Effect of irrigation by contaminated water with cloth detergent on plant growth and seed germination traits of maize (*Zea mays*)

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Abstract: People are worried about effect of household cleaning products in the environment. One of the sources of detergent is sewage that is being used for irrigation of the crops. A laboratory experiment and a pot experiment were conducted in 2012 to determine the effect of irrigation with different doses of detergent on plant growth and seed germination traits of maize (*Zea mays*). The experiments included eight doses of cloth detergent (0, 0.00002, 0.0002, 0.002, 0.002, 0.02, 0.2, 2, 20 g/L). Results showed that 20 g/L of detergent severely reduced seed germination and root length. 20 and 2 g/L of detergent reduced shoot length and seedling weight. 20 g/L of detergent produced the lowest leaf area, leaf weight, stem weight and total biomass. The results demonstrated that irrigating by the sewage contaminated by household cleaning products at high concentration should be avoided.

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Key words: Detergent; maize; seed germination; seed vigor; specific leaf weight

1. Introduction

People are worried about effect of household cleaning products in the environment. Sewage contains great deal of the product. Using sewage for irrigation is increasing for crop production. Jadia and Fulekar (2008) reported that the lower concentration of heavy metals increased root growth, shoot growth and biomass production of sunflower (Helianthus annuus). Contamination doses of 4 and 5 % of spent diesel fuel had 40% seed germination for maize (Zea mays) and 22% for peanut (Arachis hypogaea) respectively compared to control (Ehiagbonare et al., 2011). In alfalfa (Medicago sativa), 5 ppm of Cd(II) reduced shoot size by 16% compared to the control, but Cr(VI), Cu(II), Ni(II), and Zn(II) increased the shoot size by 14.0%, 60.0%, 36.0%, and 7.7%, respectively (Peralta et al, 2000). Seed germination percentage of ryegrass (Lolium multiflorum) was decreased with increasing concentrations of chlorpyrifos (pesticide) in the soil (Korade and Fulekar, 2009). Maize is one of the most important warm season crops in Iran. There is little information about effect of detergent on seed germination and plant growth, so the objective of this study was to determine maize growth and seed germination traits at different doses of detergent powder.

2. Materials and Methods 2.1. Experiment 1

The experiment included eight doses of detergent powder (T1=20, T2=2, T3=0.2, T4=0.02, T5=0.002, T6=0.0002, T7=0.00002, T8=0 g/L). Chemical ingredient of studied cloth washing powder included sodium alkyl benzen sulfonate, nonil phenol

etoxilate, sodium silicate, sodium carbonate, sodium sulphate, sodium toluene sulfonate, acrylate polymer, optical brightner, bleach, builder, essence.

The study was conducted as a randomized complete block design with three replications in 2012. Seeds of maize (Zea mays, C.V. S.C. 704) were gathered from maternal plants harvested in 2011. After harvesting seeds from maternal plants, they were stored at 25°C for six months. Before trial beginning, seeds were sterilized by sodium hypochlorite solution (1% active chlorine) for 10 minutes to avoid fungal contamination. Then each Petri dish received 20 seeds and 8 cc of solution was added to them. The control solution (0 g/L) used in this study was distilled water. The Petri dishes were categorized by dose and each category was sealed with plastic wrap to keep moisture in. The temperature during experiment period was kept at $26 \pm 1^{\circ}$ C. Two millimeters growth of coleoptile and radical was the criterion for germination. The trial period was 7 days. Seed vigor was estimated by these equations (Sharifzadeh et al, 2006; Abasian et al, 2010):

Seed vigor (% cm) = [(Radicle length (cm) + Caulicle length (cm)) * (Germination percentage (%))] Seed vigor (% g) = [(Radicle weight (g) + Caulicle weight (g)) * (Germination percentage (%))]

