HEAVY METAL CONTENT OF *ASPHODELUS AESTIVUS* BROT. FROM DEGRADED AREAS IN THE MEDITERRANEAN ENVIRONMENT (BURSA, TURKEY)

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ABSTRACT

In this study, we determined the heavy metal content (Cd, Cr, Cu, Mn, Ni, Pb and Zn) in the soils and different organs of *Asphodelus aestivus* Brot. (Walter). from degraded areas in the Mediterranean environment from Bursa, Turkey. The last degradation stage of ecosystems in the east Mediterranean Basin is dominated by this species. Soils and different organs (roots, stems, leaves and flowers) of plant samples were analyzed by ICP-OES for determining the heavy metal content. The heavy metal contents were not high in the soils of all samples sites. In general, the heavy metal contents of plant samples were not higher than the comparable levels reported in literature. But we determined the high cadmium, chromium, nickel and lead contents in plant samples compared to normal levels which reported in some studies. These results may reflect the possible Cd, Cr, Ni and Pb accumulation capacity of this species. However, the contribution of plant organs to accumulation capacity of this species was specific to metal. The possible capability of *A. aestivus* for accumulating the Cd, Cr, Ni and Pb may help to plant to become dominant on degraded areas in the Mediterranean environment.

KEYWORDS: Mediterranean environment, *Asphodelus aestivus,* heavy metal, degraded areas

1. INTRODUCTION

Land Degradation Assessment in Dry Lands (LADA) defines land degradation as a reduction in the capacity of land to perform ecosystem functions and services that support society and development [1]. It is one of the main environmental issues of our time [2-4]. Generally climatic variations and human activities are the main factors contributing to land degradation in arid and semi-arid environments [5]. Human pressures performed by different ways such as intensive grazing, fires, cutting, unsuitable agricultural practices and industrial activities and mining cause habitat fragmentation, deforestation, biodiversity loss, water shortage, soil erosion and salinization, decline in soil organic matter and land degradation in Mediterranean environments [6]. Enhanced heavy metal concentration (Cd, Cr, Cu, Ni, Pb etc.) resulted from these anthropogenic activities also can be discussed as the reason of land degradation in these environments [7]. That kind of degradation not only affects the plant cover and plant growth but also affects the health of animals and human bodies upon entering the food chain.

The response of a plant to enhanced heavy metal contents in the environment is specific to species. Some plant species can be harmed by the increase of heavy metal content in their environment whereas other plant species called indicators; they can tolerate heavy metals reflecting the external heavy metal content of the growth environment [8]. The third group of plants has the capability to safely accumulate heavy metals [9-13]. These plants are called accumulators and they have been reported from different contaminated ecosystems in many studies [14, 15]. The accumulator plants have been recommended for the remediation of heavy metal contaminated sites by the phytoremediation approach [14, 11, 16]. Phytoremediation is defined as the use of plant-based processes to remove, decrease or render harmless these environmental pollutants [17].

Vegetation disturbance by human pressure has been responsible for the formation of many secondary or subseral communities such as the characteristic shrubland communities (maquis, phrygana, matorral, garrigue, etc.) that form such a conspicuous part of Mediterranean environment [18-20]. Also, geophytes have an important role in the re-vegetation on degraded areas in Mediterranean environment due to the high sprouting capacity. The last degradation stage of ecosystems in the east Mediterranean basin is dominated by *Asphodelus aestivus* Brot. (Walter) and these ecosystems are termed “asphodel geophyte-deserts” or “asphodel-semi deserts” for different regions of the world [18, 19, 21]. *A. aestivus* is a competitive ruderal

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and spreads on slopes in agricultural lands, around the roads and calcareous soils in pastures. The ability of asphodel to spread all over the Mediterranean region and to dominate in degraded areas reflects its capacity to face not only the peculiarities (such as drought) of the Mediterranean climate [22], but also to resist the most common disturbances (overgrazing and fire) in its habitat [23]. In addition, seeds and tuberous roots have important roles in the breeding capacity of asphodel and in the conservation of degraded areas by its dominancy in such environments. Root tubers play a most important role in storing and utilizing water masses and nutrients, protecting the plant from drought stress and environmental hazards [24].

Although, some ecological properties of *A. aestivus* have been studied previously [22-24], the heavy metal content of this plant was not studied. In this study, we aimed (i) to understand the contribution of heavy metals (Cd, Cr, Cu, Mn, Ni, Pb and Zn) in land degradation in Mediterranean environments and (ii) to understand the response of *Asphodelus aestivus* Brot. spread on these areas. For this reason, we determined the heavy metal contents in plant parts (tuberous roots, leaves, stems and flowers) and soils of this species.

