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Growth, Yield and Genetic Integrity of Spinach and Chrysanthemum as Affected by Soil Supplementation with Dam Sediments Collected From King Talal and Al-Mujib Dams/ Jordan

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Abstract: In this study, sediments samples from two reservoirs; King Talal and Al-Mujib/Jordan were collected to assess their effect on growth, yield and genetic integrity of Spinach and Chrysanthemum. Soil samples from Irhab area were used as control, Irhab soil was mixed with sediments collected from two areas from each dam (Near and far from the dam wall) in different levels (15 or 30% sediments (w/w)). Results show that growing Chrysanthemum plants in soil supplemented with 30% sediment collected from KTD (Near) resulted in the maximum plant growth and yield compared to control or plants received organic or inorganic fertilizers. Whereas, Spinach plants grown in soil supplemented with sediments collected from KTD, organic or inorganic fertilizers showed similar fresh weight. Results of Comet assay showed that no DNA damage was detected for plants grown either in control soil or in soil supplemented with different dam sediments. ISSR analysis showed similar DNA fingerprinting profile between Spinach plants either grown in soil alone or in soil supplemented with sediments indicating that soil supplementation with dam sediments is not genotoxic. Heavy metals analysis indicated no significant effect of adding sediments to growing soil of Chrysanthemum but significant higher levels of Fe, Cu, Zn, Cd and Pb were observed in Spinach plants. In conclusion, the findings of this study present evidence for the potential use of King Talal and Al-Mujib dam's sediments for soil supplementation for Chrysanthemum in areas with low soil fertility and as a mean of restoring reservoir storage capacity.

Key words: Sediments · Spinach · Chrysanthemum · Genetic Integrity

INTRODUCTION

Dam sedimentation is a major global problem; the rate of sedimentation worldwide is about 0.8 % per year. High rates of dam sediment accumulation are a major problem facing reservoirs management and sustainability. Dam sedimentation resulted in a decrease in storage capacity and causing problems in hydropower production. Few studies have been conducted on reservoir sediments quality and their usability as soil additives or artificial agricultural soil. Results showed that Wadi El-Arab bottom reservoir sediments could be used as agricultural soils in areas with low soil quality, El-Radaideh recommended the use of sediments as soil additives to perennial crops and trees because the root system of these plants is in general very shallow [1]. Dam sediments have high levels of nutrients and cation exchange capacity (CEC), thus will enhance soil fertility [2]. Baran and Tarnawski [3] studied heavy metals toxicity of sediments collected from Rybnik reservoir, they found that the collected sediment samples were toxic due to the presence of high levels of heavy metals (Especially zinc, copper, cadmium, lead and nickel). They also found that Organic matter content play a major role in metals mobility. Fonseca *et al.* [4] also studied the fertility of the bottom sediments of the Maranhão reservoir, Portugal. They found that the main textural classes of the reservoir sediment were silty clay and clayey silt, where Montmorillonite was the main clay mineral. Organic matter content compared well with medium values for mineral

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soils. Sediment pH was 5.5-7.2, whereas the total levels of N, P and K compared well with medium values for mineral soils. Available water capacity in the sediments was high. They observed that growth parameters of tulips in Maranhão sediments were very similar to those of tulips in the commercial potting soil and as a result they concluded that these sediments could be used as agricultural soils.

In a similar work, Fonseca *et al.* [5] evaluated the suitability of bottom sediments from two reservoirs in south Portugal for agricultural use. They found high levels of total, exchangeable and soluble forms of nutritional elements are required for sustainable food-fibre production. They concluded that sandy sediments could be used as productive agricultural soil; on the other hand, clay fractions could be used as fertilizers for low quality soil. The suitability of reservoir sediments in Japan for agricultural use as top dressing soil was studied. They found that the quantities of the sediment were thick and suitable as top dressing material for plants [6].

The aim of this study was to investigate the usability of reservoirs bottom sediments (King Talal and Al-Mujib dams) as soil additives in areas with scarce soil or poor quality soils.

MATERIALS AND METHODS

Soil Sampling: Irhab (32°15'45.02"N, 36° 5'48.91"E) is located southern of Al Mafraq and north eastern Al Zarqa (Fig. 1). A sampling area (100 * 100 m) was erected and then this area was divided into one hundred (100) plots. Twenty plots were randomly selected and soil samples were collected from the topsoil (0 - 20 cm). Samples were collected inside labeled polythene bags and taken to the laboratory for further experimental work and analysis.

Plants Growth: Soil samples were air dried and passed through a 2-mm sieve and then mixed carefully to get a homogeneous mix. Soil samples were analyzed using standard techniques. The soil pH was determined in 1:2.5 soil-water suspensions by potentiometer method. Organic mater content was calculated by the titration method Hesse [7].

