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Effect of Detergents from Greywater on Irrigated Plants: Case of Okra (*Abelmoschus esculentus*) and Lettuce (*Lactuca sativa*)

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Abstract: Laundry detergent containing anionic surfactants was used to test their effects on plant growth through irrigation water. Lettuce and okra were cultivated in pot experiment and irrigated with distilled water containing domestic detergent at three different concentrations: low concentration (LC) of 0.1 g L^{-1}; normal concentration (NC) of 1.0 g L^{-1} and high concentration (HC) of 5.0 g L^{-1} and distilled water (DW) used as control. The experiment was conducted during three months from July to October in a green house in Ouagadougou, Burkina Faso. Lettuce leaves, okra fruits and both crops shoots were measured at harvest period as dry and/or fresh weights. Soil pH and electrical conductivity (EC) were analyzed to evaluate changes caused by watering. Soil pH and EC tended to increase with detergent concentration in irrigation solutions. They were no significant difference in okra's fruit growth (fresh and dry weight) for DW, LC and NC treatments. However plants in HC died 20 days after planting (DAP). Similarly, no significant difference was noticed in lettuce shoots (dry weight) between LC, NC and DW treatments but lettuce in HC died 12 DAP. After harvest, irrigated soils EC for all treatments were significantly increased in contrast to pH where no significant difference was obtained.The study show that more than 1.0 g L^{-1} of laundry detergent can inhibit plant growth and application of high concentrate greywater on detergent can exacerbate soil salinity.

Key Words: Greywater, Irrigation, Laundry detergents, Soil salinity, Surfactants

1. Introduction

Water scarcity is an ever-increasing concern worldwide. The reasons are manifold including low rainfall and excessive demand due to the combined effect of increased water consumption per capita and population growth. Population has increased at a rate faster than food production and will add up to 3 billion more people by the middle of the twenty-first century, mostly in poor and water - short countries (Jury *et al*., 2007). One important consequence of population growth is the necessity of wastewater reuse particularly in the Sahelian area that suffers from the consequences of climate change. In this context wastewater reuse in agriculture seems to be the most explored strategy in most water management programs as agriculture is by far the leading user of freshwater worldwide, accounting for almost 85% of global consumption (Jury *et al*., 2007). Wastewater reuse in agriculture requires implementation of good practices and particular attention to the protection of environment.

Along with the irrigation plans in the urban centers with conventional wastewater treatment systems, greywater (GW) reuse appears as the right solution for rural and peri-urban areas. Greywater includes all washing domestic water produced with the exception of the toilet water. Despite its apparent clarity these waters should not be used directly on crops without sufficient treatment as it is often the case (Gross *et al*., 2007). Generally greywater is the result of the using of detergents, vegetable oils, soaps, water and other kitchen and washing residues. Indeed, grey water is often a source of elevated levels of compounds such as surfactants, oils, boron and salt which can alter soil properties, damage plants and contaminate groundwater (Travis *et al*., 2008; Wiel-Shafran *et al*., 2006). Detergents are used in several domestic washing activities. Their efficiency is due to presence of surfactants (surface -active agents) together with components which provide cleaning and solubilization properties. Surfactants in prepared irrigation solutions with detergent water have been recognized as a major contributor to the reduction of hydraulic conductivity of soils and as component that can lead to water repellent soils with adverse impacts on agricultural productivity and environmental sustainability (Lado and Ben-Hur, 2009; Shafran *et al*., 2005). When untreated greywater is used to irrigate plants growing in soil, the fate of surfactants in greywater irrigated soil-plant systems is not well known (Misra *et al*., 2012).

Therefore this work aimed to evaluate the impact of laundry detergents on lettuce (*Lactuca sativa*) and okra

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Table 1. Properties of the soil used for experiments.

Properties	Mean value
Sand % (2.0-0.02 mm)	51.8
Silt % (0.02-0.002 mm)	28.7
Clay % (<0.002 mm)	19.5
Organic matter %	2.5
pH (soil-water ratio 1:2.5)	6.4
EC (µS.cm^{-1})	311
Bulk density of soil	1.6
Sodium Adsorption Ration (SAR)	3

(*Abelmoschus esculentus*), two common plants in Sahelian region. The plants behavior after the application of three different concentrations of detergent was studied and plants growth was measured and compared.

2. Material and Methods

2.1. Experimental design

The experiment was conducted in a green house on the experimental agricultural field station of the International Institute for Water and Environmental Engineering (Ouagadougou, Burkina Faso). The study was conducted with six (6) liter cultivation pots. Local field sandy-loam soil has been used for crop cultivation during July to October. Soil was sieved to reduce aggregate size with a 2 mm porosity sieve. The properties of soil used for the experiments are shown in **Table 1**. The pots were perforated and a system of wick and gravel provided aeration for the bottom and allowed the collection of drainage.

