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Impacts of Madhas Dam Construction on the Chemical Composition of Plant and Soil Samples from Upstream and Downstream Sites of the Dam

Saad M. Howladar*

Biology Department, Faculty of Sciences, Albaha University, 65441- Albaha, Saudi Arabia
Email: smhowladar@gmail.com

Abstract

The aim of this study was to assess and compare the impacts of Madhas dam construction on the chemical composition of five plant species (*Pluchea dioscoridis*, *Pulicaria crispa*, *Tarchonanthus camphoratus*, *Lavandula pubescens* and *Argemone ochroleuca*) together with soil samples collected from upstream and downstream sites of the dam. Plant samples (stem and leaf) were analyzed for determining total soluble sugars, total free amino acids, free proline, polyphenols, flavonoids and elemental composition. Organic matter and element contents were determined in each soil sample. The studied plants collected from the two sites showed profound variations in their chemical and elemental composition. A significant reduction of sodium content was observed in all plant tissues collected from downstream site of the dam. All plant species from downstream site showed apparent increasing of total soluble sugar, free proline, total polyphenol, flavonoid, nitrogen and potassium contents. Results suggest that the accumulation of these components, in plant species collected from downstream site of the dam, may have an important role in the tolerance of these plants to water stress. Apparent increased of nitrogen, phosphorus, potassium, sodium, calcium, aluminum and manganese levels was noticed in soil samples collected from downstream site of the dam, while copper, nickel, lead and iron contents showed marked decreased. It was clear that the constructed Madhas dam caused changes in the chemical composition of the studied plant species as well as changes in element and organic matter contents of soil samples collected from the two sites of the dam.

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* Corresponding author.
E-mail address: smhowladar@gmail.com.

Keywords: Dam constructions; plants chemical composition; soil elements; hydrologic conditions.

1. Introduction

Dams construction may cause far-reaching influence on hydrological regime and the river ecosystem [1-4]. The alteration of the natural flow regime has led to changes to hydrological, geomorphological and ecological conditions in both upstream and downstream [5-8]. The loss of natural flow in dammed rivers interferes with the degree and frequency of natural disturbance, and limits sediment sources that create new habitats for plant colonization and establishment downstream [9]. The difference in hydrologic and geomorphic conditions between the upstream and downstream reaches of a dammed river can affect plant species dispersal, colonization, and establishment which in turn can have a dramatic effect on plant communities over time [10]. Assani and his colleagues [11] have reported that the interannual variability of stream flow affects the composition and species richness of vegetation in low-flow channels and alluvial plains.

Water storage for later use is essential for Kingdom of Saudi Arabia, as there are no natural surface water resources. The main natural water resources in Kingdom of Saudi Arabia (KSA) are ground water and rain water falling only in some provinces. Water is stored mainly by dams [12]. The volume of renewable surface water is not negligible. An extensive network of dams has, therefore, been built to collect it and utilize it optimally, and these also provide protection against floods, help recharge ground water wells and directly provide drinking and irrigation water [13]. Compared to other regions of the country, rainfall in the South-Westem region is relatively high, exceeding 600 mm/year in some of the mountainous areas [14].

In Al-Baha province, western south of KSA, there are 26 dams serving various purposes and having various sizes, with a total storage capacity of 31.2 million cubic meters [13]. Madhas dam is one of these dams, a concrete dam, was constructed in 1986. The length of the dam is 350 (m) and the height is 10 (m), with capacity of 1,500,000 (m^3) [15]. The dam area is located between latitude 20.1267 N and longitude 41.2646 E, 1763.1 ± 10 m height above sea level. The area is characterized by variable parent materials, climate, vegetation cover and elevation [16, 17]. Sillanpaa [18] reported that intensity and type of weathering, climate and other factors dominating during soil formation affect soil physical, chemical and nutrients status in soils.

There is lack of research concerning the influence of dams on the chemical and elemental composition of plants and soil at upstream and downstream sites of the dams. Therefore, the overall aim of this study was to evaluate and compare the chemical constituents of five plant species and the element as well as the organic matter contents of the soil samples collected from upstream and downstream sites of Madhas dam, Al-Baha province, Kingdom of Saudi Arabia.