Spinach and chrysanthemum plants were planted in either soil brought from Irhab area alone or in mixed soil made up by mixing sediments with Irhab soil in different ratios (15%, 30% (Calculated on soil dry weight basis)). Sediments of each dam were divided into two groups; the first group refereed to samples collected from areas close to the dam wall (Named hereafter as Near) and the second group refereed to samples collected from areas far from the dam wall (Named hereafter as Far). Sediments were added and mixed thoroughly by hand. The pots were filled with 5 Kg soil alone or mixed soil. All treatments were replicated at least four times. Control pots were soil without sediment addition. Pots were watered and stored in a greenhouse for 4 weeks to settle at room temperature before planting crops. The above mentioned crops were grown in greenhouse for 14 weeks with regular watering and random rotation of the position of the pots. Data were collected on plant height, number of leaves, number of roots, leaf area, chlorophyll content. Heavy metals content, the amount of DNA damage and DNA fingerprint were assessed from leaf samples at the end of the experiment.

Also we compared the effectiveness of sediment application with the application of commercial organic and inorganic fertilizers used by farmers in the study area. For inorganic and organic fertilization treatments, Irhab soil was enriched with the recommended rates of either inorganic fertilizers (Urea, as N fertilizer, added to each pot at the rate of 150 mg N per kilogram soil, Superphosphate and potassium sulfate were applied in each treatment at the rates of 100 mg P_2O_5 and 150 mg K_2O per kg soil, respectively), or animal manure (5 ton sheep manure. Ha^{-1}) as organic fertilizer. After harvest, soil samples were analyzed for total Nitrogen, available Phosphorous, soil organic mater, Cation Exchange Capacity and porosity to study the effect of treatments on soil properties. Water holding capacity was calculate by mass using the following equation:

$$\text{Water holding capacity (\%)} = (Mass_{wet} - mass_{dry}) / mass_{dry} * 100\%$$

Chlorophyll Content: Plant tissues were extracted with 80% acetone overnight, the A645 and A663 were determined in a spectrophotometer (Model 2100 pro, Ultrospec) and chlorophyll content was calculated according to the method of Mackinney [8].

DNA Damage Detection Using Comet Assay: Root samples were chopped with a razor blade in 1 ml of ice-cold Tris-MgCl2 (pH=7.5). Then were filtered and precipitated by centrifugation at 200 g for 5 min at 4°C to get the nuclei. The pellet was resuspended in 200µl of Tris–$MgCl_2$ buffer and kept on ice [9]. To detect the DNA damage in plant cells, Oxiselect comet assay kit

Fig. 1: Location of Irhab area/ Jordan

(Cell Biolabs, Inc, San Diego, USA) was used; lysis buffer, alkaline solution and electrophoresis running solution were prepared and chilled at 4 C° before performing the assay. Agarose was heated to 90-95°C for 20 min and cooled to 37°C. Plant cells samples were prepared by centrifugation at 700 g, then 10 µl from cells was mixed with 90 µl from molten agarose, then the mixture was placed onto the comet slide. Slids were set in the dark at 4°C for 15 min, then transfered to basin containing pre-chilled lysis buffer (25 ml/slide) and incubated in the dark at 4°C for 30-60 min, then lysis solution was replaced with alkaline solution for 30 min in the dark.

Prepared slides were transferred to electrophoresis chamber and covered with cold TBE buffer (Electrophoresis running solution). The run was started at 1 Volt/cm for 15-30 min, then slides were transferred carefully to basin and washed twice with pre-chilled deionized water (DI) for 2 min for each wash then left to dry, when completely dry, slides were incubated at room temperature for 15 minutes after addition of 100 µL/well Vista green DNA dye. After that, slides were examined under fluorescence microscope (EVOS ®) on 100x magnification (GFP filter, 470 nm excitation, 525 nm emission). Comet images per sample were analyzed with image analysis software (Comet Assay IV).

ISSR Analysis: DNA samples were extracted from chrysanthemum and spinach plants using CTAB (Cetyltrimethylammonium bromide) method with some modifications [10]. DNA quantity and quality was measured spectrophotometrically at 260 nm. The ISSR reaction was performed in a total volume of 40 µL containing 4 µL template DNA, 10 × PCR buffer, 3 mM MgCl2, 200 µM deoxynucleoside triphosphates, 1.2 U of Taq DNA polymerase and 0.5 µM primer. PCR products were loaded on agarose gel (1% agarose) and run with Tris-borate-EDTA (TBE) buffer for 1 hour.

Heavy Metals Analysis: After plant harvesting, roots were carefully removed from each experimental pot, plant shoots and roots were washed thoroughly using deionized water to wash away all soil particles. Plants shoots and roots were then placed in an oven to dry at 65 C for 2 days. To measure Pb, Cd, Mn, Fe, Cu, Mg, Zn, Mo, Ni, Co and Cr concentrations in plants tissues, dried plant samples were digested in a 15 ml HNO_3 and HClO4 solution. Then samples were filtered, reconstituted to the preferred volume and analyzed using ICP-MS using standard methods.

