Water Relations and Cadmium Uptake of Wheat Grown in Soil with Particulate Plastics

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INTRODUCTION

Particulate plastics contaminate both the terrestrial and aquatic environments, as documented in a book edited by Bolan et al. (2020) (book-cover images shown in Fig. 1). Particulate plastics include both microplastics and nanoplastics (<100 nm in diameter). Particulate plastics in the aquatic environment have been widely studied. But those in the terrestrial environment, especially those from agriculture (Fig. 2), have received less attention, and essentially no information exists concerning the water relations of plants grown in soil with particulate plastics. Therefore, the first objective of this experiment was to determine the growth, evapotranspiration rate, and stomatal resistance of wheat when grown in soil with particulate plastics. Because particulate plastics can be a vector for toxic trace-element uptake (Bradney et al., 2019), the second objective of this experiment was to determine the uptake of cadmium in the presence of particulate plastics.

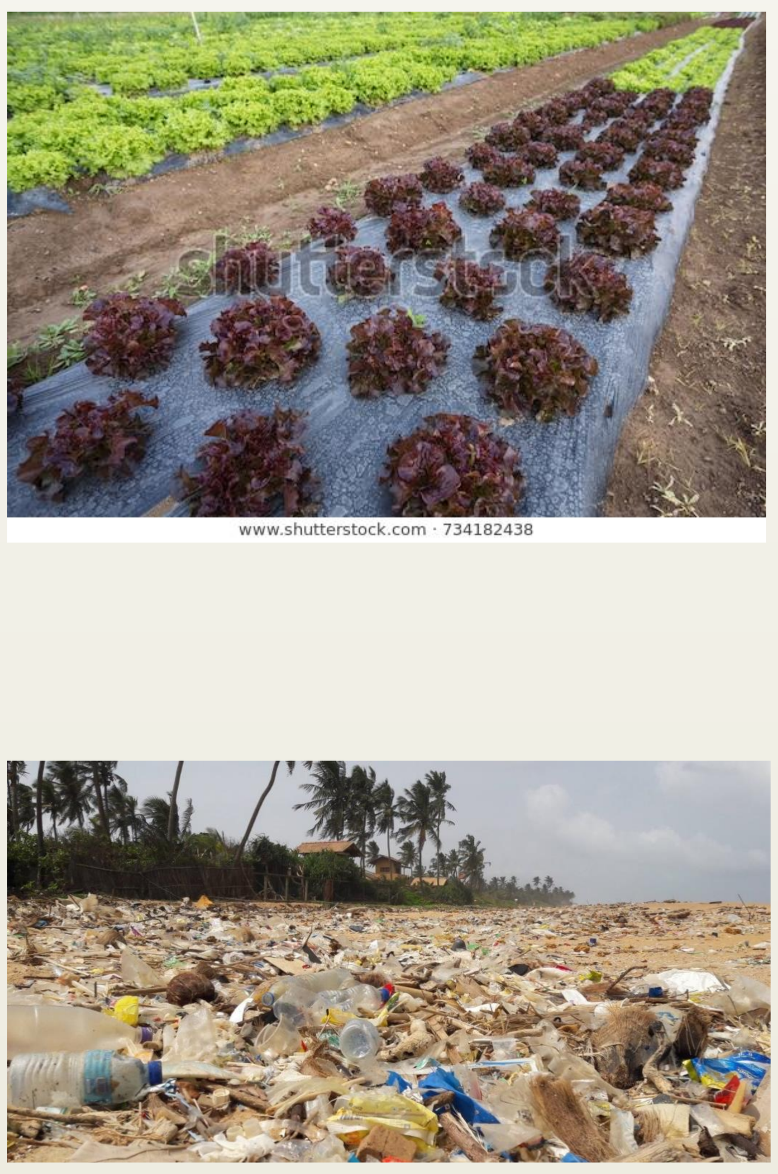

Figure 1 (left). Cover images for the book "Particulate Plastics in Terrestrial and Aquatic Environments." The upper image shows plastic mulch being used to grow agricultural crops. The bottom image shows a beach in Sri Lanka covered with plastic trash. The plastics break down into small pieces (particulate plastics), which then contaminate soils and waters.

