Surfactant-coated Seed Emergence and Establishment Under Deficit Irrigation in Hydrophilic and Hydrophobic Soils

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Abstract

Soil water repellency inhibits seed germination and emergence, whereas soil surfactants improve the wettability of water-repellent or hydrophobic soils. An improvement in seed germination and emergence can occur when a soil surfactant is applied directly to the seed and/or to the water repellent soil at sowing. Therefore, a coating process was developed to utilize seed as a soil surfactant carrier. Greenhouse experiments were conducted to evaluate establishment of perennial ryegrass (*Lolium perenne* L.) seed coated with a soil surfactant (SCS = surfactant- coated seed), as compared to uncoated seed (CHK). Both SCS and CHK were sown in two hydrophilic substrates (100% sand [WSAND], 90:10% v/v sand:peat [WSP], and in two severely hydrophobic sands (100% hydrophobic stearic acid-treated sand [HSS], and hydrophobic 90:10% v/v sand:peat [HSP]). Due to the weight of the coating, SCS was sown at half the amount as compared to CHK; however, final turfgrass establishment in all rootzones with SCS was similar or better than CHK. In WSAND, WSP, and HSP, the volumetric water content was consistently higher in rootzones of SCS treatments versus CHK. SCS represents an opportunity to improve stand establishment and rootzone soil-water dynamics in challenging environmental conditions such as limited precipitation.

Species used in this study: Perennial ryegrass, *Lolium perenne* L.

Index words: soil surfactant, soil water, turfgrass, turfgrass ecology.

Significance to the Horticulture Industry

Soil surfactants are recognized as a valuable tool to treat hydrophobic or water repellent soils and also to maintain and improve turfgrass growth under deficit irrigation. Soil surfactants can achieve this through their influence on soil hydrological properties. Turfgrass seed treatment with a soil surfactant is novel and represents an opportunity to improve germination, emergence, and stand establishment, as well as improve rootzone soil-water dynamics in challenging environmental conditions of drought, limited precipitation or irrigation, and hydrophobic soils.

Introduction

Soil water repellency negatively affects soil hydrological processes (Doerr et al. 2000). For example, as little as 3% v/v hydrophobic particles can change the wetting behavior in bulk soil, leading to irregular wetting, increased runoff, preferential flow path formation, lack of infiltration, and low volumetric soil water status (Bauters et al. 1998, Thompson et al. 2016, Moral Garcia et al. 2003, Ferreira et al. 2003, Hendricx et al.1993). Water-repellent soils can also negatively affect crop growth and performance. For example, Bond (1972) provided one of the earliest reports to indicate significant reductions in barley (*Hordeum vulgare* L.) yield due to lack of germination in water-repellent soils. Soil water repellency inhibited seedling germination and emergence of the non-native bunchgrass crested wheatgrass [*Agropyron cristatum* (L.) Gaertn.] and the native bunchgrass bluebunch wheatgrass [*Pseduoroegneria spicata* (Pursh) A. Love] by limiting access to available soil water (Madsen et al. 2009).

Soil surfactants (i.e., commonly referred to as a “wetting agents”) have been used in agriculture and turfgrass production systems to alleviate water repellency and improve uniformity of water status in soils (Cooley et al. 2009, Fidanza et al. 2020, Kostka 2000). A one-time wetting agent application improved grass establishment on fire-induced water-repellent soil in southern California, USA (Valoras et al. 1969). In research conducted by Debano et al. (1974), however, nonionic wetting agents did not have any negative effect on perennial ryegrass (*Lolium perenne* L.) seed but were phytotoxic to mustard (*Brassica* sp.) seed. The wetting agent (unknown chemistry) in that study was associated with higher surface moisture content (Debano et al. 1974). Miyamoto and Bird (1978) reported that a wetting agent, composed of linear sulfonate and an alkyl polyethylene glycol ether, applied to soil rather than directly onto seed resulted in reduced germination and emergence of galleta [*Hilaria jamisii* (Torr.) Benth] and sacaton (*Sporobolus airoides* Torr.), most likely due to excess soil moisture conditions. Rigid ryegrass (*Lolium rigidum* L.) planted in water-repellent sloping soils germinated more effectively in soil-surfactant-treated (unknown chemistry) soil compared to untreated soil (Osborn 1968). In contrast, when the same wetting agent was used on wettable sand, rigid ryegrass germination was reduced (Osborn 1968).