2. Materials and Methods

2.1 Materials

Five different plant species: *Pluchea dioscoridis* (L.) DC (Asteraceae), *Pulicaria crispa* (Forssk.) Oliv. (Asteraceae), *Tarchonanthus camphoratus* L. (Asteraceae), *Lavandula pubescens* Decne. (Lamiaceae) and

Argemone ochroleuca Sweet (Papaveraceae) together with soil samples were collected from upstream and downstream sites of Madhas Dam. The collected plant species were authenticated then dried under shade. The dried stems and leaves were coarsely powdered separately in a hammer mill. Soil samples were collected close to where the plant samples were collected. They were taken from a depth of 1-30 cm in the soil then air-dried, crushed and sieved to 2 mm.

2.2 Methods

2.2 .1 Determination of total soluble sugars, total free amino acids and free proline

Total soluble sugars were determined according to method described by Irigoyen and his colleagues [19]. Plant sample (0.2 g) was homogenized in 5 ml of 96% (v/v) ethanol then centrifuged at 3500 × g for 10 min. Three ml of freshly-prepared Anthrone reagent was added to 0.1 ml of the ethanol extract. After incubation in water bath for 10 min, the absorbance of the mixture was recorded at 625 nm using a Bausch and Lomb-2000 Spectronic Spectrophotometer. Total soluble sugars (mg g^{-1} DW) were determined in each sample using glucose standard curve.

Dubey and Rani [20] method was used for determining the total free amino acids in each plant part with some modifications. Each sample (0.2 g) was extracted in 10 ml of 80% (v/v) ethanol then filtered. Five ml of ninhydrin reagent was added to a 0.1 ml aliquot of the extract, shaken vigorously and heated in a boiling water bath for 10 min. After cooling, the absorbance was read at 570 nm using a Bausch and Lomb-2000 Spectronic Spectrophotometer.

The method described by Bates and his colleagues [21] was used to determine free proline content in each plant sample. Proline was extracted by grinding 0.5 g from each sample in 10 ml of 3% (v/v) sulphosalicylic acid. After centrifugation at 10,000 × g for 10 min, two ml of the supernatant was transferred to a test-tube and 2 ml of freshly prepared acid–ninhydrin solution was added. The tubes were incubated in a water-bath at 90°C for 30 min, and the reaction was terminated in an ice-bath. The reaction mixture was extracted with 5 ml of toluene and vortex mixed for 15 seconds. The tubes were allowed to stand for 20 min in the dark at room temperature to separate the toluene and aqueous phases. Each toluene phase was collected carefully into a test-tube and its absorbance was read at 520 nm. The proline concentration (µg g^{-1} DW) was determined using a standard curve of analytical-grade proline.

2.2 .2 ***Determination of polypenol and flavonoid compounds***

Plant samples (1 g) were extracted with 10 ml of methanol: HCl (99:1, v/v). An aliquot of the filtered extract was used to determine total polyphenols and flavonoids in each sample. Total polyphenols in the extract were determined spectrophotometrically (CECIL 1000 series, Cecil Instruments Ltd, Cambridge, UK) using the Folin-Ciocalteu colorimetric method [22], [23] which modified by Meyers and his colleagues [24]. Aliquots (0.125 ml) of the diluted extract (in distilled H_2O) were mixed with 0.5 ml H_2O. Then, 0.125 ml of Folin-Ciocalteu reagent was added and after 6 min, 1.25ml of 7% aqueous sodium carbonate solution was added. Finally, distilled water was added to adjust the final volume to 3 ml and samples were allowed to stand for 90

min at room temperature. Results were expressed as mg of gallic acid per g of dry weight. Total flavonoid contents of the extracts were determined spectrophotometrically using a modified colorimetric method described by Meyers and his colleagues [24]. Aliquots (0.25 ml) of the diluted extract (in distilled H_2O) were mixed with 1.25 ml H_2O followed by the addition of 0.075 ml of 5% $NaNO_2$. After 6 min, 0.15 ml of 10% $AlCl_3.6H_2O$ were added and allowed to stand for 5 min. Then, 0.5 ml of NaOH was added followed by the addition of water to adjust the final volume to 2.5 ml and samples were allowed to stand for 90 min at room temperature. Results were expressed as mg of catechin per g dry weight.