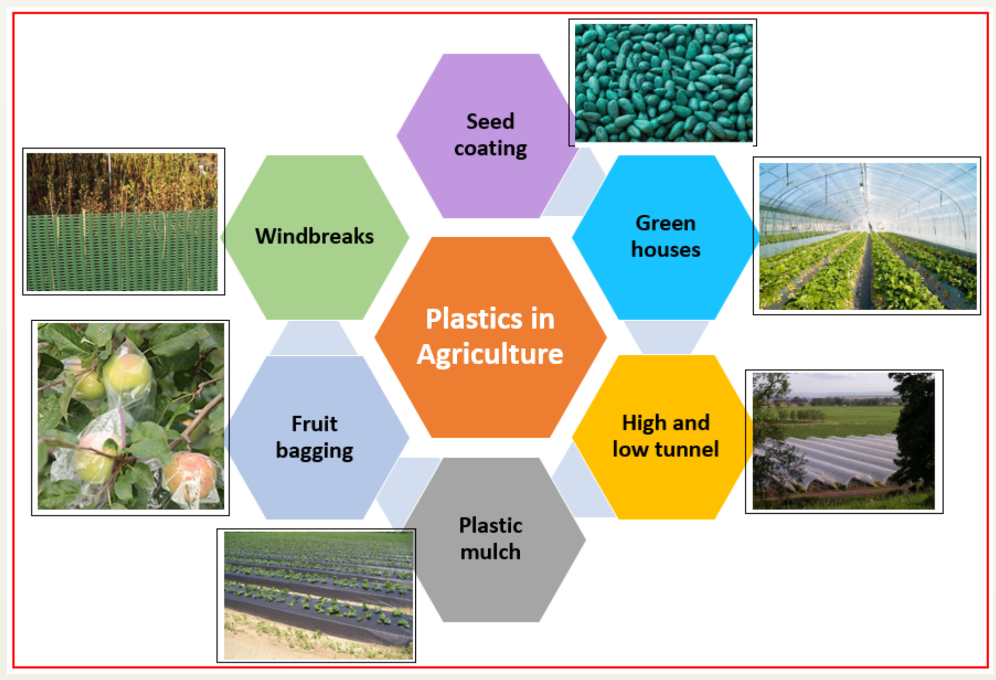

Figure 2 (above). Uses of plastics in agriculture. They include (from upper right and counterclockwise: green-houses; high and low tunnels; plastic mulch; fruit bagging; windbreaks; and seed coatings. The plastics break down and contaminate soils and waters.

MATERIALS AND METHODS

Wheat (*Triticum aestivum* L. 'Everest') was grown for 28 days under greenhouse conditions in pots (5 seeds per pot) with a commercial potting soil. The particulate plastic was polyethylene glycol with a molecular weight of 8000 (called PEG 8000). At the beginning of the experiment, pots were divided into three sets: pots with soil that received no PEG 8000 (called the no-PEG treatment); pots with soil into which dry PEG 8000 was mixed at a rate of 2% on a dry-weight basis (called the dry PEG treatment); and pots with soil that received PEG 8000 via irrigation of a 2% solution of PEG 8000 (call the wet-PEG treatment). The three sets of pots were divided in half, and during the experiment, half of the pots were irrigated with a 100 µg/mL Cd solution. The pots in the no-PEG treatment and dry-PEG treatment were irrigated with tap water or the 100 µg/mL Cd solution. The pots in the wet-PEG treatment were irrigated with a solution containing 2% PEG and no Cd or 2% PEG and 100 µg/mL Cd. Germination was measured, and ,during the experiment, height was measured with a ruler, evapotranspiration rate was determined by weighing the pots, and stomatal resistance was measured with a porometer (Model SC-1, METER Group, Pullman, WA). The experimental design was a strip-plot design. Means and standard errors were calculated.

RESULTS AND DISCUSSION

There was no difference in germination due to the Cd, so the pots with and without Cd were averaged together. Seeds germinated fastest in pots with PEG irrigated onto the soil (Fig. 3). The PEG probably covered the seeds and attracted water to the seeds, which allowed a few seeds to germinate fast. But the PEG solution did not allow the water to evaporate (as will be seen below), and the soil probably became anaerobic, which hindered further germination. By the end of the experiment, pots with PEG solution irrigated onto them had the lowest number of seeds germinate.

