SSC) for improving soil water content in water repellent soil, and determine how SSC influences turfgrass seedling emergence, cover, and biomass production.

MATERIALS AND METHODS

Experimental design

The study was conducted over 34 days, from 10 July 2012 to 13 August 2012, at the Eastern Oregon Agricultural Research Centre (Burns, OR, USA). Tall fescue 'SR 8650' (*Schedonorus phoenix* (Scop.) Holub) obtained from Seed Research of Oregon (Corvallis, OR, USA) was used as the test turfgrass species. Seeds were either left uncoated (control) or coated with a SSC at 60, 80, and 100 % weight of product to weight of seed (w:w). Seed coating was performed according to Madsen *et al*. (2010) using a RP14DB® rotostat seed coater by BraceWorks Automation and Electric (Lloydminster, SK, CAN). The surfactant chemistry used was ACA-1820, which is a nonionic, alkyl-terminated, EO/PO alkyl-terminated block copolymer from Aquatrols Corporation of America (Paulsboro, NJ, USA). Seeds were sown in 10-cm deep pots filled with either water repellent or non-water repellent soil for a total of 8 treatments [(3 surfactant coatings rates + 1 uncoated control) x 2 soil types]. Pots were arranged in a randomized block design with six replications.

The growing medium for all treatments consisted of a 1:10 mixture by weight of finely ground sphagnum peat moss to fine-sand. Growing medium bulk density and volumetric water content at field capacity were 0.93 g/cm^3 and 55%, respectively. Water repellent soil was produced by heating the growing media, within 5.0 cm deep pans, in a soil oven at 185°C for 2 hours. Soil water repellency severity was assessed using the water drop penetration time (WDPT) test (n=10). Pots were broadcast seeded at 48.8 g /m^2, after which seeds were raked into the top 1.5 cm of soil. Immediately after seeding, pots were placed on a 5% slope and misted with enough water to bring the soil to 115% of field capacity (50 mm of water at a rate of 24 mL/hr). Water that did not infiltrate into the soil was allowed to run off. Throughout the remainder of the study, pots were watered every other day with the amount of water required to bring the treatment with uncoated seed planted in wettable soil, back to field capacity. Soil water content was determined by weighing pots two hours after the first watering and then weekly prior to watering. Volumetric water content was determined by dividing the volume of water retained by the volume of soil in the pot. Super Start Plus ® 12-45-10 fertilizer (Plant Marvel Laboratories Inc., Chicago Heights, IL, USA) was added to the irrigation water at 2.0 g/m^2, 2 and 18 days after seeding. Pots were incubated at 24°C ± 3.0 for 34 days under 632 W/m^2 of fluorescent lighting with a 12-h dark/light cycle.

Assessments and analyses

Plant cover was assessed from digital images taken of each pot every four days, starting the sixth day after seeding. Digital images were obtained using a Nikon COOLPIX VR camera (Nikon Inc., Melville, NY), and had an image size of 3264 x 2448 pixels (about 190 kilobytes per image) and 0.01cm pixel resolution. Images were processed using object-based image analysis (OBIA) techniques in eCognition Developer 8.64 (Trimble Germany GmbH, Munich, Germany). Accuracy assessments were conducted on two random classified images per imagery date (2 images x 7 imagery dates = 14 accuracy assessments) using ERDAS Imagine 11.0 software (ERDAS Inc., Atlanta, GA) to calculate the overall accuracy and K_{hat} coefficient of agreement (Jensen 2005). Within each image, plant cover was calculated by dividing the total area classified as plant cover by the total area of the greenhouse pot. At the conclusion of the study, four of the six pots per block were harvested. The number of seedlings in a pot were counted, and above and below-ground biomass was measured after oven-drying at 65°C for 72 hrs.