2.2. Experiment 2

Plant materials, experimental design and treatments: The pot experiment was conducted in 2012 at Faculty of Agriculture, University of Razi, Kermanshah, Iran. Maize seeds (*Zea mays*, CV S.C. 704) were planted in 24 pots (7 cm in diameter, 7.5 cm in depth) on Jun 26, 2009. The pots were filled with

clay soil. Seeds were densely sown 1 cm deep but after emergence seedling were thinned to five plants per pot. Plants were initially well-watered and treatments of irrigation with contaminated water were only imposed 8 days after sowing. 336 mg nitrogen per 1 kg of soil as urea was used for nourishing plants after 17 days from sowing. The study was involved a factorial experiment in a randomized complete block design (RCBD) with three replications. The treatments were different detergent doses. There were eight doses of contaminated water with cloth detergent for irrigation: T2=2, T3=0.2, T4=0.02, T1=20, T5=0.002, T6=0.0002, T7=0.00002, T8=0 g/L). At each irrigation event, enough water was allowed to be absorbed by the soil in each pot, and any excess water was allowed to drain.

Plant sampling and measurements: Leaf Area (LA) was measured using LA=Leaf Width * Leaf Length * 0.75 (Chaab et al., 2009). LA and Leaf Dry Weight (LDW) were used to calculate Specific Leaf Weight (SLW) as:

SLW = LDW/LA

Measurement of dry weight, leaf to stem ratio, specific leaf weight and leaf dry weight was carried out by five plants while plant height, leaf number per plant and leaf area were measured by random selection of three plants per each pot. Harvest time for total dry weight was 23 days after sowing and plant samples were dried in a forced-air oven at 65 °C for 2 days.

2.3. Statistical analysis

Analysis of variance (ANOVA) was used to determine significant differences. The Multiple Range Test of Duncan performed the separation of means (P < 0.05). Correlation coefficients were calculated for the relationship between several crop parameters. All statistics were performed with the program MINITAB (version 14.0), SAS (version 9.1) and SPSS (version 16.0).

3. Results and Discussion

3.1. Experiment 1

Seed germination percentage: The highest dose of detergent (T1) reduced seed germination severely compared to other treatments (Table 1). Control (T8) had higher seed germination than T1 and T6. Seed germination percentage had a positive and

significant correlation with all traits (Table 2). It was reported that the seed germination of *Lolium multiflorum* was not affected by the anthracene amended in the soil (Korade and Fulekar, 2009). The results are compatible with findings of Ehiagbonare et al (2011), Barua et al (2011) and Ashraf and Ali (2007). Reduction in seed germination may be due to induced oxidative stress, resulting in lipid peroxidation and increase in cell membrane permeability to toxic ions (Hejazi Mehrizi et al, 2012).

Shoot length: High doses (T1, T2) of detergent reduced shoot length (Table 1). Shoot length had a positive and significant correlation with all traits (Table 2). Jadia and Fulekar (2008) reported that increasing doses of cadmium to sunflower grown at pot increased shoot length compared to control. Reduction in shoot length is probably due to oxidative stress.

Root length: The highest dose of detergent (T1) reduced root length severely compared to other treatments (Table 1). Root length had a positive and significant correlation with all traits (Table 2). Jadia and Fulekar (2008) reported that increasing doses of cadmium to sunflower grown at pot reduced root length compared to control. Plants under high osmotic potential cannot uptake water to initiate seed germination processes and other stresses such as heavy metal stress and salinity stress can increase root damage.

Seedling weight: T7 and T8 had higher seedling weight than T1 and T2 (Table 1). Seedling weight had a positive and significant correlation with all traits (Table 2). High osmotic potential due to high concentration of detergent does not let seed absorb required water for starting metabolic activities and probably production of oxygen free radical at the condition can damage cell membrane (Sharifzadeh et al, 2006).

Seed vigor: T1 had the lowest seed vigor (Table 1). Seed vigor had a positive and significant correlation with all traits (Table 2). Reduction in seed vigor due to high doses of detergent can be described by higher osmotic water potential, salinity and heavy metal stresses (Sharifzadeh et al, 2006; Jadia and Fulekar, 2008).