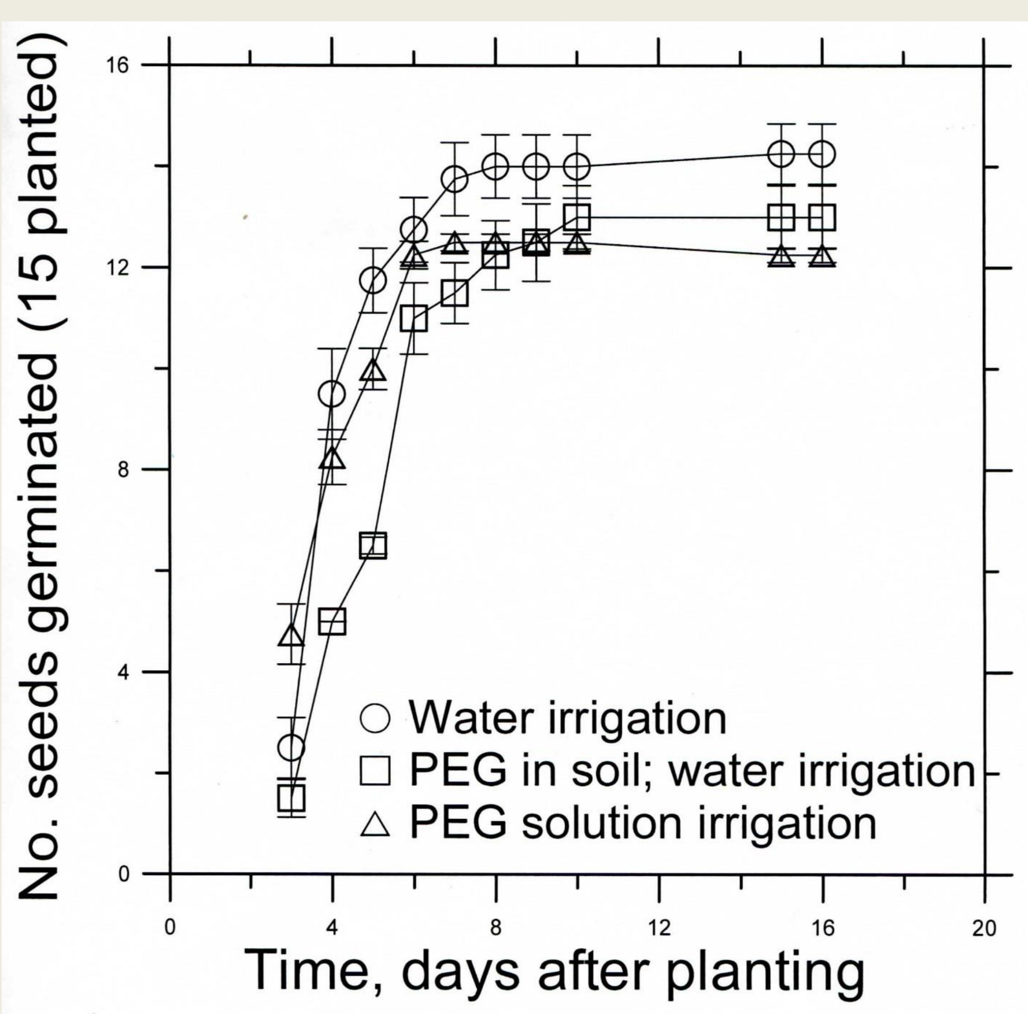

Figure 3 (left). Germination of wheat seeds in pots of soil with no polyethylene glycol 8000 (PEG 8000) and irrigated with tap water (circles); with dry PEG 8000 (2% w:w) mixed into the soil before planting and irrigated with tap water (squares); and with a 2% solution of PEG 8000 irrigated onto the soil without PEG 8000 in it (triangles). Five seeds were planted in each pot, and three pots under the same treatment were combined to get a data point. Mean and standard error are shown (n = 12).

RESULTS AND DISCUSSION (continued)

After germination, results for the plants in the no-PEG treatment were similar to those for plants in the dry-PEG treatment. Therefore, for measurements taken daily, only results for the plants without PEG and the plants irrigated with PEG will be shown. Both without Cd (Fig. 4, left) and with Cd (Fig. 4, right), 18 days after planting plants in the wet-PEG treatment were shorter than the plants in the no-PEG treatment. Plants grown with the PEG began to turn yellow at the end of the experiment. Cadmium had little effect on the height of the plants. However, plants grown with PEG irrigations and with Cd rapidly died off at the end of the experiment. Both without Cd (Fig. 5, left) and with Cd (Fig. 5, right), the evapotranspiration rate of plants in the wet PEG treatment was less than that of plants in the no-PEG treatment.