2. MATERIAL AND METHODS

2.1 Study species

Asphodelus aestivus Brot. (*A. microcarpus* Viv.) belonging to the *Liliaceae* family is a perennial tuberous root geophyte and it spreads all over the Mediterranean basin [23]. Two major phenological phases are distinguished within lifecycle of asphodel: a photosynthetic active phenophase from leaf emergence (early autumn) to the senescence of the above-ground plant parts (late spring) and an inactive one which lasts until leaf emergence [24, 25]. Leaves (40-90 cm in length and 2-4 cm in width) appear between January and March. Peduncle which is consisting of 60-200 flowers occurs during April-May. Before the fruit maturation, senescence happens in June but most of the tuberous roots remain attached to the mother plant.

2.2 Study site

Bursa city is characterized by Mediterranean climate with wet and mild seasons from autumn to spring and with dry and warm seasons from spring to autumn. The soils are generally formed under Mediterranean climate characterized by hot summers and mild winters. The soil moisture and temperature regimes are xeric and thermic [26]. In general, precipitation is in the form of rain during winter and spring with an annual precipitation of 697 mm. The mean annual temperature is 14.6 ºC. January is the coldest month with the mean minimum temperature of 1.7 °C and August is the warmest month with the mean maximum temperature of 30.9 °C [27]. Phytogeographically, Bursa lies in the Eastern Mediterranean. The expanded land degradation has been reported in the last two decades around Bursa due to increased human activities such as cultivation, industrialization, urbanization, pollution [28].

2.3 Methods

Sampling was made from four different sites around Bursa, Turkey (10 x 10 m) (Figure 1). Sampling Site I and II were selected from around the Taşpınar village (Figure 1). Although, the agricultural practices are the main anthropogenic activities around this village, vehicle traffic on the road connecting Taşpınar village to other village can also contribute to land degradation on these areas. *A. aestivus* spreads on opened areas in degraded maquis which is composed of shrub species such as *Phillyrea latifolia* L., *Jasminum fruticans* L., *Pyrus amygdalus* Vilm. on Site I. Instead of these species, grass species form the plant cover on Site II owing to the possible high soil moisture. For this reason, the grazing and gathered animal manures cause land degradation on this site (Figure 1). The third sampling site (Site III) is near the highways connecting Bursa and Izmir (Bursa-Izmir Road) and traffic intensity is very high on this site (Figure 1). The last sample site (Site IV) was on the grassland around the Uluabat village (Figure 1). This site is located near the village road among the agricultural lands. The Flora of Turkey and the East Aegean Islands was used for the identification of *A. aestivus* [29].

Soil and plant samples were collected from five points of each sampling site in May 2008. Sampling of all plants was performed in the flowering phase. Plant samples were harvested together with aboveground and belowground parts using a shovel. The surrounding soils of each plant were also taken from 10 cm depth and they were sifted with a standard 4-mm stainless steel sieve. Then, soil and plant samples were transferred to the laboratory in plastic bags. While soil samples were air-dried for heavy metal analyses, plant samples were washed with tap water and then with deionized water. They were carefully separated into different organs (tuberous roots, stems, leaves, and flowers). Plant materials were dried in an oven (105°C) until their weight became constant. Then, all plant material was homogenized by grounding with a mortar and pestle. Homogenized plant material (1.3-mm size) and soil samples were stored in clear paper bags for heavy metal analyses.

Soil samples (0.5 g dry weight) were digested with 10 ml pure HNO_3 (65%), using a CEM-MARS 5 (CEM Corporation Mathews, NC, USA) microwave digestion system. The digestion conditions were as follows: maximum power 1200 W, power was 100%, ramp was 20min, pressure was 180 psi, temperature was 180 and hold time was 10 min. After digestion, the volume of each sample was adjusted to 25 ml using double de-ionized water [30]. Homogenized plant samples (0.5 g dry weight) were also prepared using the same procedure for heavy metal analyses. The solution of soil and plant samples was analyzed for Cd, Cr, Cu, Mn, Ni, Pb and Zn by inductively couple plasma optical emission spectroscopy (Varian-Liberty II, ICP-OES). All chemicals were of analytical reagent grade.