The data were analyzed in SAS (Version 9.3; SAS Institute, Cary, NC). A repeated measures mixed model was used for soil water content and plant cover data. The fixed effects were soil, surfactant coating rate, day and their interactions. The random effects were block and soil x surfactant coating rate x block. The correlations among the repeated measures were modelled with a first order, autoregressive, moving average covariance structure. Significant interactions and/or main effects were identified and the corresponding means and 95% confidence intervals were computed. Metrics that did not involve repeated measures, namely seedling density and root and shoot biomass, were subjected to a two-way randomized complete block analysis of variance (ANOVA). The LSMEANS procedure with a Bonferroni post-hoc test was used to make mean comparisons between each coating level and the controls. Significance was determined at $P \leq 0.05$.

RESULTS AND DISCUSSION

Water repellency severity and soil water content

Non-treated soil was found to be wettable with WDPTs close to zero. Water repellent soil, produced by heating the same growing media was found to be severely water repellent with WDPTs equal to 5.08±0.24 hrs. Soil water content differed by soil type, surfactant coating rate, day of measurement, and their interactions (Table 1). Within the uncoated seed treatment, wettable soil had soil water content values 2.2-fold higher than water repellent soil after the first irrigation event (Fig. 1A). Differences in soil water content between the two soil types in the uncoated seed treatment decreased overtime, but remained statistically different over the period of the study.

TABLE 1: ANOVA analysis (*F*, and P values) for effect of soil type and coating rate on soil water content, turfgrass cover, density, and root and shoot biomass.

	Soil water content		Cover		Density		Root biomass		Shoot biomass	
Source	*F*	P	*F*	P	*F*	P	*F*	P	*F*	P
Soil	16.3	< **0.001**[†]	169.2	< **0.001**	4.7	**0.042**	19.8	< **0.001**	58.2	< **0.001**
Seed treatment	56.6	< **0.001**	73.6	< **0.001**	43.4	< **0.001**	15.9	< **0.001**	24.0	< **0.001**
Soil X seed t.	35.5	< **0.001**	39.7	< **0.001**	0.5	0.667	8.0	**0.001**	17.4	< **0.001**
Day	201.3	< **0.001**	885.1	< **0.001**						
Soil X day	15.4	< **0.001**	33.6	< **0.001**						
Seed t. X day	3.2	< **0.001**	16.9	< **0.001**						
Soil X seed t. X day	4.8	< **0.001**	12.3	< **0.001**						

[†] **numbers in bold are significant at P < 0.05.**

All SSC coating rates (60, 80, and 100% w/w) were highly effective in ameliorating water repellency and increasing soil water content (Fig. 1A). During the first 9 days of the study when turfgrass was germinating and emerging, soil water content in the water repellent soil was 2-fold higher for SSC than the uncoated seed treatment. The amount of surfactant coated onto the seed did not influence soil water content (Fig. 1A). Soil water content in the wettable soil was statistically similar between all seeding treatments. There was an overall decrease in soil water content after day 21, for all seed treatments in the wettable soil and those with a SSC treatment in the water repellent soils. We suspect this is a result of higher plant water use from maturing plants. A gradual increase in soil water content overtime in the uncoated-water repellent soil treatment may be due to declines in the severity of the water repellent soil with repeated watering.

