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Using a Sprayable Biodegradable Polymer to Reduce Soil Evaporation in Greenhouse Conditions

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Summary

Sprayable biopolymer membranes (SBM) is an emerging mulching alternative to increase horticultural and agricultural productivity by reducing soil erosion and evaporative losses. The SBM is usually applied in liquid form directly to the soil surface where the polymer molecules form a thin biodegradable film. In order to test this technology, an experiment was performed in greenhouse conditions with the goal of quantifying the impact on soil evaporation rate and biomass accumulation in winter wheat.

Introduction

About 60% of the annual water supply in agricultural systems of the southern Great Plains is lost as soil evaporation, making evaporative losses the single greatest loss of water (Warren et al., 2009). Previous micro-lysimeter studies have shown that evaporative losses can account for 30% of the growing season water supply losses for corn on sandy and silt loam soils in western Kansas (Klocke, 2004). Scientists and stakeholders alike have tested several management strategies that reduce soil water evaporation. Long-known alternatives include the use of nylon, sand, and gravel mulching, but these alternatives involve costly or heavy products that require specialized machinery, which can make applications over large fields impractical. A common management strategy to reduce soil water evaporation in extensive agricultural fields is the adoption of no-tillage, which consists of leaving crop stubble on the soil surface after harvesting the preceding crop. However, no-tillage has proven effective to reduce evaporative losses compared to bare soil only when >75% of the soil surface is covered with crop residue, a value hard to achieve and sustain in environments such as central and western Kansas. An evaporation study in a fallow field using micro-lysimeters near Garden City, KS, showed that corn residue covering 25 to 75% of the soil surface caused no reductions in soil evaporation (Klocke et al., 2009). Intensive cropping and horticultural systems have long solved this problem using plastic mulches, but the products generated much plastic waste, which contributes to environmental pollution.

Sprayable biopolymer membranes are an innovative technology with potential to minimize evaporative losses and increase soil water storage in both rainfed and irrigated cropland. The SBM has several advantages over similar methods of moisture loss prevention strategies, such as plastic mulch coverings that are disposed of in landfills,

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because of its ability to naturally degrade over time and offer a high ease of application (Adhikari et al., 2015). This experiment aims to quantify the reduction in soil water evaporation using SBM. We hypothesize that the SBM will reduce evaporative losses and that actively growing plants will be able to take advantage of soil water remaining longer in the soil profile to shift evaporative unproductive losses into transpirational losses.

Procedures

The study was conducted in winter wheat (*Triticum aestivum* L.) under greenhouse conditions. A total of 20 plastic containers with a volume of 16 L (4.2 gallons) were filled with a loam soil to reach a target bulk density of 1.1 g cm^{-3}. The experimental design consisted of a randomized complete block design with three treatments and four replications. Blocking was necessary to account for the effect of a small thermal gradient in the greenhouse caused by the refrigeration and ventilation system. The treatments consisted of a check without the SBM and two rates of biopolymer. The treatments consisted of a 2:1 ratio of water to polymer at a low rate (LR, 8 mg cm^{-2} of active ingredient) and high (HR, 21 mg cm^{-2} of active ingredient) application rates. After packing the soil, we applied a solution consisting of 3 L (0.8 gallons) of tap water with 18 g (0.04 oz) of all-purpose Miracle-Gro fertilizer (24-8-16) to each container. After watering the pots, the containers were left covered for 24 hours to allow soil moisture to redistribute in the soil. A total of 25 seeds of winter wheat were planted in a cross formation per pot. The day following planting, we applied the two treatments of the biodegradable polymer. The biopolymer was applied with a handheld sprayer equipped with an automatic pump that kept the pressure constant at 30 psi during the application. After the application of the biopolymer treatments, the plants were left to grow in the greenhouse environment with the initial soil water content. One soil moisture sensor (Teros 11, Meter Group Inc.) was installed in each treatment to monitor near-surface soil moisture conditions over the extent of the experiment. Downward-facing pictures were taken weekly to monitor and record the plant growth in each container. At a midpoint in the experiment, the number of weeds was recorded prior to their removal. The mass of the containers was also recorded periodically to track the amount of mass lost due to evaporation. The experiment was terminated when the plants of the check treatment were under severe water stress and had signs of premature senescence. Biomass was determined by clipping above-ground stems and leaves and then drying them at 60°C (140°F) for 48 hours.

Results

The total evapotranspiration ranged from 2.54 to 2.61 mm (approximately 1 inch) over the 35 days of the experiment. The total amount of above-ground dry biomass for the check was 1.12 g, while the LR resulted in 3.0 g of above-ground biomass and the HR treatment resulted in 3.3 g of above-ground biomass. Because the total water loss was similar, but the amount of biomass produced in pots treated with the biopolymer was significantly different ($P < 0.01$) than the check, the water use efficiency (WUE) of the LR treatment was 2.76 higher than the check, and the WUE of the HR treatment was 2.95 times higher than the check.