^a Treatments	Germination (%)	Shoot length (cm)	Root length (cm)	Seedling weight (g/plant)	Vigor (% g)	Vigor (% cm)
T1	11.67 d	0.79 d	1.23 b	0.0077 c	0.0010 c	0.240 b
T2	83.33 abc	2.93 c	11.76 a	0.0313 b	0.0262 b	12.348 a
Т3	88.33 abc	4.49 ab	12.50 a	0.0360 ab	0.0319 ab	15.029 a
T4	95.00 a	4.47 ab	13.01 a	0.0387 ab	0.0367 a	16.612 a
T5	91.67 ab	5.29 a	12.95 a	0.0387 ab	0.0356 ab	16.806 a
T6	78.33 c	4.94 ab	11.33 a	0.0393 ab	0.0310 ab	12.773 a
T7	80.00 bc	3.52 bc	13.86 a	0.0420 a	0.0337 ab	13.921 a
T8	91.67 ab	5.13 a	11.73 a	0.0413 a	0.0379 a	15.540 a

Table 1. Effect of detergent doses on maize seed germination traits.

^aT1=20, T2=2, T3=0.2, T4=0.02, T5=0.002, T6=0.0002, T7=0.00002, T8=0 g/L

	Germination percent	Shoot length	Root length	Seedling weight	Vigor weight	Vigor length
Germination percent	1	.877**	.963**	.935**	.972**	.988**
Shoot length	.877**	1	$.807^{*}$.890**	.917**	.906**
Root length	.963**	$.807^{*}$	1	.957**	.954**	.960**
Seedling weight	.935**	.890**	.957**	1	.981**	.945**
Vigor weight	.972**	.917**	.954**	.981**	1	.985**
Vigor length	.988**	.906**	.960**	.945**	.985**	1

Table 2. Pearson's correlation coefficients among studied traits in maize under different doses of cloth detergent

*.Correlation is significant at the 0.05 level; **.Correlation is significant at the 0.01 level

3.2. Experiment 2

Plant height and leaf number per plant: High doses of detergent (T1 and T2) reduced plant height and leaf number per plant (Table 3). T1 had the lowest plant height and leaf number per plant. Plant height and leaf number per plant had a positive and significant correlation with most traits (Table 4). In rosemary, increasing salinity was associated with a significant increase in the electrolyte leakage and lipid peroxidation (Hejazi Mehrizi et al, 2012). Reduction in plant height is an obvious effect of salinity. This decrease in plant height may be attributed to intelligent response of plant to prevent shoot transpiration (Karam et al, 2003), reduction of cell size and internodes length and accumulation of Abscisic Acid (Sharp, 1996).

Leaf area and leaf weight: T1 produced the lowest leaf area and leaf weight (Table 3). T7 had higher leaf weight than T8. It is probably due to that under low dose of detergent, soil can be sterilized against microbes or maybe some elements present in detergent such as sulphate can be readily absorbed by plant. Increasing doses of cadmium to sunflower increased shoot length compared to control (Jadia and Fulekar, 2008).

Stem weight and total biomass: High doses of detergent (T1) reduced stem weight and total biomass compared to control (T8) (Table 3). T7 produced higher stem weight and total biomass. Like leaf

weight it may be attributed to sterilizing soil against microbes or absorbing some elements present in detergent such as sulphate. Total biomass had a positive and significant correlation with most traits except specific leaf weight (Table 4). Elevated salinity reduced water uptake by seeds, thereby inhibits root elongation (Rahimi et al, 2006). Presence of elements such as Na in contaminated water can inhibit activities of some enzymes and decrease availability of some nutrients (Al-Taisan, 2010). Lower biomass accumulation under higher doses of contaminated water by detergent powder can be explained by three stresses; salinity stress, water stress and heavy metal stress (Sharifzadeh et al, 2006; Jadia and Fulekar, 2008).