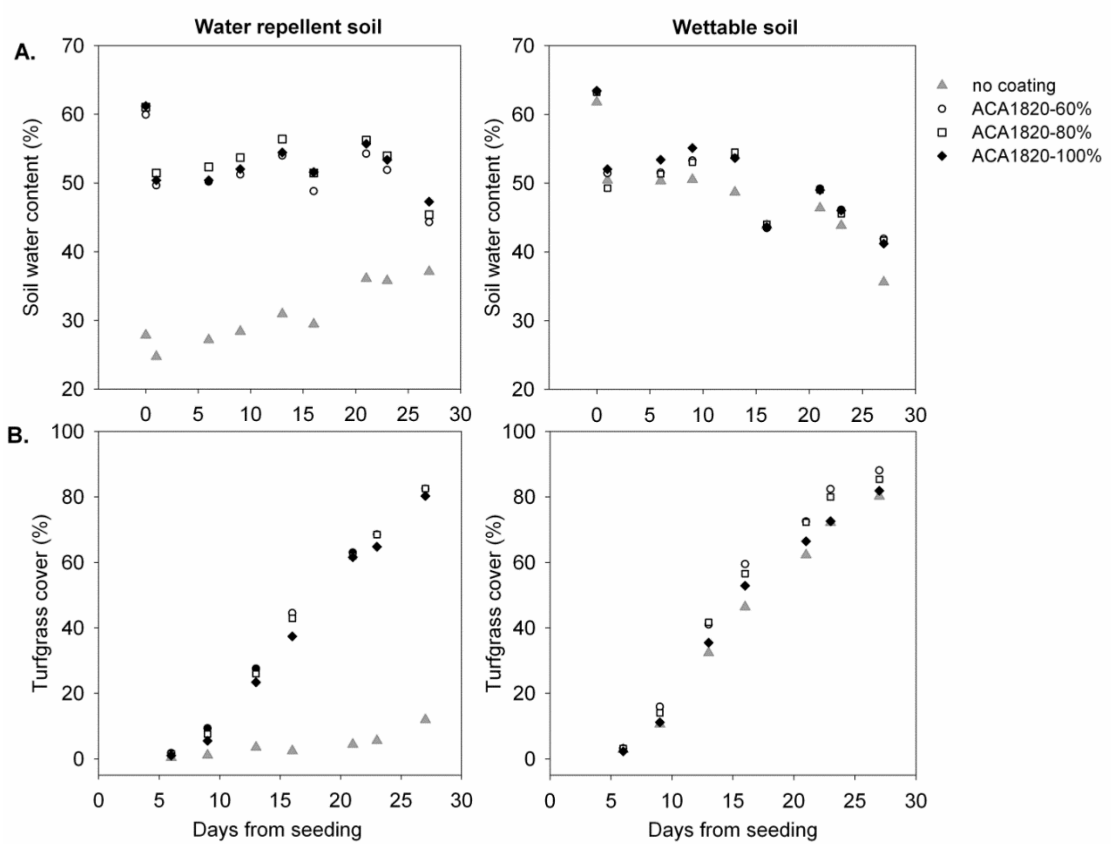

FIGURE 1: Average A. soil water content and B. turfgrass cover for uncoated and surfactant coated seed, planted in water repellent and wettable soils over a 27 day period.

Classified imagery and plant cover

Overall accuracy and the K_{hat} statistic of the classified imagery were 93% and 85%, indicating a strong agreement between the extracted turfgrass cover and the reference data. Turfgrass cover differed by soil type, surfactant coating rate, day of measurement, and their interactions (Table 1). The speed and amount of turfgrass coverage produced from the uncoated seed treatment was drastically lower in the water repellent soil as compared to wettable soil (Fig. 1B). SSC treatments in the water repellent soil were not affected by soil water repellency and produced similar cover values as that from uncoated and surfactant coated seeds planted in the wettable soil. Thirteen days after planting significant differences were detected in turfgrass cover between SSC treatments and uncoated seed in the water repellent soil. By the conclusion of the study (day 27), turfgrass cover, in the water repellent soil was 7.5-fold greater in the SSC treatments in comparison to uncoated seed. In the wettable soil, turfgrass cover in general was statistically similar among the SSC rates and untreated seed.

Plant density and biomass

Seedling density was primarily impacted by seed treatment (Table 1). Soil type's degree of influence was not as great for seedling density as compared to other response parameters measured in this study. The SSC treatments improved plant density in both water repellent and wettable soils (Fig. 2A). Seed treatments with a SSC were similar to each other and on average produced 1.7-fold more plants, than uncoated seed. For all of the parameters measured in this study, improved turfgrass response from the SSC is most likely a function of surfactant increasing soil water availability. However, because SSC enhanced plant density with both wettable and water repellent soils, other factors may also be at play. In addition to being effective at ameliorating soil water repellency, alkyl-terminated block copolymer (ACA-1820) has been shown to enhance turfgrass growth, density, colour and overall quality under limited fertilizer inputs (Kostka & Schuermann 2008; van Mondfrans et al. 2010).