Madsen (2009) first coated native and non-native species seeds with soil surfactants to improve germination and

Received for publication August 19, 2022; in revised form December 15, 2022.

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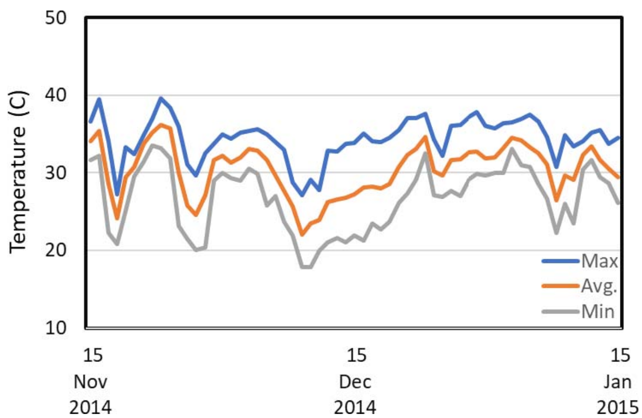

Fig. 1. Minimum, maximum and average greenhouse temperature (F) during experiment one. Conversion: F = [(C × 1.8) + 32].

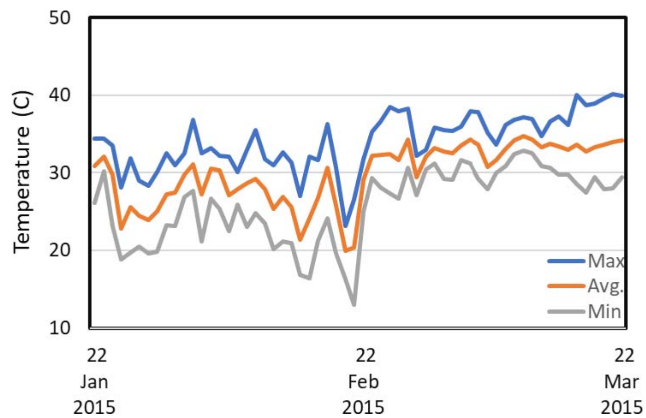

Fig. 2. Minimum, maximum and average greenhouse temperature (F) during experiment two. Conversion: F = [(C × 1.8) + 32].

emergence in wildfire-affected sites in the United States. In that study, the non-native bunchgrass crested wheatgrass seeds and the native bunchgrass bluebunch wheatgrass seeds were coated with an alkylpolyglycoside-ethylene oxide/propylene oxide block copolymer surfactant blend. The surfactant-coated crested wheatgrass seed established under a low irrigation water regime produced a significant increase in both above and below ground biomass by 690% and 1,056%, respectively, and in bluebunch wheatgrass by 722% and 1,196%, respectively, compared to uncoated seed. Fidanza et al. (2014, 2016) reported one to three days faster germination with both surfactant-coated perennial ryegrass and Kentucky bluegrass (*Poa pratensis* L.) seed in addition to greater seedling vigor and quality compared to uncoated seed. Coating tall fescue [*Schedonorus arundinaceus* (Schreb.) Dumont; formerly *Festuca arundinaceae*] seed with either an ethylene oxide/propylene oxide block copolymer soil surfactant or an alkylpolyglycoside-ethylene oxide/propylene oxide block copolymer soil surfactant blend at loading rates of 60%, 80%, and 100% (wt/wt) significantly increased root and shoot biomass as well as plant cover when seeds were sown in a water-repellent soil (Madsen et al. 2013). Therefore, the goal of this experiment was to determine if coating seeds with a soil surfactant would enhance germination, emergence, and establishment of turf-type perennial ryegrass in naturally occurring hydrophilic (i.e., wettable) soil and synthetically produced and severely hydrophobic (i.e., non-wettable or water repellent) soil, and sown under deficit irrigation conditions.