Statistical Analysis: All data were analyzed using ANOVA. Means, standard deviation and standard error were calculated using SPSS, at least four replicates were used for each treatment. To test the significance of treatments, statistical significance was accepted at $P \leq 0.05$. Differences between means were determined using the least significant difference (LSD) test, with a significance level of $P<0.05$

RESULTS AND DISCUSSION

Control soil used in this study was collected from Irhab area. Low level of organic matter was observed in this soil which indicates the low fertility levels as agricultural soil for crop production. Irhab soil texture was classified as sandy loam according to soil texture triangle. Dam sediments are characterized by high levels of nutrients due to their ability to collect and carry clay and organic materials throughout their transport. Sediments are considered as a source of mineral fertilizers, they originate from natural processes and human-induced erosion and showed high levels of nutritional elements that are needed for plant survival [5].

The Effect of King Talal and Al-Mujib Dams Bottom Sediments on Plants Growth: In the present study spinach and chrysanthemum were planted in Irhab soil supplemented with different levels of dams sediments (0% = control, 15% and 30%). Analysis of variance revealed significant effect for sediments addition for most of the studied parameters (Number of leaves, plant length, number and root length).

A significant increase ($P \leq 0.05$) in plant height was observed for spinach and chrysanthemum plants by addition of dam's sediments (Table 1). In general, plants grown in soil supplemented with sediments from KTD showed longer shoots than plants grown in soil supplemented with sediments from MD. The longest chrysanthemum shoots were observed in plants grown in soil supplemented with 30% sediments (Near) collected from KTD (37.4 cm). Whereas, the longest shoot of spinach was observed in plants grown in soil supplemented with 30% sediments (Near) collected from MD (18.4 cm).

Results show that growing chrysanthemum and spinach in soil supplemented with sediments collected from both dams resulted increase in leaves number (Table 2). KTD sediments resulted higher increase in number of leaves compared to those collected from MD. Also, using higher ratios (30%) of sediments in the growing medium showed more leaves than lower ratios (15%). The maximum number of leaves in chrysanthemum and spinach were observed in plants grown in soil supplemented with 30% sediments (Near) collected from KTD (27.9 and 13.55 leaves in average, respectively).

Results showed that chrysanthemum plants grown in soil supplemented with sediments collected from both dams larger leaf area than similar plants grown in soil only (Table 1). Chrysanthemum plants grown in soil supplemented with sediments collected from KTD showed higher leaf area than plants grown in soil supplemented with sediments collected from MD (Table 1). The largest leaves for chrysanthemum were observed in plants grown in soil supplemented with 30% sediments (Near) collected from KTD (91 cm^2). Similarly, largest leaves for Spinach were observed in plants grown in soil supplemented with 30% sediments (Near) collected from KTD (138 cm^2).

Table 1: The effect of King Talal (KTD) and Al-Mujib (MD) dams bottom sediments on height, leaves number, leaf area, roots number and Chlorophyll content (µg/mg fresh weight) of Chrysanthemum and Spinach plants

			KTD				MD				
		Control	15% Near	30% Near	15% Far	30% Far	15% Near	30% Near	15% Far	30% Far	LSD
Height	Chrysanthemum	17.8	25.5	37.4	20.2	28.5	20.1	24.7	19.7	22.5	3.68
	Spinach	10.8	18.1	17.1	15.3	16.2	18.3	18.4	13.9	14.4	2.14
Leaves number	Chrysanthemum	21.11	22.33	27.92	21.95	24.25	21.07	24.84	20.57	24.22	1.81
	Spinach	8.17	9.33	13.55	9.60	11.83	9.06	11.96	10.42	11.12	1.77
Leaf area	Chrysanthemum	74	82	91	80	84	79	88	77	83	8
	Spinach	112	127	138	119	129	121	134	126	133	12
Roots number	Chrysanthemum	5.3	6.1	6.6	6.2	6.9	6.1	5.8	6.3	6.1	1.2
	Spinach	7.2	9.4	9.2	8.6	9.2	8.5	8.7	8.7	8.5	1.9
Chlorophyll content	Chrysanthemum	1.07	1.42	1.54	1.28	1.24	1.32	1.46	1.23	1.37	0.33
	Spinach	1.71	2.12	2.56	2.24	1.96	1.98	2.87	1.85	1.89	0.27

Table 2: Effect of KTD sediments, MD sediments, Organic and inorganic fertilizers on height, leaves number, root length and roots number of Chrysanthemum and Spinach plants