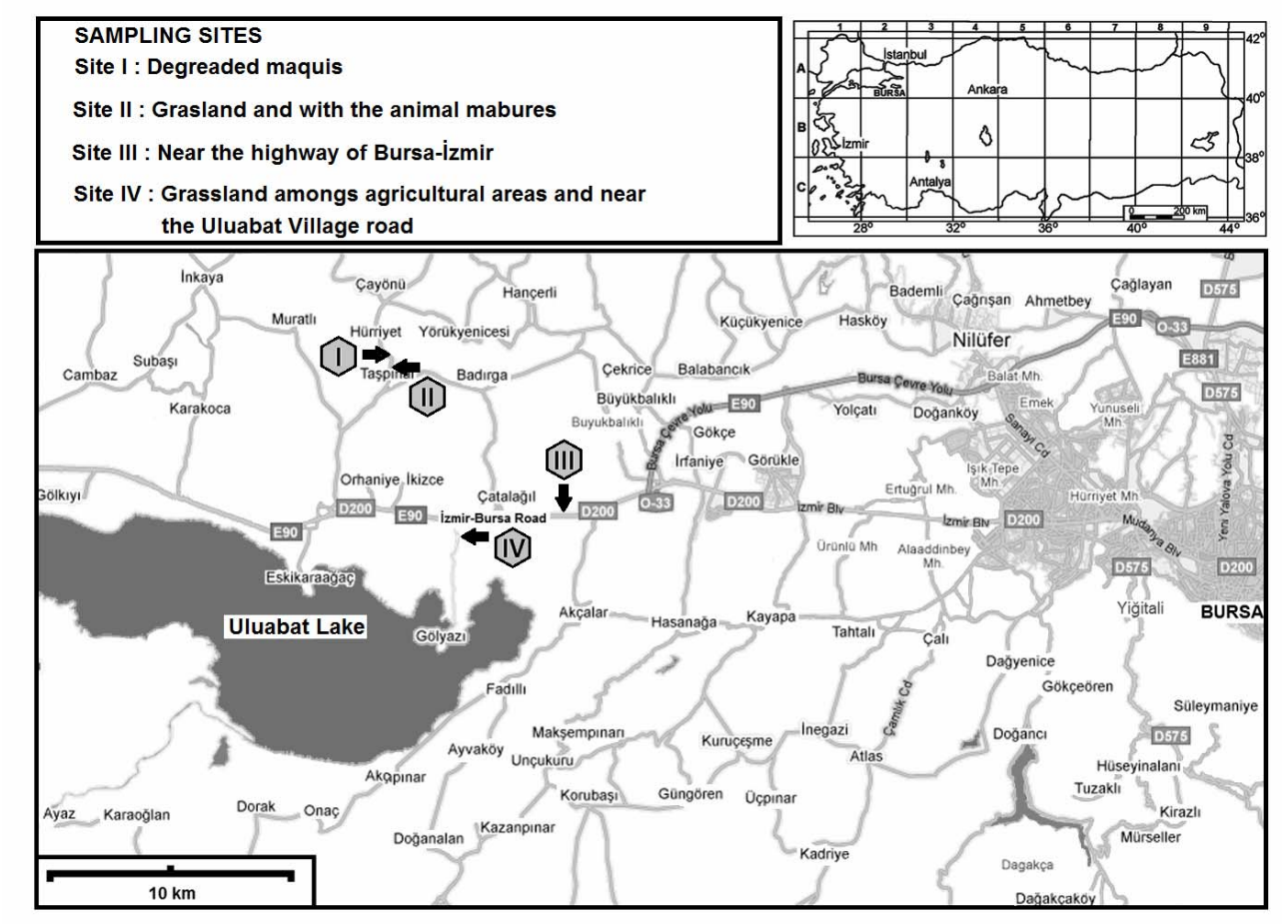

FIGURE 1 - Location map of the study area and sampling sites around Bursa, Turkey

The difference between the study sites regarding heavy metal contents of soils and plant organs (roots, leaves, stems, flowers) were tested by one-way ANOVA. The difference groups among sample sites were determined by Tukey HSD post doc test (HSD, honestly significant difference). Simple correlations between heavy metal contents of the soils and plant organs were also tested. All tests were analyzed in the significance level of 0.05. Statistical analyses were carried out by using the Statistica 5.0 software package [31].

Also, bioconcentration and translocation factors (BF and TF) were calculated for each heavy metal. While the BF was obtained by dividing the total content in shoots by the total content in the soil, TF was calculated by dividing the total element content in the shoots by the total element content in roots [32].