Materials and Methods

A greenhouse study was conducted at the University of Florida's Institute of Food and Agricultural Sciences (IFAS), Fort Lauderdale Research and Education Center, at Davie, FL (26.0840°N, 80.2372°W). The greenhouse was screened on the sides with a covered roof. Two experiments were conducted for a duration of 60 days each, with the first on 15 November 2014 - 15 January 2015, and the second on 22 January - 22 March 2015. The experiments were set up as a completely randomized design with four replicates. Of note, these experiments were conducted at higher air temperatures atypical for seeding perennial ryegrass, which would optimally occur when air temperatures are between 15.5 to 23.8 C (60 to 75 F). In Experiment One, greenhouse air temperatures averaged between 18 to 39 C (64.4 to 102.2 F) (Fig. 1) and between 13 to 40 C (55.4 to 104 F) in Experiment Two (Fig. 2). No supplemental lighting was used in either experiment.

Plastic containers (6.35 cm × 6.35 cm × 10.16 cm; 2.5 in × 2.5 in × 4.0 in) were filled to approximately 1.25 cm (0.5 in) below the top of the container with one of the following five substrates: 100% hydrophilic (or wettable) sand (WSAND), hydrophilic 90:10% v/v sand:peat (WSP), 100% hydrophobic (non-wettable) stearic acid-treated sand (HSS), and hydrophobic 90:10% v/v sand:peat (HSP). The methods to synthetically induce hydrophobicity of sand were either the Ivory® bar soap (HSS) (Proctor and Gamble Corp., Cincinnati, OH) method or peat (Dakota Peat and Equipment Inc., Grand Forks, ND.) (HSP) method (McMillan, 2016). HSS was made by placing five grams of Ivory® soap (Proctor & Gamble, Cincinnati, OH, USA) in 500 mL of deionized water and using a laboratory microwave (1,000 watts) for 140 seconds to completely dissolve the soap. An additional 500 mL of deionized water was added to the microwaved stearic acid solution. One 22.6 kg bag of coarse sand (Florida Silica Sand, Miami, FL, USA) was poured into a small cement mixer followedby the 1,000 mL stearic acid solution being poured onto the sand. The sand and soap solution were blended for ten minutes until the sand appeared thoroughly and completely wetted. The coated sand was poured into 30 cm length × 23 cm width × 10.25 cm (12 × 9 × 4 in) depth aluminum pans until half full and then dried in an oven for four hours at 65 C (149 F). HSP was made by blending a 90:10 v/v of coarse sand (Florida Silica Sand; Miami, FL, USA) and reed sedge peat (Dakota Peat and Equipment Inc.; Grand Forks, ND, USA) in a small cement mixer until thoroughly and uniformly mixed. The sand and peat mixture was placed into 30 cm length × 23 cm width × 10.25 cm depth aluminum pans until half full then dried in a 180 C (356 F) oven for two hours. WSAND and WSP were determined as wettable based on water drop penetration time (WDPT) of < 5 sec, and HSS and HSP were determined to be severely

Fig. 3. **Example of irrigation water beading on the surface of HSP substrate (hydrophobic 90:10% v/v sand:peat).**

Fig. 4. **Example of irrigation water beading on the surface of HSS substrate (100% hydrophobic stearic acid-treated sand).**

water repellent with WDPT > 600 sec (Dekker et al. 2009) (Fig. 3 and 4).

Perennial ryegrass ('Shining Star') seed was coated at 10% w/w with a composition containing an alkyl-terminated block copolymer soil surfactant (Aquatrols Corporation of America, Paulsboro, NJ) utilizing a method described by Madsen (2009). Soil-surfactant-coated seed (SCS) and uncoated seed (CHK) of perennial ryegrass were sown at the recommended rate of 39.6 g•m^{-2} (8 lbs•1,000 ft^{-2}) (Turgeon and Kaminski 2019). Due to the added weight of the coating, it was determined that the actual number of SCS seed sown was 50% less versus CHK, or 20.0 g•m^{-2} (4 lbs•1000 ft^{-2}) After seeds were hand sown into each of the four substrates, seeds were covered with an additional 0.65 cm (0.25 in) of substrate. All substrates were watered immediately with approximately 6.5 mm (0.25 in) of water to facilitate movement of the soil surfactant off the seed surfaces and into the substrate. Irrigation was the same for all treatments. A deficit irrigation regime was imposed on all treatments with overhead misters applying 2.5 mm (0.1 in) of water every other day during the establishment phase. Fertilizer was applied every two weeks at a rate of 2.4 g N•m^{-2} (0.5 lb N•1,000 ft^{-2}) from 12N-1P_2O_5-10K_2O (Harrell's Foliar Fertilizer, Lakeland, FL). All treatments (i.e., four substrates sown with SCS and four substrates sown with CHK) were arranged on the greenhouse benchtop in a completely randomized design with four replications.