		Control	KTD 30% Near	MD 30% Near	Organic	Inorganic	LSD
Height	Chrysanthemum	17.8	37.4	24.7	25.3	33.1	4.1
	Spinach	11.1	17.4	18.8	21.7	20.9	2.9
Leaves number	Chrysanthemum	21.58	28.31	25.74	25.88	24.61	2.07
	Spinach	8.21	13.86	12.14	13.12	15.8	1.88
Root Length	Chrysanthemum	16.91	21.47	21.92	18.28	18.65	1.83
	Spinach	20.71	20.61	21.54	21.42	22.41	1.97
Roots number	Chrysanthemum	5.6	6.3	5.5	4.5	4.8	1.8
	Spinach	6.9	8.9	9.2	7.6	8.4	2.4

No significant effect of sediments addition (Either KTD or MD) on root number was observed for chrysanthemum (Table 1). Whereas, spinach plants grown in soil supplemented with either 15 or 30% sediments showed an increase of about 25% in root number compared to control soil. In this study, plants grown in soil supplemented with sediments collected from the area close to the dam wall (Which is called here Near) showed in general better growth than plants grown in soil supplemented with sediments collected from area far from the dam wall. Sediments collected from areas close to the dam wall (Either KTD or MD) showed clay or clay silt texture (Data not shown). Clay affects nearly every soil reaction. The physical and chemical characteristics of soils are highly controlled by clay proportion. Plant growth and production under any environmental condition is greatly influenced by soil texture and structure that result from reactions concerning clay. Soil that is low in clay content will be unfavorable for plants growth due to the low water holding capacity and nutrients availability [11, 12]. In addition, these sediments showed high values of CEC, which indicates the availability of potassium, magnesium and other cations for plant in these sediments and less cation leaching. All together, high level of CEC and clay/silt clay texture of the collected sediments would enhance fertility of the growing soil by increasing the availability of micro and macronutrients and subsequently enhanced plant growth and yield.

A significant increase in chlorophyll content was observed for chrysanthemum and spinach plants grown in soil supplemented with sediments in different ratios collected from both dams (KTD and MD) (Table 1). The highest chlorophyll content of Chrysanthemum was observed in plants grown in soil supplemented with 30% sediments (Near) collected from KTD (1.54 µg/mg fresh weight), whereas, the highest Chlorophyll content of Spinach was observed in plants grown in soil supplemented with 30% sediments (Near) collected from MD. Pramanik and Bera [13] found that chlorophyll content of rice plants increased with increasing soil nitrogen levels. It has been shown that Nitrogen fertilization affect photosynthetic pigments content, synthesis of several enzymes important in carbon reduction, the formation of chloroplasts membrane system. Therefore, the increase in plant growth and productivity due to N fertilization could be the result of the important role of N in nucleotides, proteins and several enzymes involved in many metabolic processes that have direct impact on plant growth and development

[14]. Nitrogen level in plants affects the outcome of photosynthesis process by interfere with the major enzymes required in photosynthesis and chlorophyll formation. N is important in glutamic acid synthesis which play a crucial role in the formation of chlorophyll [15].

Then, a comparison between commercial organic and inorganic fertilizers with sediments application was done. The objective of this experiment was to assess the effectiveness of sediment addition to Rehab soil compared to the application of either organic or inorganic fertilizers used by farmers in the study area. Data were taken for plant height, number of leaves, number of roots and root length. After harvest, soil samples were analyzed for total Nitrogen, available Phosphorous, Soil Organic mater, Cation Exchange Capacity and porosity to study the effect of treatments on soil properties. Results show that growing Chrysanthemum plants in Irhab soil supplemented with sediments collected from KTD Near (30%) resulted in the maximum plant height (37.4 cm). Chrysanthemum plants grown in soil supplemented with sediments collected from MD (30%) showed similar height to those grown in soil supplemented with the recommended rates of organic fertilizers (Table 2). On the other hand, growing Spinach in Irhab soil supplemented with either organic or inorganic fertilizers resulted in the maximum height followed by plants grown in soil supplemented with dam sediments and the shortest plants were observed in plants grown in Irhab soil alone. Regarding number of leaves, Chrysanthemum plants showed the maximum number of leaves was observed in plants grown in soil supplemented with 30% N KTD sediments. Results show that growing Spinach in soil supplemented with inorganic fertilizers (Table 2) resulted in the maximum number of leaves. Furthermore, using KTD and MD sediments as soil amendments resulted in higher number of leaves compared to Irhab soil only (Table 2). Results also showed that growing Chrysanthemum in soil supplemented with KTD and MD sediments resulted in plants with longer roots compared to control and plants grown in soil supplemented with organic or inorganic fertilizers (Table 2). Spinach plants showed similar root length under all treatments. Finally, no significant differences were observed between different soil amendments for number of roots for all grown plants (Table 2).

Our results are in agreement with Fonseca *et al.* [16] who found that growing pepper plants in soil supplemented with dam sediments collected from Monte Novo dam in Portugal resulted in better growth compared to plants grown in soil alone. Similarly, Fonseca *et al.* [4] conducted a study to compare the fertility of commercial potting soil with soil supplemented with sediments from Maranhão reservoir in Portugal. They found that similar growth rate was observed for tulips grown either in soil supplemented with Maranhão sediments or in commercial potting soil.