The plants that received the check treatment did initially grow at a faster rate, but they were not able to sustain that growth rate for the duration of the experiment like the polymer treated plants. Figure 1 shows pictures of the check treatment and the high rate single treatment at the time of harvest. Plants in the check pot show declining health, compared with the healthy plant growth seen in the polymer treated plot. As an additional advantage to the application of the polymer, we observed a lower number of weeds compared to the check (Table 1). The SBM may represent a physical barrier that helps suppressing weed emergence.

The soil moisture dynamics also showed how the HR treatment, in part, delayed the soil water depletion, likely by reducing the evaporative rate (Figure 2). The LR treatment exhibited a similar time series as the check, but despite similar changes in soil moisture, the water losses could have been attributed to different evapotranspiration partitioning.

Preliminary results show that the SBM has potential to shift evaporative unproductive water losses into productive transpiration that results in greater biomass. Our study was confined to greenhouse conditions and only explored biomass production during the early stages of winter wheat. Future research efforts will be focused on longer growing periods in both greenhouse and field conditions.

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Table 1. Average initial pot mass, final pot mass, above-ground biomass, evapotranspiration (ET), and water use efficiency (WUE) for the three different treatments

Biopolymer treatment	Initial pot mass	Final pot mass	Aboveground dry biomass	Weed count	Total ET	WUE†
	kg	kg	g	number	mm	g/mm
Check	16.6	15.4	1.12	4	2.57	0.43 a
Low rate	16.2	14.7	3.0	0	2.54	1.19 b
High rate	16.5	14.8	3.3	0	2.61	1.27 b

† Water use efficiency computed as the above-ground dry biomass divided by the total evapotranspiration. Letters represent treatments that have means significantly different at 1% level using Fisher's least significant difference.

Figure 1. Downward-facing images of a pot with the check treatment (left) and the high rate biopolymer treatment (right) on the day of harvest (December 8, 2020). Plant on the right resulted in greater biomass over the study period with the same amount of water as the check treatment plant.

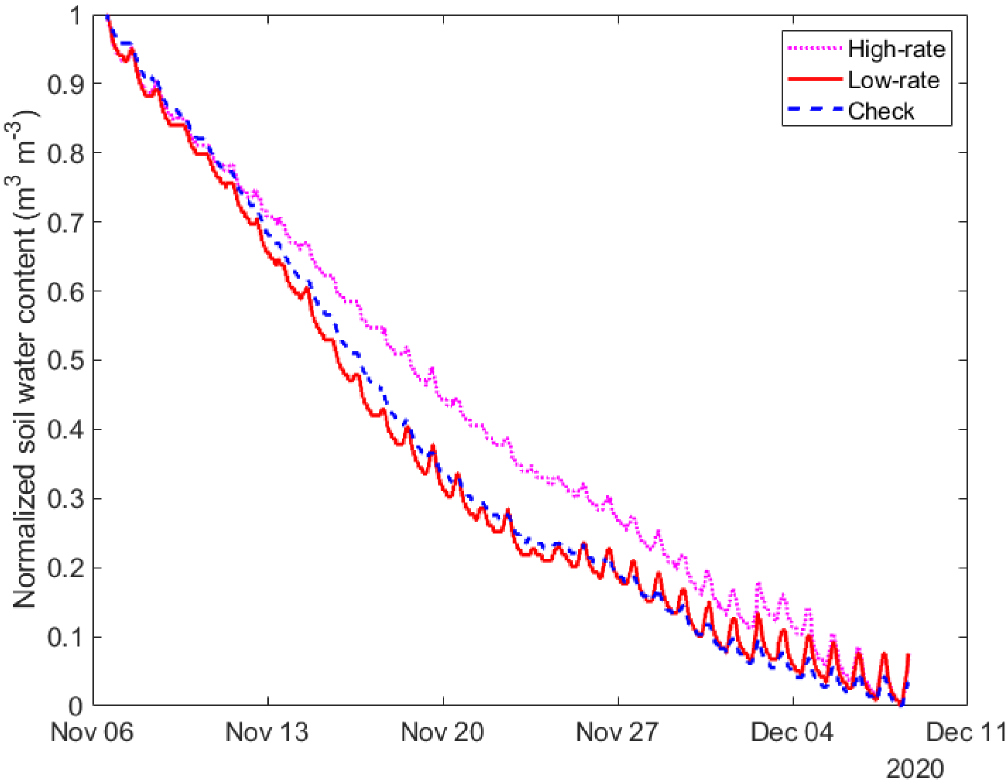

Figure 2. Normalized soil moisture dynamics for the check (no biopolymer), low application rate, and high application rate of the biodegradable polymer.