First day of seedling emergence as indicated when the coleoptile was first observed was considered the days to emergence (DTE) and recorded as the average for all seed per treated 'plot' over the 60-day experiment time. Percent turfgrass cover was visually determined using a scale of 0-100%, where 0% no coverage of surface of substrate, and 100% complete visual coverage of seedling emergence on the substrate surface within the container. Soil volumetric water content (VWC) measurements were obtained every 24 to 72 hr using a ML2 ThetaProbe Soil Moisture Sensor with a HH2 Data Collector (Delta-T Devices, Cambridge, United Kingdom) at the 6 cm (2.36 in) substrate rootzone depth. The VWC measurements were routinely collected once seedlings emerged to minimize any substrate rootzone disruption.

Deficit irrigation also included imposed dry-downs to determine potential rewettability as affected by seed treatments and substrates. All treatments were brought to field capacity (i.e., saturated rootzone) then allowed to dry-down (i.e., irrigation withheld) until seedlings showed visible signs of wilt. In Experiment One, four dry-down periods were conducted on 4, 7, 9, and 12 January 2015, and after the last dry-down all treatments were brought to field capacity and a final VWC was collected one hour after soils had finished draining. In Experiment Two, two dry downs were conducted on 4 and 13 Mar 2015, and again after the last dry-down all treatments were brought to field capacity and a final VWC was collected one hour after soils had finished draining.

Data Analysis. All data were subjected to analysis of variance utilizing PROC GLIMMIX in SAS 9.2 (SAS Institute 2009). All data means were compared using Tukey's honestly significant difference test to identify significant differences among treatment means at $p \leq 0.05$ (Mead et al. 2003).

Results and Discussion

Soil analysis. Particle size analyses revealed all substrates were composed of sand that was ≥ 98% of a diameter 0.05 - 2.0 mm (0.019 - 0.78 in), and the majority (≥ 75%) of sand content in all substrates were categorized as coarse (0.5 - 1.0 mm diameter; 0.019 - 0.039 in) (Table 1). Organic matter content in all substrates was < 1% (ASTM F 1647-11) (Table 1). Bulk density and particle size for all substrates ranged from 1.67 - 1.69 g•cm^{-3} and 2.63 - 2.65 g•cm^{-3}, respectively. Saturated hydraulic conductivity measurements revealed water flow rates were higher in SAND and HSS (range of 119.6 – 129.3 cm•hr^{-1}) compared to WSP and HSP (range of 73.2 - 91.4 cm•hr^{-1}) (Table 2). Total porosity and aeration porosity for all substrates ranged from 36.4 - 36.7% and 27.5 - 32.1%, respectively. Chemical analysis of the four substrates revealed a pH range of 6.5 - 7.6, which is acceptable for turfgrass establishment (Turgeon and Kaminski 2019). Phosphorus measured in WSAND, WSP, HSS, and HSP was 16.7, 11.8, 32.9, and 13.4 mg•kg^{-1}, respectively. The

Table 1. Particle size analysis for substrates used in Experiments One and Two.