The Effect of King Talal and Al-mujib Dams Bottom Sediments on Yield: The maximum number of flowers produced by Chrysanthemum was observed in plants grown in soil supplemented with sediments collected from KTD or soil received organic fertilizers (Fig. 2). All treatments showed significantly higher number of flowers compared to control. Chrysanthemum plants grown in soil supplemented with sediments collected from KTD or organic fertilizers showed significantly bigger flowers than other treatments.

Results show that addition of dam sediments or fertilizers significantly enhanced Spinach fresh weight ($P<0.05$). The maximum plant fresh weight was observed in plants grown in soil supplemented with inorganic fertilizers (54.6 g). Similar fresh weight was observed for plants grown in soil supplemented with either KTD sediments or organic fertilizers (45.9 and 48.7 g, respectively) (Fig. 2). Results show that growing plants in soil supplemented with sediments collected from both dams enhanced growth and yield of the cultivated plants. However, growing plants in soil supplemented with KTD sediments showed significantly better growth rate than those grown in soil supplemented with sediments collected from MD. KTD sediments have loam texture, whereas MD sediments are clay loam. Loam texture is considered the perfect soil texture for growing plants followed by clay loam. Also, KTD sediments showed higher CEC value and organic matter content. Soil cation exchange capacity is influenced by the amount of clay present. Soils rich in sand with low amount of organic matter will have low CEC. In contrast, soils with high clay and OM levels will have greater capacity to hold cations. CEC facilitates retention of positively charged nutrients from leaching, however it gives nutrients to plant root by an exchange of Hydrogen ions. Low CEC values limited the availability of nutrients to plants [17, 18]. All of these could explain the higher growth rates of plants grown in soil supplemented with sediments from KTD over MD dam.

A study aimed to test the effect of soil supplementation with sediment collected from a dam in Ethiopia on growth and yield of wheat found that application of dam sediments significantly increased plant

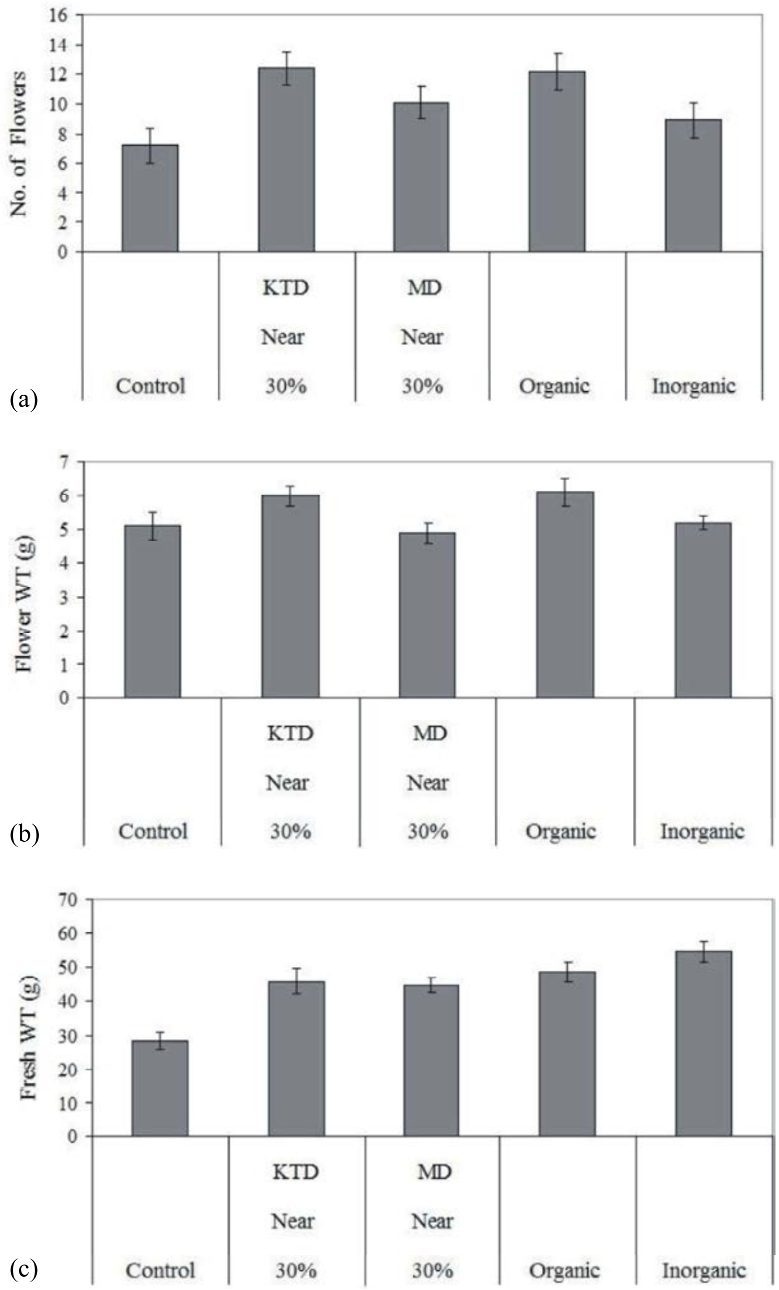

Fig. 2: Effect of KTD sediments, MD sediments, Organic and inorganic fertilizers on Chrysanthemum (A and B) and Spinach (C) yield