2.2 .3 *Determination of elements*

For digestion of the plant parts, 0.2 g samples were digested for 3 h at 85°C with a conc. HNO_3: HCl (3:1) mixture. Then, conc. $HClO_4$ (1 ml) was added. The solutions were filtered and diluted to 100 ml with distilled water. For digestion of soil, 0.5 g samples were digested for 6 h at 90°C with conc. HCl: HNO_3 (3:1) mixture, then conc. $HClO_4$ (1 ml) was added. The residue was filtered and diluted to 50 ml with distilled water.

Nitrogen concentration (mg g^{-1} DW) was colorimetrically determined using the Orange G dye [25]. Phosphorus was (mg g^{-1} DW) and colorimetrically estimated using chlorostannus molybdophosphoric blue colour method in sulphuric acid system [26]. Potassium, calcium and sodium contents (mg g^{-1} DW) were determined in each plant sample using a Perkin-Elmer Model 52- A Flame Photometer [27]. The analysis of the other elements was carried out by inductively coupled plasma mass spectrometry (ICP-MS; Agilent 7500cx). Soil organic matter content was estimated by oxidation according to the modified Walkley and Black method as described by Jackson [28].

3. Results and Discussion

3.1 Total soluble sugar, total free amino acid and free proline contents

The data in Table 1 show the amount of total soluble sugars, total free amino acids and free proline in the dry samples of the studied plant species collected from upstream and downstream sites of the dam. All plant samples (stem and leaf) from downstream site of the dam showed relatively high amount of total soluble sugars and free proline content than that of the upstream site of the dam. The highest level of total soluble sugars (3.37 ± 0.17 mg g^{-1} DW) was detected in the dry leaf of *P. dioscoridis* (downstream) while the lowest level (1.13 ± 0.19 mg g^{-1} DW) was determined in the dry stem of *T. camphorates* (upstream). The overall average of total soluble sugars in all plant tissues at upstream site of the dam was 3.92 mg g^{-1} DW while the overall average of total soluble sugars in all plant tissues at downstream site of the dam was 4.91 mg g^{-1} DW. However, the tolerance mechanism in water-deficit may be associated with accumulation of osmoprotectants such as proline and soluble sugars. The accumulation of soluble sugars is strongly correlated to the acquisition of drought tolerance in plants [29]. Among amino acids, the accumulation of proline is frequently reported in many plants or tissues in response to a variety of abiotic stresses [30].

The amount of total free amino acids in the dry stem of the studied plant species at the upstream site of the dam was in the range of 146.6 ± 32.2 - 304.9 ± 87.8 µg g^{-1} DW while at the downstream site of the dam was in the

range of 142.6 ± 30.6 - 325.2 ± 25.3 µg g $^{-1}$ DW. The amount of the total free amino acid contents (382 ± 49.2 µg g^{-1} DW) in the dry leaf of *A. ochroleuca* at downstream site of the dam was high as compared with the recorded values for stem and leaf of the other plant species. Stem and leaf of *A. ochroleuca* at downstream site accumulated high amount of total amino acids. However, free amino acids are group of compounds which may be affected by water deficit. Proline and total free amino acids are often increased in water-stressed leaves [31, 32]. These findings suggest that the differences in water status conditions between the upstream and downstream sites of Madhas dam as well as the other environmental factors could have significant impacts on the chemical composition of the plants.

Table 1: Total soluble sugar, total amino acid and free proline contents in plant tissues collected from upstream and downstream sites of Madhas dam.