	Soil separate				Sieve size/Sand fraction sand particle diameter as percent retained						
Substrate[z]	Sand	Silt	Clay	OM[y]	No. 10 Gravel 2 mm	No. 18 V. Coarse 1 mm	No. 35 Coarse 0.5 mm	No. 60 Medium 0.25 mm	No. 100 Fine 0.15 mm	No. 140 V. Fine 0.10 mm	No. 270 V. Fine 0.05 mm
	%				%						
WSAND	99.3	0.2	0.5	0.04	0.0	6.9	80.0	11.7	0.6	0.0	0.1
WSP	98.9	0.5	0.6	0.08	0.0	6.5	78.0	13.2	1.0	0.1	0.1
HSS	99.6	0.0	0.4	0.06	0.0	8.3	80.3	10.7	0.3	0.0	0.0
HSP	99.0	0.3	0.7	0.68	0.0	5.8	77.7	14.2	1.1	0.1	0.1

[z]WSAND (100% hydrophilic or wettable sand); WSP (hydrophilic 90:10% v/v sand:peat); HSS (100% hydrophobic or non-wettable stearic acid-treated sand); and HSP (hydrophobic 90:10% v/v sand:peat).

[y]OM (organic matter) determined as percent loss-on-ignition.

cation exchange capacity (CEC) for WSAND and HSS was 1.1 and 1.7 cmol•kg^{-1}, respectively, and the CEC for WSP and HSP was 3.0 and 3.6 cmol•kg^{-1}, respectively (McMillan 2016).

Days to emergence. In Experiment One, DTE ranged from 8.0 to 9.0 days for all treatments (Table 3). No significant difference with DTE was observed between SCS and CHK in WSAND, WSP, or HSS; however, in HSP the SCS emerged at 8.0 days which was one day faster versus CHK at 9.0 days (Table 3). Thus, no improvement or advantage in DTE was observed from soil-surfactant-coated seed (SCS) over conventional or uncoated seed (CHK) in wettable sand (WSAND), wettable sand:peat (WSP), or non-wettable sand (HSS) rootzones. A one-day faster DTE could be advantageous when seeding at an unfavorable time-of-year or during unfavorable environmental conditions (Hendrickx et al. 1993, Madsen et al. 2016, Turgeon and Kaminski 2019).

In Experiment Two, DTE ranged from 6.0 to 52.2 days (Table 4). No significant difference in DTE between SCS and CHK was observed with WSAND or WSP with a range of 6.0 to 6.5 DT (Table 4). Thus, in those wettable rootzones, SCS provided no significant improvement or advantage in DTE compared to CHK. Although DTE in HSS was significantly slower in SCS versus CHK at 52.2 and 22.5 days, respectively, this was an unusually slow and delayed germination and emergence response for perennial ryegrass (Table 4). DTE in HSP was significantly faster in SCS versus CHK at 14.0 and 38.2 days, respectively (Table 4), but also considered a slower germination and emergence time for perennial ryegrass (Turgeon and Kaminski 2019). In Experiment Two, both SCS and CHK had a delayed germination and emergence time only in HSS and HSP (Table 4), but it is not understood why this same effect was not observed in Experiment One (Table 3). Of note, the minimum temperature in Experiment One was < 20 C for only two consecutive days, however in Experiment Two it was < 20 C for seven different days. Therefore, the lower temperatures in Experiment Two may have had an influence on the delayed germination observed in Experiment Two and not in Experiment One.

While stearic acid is effective at rendering sand hydrophobic, it also can have a deleterious effect on plant growth (González-Peñaloza et al. 2012). As observed in Experiment Two, the stearic acid utilized to impose hydrophobicity in HSS may have contributed to those delayed seed germination and emergence times for both SCS and CHK (Table 4). Thus, stearic acid would not be recommended to synthetically produce hydrophobic sand due to potentially negative effects on perennial ryegrass seedling emergence and establishment as observed in Experiments One and Two (Table 4).

Final cover. In Experiment One, final percent plot area covered with perennial ryegrass growth after 60 days ranged from 33.8 to 55.0% (Table 3). No significant difference with final turfgrass cover between SCS and CHK was observed with WSAND, WSP, or HSS; however, in HSP the final cover was significantly higher with SCS versus CHK (Table 3). Although SCS contained 50% less actual seed versus CHK, turfgass cover between SCS and CHK was statistically similar in WSAND, WSP, and HSS. Thus, surfactant-coated seed (SCS*) may* represent an opportunity to establish turfgrass when there are restrictions on seed availability or other resource limitations such as costs, labor, water, total area to be seeded, environmental conditions, or other factors (Fidanza et al. 2020, Kostka 2000, Madsen 2009, Madsen et al. 2016). In HSP, the SCS appeared to provide a significant advantage with perennial

Table 2. Physical characteristics of substrates used in Experiments One and Two.