height, plant density and grain yield compared to control soil [19]. Fonseca *et al.* [16] compared the efficiency of sediments collected from two dams; one in Portugal and another in Brazil to be used as soils or additives to eroded soil. In general, they found that sediments collected from both dams could be used for agricultural. However, they found significant differences between both dams in terms of sediment fertility. Sediments collected from Portugese dam showed better effect on plant growth compared to Brazil dam sediments. They claimed that this difference could be explained by the higher levels organic matters and clay minerals that increase soluble and exchangeable forms of nutrients in the collected sediments and make them more available to plants. In addition they found that sediments collected from the Brazilian dam were acidic.

Table 3: Heavy metals content (µg/g plant dry weight) in plants grown in soil supplemented with 30% Near dams sediments

		Mg	Mn	Fe	Cu	Zn	Cd	Pb
Chrysanthemum	Control	4028.3	24.3	407.3	9.5	68.3	0.76	1.70
	KT	4268.2	27.2	427.9	13.3	89.6	0.97	2.21
	MD	4113.2	22.3	442.3	12.2	69.3	0.73	2.08
Spinach	Control	5917.3	47.3	371.2	16.8	114.3	0.47	1.63
	KT	6171.2	52.3	402.9*	22.6*	217.3*	0.82*	2.47*
	MD	6073.8	48.3	343.8	15.9	128.1	0.92*	2.23*

*: significantly different than control at P<0.05.

In general, our results show that chrysanthemum and spinach plants grown in soil supplemented with sediments collected from KTD or supplemented with inorganic fertilizers showed the best growth and yield. Sediments have the advantage of nutrients slow release to soil which allows plant roots to use it in the following years. In addition, the combined effect of sediment addition to soil of improving the soil physical and chemical prosperities not only the increase in nutrients concentration as the case in inorganic fertilizers. Crops production in dry areas such as the Jordanian environment is largely influenced by environmental conditions such as insufficient rainfall amount and frequency. One advantage of using sediments as soil additives over inorganic fertilizers is the slow nutrients release over a longer period. Although inorganic fertilizers are soluble and release nutrients fast and easily but they need favorable conditions and water supply in order to get the expected results [19]. Latham and Ahn [20] found that plant yield is highly affected by increasing water availability than by fertilizers application in dry areas. It has been shown that under low moisture content, chemical fertilizers application may result in a toxic effect and subsequently plants grown under such conditions will be adversely affected by fertilizers [19].

Heavy Metals Analysis: Heavy metals analysis indicated a significant effect of adding sediments to growing soil of only Spinach plants, which showed higher accumulation levels of Fe, Cu, Zn, Cd and Pb when grown on soil supplemented with 30% dam sediments (Table 3). Although, soil supplementation with dam sediments increased some times heavy metals content, but they are still within the normal ranges. Nafees and Amin [21] found that Cd, Cr and Ni levels were similar in wheat plants grown in soil supplemented with dam sediments and control soil. Baran *et al*. [22] showed that Zn, Pb, Cd and Cr content in corn plants grown in soil supplemented with different ratios of dam sediments similar to those grown on control soil. This indicates that sediments of these two dams can be used as fertilizers/supplements for areas with poor quality soils.

Effect of King Talal and Al-Mujib Dams Bottom Sediments on Plants Genetic Integrity: No DNA damage was detected for plants grown either in control soil or in soil supplemented with different dam sediments as assessed by comet assay analysis (Fig. 3). For ISSR analysis, nine primers were used in this study (Fig. 4). Fingerprinting profiles of these primers showed similar DNA fingerprinting profile of chrysanthemum and Spinach plants either grown in soil alone or in soil supplemented with sediments in terms of number and size of DNA bands. The ISSR fingerprint profiles showed bands ranged in size between 100 and 1500 bp in length. The total number of bands scored was 142 bands. All scored bands were similar regardless the growing soil. This indicates that growing these plants in soil supplanted with dam sediments is not genotoxic (Fig. 4). Comet assay (Single cell gel electrophoresis) is a simple, sensitive and rapid tool for assessing DNA damage in eukaryotic as well as some prokaryotic cells. Comet assay is a rapid and quantitative technique by which visual evidence of DNA damage can be measured based on quantification of the denatured DNA fragments migrating out of the cell nucleus during electrophoresis [23]. Gichner *et al*. [24] assessed DNA damage in tobacco plants grown in soil collected from dump site that is highly polluted with polychlorinated biphenyls (PCBs) in Czech Republic. They found that tobacco plants grown for 8 weeks in polluted soil showed reduction in growth rate compared to control plants. In addition, DNA damage measured using comet assay was higher in plants grown in polluted soil compared to controls. In another study, Sriussadaporn *et al*. [25] compared the degree of DNA damage in roadside and non-roadside environments in Japan using comet assay. They found that plants grown in roadsides have significantly higher levels of DNA damage compared to non-roadside plants. Recently, a study aimed to assess the status of potentially polluted soil and water samples collected from different sites in Jordan using Comet Assay. Low level of DNA damage was found in *Allium cepa* plants irrigated with water samples collected from most of Al Ghour sites especially those in Ghour Mashare', which indicate low level of

