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Potato (*Solanum tuberosum* L.) Production under Phosphate-mining Wastewater in Jordan

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Abstract: This study is concerned with potato performance under phosphate mining waste water as an alternative sustainable source of water. It was conducted in Al-Quwayrah area south of Jordan. Class (A) tubers of (Spunta and Mondial) potato (*Solanum tuberosum* L.) cultivars were planted under drip irrigation system. Water from phosphate mining activities, hybrid water (consisting of 50% fresh and 50% mine wastewater) and fresh groundwater were tested. Water, soil and tuber samples were evaluated for each plot and analyzed for heavy metal (Ni^{+2}, Zn^{+2} and Pb^{+2}) in addition to major ionic composition of the water used for irrigation. Potato vegetative growth, tuber specific gravity and yields were estimated at the end of the experiment. The fresh groundwater showed the lowest vegetative dry matter content (15.1%) compared to those of the mining water (16.9%) which was significantly similar to those (16.3%) of the hybrid water. Phosphate mining water showed yield reduction of 11.9 and 16.3% of those of the hybrid and the fresh water, respectively. Generally, Ni, Zn and Pb concentrations in the potato tubers were varied among treatments of water types used, with tendency of higher concentrations in the tubers of mining water. Soil site contents of Ni and Zn at the end of the study, were significantly increased due to mining and hybrid water, while Pb contents were not affected by water types used. According to results obtained, phosphate mining waste water can be used in potato fields and can be part of crop irrigation regimes.

Key words: *Solanum tuberosum*, hybrid water, heavy metals, drip irrigation

INTRODUCTION

Jordan is located in the Middle East and is considered as semi-arid to hyper arid area with major shortage in water resources and rainfall (Al-Zubi *et al*., 2010). The phosphate industry is one of the major contributors to the Jordanian economy. Large volumes of fresh water are required by the mining industry for processes such as washing and flotation in areas where water resources are scarce. Yearly, phosphate mining in Jordan consumes around 20 MCM of fresh water, but the effluent produced discharged to the nearby Wadies and lost through evaporation, (JOPH, 2009). The contaminated water affects surface water quality and more recently studies focused on the environmental impacts from mining activities.

Sappin-Didier *et al*. (1997) found that the concentration of cadmium or lead dissolved in contaminated soil produced from mining activities can be reduced using hydrous oxides of iron and manganese. Water quality produced from phosphate mining activities in south Jordan was investigated by Rimawi *et al*. (2009) found that water produced by phosphate mining activities can be used for irrigation. El-Hasan (2006) conducted a study to compare the content of Jordanian phosphate rocks and found that heavy meals and toxic elements are low compared with several deposits around the world. Chakroun *et al*. (2010) reported remarkably high levels of Cr and Cd concentrations in the plants and soil around the phosphate mines in Tunisia which make them toxic for human use. Worldwide, potato is among the most important vegetable crops in the world; Fernie and Willmitzer (2001) reported that potato is ranked in fourth grade in annual production after the cereal species rice, wheat and barley. In 1980, Thornton indicated that potatoes produce more food energy and protein production per acre than wheat and rice. Different potato varieties differ markedly in yielding ability (Allen *et al*., 1978; Santerre *et al*., 1986). Jordan's water availability ranks among the lowest in the world. In the light of this, a wide spectrum of national and international efforts is currently in place in order to tackle these challenges confronting the Jordanian water sector. Part of that demand is currently met by developing renewable

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supplies for humanity and agricultural water consumption needs. The reuse of mining water sources may be an important strategy in sustainable agriculture in Jordan (Rimawi *et al*., 2009). This experiment was conducted to study the response of potato cultivars to the use of mine waste-water in the southern portion of Jordan and to identify the potential risks of contaminant transfer to potato crop induced by the use of mine waste-water.