Substrate[z]	Bulk density (g•cm^{-3})	Particle density (g•cm^{-3})	Saturated hydraulic conductivity (cm•hr^{-1})	Total porosity (%)	Aeration porosity (%)
WSAND	1.69	2.65	129.3	36.4	31.4
WSP	1.67	2.63	73.2	36.4	27.5
HSS	1.68	2.65	119.6	36.7	32.1
HSP	1.67	2.63	91.4	36.7	29.9

[z]WSAND (100% hydrophilic or wettable sand); WSP (hydrophilic 90:10% v/v sand:peat); HSS (100% hydrophobic or non-wettable stearic acid-treated sand); and HSP (hydrophobic 90:10% v/v sand:peat).

Table 3. Days to emergence and final cover analysis for Experiment One, 15 Nov 2014 - 15 Jan 2015.

Experiment One				
Perennial ryegrass (*Lolium perenne* L.) seed	Substrate[z]			
	WSAND	WSP	HSS	HSP
	Days to emergence[xy]			
SCS	8.0 a[w]	8.0 a	9.0 a	8.0 b
CHK	8.0 a	8.0 a	8.7 a	9.0 a
	Final Cover (percent)[xy]			
SCS	40.0 a	53.8 a	33.8 a	55.0 a
CHK	43.8 a	50.0 a	35.0 a	37.5 b

[z]WSAND (100% hydrophilic or wettable sand); WSP (hydrophilic 90:10% v/v sand:peat); HSS (100% hydrophobic or non-wettable stearic acid-treated sand); and HSP (hydrophobic 90:10% v/v sand:peat).

[y]SCS = surfactant-coated seed sown at 39.5 g•m^{-2} (8 lbs•1000 ft^{-2}), however, approximately 20 g actual seed•m^{-2} (4 lbs•1000 ft^{-2}); CHK = uncoated seed sown at 39.5 g•m^{-2} (8 lbs•1000 ft^{-2}).

[x]Days to emergence = number of days when perennial ryegrass (*Lolium perenne* L.) seedlings first emerged from the substrate surface over the 60-day experiment time; final cover = percent (0 to 100%) surface area covered with perennial ryegrass shoot growth.

[w]Means (n=4) with the same letter are not statistically significant according to Tukey's honestly significant difference test at $p \leq 0.05$.

ryegrass emergence and establishment versus CHK (Table 3).

In Experiment Two, final percent plot area covered with perennial ryegrass growth after 60 days ranged from 3.5 to 53.7% (Table 4). No significant difference with turfgrass cover in WSAND was observed between SCS and CHK, with 47.5 and 43.7%, respectively (Table 4). In WSP, turfgrass cover was higher with SCS versus CHK, at 53.7 versus 42.5%, respectively (Table 4). Therefore, SCS sown at 50% less actual seed rate established similar to CHK in wettable sand (WSAND), but established better than CHK in wettable sand:peat (WSP) (Table 4). In HSS, turfgrass cover was not significantly different at 3.5 and 9.5% for SCS and CHK, respectively; and in HSP turfgrass cover was significantly different at 32.5 and 4.7% for SCS and CHK, respectively (Table 4). As in Experiment One, the stearic acid component of the hydrophobic sand in HSS may have been detrimental to seedling growth and development, and therefore contributed to lower turfgrass establishment and final cover with both SCS and CHK in Experiment Two.

Table 4. Days to emergence and final cover analysis for Experiment Two, 22 Jan 2015 - 22 Mar 2015.