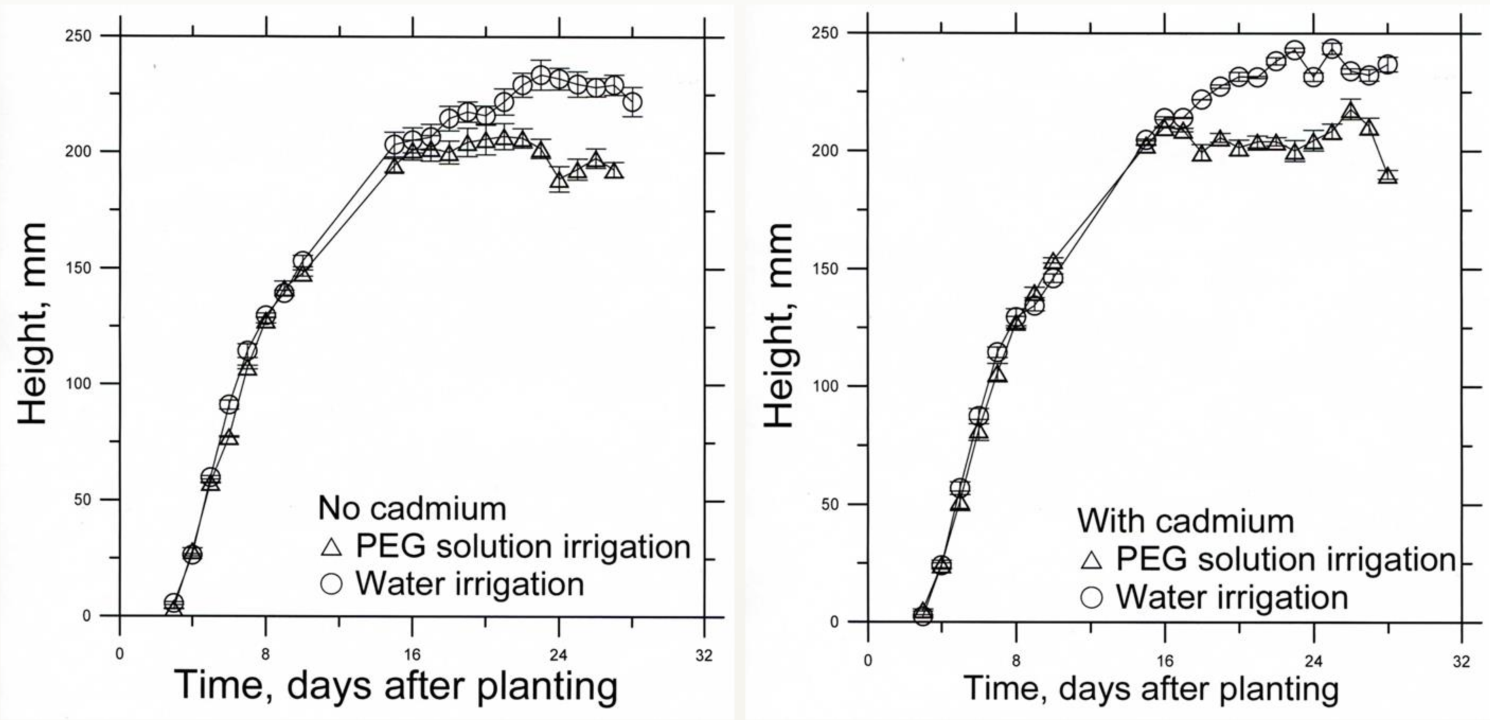

Figure 4. Height of wheat grown with water or PEG irrigations and without Cd (left) or with Cd (right). Mean and standard error are shown (n = 6).