Lettuce was selected because of its short life cycle and its sensitivity to environmental conditions (Castillo *et al*., 2000) and surfactants (Eriksson *et al*., 2006). Okra was chosen because it is a popular tropical leafy vegetable, well-known and appreciated in the sub-Saharan area as its fruits can be harvested and dried for off-season consumption (Nana *et al*., 2009). Four (4) replicates were conducted for each crop and for each watering greywater solution. At least 32 cultivation pots for the experiment were used during around seventy (70) days treatment.

2.2. Irrigation treatments

For the watering of crops, distilled water (DW) and three (3) watering solutions were prepared by dissolving in distilled water respectively 0.1 gram (low concentration, LC), 1 gram (normal concentration, NC) and 5 grams (high concentration, HC) of a commercial laundry detergent (Omo, manufactured by Unilever). Prior to irrigation, each watering solution was freshly prepared to assure consistency and repeatability. Frequency of irrigation varied over time and crop so as to satisfy the daily water needs of both cultures to avoid any hydric stress (Misra *et al*., 2012; Nana *et al*., 2009) : 65 ml every day for lettuce and 130 ml every two days for okra.The properties of the watering solution were described in the **Table 2**.

Table 2. Irrigation solutions selected parameters value.

Watering solutions	DW	LC	NC	HC
pH	6.9	9.1	9.9	10.2
EC (µS.cm^{-1})	28	159	1082	4870
LAS (mg.L^{-1})[a]	nd	13.5	135.6	678
Ntotal (mg.L^{-1})[a]	nd	0.01	0.12	6.6
Ctotal (mg.L^{-1})[a]	nd	15.3	153	765.1
Ptotal (mg.L^{-1})[a]	nd	13.2	132.3	661.6

nd : not detected.

a: concentrations estimated based on the findings of the analyzes of the detergent used.

2.3. Chemical measurements and statistical analyses

The pH and electrical conductivity (EC) of irrigation water samples were measured with a pH meter and a conductivimeter fitted with calibrated electrodes using the manufacturer WTW instructions. For soils, pHw and EC were determined respectively in a soil-distilled water suspension of 1-2.5 and 1-5. Total C and Total N in the detergents were measured by Sumigraph NC-220F (Sumika Chemical Analysis Service, Japan). Total phosphorus (P), was analysed by ascorbic acid method using a spectrophometer at 880 nm (Hack Lange, DR 5000). Linear alkylbenzene sulphonate (LAS) which is one of surfactant widely used in the world (Cirelli, 2008), were assesed by LC/MS (W3100, Waters) following Huelgas and Funamizu (2010) method but the separation condition of LC/MS was slightly modified to isocratic mode with 60% of 0.2 mM ammonium acetate and 40% of acetonitrile. The concentration of Na, Ca and Mg were determined by atomic absorption spectrometry with flame analyzer (Perkin Elmer; Model Analyst 200).

Plant growth parameters were measured every week. At harvest, shoots were severed close to the soil surface and sorted into stems and leaves. The root system of each plant was removed from soil after overnight soaking of each pot in tap water. The whole root system of the plant with some soil attached to the root system was removed first. The remaining soil with roots was washed over a sieve with a 2 mm pore size to reduce root loss during washing. Fresh roots were dried with a paper towel before drying at 70°C for 48 hours in a convection oven to determine dry weight. The dry weight of stems and leaves of all plants was also measured in a similar way. Statistical analysis was conducted with SPSS statistic

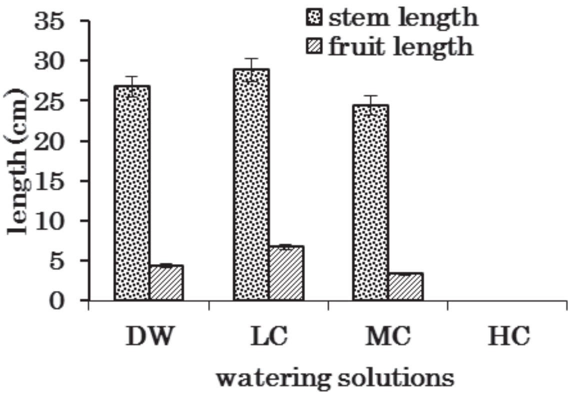

Fig. 1. Effects of different irrigation waters on okra stem and fruit length.

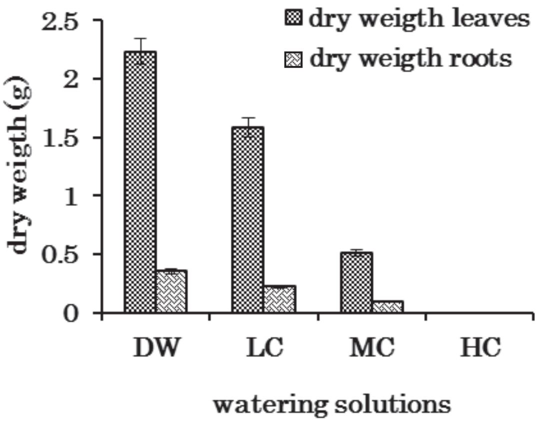

Fig. 2. Effects of different treatments on lettuce root and leave dry weight.