Experiment Two				
Perennial ryegrass (*Lolium perenne* L.) seed	Substrate[z]			
	WSAND	WSP	HSS	HSP
	Days to emergence[xy]			
SCS	6.5 a	6.0 a	52.2 a	14.0 b
CHK	6.2 a	6.5 a	22.5 b	38.2 a
	Final Percent Cover[xy]			
SCS	47.5a	53.7 a	3.5 a	32.5 a
CHK	43.7a	42.5 b	9.5 a	4.7 b

[z]WSAND (100% hydrophilic or wettable sand); WSP (hydrophilic 90:10% v/v sand:peat); HSS (100% hydrophobic or non-wettable stearic acid-treated sand); and HSP (hydrophobic 90:10% v/v sand:peat).

[y]SCS = surfactant-coated seed sown at 39.5 g•m^{-2} (8 lbs•1000 ft^{-2}), however, approximately 20 g actual seed•m^{-2} (4 lbs•1000 ft^{-2}); CHK = uncoated seed sown at 39.5 g•m^{-2} (8 lbs•1000 ft^{-2}).

[x]Days to emergence = number of days when perennial ryegrass (*Lolium perenne* L.) seedlings first emerged from the substrate surface over the 60-day experiment time; final cover = percent (0 to 100%) surface area covered with perennial ryegrass shoot growth.

[w]Means (n=4) with the same letter are not statistically significant according to Tukey's honestly significant difference test at $p \leq 0.05$.

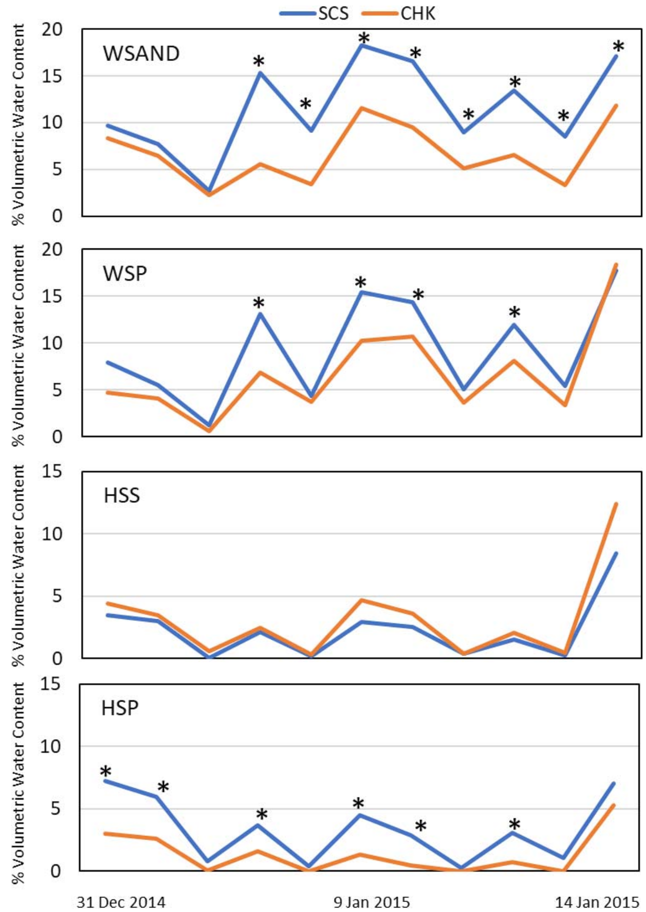

Fig. 5. Root zone volumetric water content (VWC) analysis for each substrate for Experiment One, 15 Nov 2014 - 15 Jan 2015. SCS = surfactant-coated perennial ryegrass (*Lolium perenne* L.) seed; CHK = uncoated seed. WSAND (100% hydrophilic or wettable sand); WSP (hydrophilic 90:10% v/v sand:peat); HSS (100% hydrophobic or non-wettable stearic acid-treated sand); and HSP (hydrophobic 90:10% v/v sand:peat). Imposed dry-down occurred on 4, 7, 9, and 12 Jan 2015. VWC means (n=4) with the " * " symbol indicates statistical significance according to Tukey's honestly significant difference test at $p \leq 0.05$; no symbol indicates not significantly different.