Plant species	Total soluble sugars (mg g^{-1} DW)		Total free amino acids (µg g $^{-1}$ DW)		Free proline (µg g $^{-1}$ DW)	
	Upstream	Downstream	Upstream	Downstream	Upstream	Downstream
P. dioscoridis (stem)	1.61 ± 0.06	1.84 ± 0.23	187.2 ± 18.5	142.6 ± 30.6	0.75 ± 0.14	1.1 ± 0.22
P. dioscoridis (leaf)	2.96 ± 0.31	3.37 ± 0.17	235.9 ± 18.6	292.7 ± 76	1.51 ± 0.08	1.56 ± 0.29
P. crispa (stem)	1.64 ± 0.3	2.41 ± 0.28	146.6 ± 32.2	175 ± 49.2	1.23 ± 0.36	1.94 ± 0.09
P. crispa (leaf)	2.34 ± 0.26	3.15 ± 0.19	183.2 ±12.2	296.8 ± 62.5	1.89 ± 0.16	1.99 ± 0.27
T. camphoratus (stem)	1.13 ± 0.19	1.64 ± 0.17	223.7 ± 18.6	166.9 ± 46.1	0.50 ± 0.13	0.78 ± 0.12
T. camphoratus (leaf)	2.47 ± 0.24	3.07 ± 0.36	244 ± 12.2	288.7 ±73.4	1.68 ± 0.24	1.98 ± 0.24
L. pubescens (stem)	1.63 ± 0.3	2.04 ± 0.32	304.9 ± 87.8	244 ± 87.8	0.84 ± 0.15	1.1 ± 0.09
L. pubescens (leaf)	2.35 ± 0.23	2.47 ± 0.41	179.1 ± 30.6	240 ± 35.1	0.96 ± 0.21	1.89 ± 0.42
A. ochroleuca (stem)	1.58 ± 0.34	2.04 ± 0.11	211.6 ± 39.1	325.2 ± 25.3	2.05 ± 0.16	2.25 ± 0.16
A. ochroleuca (leaf)	1.9 ± 0.23	2.51 ± 0.30	223.7 ± 18.6	382 ± 49.2	2.10 ± 0.09	2.35 ± 0.28

Values are means of three replicates ± SD

3.2 Total polyphenol and flavonoid contents

The concentrations of total polyphenols in the plant tissues are presented in Figure 1. It was observed that the collected plant species from downstream site of the dam had relatively high amount of total polyphenols as compared with that of the upstream site of the dam. The amount of total polyphenols in the plants collected from upstream site of the dam was in the range of 0.22 – 1.04 mg g^{-1} while it was in the range of 0.41 – 1.11 mg g^{-1} in the collected plants from downstream site of the dam. Figure 2 shows the amount of flavonoids in the studied plant species at both sites of the dam. Apparent increased in flavanoids content was noticed in the plant

tissues collected from downstream site of the dam. The dry leaves of *P. dioscoridis* and *A. ochroleuca* at the downstream site of the dam contained considerable high amount of flavonoids as compared with other plant species. No significant differences were found among the studied plant species in their stem flavonoids content at the upstream site of the dam. The variation in polyphenol and flavonoid contents in the plant tissues collected from the two sites could be attributed to the difference in hydrologic conditions between the upstream and downstream sites of Madhas dam. However, Awate and Gaikwad [33] have reported that polyphenol, tannin, alkaloid and flavonoid contents increased in *Simarouba glauca* DC with increasing water stress treatments. Drought stress is also known to increase secondary metabolite production in variety of medicinal plants, like hyperforin in *Hypericum perforatum* leaf tissue [34] and ajmalicine in *Catharanthus roseus* roots [35].