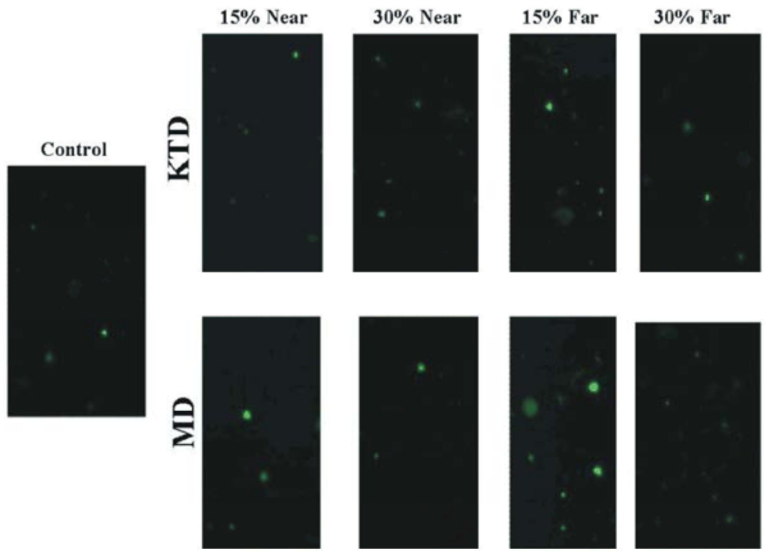

Fig. 3: Comet assay for Spinach plants grown in Irhab soil supplemented with KTD and MD sediments

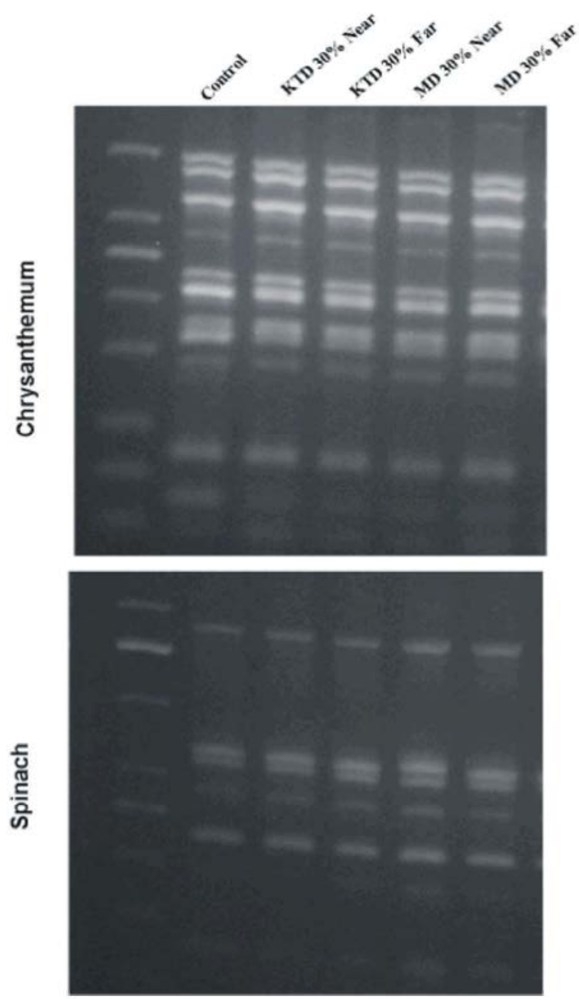

Fig. 4: ISSR DNA fingerprint of Chrysanthemum and Spinach plants grown in Irhab soil supplemented with KTD and MD sediments

Table 4: Effect of KTD a MD sediments, Organic and inorganic fertilizers on Irhab soil prosperities

	Control	30% Near KTD	30% Near MD	Organic	Inorganic
% Organic mater	1.93	4.95	4.52	6.84	2.11
Cation Exchange Capacity (c mol kg^{-1})	14.6	17.3	16.4	16.7	20.9