Root and shoot biomass both differed by soil type, surfactant coating rate, and their interactions (Table 1). While there may have been a similar number of plants grown from uncoated seed, within the water repellent and wettable soils, plants were unambiguously larger in the wettable soil as compared to the water repellent soil. Root and shoot biomass from uncoated seed was 5.27 and 3.72-fold larger in the wettable soil in comparison to the water repellent soil, respectively (Fig. 2B and C). Root and shoot biomass produced from SSC treatments, in the water repellent soil were comparable to each other, and similar to that in wettable soils. These results indicate that soil water repellency did not limit the growth of plants produced from SSC treatments.

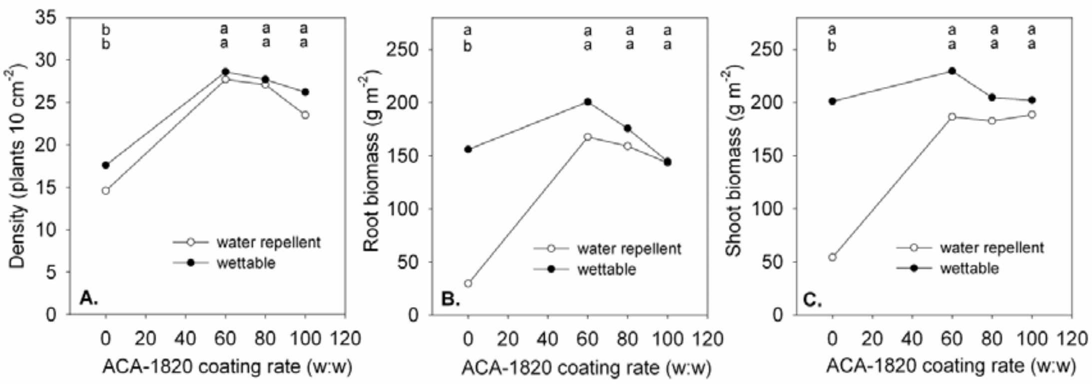

FIGURE 2: Mean turfgrass density A., root biomass B., and shoot biomass C., 27 days after seeding, from uncoated seed, and seed coated with ACA-1820 surfactant at 60, 80, and 100% weight of product to weight of seed (w:w).

CONCLUSIONS

Water repellency can be a formidable barrier to seed germination and plant establishment in turfgrass systems. This work demonstrates the ability of SSC technology to ameliorate a severely water repellent soil, and subsequently increase rootzone water reserves for turfgrass seedling emergence, cover and biomass production. Among the SSC rates evaluated in this study, response parameters did not significantly differ, although lower coatings rates tended to be the top performing SSC treatments on average. Additional research is warranted for evaluating SSC technology at lower coating rates.

The results of this study confirm research by Madsen *et al*. (2012) that demonstrates SSC technology can improve soil hydrologic properties, and seedling emergence and growth in rangeland soils impacted by wildfire. Improvements in root-zone water reserves and turfgrass quality in this study are also consistent with previous turfgrass studies where soil surfactants with similar chemistries were applied as a solution with irrigation water (Kostka & Bially 2005; Throssell 2005; Dekker *et al*. 2005; Oostindie *et al*. 2006; Kostka *et al*. 2007; Kostka & Schuermann 2008). The merger of seed coating and surfactant technologies could potentially reduce the cost, time, and amount of seed needed in the agricultural, horticultural, and turfgrass industries. With increasing demands on water resources coupled with diminishing supplies, SSC technology may provide a direct solution to addressing water scarcity issues.

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