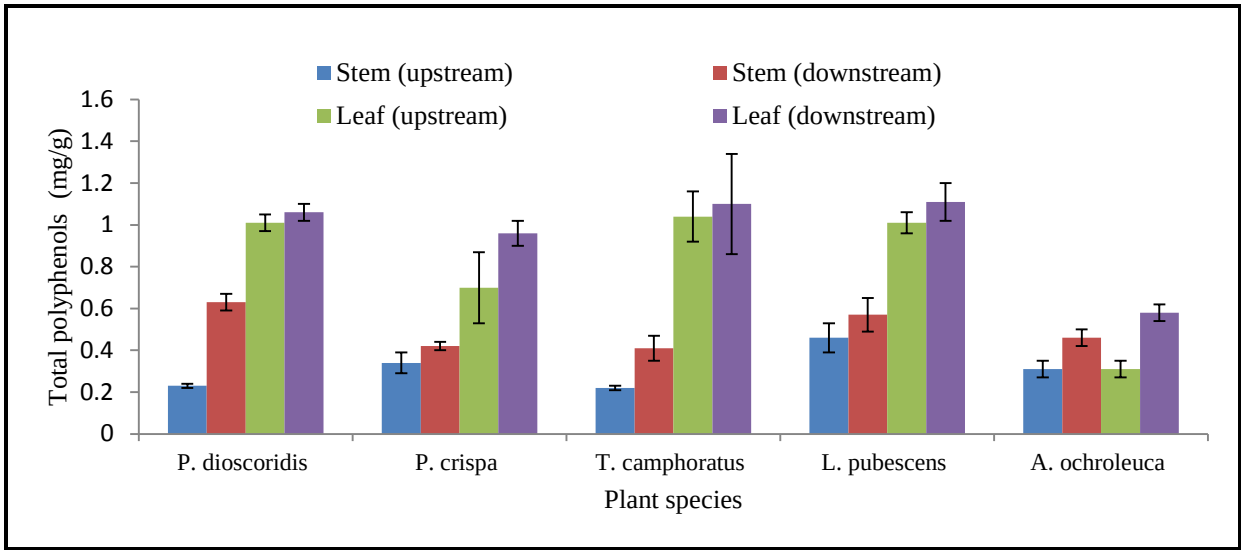

Figure 1: Total polyphenol contents in stem tissues of plant species collected from upstream and downstream sites of Madhas dam. Error bar represents standard deviation of three replicates.

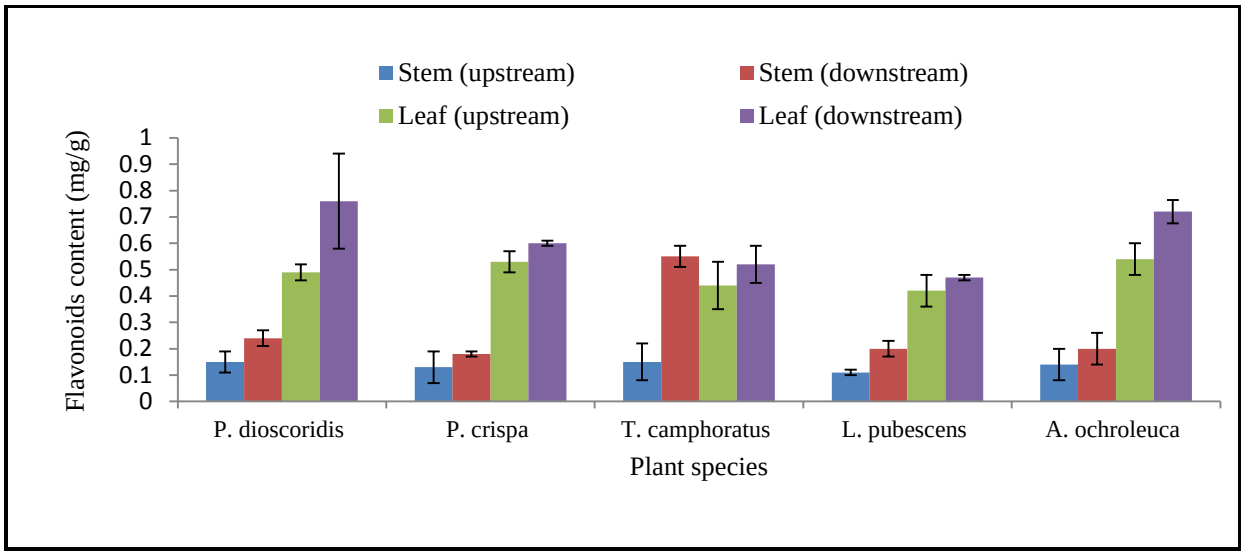

Figure 2: Flavonoid contents in leaf tissues of plant species collected from upstream and downstream sites of Madhas dam. Error bar represents standard deviation of three replicates.

Table 2: Elemental composition of plant species collected from upstream and downstream sites of Madhas dam.