MATERIALS AND METHODS

Study Area: Al-Quwayrah area (29°48' 0" North, 35°19' 0" East) is considered a major potato production area in Jordan. The soil in the area is sandy loam in composition with very low organic matter content. Seed tubers of class A potato cultivars (Spunta and Mondial) were hand planted at 10 cm depth on the main plots on the 15th of February, 2011 in Al-Quwayrah area under drip irrigation system using a split plot design with 3 replications. Fresh water from the surrounding wells, hybrid water of 50% fresh water and 50% mine wastewater and mine wastewater were investigated in the sub main plots. Each treatment was consisted of one planting row, three meters long with plants spaced approximately 0.3 m within the row. Each experimental unit was irrigated twice a week with a seasonal total of 500 L m^{-2} of the above mentioned types of water. Empty half meter was left between every two treatments to prevent cross movement of elements. One month after planting, a total of 200 kg ha^{-1} of each N and K and 150 kg ha^{-1} of P as foliar soluble fertilizers were spread through ten applications during the growing season at 3-4 days intervals. Weeds were kept under control by using glyphosonate herbicide. Protection against blights was accomplished by the applications of chemical fungicides of Dithane and Ridomil (Olanya *et al*., 2001) during the vegetative growing period. Data on potato vegetative growth dry weight and tuber yield was recorded at the harvest time. The dry weight after a representative whole plant leaves were oven dried at 70°C to a constant weight was determined. Specific gravity was then determined by weighing each tuber of representative samples in air and then in water (Lulai and Orr, 1979). For each type of water used in irrigation, water samples were analyzed for major ionic composition using the ion chromatographic method (Knudsen *et al*., 1982). Soil chemical analysis (at 20 cm depth) was applied before planting and after termination of the field study. Soli site analysis before planting were 7.5, 0.58, 3.5, 20.0 and 12.5 for pH, EC, Ni (ppm), Zn (ppm) and Pb (ppm), respectively. Heavy metal content was determined for the water treatments, soil in each plot and for five separate tuber samples of each plot using the Atomic Absorption Spectroscopy (AAS) method (Knudsen *et al*., 1982).

Statistical Analysis: Obtained data were subjected to analysis of variance and treatments mean were compared using the Duncan's Multiple Range Test at 5% level of probability according to the general linear model of SAS Institute (1996), as for the split plot design outlined by Steel and Torrie (1980).

RESULTS AND DISCUSSION

Mining activities (Table 1) increased all ions in the mine wastewater, including NO_3, Na and the heavy metals (Ni, Zn and Pb). Moreover, mining activities increased water salinity by doubling the EC of the fresh water (1088 ppm) to 2311 ppm while hybrid water showed EC of 1700 ppm. The increment of ionic concentration including heavy metals of the hybrid water ranged between fresh water and mine wastewater was due to mixing the above mentioned types of water. Potato cultivar had no significant effects on vegetative dry weight% or on tuber specific gravity (Table 2). However, Spunta cultivar was superior in yield (24.0 t ha^{-1}) over that (22.0 t ha^{-1}) of Mondial cultivar. This could be attributed to direct effect of genetically variation among different varieties used (Hassanpanah and Azimi, 2010). Plant vegetative dry matter contents were significantly affected by irrigation water type (Table 2). Mining water gave relatively the highest percentage of dry matter content (16.9%) which was statistically similar to that of the hybrid water (16.3%). However, fresh water produced the lowest dry matter

Table 1: Ionic and heavy metal concentrations for the irrigation water used

Parameters	Phosphate water	Hybrid water	Fresh water
pH	7.3	7.4	7.5
EC (MS cm^{-1})	2311	1700	1088
NO_3 (ppm)	16.8	13.9	12.3
Na (ppm)	248.5	162.1	108.6
Ni (ppm)	11.02	8.95	9.11
Zn (ppm)	4.63	2.94	0.40
Pb (ppm)	80.72	67.1	61.83

Table 2: Vegetative dry matter, tuber specific gravity and yield of potato grown under different types of mining water

Variables	Treatment	Vegetative dry matter (%)	Tuber specific gravity (kg L^{-1})	Yield (t ha^{-1})
Cultivar	Spunta	15.9a	1.05a	24.00
	Mondial	16.4a	1.07a	22.00
	LSD	0.91	0.04	118.56
Water	Mining	16.9a	1.07a	20.40c
	Hybrid	16.3a	1.05a	22.94b
	Fresh	15.1b	1.04a	24.55a
	LSD	0.88	0.3	1.64
Cultivar×water (Interaction)		*	NS	**