Leaf to stem ratio and specific leaf weight: T2 had higher leaf to stem ratio (Table 3). It is due to that under T2, maize saved its leaf weight, but its stem weight was reduced severely compared to leaf weight (Table 3). These data show that by increasing detergent dose, the leaf became thicker (higher specific leaf weight) and its leaf area was reduced (Table 3). Pace and Benicasa (2010) reported similar results. T1 had the highest specific leaf weight (Table 3). Similar result was reported by Alyemeny (1998). Save et al (1993) reported that water stress resulted in decreasing cell size and increasing solute concentration so specific leaf weight increases under high level of detergent stress.

Table 3. Effect of contaminated water by different doses of detergent powder on maize traits

Treatments	^b Plant height (cm)	Leaf number per plant	Leaf area (cm ² / plant)	Stem weight	Leaf weight (mg/plant)	Leaf to stem ratio	Total biomass	Specific leaf weight (mg/cm ²)
				(mg/plant)			(mg/plant)	
T1 ^a	12.2 c	2.3 d	6.44 b	16.0 d	33.87 c	2.11 b	49.87 c	4.53 a
T2	29.4 b	2.9 c	40.07 a	28.9 c	80.13 ab	2.88 a	109.07 b	2.04 b
Т3	33.9 ab	3.2 abc	38.34 a	38.9 ab	83.00 ab	2.13 b	121.93 ab	1.81 b
T4	35.4 a	3.5 a	47.04 a	41.0 ab	85.60 ab	2.09 b	126.60 ab	1.51 b
T5	34.9 a	3.1 bc	46.41 a	36.8 bc	92.13 ab	2.53 ab	128.93 ab	2.05 b
Т6	32.3 ab	3.4 ab	37.81 a	42.1 ab	83.20 ab	1.98 b	125.27 ab	1.90 b
Τ7	35.9 a	3.2 abc	45.85 a	46.7 a	98.93 a	2.11 b	145.68 a	2.16 b
Т8	32.8 ab	3.4 ab	33.07 a	35.8 bc	75.73 b	2.12 b	111.53 b	2.31 b

^a T1, T2, T3, T4, T5, T6, T7 and T8 are different doses of contaminated water by detergent powder (T1=20, T2=2, T3=0.2, T4=0.02, T5=0.002, T6=0.0002, T7=0.00002 and T8=0 g/L respectively).

^b Means followed by the same letter within each column are not significantly different at P < 0.05 as determined by Duncan's Multiple Range Test.

	Plant height	Leaf number per plant	Leaf area	Stem weight	Leaf weight	Leaf to stem ratio	Total biomass	Specific leaf weight
Plant height	1	.896**	.954**	.922**	.965**	.023	.970**	948 ^{**}
Leaf number per plant	.896**	1	$.784^{*}$.881**	$.780^{*}$	273	.829*	882**
Leaf area	.954**	.784*	1	.850**	.973**	.218	.952**	938**
Stem weight	.922**	.881**	.850**	1	.909**	283	.958**	836**
Leaf weight	.965**	$.780^{*}$.973**	.909**	1	.136	.990**	900***
Leaf to stem ratio	.023	273	.218	283	.136	1	.000	118
Total biomass	$.970^{**}$.829*	.952**	.958**	.990**	.000	1	898**
Specific leaf weight	948**	882**	938**	836**	900**	118	898**	1

Table 4. Pearson's correlation coefficients among studied traits in maize under different doses of contaminated water by detergent powder

*.Correlation is significant at the 0.05 level; **.Correlation is significant at the 0.01 level

4. Conclusion and Suggestions

Cloth detergent powder in high concentrations (2 and 20 g/L) can reduce seedling weight, seed vigor and leaf number per plant of maize probably by means of high osmotic potential, oxidative stress, salinity stress and heavy metal stress. At early growth stage, most maize growth parameters showed a reduction initiated from 2 g/L of detergent powder. Germination stage was more sensitive to detergent than the next stage (early growth stage). However under lower doses (< 2 g/L), the adverse effects of detergent were not observed, it is need to test plant quality traits to suggest this dose. Due to little information about effect of detergent powder, it is recommended to study effect of detergent on wide range of crop plants to find the tolerant crops for irrigation with contaminated water.

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