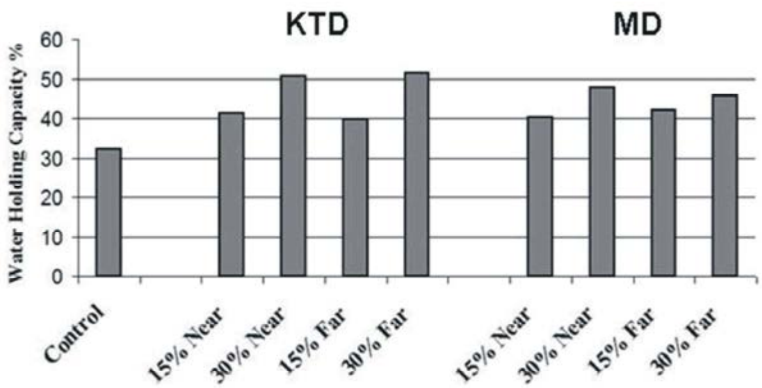

Fig. 5: The effect of KT and MD sediments on water holding capacity of Irhab soil (control)

genotoxicity in that region. Whereas, *Allium cepa* plants irrigated with water samples collected from Zarqa river showed high level of DNA damage. On the other hand, no DNA damage was observed in *Allium cepa* planted in soil samples collected from different areas in Jordan. These observations imply that plant comet assay is a useful tool for genotoxicity biomonitoring (Unpublished data Wesam Al Khateeb, Yarmouk University). The results of this study that no DNA damage was detected in all plants grown in soil supplemented with dam sediments indicates that sediment addition to growing soil has no potential side effect and further pollution consequences as the genetic makeup and genome fidelity of the cultivated plants did not affected.

In conclusion, the findings of this study present evidence for the potential of using King Talal and Al-Mujib dam's sediments for soil supplementation for different crops other than leaf vegetables in areas with low soil fertility and as a mean of restoring reservoir storage capacity.

Effect of KTD and MD Sediments, Organic and Inorganic Fertilizers on Irhab Soil Prosperities: Results show that addition of sediments from both dams increased organic matter content of Irhab soil (Table 4). However, adding sediments from KTD to Irhab soil increased the organic matter content to 4.95% compared to sediments from MD that increased organic matter content of Irhab soil to 4.52%. This difference could be due to the lower level of organic matter in MD which indicates lower entrance of organic material into the dam. In addition, plankton, vegetation and other organisms' accumulation could be different in the two dams. Furthermore, soil supplementation with organic fertilizers significantly raised its organic matter content to 6.84%. The normal amount of soil organic matter is 2%-7% [26]. Also, soil supplementation with Dam sediments increased CEC values. The maximum CEC value was observed in soil supplemnted with Inorganic fertilizers (Table 4).

Water Holding Capacity: Soil water holding capacity is affected by soil porosity and by soils specific surface area. Results show that soil supplementation with dam sediments increase water holding capacity of Irhab soil (Fig. 5). The increase in water holding capacity of soil will increase the quantities of water being stored in the soil and percolated deeper to recharge groundwater. Reducing the quantities of water runoff lost to evaporation (Decrease in wasted water and increase the potential for effective, productive and profitable use of water). Reducing surface water runoff will reduce soil erosion. Clay particles are very fine and have lots of pore spaces, this make water move in slow motion. In general, sandy soil is considered as good drainage soil but at the same time it has low water holding capacity. Thus, soil texture significantly affects plant growth. Water holding capacity of soil is affected by soil texture. Sediments collected from KTD are clay loam, these sediments have 35.2% sand, 32.4% silt and 32.4% clay sized particles. In general, soil having high levels of silt and clay particles will have higher water holding capacity. Also, small size particles such as clay and silt have larger surface areas which give them the potential to hold more water than the large particles (Sand). In addition, the amount of organic material in the soil affects its water holding capacity, soil rich in organic matter showed high levels of water holding capacity compared to soil with low organic matter content, this could be due to the high affinity of organic matter for water.

Adding fertilizers is a key factor in reaching optimum crop yield. Nutrients are important for protein and carbohydrate synthesis, growth and development of plant body. The effect of nutrients on crops growth and productivity are resulting from different bio chemical, physiological and morphological routes in plant system. Though, commercial fertilizers are of the most expensive inputs and if used inappropriately, can pollute and damage ground water [27]. The optimum rate of fertilization depends on soil type and water availability. Nevertheless, rate of fertilization is also influenced by different socio-economic factors, including production cost, the availability of fertilizers and the economic and educational situation of the farmers. It is very important to use adequate amounts of fertilizers not only to achieve the maximum economic return, but also to diminish environmental pollution caused by excess applications [28].

In conclusion, the findings of this study present evidence for the potential of using King Talal and Al-Mujib dam's sediments for soil supplementation in areas with low soil fertility and as a mean of restoring reservoir storage capacity.

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