Values within each column having different letters have significant difference according to LSD at 5% level of probability. NS: Not Significant, *: Significant at $p \leq 0.05$ and ***: Significant at $p \leq 0.00$

Table 3: Heavy metal concentrations of potato grown under different types of mining water

Variables	Treatment	Ni (ppm)	Zn (ppm)	Pb (ppm)
Cultivar	Spunta	3.5a	15.2a	4.9a
	Mondial	3.4a	15.0a	5.1a
	LSD	0.28	10.75	0.46
Water	Mining	4.7a	22.5a	7.6a
	Hybrid	4.3a	19.0a	7.2a
	Fresh	3.6b	11.3b	6.8a
	LSD	0.55	30.97	0.77
	Significancy	***	***	NS
Cultivar×Water (Interaction)		NS	NS	NS

Values within each column having different letters have significantly different according to LSD at 5% level of probability. NS = Not Significant * = Significant at $p \leq 0.05$ *** = Significant at $p \leq 0.001$

Table 4: Some soil site properties at the end of the harvest of potato grown under different types of mining water

Variables	Treatment	pH (1: 2.5)	EC (mS cm^{-1}) (1: 2.5)	Ni	Zn	Pb
Cultivar	Spunta	7.5a	0.59a	4.0a	21.5a	13.5a
	Mondial	7.5a	0.60a	3.8b	22.0a	14.0a
	LSD	1.03	0.03	0.53	10.69	10.24
Water	Mining	7.4a	0.61a	5.0a	27.5a	14.0a
	Hybrid	7.4a	0.60a	4.2b	23.0b	14.0a
	Fresh	7.5a	0.60a	3.6c	22.5b	13.2a
	LSD	0.89	0.02	0.44	10.59	10.11
Significancy	NS	NS	***	*	NS	
Cultivar×water (Interaction)	NS	NS	*	NS	NS	

Values within each column having different letters are significantly different according to LSD at 5% level of probability. NS: Not Significant, *: Significant at $p \leq 0.05$ and ***: Significant at $p \leq 0.001$

content (15.1%) of potato plants. On the other hand, water different treatments showed no significant effects on tuber specific gravity. Different water types showed significant differences in their effects on yield production. Fresh water (24.55 t ha^{-1}) produced statistically more yields over the hybrid treatment which gave superior production (22.94 t ha^{-1}) over that of the mining water (20.40 t ha^{-1}). This could be attributed to direct effect of relatively high salinity manifested by the mining effects; this was coincided with the findings of Rimawi *et al.* (2009) who mentioned an inverse relationship between salinity of mine waste water and crop yield for *Zea mays* and *Medicago lupulina*. The heavy metal concentrations in plants resulting from different types of irrigation water are shown in Table 3. The results showed that Ni and Zn concentrations varied with type of irrigation used, while Pb accumulation in the tubers did not affected by the water type used; which may be due to the release of Ni and Zn by mining activity whereas the Pb was from the water sources. This origin of Pb in the water is most probably from the old casing and pipes used to pump the fresh groundwater to the phosphate mine. Potato analyses indicated a general low concentration of heavy metals in the tubers. This could be attributed to low heavy metal concentrations in the soil before starting the experiment (Rimawi *et al.*, 2009). The use of mine waste water for irrigation had detectable impacts on soil salinity at the end of the experiment. Results in Table 4 showed higher salinity in soil site compared to the start of irrigation. The increment in soil salinity when mine waste water was used as a source of irrigation may be a direct consequence of the high salinity contained in this type of water used compared to the other two types of irrigation water used.

CONCLUSIONS

Under similar conditions; for better sustainable conservation of scarcity water, it could be recommended to use the mining waste water for irrigation of potato fields. Nevertheless, potato tubers are safe in terms of heavy metals for human consumption.

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