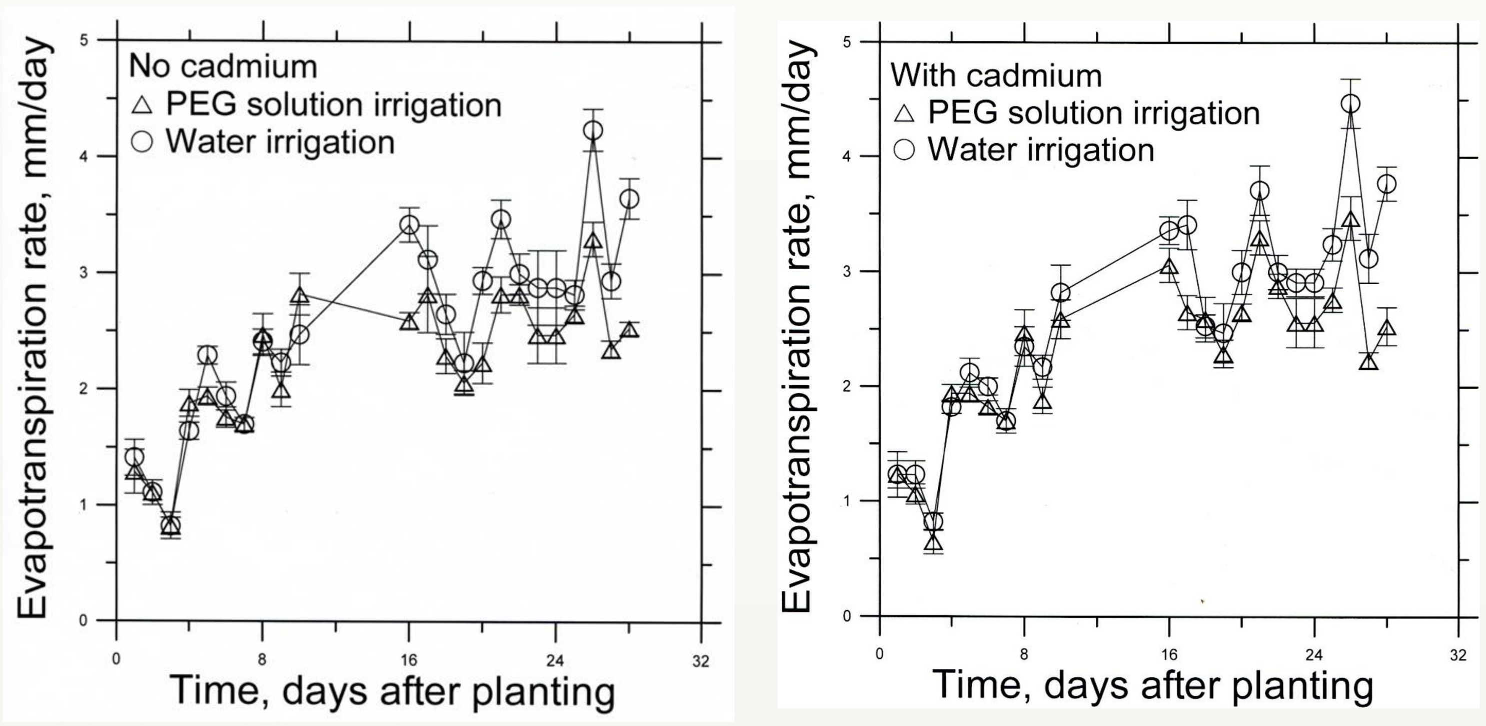

Figure 5. Evapotranspiration rate of wheat grown with water or PEG irrigations and without Cd (left) or with Cd (right). Mean and standard error are shown (n = 6).

Without Cd, the average stomatal resistances of plants grown in the wet-PEG treatment and in the no-PEG treatment were 295 s/m and 178 s/m, respectively (Fig. 6, left); for plants grown with Cd, these values were 322 s/m and 231 s/m, respectively (Fig. 6, right). Shoots of plants grown in the no-PEG treatment with Cd and in the dry-PEG treatment with Cd had an average Cd concentration of 130.0 mg/kg (Table 1). Plants grown in the wet-PEG treatment with Cd had a Cd concentration of 204.8 mg/kg. The presence of wet PEG in the soil increased the Cd in the plants by 1.5 times (204.8 vs.130.0 mg/kg).