Volumetric water content. In Experiment One in WSAND, WSP, and HSP, the VWC was significantly higher on the majority of evaluation dates in plots sown with SCS versus CHK (Fig. 5). In HSS, however, no significant differences with VWC were observed between SCS and CHK (Fig. 5). On wettable substrates (i.e., WSAND and WSP), and on a non-wettable substrate (i.e., HSP), SCS effectively "delivered" the soil surfactant into the rootzone as demonstrated from improved soil water

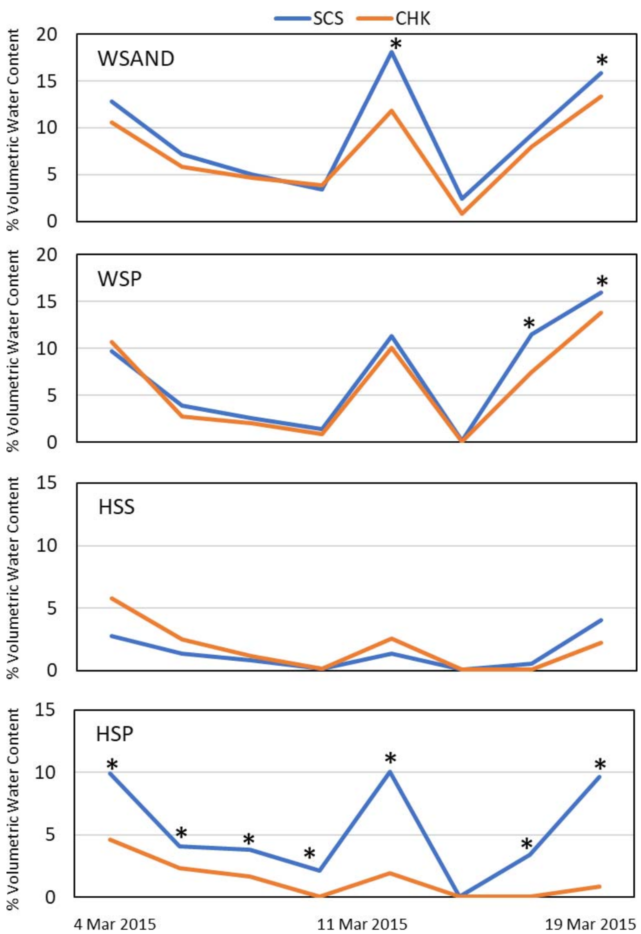

Fig. 6. Root zone volumetric water content (VWC) analysis for each substrate for Experiment Two, 22 Jan 2015 - 22 Mar 2015. SCS = surfactant-coated perennial ryegrass (*Lolium perenne* L.) seed; CHK = uncoated seed. WSAND (100% hydrophilic or wettable sand); WSP (hydrophilic 90:10% v/v sand:peat); HSS (100% hydrophobic or non-wettable stearic acid-treated sand); and HSP (hydrophobic 90:10% v/v sand:peat). Imposed dry-down occurred on 4 and 13 Mar 2015. VWC means (*n*=4) with the " * " symbol indicates statistical significance according to Tukey's honestly significant difference test at $p \leq 0.05$; no symbol indicates not significantly different.

content as compared to CHK (Fig. 5). This improvement in water retention would be beneficial when seeding sites with limited access to precipitation or irrigation water.

In Experiment Two in WSAND and WSP, the VWC was significantly higher on only two evaluation dates in plots sown with SCS versus CHK (Fig. 6). In HSP, however, VWC again was significantly higher on most evaluation dates in plots sown with SCS versus CHK (Fig. 6). In HSS, no significant differences with VWC again were observed between SCS and CHK (Fig. 6). In both Experiments, the surfactant did not have an effect on VWC in HSS, and this may be related to the specific chemical properties of the surfactant and its interaction with synthetically produced hydrophobic surfaces (Fidanza et al. 2020, Zontek and Kostka 2012).

In conclusion, in both Experiments the CHK had twice the number of seeds sown compared to SCS, and yet final cover was not essentially doubled with CHK versus SCS. These observations indicate that soil surfactant-coated turfgrass seed represents an opportunity to improve emergence and stand establishment and improve rootzone soil-water dynamics in challenging environmental conditions of deficit irrigation, limited precipitation or irrigation, and hydrophobic soils.

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