Plant species	N (mg g^{-1})	P (mg g^{-1})	K (mg g^{-1})	Na (mg g^{-1})	Ca (mg g^{-1})	Cu (µg g^{-1})	Ni (µg g^{-1})	Pb (µg g^{-1})
P. dioscoridis (stem)								
Upstream	22.3 ± 4.8	0.32 ± 0.06	17.6 ± 0.2	4.2 ± 0.3	3.2 ± 0.8	16.6 ± 1.1	4.3 ± 1.2	4.2 ± 0.3
Downstream	29.3 ± 2.9	0.75 ± 0.13	18.1 ± 1.3	1.9 ± 00	2.8 ± 0.3	11.4 ± 0.5	2.3 ± 0.1	1.5 ± 0.2
P. dioscoridis (leaf)								
Upstream	36.9 ± 2.9	0.60 ± 0.07	12.4 ±1.8	5.8 ± 0.9	3.2 ± 0.8	16.8 ± 7.2	6.7 ± 2.5	3.7 ± 0.5
Downstream	45.9 ± 11.9	1.17 ± 0.09	20.1 ± 0.2	1.8 ± 0.3	2.3 ±0.3	15.6 ± 2.3	3.7 ± 0.3	1.6 ± 0.9
P. crispa (stem)								
Upstream	22.9 ± 5.1	0.36 ± 0.03	12.2 ± 2.1	2.9 ± 0.5	2.3 ± 0.6	9.8 ± 0.5	4.9 ± 0.1	1.6 ± 0.9
Downstream	27.4 ± 7.7	0.25 ± 0.04	14.3 ± 0.4	2.6 ± 0.3	2.3 ± 0.3	8.9 ± 1.4	3.8 ± 1.0	1.7 ± 0.4
P. crispa (leaf)								
Upstream	28.7 ± 1.9	0.50 ± 0.04	16.2 ± 2.9	2.3 ± 0.3	4.0 ±2	15.2 ± 1.8	5.4 ± 0.7	4 ± 1.4
Downstream	46.5 ± 9.8	0.62 ± 0.24	16.4 ± 0.4	2.1 ± 0.3	2.0 ±1	14.3 ± 1.9	6.1 ± 0.5	1.6 ± 0.1
T. camphoratus (stem)								
Upstream	26.2 ± 7.2	0.66 ± 0.15	3.8 ± 0.4	1.9 ± 0.5	2.2 ± 0.3	9.9 ± 2.3	4.7 ± 0.7	1.3 ± 0.6
Downstream	35.1 ± 2.9	0.25 ± 0.07	11.2 ± 0.2	1.6 ± 0.3	2.7 ± 0.6	12.9 ± 1.4	5.6 ± 2.1	1.9 ± 0.2
T. camphoratus (leaf)								
Upstream	38.3 ± 1.9	0.67 ± 0.09	5.8 ± 0.5	1.8 ± 0.3	2.7 ± 0.6	11.4 ± 2.7	2.6 ± 0.3	1.2 ± 0.4
Downstream	45.2 ± 11.5	0.51 ± 0.15	10.4 ± 0.9	1.7 ± 1.0	3.5 ± 0.5	11.6 ± 0.9	4.4 ± 0.9	2.5 ± 0.5
L. pubescens (stem)								
Upstream	28.1 ± 4.8	0.33 ± 0.07	12.8 ± 0.5	2.6 ± 0.3	3.0 ± 0.2	8.5 ± 0.8	4.6 ± 0.3	0.8 ± 0.1
Downstream	38.3 ± 3.8	0.44 ± 0.06	12.9 ± 1.4	1.9 ± 0.5	1.8 ± 0.1	8.6 ± 0.9	3.1 ± 0.4	1.0 ± 0.2
L. pubescens (leaf)								
Upstream	37.6 ± 5.5	0.48 ± 0.10	13.8 ± 1.5	5.2 ± 0.7	3.0 ±1	17.6 ± 8.9	4.5 ± 1.4	1.4 ±1.8
Downstream	47.8 ± 13.8	0.74 ± 0.07	18.1 ± 1.6	5.0 ± 1.0	1.7 ± 1.2	11.3 ± 1	3.4 ± 1.1	1.9 ± 0.9
A. ochroleuca (stem)								
Upstream	33.2 ± 6.1	0.30 ± 0.01	14.1 ± 1.8	2.1 ± 0.3	3.7 ± 0.6	14.4 ± 1.9	3.9 ± 0.2	1.8 ± 0.3
Downstream	50.9 ± 3.9	0.31 ± 0.06	15.0 ± 2.1	1.6 ± 0.6	2.3 ± 0.6	6.5 ± 0.4	3.1 ±0.4	1.0 ± 0.4
A. ochroleuca (leaf)								
Upstream	35.07 ± 2.9	0.67 ± 0.13	13.5 ±1.7	2.8 ± 0.7	2.5 ± 0.5	17.3 ±1.8	4.3 ± 1.3	1.1 ± 0.1
Downstream	59.9 ± 7.7	0.49 ± 0.13	20.5 ± 2.4	2.3 ± 0.3	0.87 ± 0.7	8.7 ±0.9	4.8 ± 0.2	1.6 ± 0.1