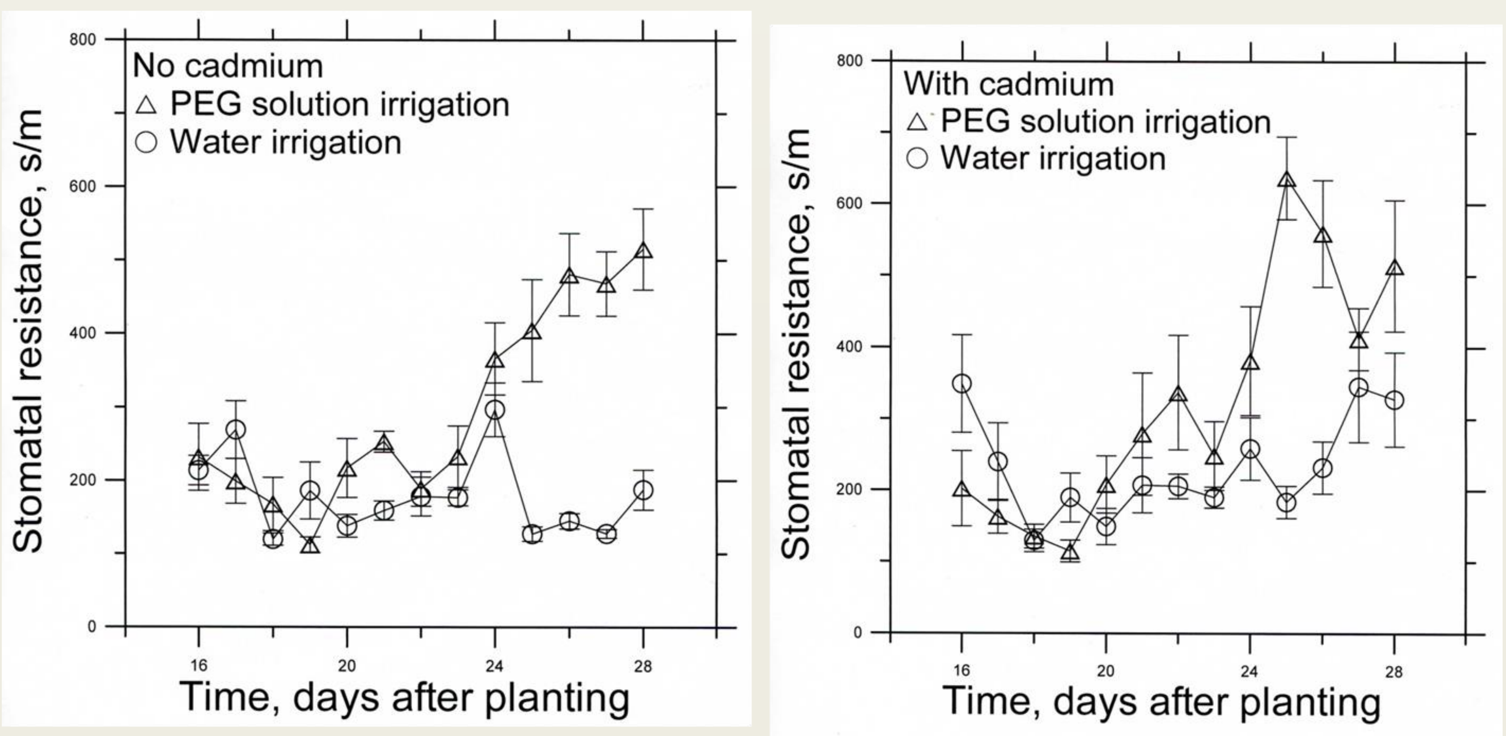

Figure 6 (left). Stomatal resistance of wheat grown with water or PEG irrigations and without Cd (left) or with Cd (right). Mean and standard error are shown (n = 6).

Table 1. Fresh weight, dry weight, and Cd concentrations of wheat plants grown with water or PEG irrigations and with and without Cd. Mean and standard error are shown (n = 6).

Treatment	Fresh weight, g	Dry weight, g	Cd in leaves, mg/kg
No PEG, Water irrigation	0.983 ± 0.105	0.133 ± 0.014	10.6 ± 4.3
No PEG, Cd in water irrigation	1.143 ± 0.048	0.156 ± 0.009	129.6 ± 9.0
Dry PEG, Water irrigation	0.919 ± 0.119	0.127 ± 0.017	5.7 ± 3.9
Dry PEG, Cd in water irrigation	1.031 ± 0.084	0.140 ± 0.010	130.5 ± 24.4
Wet PEG irrigation, No Cd	0.924 ± 0.115	0.119 ± 0.012	7.3 ± 2.2
Wet PEG irrigation, With Cd	0.811 ± 0.067	0.122 ± 0.010	204.8 ± 33.7

CONCLUSIONS

Polyethylene glycol irrigated onto soil reduced the plant growth and evapotranspiration rate of wheat and increased its stomatal resistance. The observations of Bradney et al. (2019) were confirmed. That is, polyethylene glycol was a potent vector for the transport of the toxic trace element, Cd, to leaves. When soil was irrigated with a PEG solution containing Cd, wheat plants had 1.5 times more Cd in the shoots (204.8 mg/kg) than plants irrigated with Cd without PEG (130.0 mg/kg). The results suggest that if particulate plastics are in water used to irrigate plants on soil contaminated with Cd, the Cd will be more readily taken up than if the particulate plastics are not present.

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