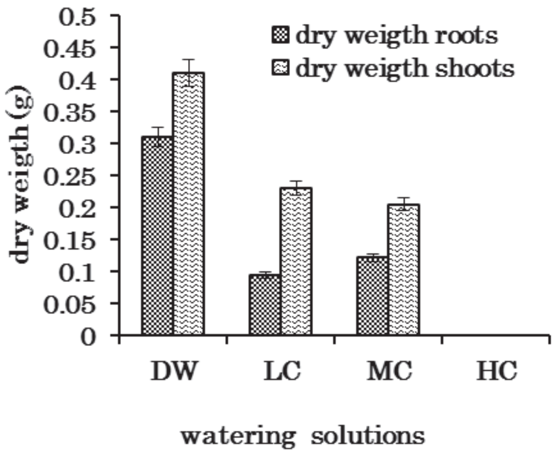

Fig. 3. Effects of different irrigation waters on okra root and shoot dry weight.

Table 3. Soil pH and EC values before and after cultivation in a green house during around 70 days.

	pH		EC ($\mu S.cm^{-1}$)	
	lettuce	okra	lettuce	okra
Initial soil	6.4±0.2	6.4±0.2	311±7	311±7
Distilled water	8.2±0.2	8.3±0.3	149±6	178±13
Low conc.	8.3±0.2	8.3±0.2	187±9	211±12
Normal conc.	8.3±0.3	8.5±0.3	433±17	437±26
High conc.	8.5±0.2	8.7±0.2	1537±23	1772±52

conc.: concentration.

21 software (IBM). Significant difference in each comparison group was evaluated with one-way ANOVA and turkey-HSD test (p<0.05) underequal variance (F-test, p>0.05). In the case of unequal variance, Dunnett test was conducted.

3. Result and Discussion

Higher concentration of detergent led to higher pH and EC of irrigation waters. The pH and EC of MC values were comparable to those of grey water used in previous studies (Pinto *et al*., 2010; Wiel-Shafran *et al*., 2006). The increase of detergent concentration leads to more salts in irrigation waters. The salinity of the treatment with 5 grams of detergent (HC) was around 1800 $\mu S\ cm^{-1}$. This is very high compared to the normal salinity level in laundry greywater given by Anwar Faisal (2011). This means, irrigation with HC could have negative effect on plant production and health. Therefore, this can explain the death of plants in all the pots irrigated with high concentration of detergent. Indeed for the concentration of 5 g L^{-1}, there was slow growth of plants and the complete death of plants during the 20th DAP for okra and 12th DAP for lettuce. Okra is therefore more resistant to salts than lettuce.

For okra, the plants irrigated with LC had the best results in term of fruit and stems length (**Fig. 1**).

The results show an increasing of organic mater and nutrient with the quantity of detergent in the treatment solutions. This contribution of organic matter and nutrients through greywater can explains the good behavior of plants in the pots watered with LC. Increasing the concentration of surfactants and salts explains the decrease in the length of stems and fruits when we pass from LC to NC.

Figures 2 and **3** show the effects of the different irrigation solutions on the shoot and root dry biomass. The results obtained are in the following order DW > LC > NC > HC both for okra and lettuce (Figs. 2 and 3). The statistical analyses indicate that shoot and root dry biomass were significantly affected by the irrigation with HC. As reported in previous studies, the high contents of salts combined to the action of other pollutants such as surfactants led to the gradual degradation of soil structure and affected plant health (Wiel-Shafran *et al*., 2006; Gross *et al*., 2005).

Table 3 summarized the pH and EC values of cultivated soil before and after crops harvest. There was no significant difference of soil pH for watering solution. Compared to initial soil, pH values increased from 6.4 to 8.5 and 8.7

respectively for lettuce and okra. The same range of increase has been reported by Anwar Faisal (2011) who reported that high pH liquids act as dispersing agents, causing the soil particles to separate and led to soil structure decline. The normal pH range for vegetables biological activity is between 5 to 9. Finally he concluded that, if pH value reached more than 9, biological activity would decrease and dissolved organic material could leach out of soil. On the other hand, there is a large gap between the DW EC compared to irrigated soil. This increase in soil pH and EC after greywater application has been also noted by Pinto *et al.* (2010) in a similar study. This can be explained by a contribution of nutrients to the soil by irrigation solutions through the detergent (Fig. 2).

4. Conclusions

The use of water with high concentrations of detergent is not suitable for application in agricultural irrigation, because they have a very alkaline pH and high electrical conductivity. Compared to the control, the use of greywater in agriculture could be a minor source of nutrients for crops but can also negatively affect plant growth and health if the detergent content is high. This study confirms the greater sensitivity of lettuce following application of greywater with high salt content. After irrigation, there is a significant increase of soil pH. However the EC increases with increasing detergent content which in the long term can increase soil salinity and make it unfavorable for the growth of crops.

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