Values are means of three replicates

3.3 Elemental composition of plant species

Table 1 shows the elemental composition of the collected plant species from the upstream and downstream sites of Madhas dam. Variations in element contents were observed among the studied plant species collected from the two sites of the dam. A marked increasing in nitrogen and potassium contents was recorded in the plant tissues collected from the downstream site of the dam. On contrast, apparent decreasing of sodium content was recorded in the plant tissues collected from downstream site of the dam. Heavy metals (copper, nickel and lead) were detected in all plant tissues and the highest level of lead was recorded in the stem (4.2 ± 0.3 µg g^{-1}) and leaf (3.7 ± 0.5 µg g^{-1}) of *P. dioscoridis.* The increasing and reduction of these elements in the plant parts could

be attributed to the water status upstream and downstream reaches of the dam or other geomorphological conditions. However, research reports have shown that water stress causes increase in nitrogen content of plants [36, 37]. Martinez and his colleagues [38] and Paranychianakis and Angelakis [39] have indicated that water stress results to increase level of sodium in plant parts. Water stress is also documented to lead to reduction in potassium content of plants [40].

3.4 Organic matter and element contents of soil

Total concentrations of organic matter and elements detected in the soil samples collected from upstream and downstream sites of Madhas dam are illustrated in Table 3. The organic matter content in the soil samples from downstream site of the dam was high (5.13 ± 3.51%) as compared with that of the soil samples from upstream site (3.89 ± 1.14%) of the dam. Apparent increased of nitrogen, phosphorus, potassium, sodium, calcium, aluminum and manganese levels was noticed in soil samples collected from downstream site of the dam, while copper, nickel, lead and iron contents showed marked decreased. Soil samples from the two sites were very rich in aluminum (48.08 ± 2.34 -52.83 ± 1.64 g kg^{-1}), calcium (20.01 ± 0.8 - 20.3 ± 0.6 g kg^{-1}) and iron (14.96 ± 1.61 -16.92 ± 0.81 g kg^{-1}) contents. Sodium content of soil samples from downstream was twice that of soil samples from upstream sites of the dam. The collected soil samples from the two sites contained nearly equal amount of calcium content. Howladar [41] who studied chemical constituents of soil and vegetation of two locations in AL Baha area (Saudi Arabia) reported that the soil was very rich in organic matter and minerals contents. However, the bioavailability of metals in soil is a dynamic process that depends on specific combinations of chemical, biological, and environmental parameters [42 - 44].

Table 3: Organic matter and elemental composition of soil samples collected from upstream and downstream sites of Madhas dam.

Element	Upstream site	Downstream site
Organic matter (%)	3.89 ± 1.14	5.13 ± 3.51
N (%)	0.11 ± 0.05	0.25 ± 0.07
P (g/kg)	1.9 ± 0.12	2.7 ± 0.32
K (g/kg)	2.7 ± 0.31	2.9 ± 0.83
Na (g/kg)	1.7 ± 0.16	3.4 ± 1.2
Ca (g/kg)	20.01 ± 0.8	20.3 ± 0.6
Mg (g/kg)	3.61 ± 200	3.03 ± 1.02
Al (g/kg)	48.08 ± 2.34	52.83 ± 1.64
Fe (g/kg)	16.92 ± 0.81	14.96 ± 1.61
Cu (mg/kg)	51 ± 5	46 ± 11
Mn (mg/kg)	597 ± 96	806 ± 229
Ni (mg/kg)	34 ± 2	13.7 ± 1.2
Pb (mg/kg)	12 ± 2	17 ± 7

Values are means of three replicates ± SD

4. Conclusions

Chemical analysis of both plant species and soil samples collected from upstream and downstream sites of Madhas dam revealed clear variations among the samples in their chemical and elemental compositions. There was a slight increase of total soluble sugars, free proline, total polyphenol, flavonoid, nitrogen and potassium contents in stem and leaf of the plant species collected from the downstream site of the dam. Soil samples from downstream site were rich in organic matter and element contents as compared with that of the upstream soil samples. However, these marked variations in chemical composition of the studied plant species and mineral components of the soil samples collected from the two sites of the dam could be attributed to the changes on flow regime and sediment deposition produced by Madhas dam.

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