3. RESULTS AND DISCUSSION

The mean heavy metal contents (Cd, Cr, Cu, Mn, Ni, Pb and Zn) in of soils and different organs of *A. aestivus* were given in Table 1 and Table 2. The bioconcentration factor (BF) and translocation factor (TF) were also given in Table 3. There were significant differences among sample sites regarding to soil heavy metal content ($P< 0.05$) (Table 1). The highest Cd content was determined in the soils of Site I (0.11 mg/kg dry weight) whereas the lowest was determined in the soils of Site III (0.04 mg/kg dry weight). The highest Cd value was not above the average Cd range in soils (1-2 mg/kg dry weight) [33]. This suggests that the soils of *A. aestivus* were not contaminated by cadmium. The mean Cd content of plant samples varied between 0.40 and 0.20 mg/kg dry weight and it was lowest in the plant samples taken from Site IV (Table 2). According to Maestri et al. (2010) [34], the average Cd range in plant tissues was 0.03-0.5 mg/kg dry weight. If we consider these values, we cannot say that accumulation of Cd in *A. aestivus* plants occurred. On the other hand, it was reported that the Cd content in a plant taken from non-polluted environment varied between 0.01-0.03 mg/kg dry weight [35]. The mean highest Cd content in *A. aestivus* plants taken from Site II (0.40 mg/kg dry weight) may point out the high Cd uptake and accumulation in this species. Also, high BF and TF factors (3.59 and 3.33; respectively) (Table 3) can indicate the cadmium uptake and translocation ability of *A. aestivus*. The mean Cd content in roots of all plant samples was lower than the above

TABLE 1 - Comparison of the sampling sites according to mean values of elements (Cd, Cr, Cu, Mn, Ni, Pb and Zn) determined in soil solution digested in HNO_3 (65 %). [For mean soil element values, different letters indicate significant differences between the sampling sites according to Tukey's HSD Test (rejection level 0.05) *n*= 5, Means ± Standard Deviation]

	Sampling Sites			
Elements [mg/kg DW]	**Site-I**	**Site-II**	**Site-III**	**Site-IV**
Cd	$0.11^{a} \pm 0.02$	$0.07^{b} \pm 0.02$	$0.04^{bc} \pm 0.02$	$0.08^{ab} \pm 0.01$
Cr	$0.41^{ab} \pm 0.15$	$0.78^{a} \pm 0.37$	$0.45^{ab} \pm 0.12$	$0.19^{b} \pm 0.03$
Cu	$0.83^{a} \pm 0.20$	$0.83^{a} \pm 0.18$	$0.39^{b} \pm 0.06$	$0.18^{b} \pm 0.04$
Mn	$5.10^{bc} \pm 0.52$	$5.63^{b} \pm 1.34$	$7.48^{ab} \pm 1.37$	$8.86^{a} \pm 0.89$
Ni	$2.19^{b} \pm 0.22$	$2.61^{b} \pm 0.82$	$5.24^{a} \pm 0.72$	$1.10^{c} \pm 0.16$
Pb	$0.79^{b} \pm 0.14$	$2.78^{a} \pm 0.98$	$3.38^{a} \pm 1.00$	$0.67^{b} \pm 0.16$
Zn	$8.38^{b} \pm 1.53$	$12.47^{a} \pm 0.97$	$10.56^{ab} \pm 1.67$	$7.50^{bc} \pm 1.12$

TABLE 2 - Mean values of Cd, Cr, Cu, Mn, Ni, Pb and Zn determined in organs and whole plant (mg/kg DW) of *Asphodelus aestivus* Brot. collected from different sites. [For mean soil element values, different letters indicate significant differences between the sampling sites according to Tukey's HSD Test (rejection level 0.05). *n*= 5, Means ± Standard Deviation]

	Plant	**Sampling Sites**			
	Organ	**Site-I**	**Site-II**	**Site-III**	**Site-I**
Cd	Flowers	$0.11^{b} \pm 0.04$	$0.10^{bc} \pm 0.02$	$0.13^{a} \pm 0.08$	$0.04^{c} \pm 0.00$
	Leaves	$0.10^{a} \pm 0.02$	$0.09^{ab} \pm 0.05$	$0.06^{ab} \pm 0.08$	$0.04^{b} \pm 0.01$
	Stems	$0.05^{a} \pm 0.03$	$0.08^{a} \pm 0.06$	$0.05^{a} \pm 0.02$	$0.05^{a} \pm 0.01$
	Aboveground total	$\mathbf{0.26^{a} \pm 0.02}$	$\mathbf{0.26^{a} \pm 0.01}$	$\mathbf{0.18^{ab} \pm 0.14}$	$\mathbf{0.13^{b} \pm 0.01}$
	Roots	$0.10^{a} \pm 0.03$	$0.14^{a} \pm 0.02$	$0.03^{b} \pm 0.01$	$0.07^{b} \pm 0.02$
	Whole Plant	$\mathbf{0.36^{ab} \pm 0.04}$	$\mathbf{0.40^{a} \pm 0.08}$	$\mathbf{0.26^{ab} \pm 0.14}$	$\mathbf{0.20^{b} \pm 0.02}$
Cr	Flowers	$0.07^{b} \pm 0.02$	$0.07^{b} \pm 0.02$	$0.08^{b} \pm 0.06$	$0.43^{a} \pm 0.08$
	Leaves	$0.21^{ab} \pm 0.10$	$0.11^{b} \pm 0.03$	$0.06^{bc} \pm 0.04$	$0.27^{a} \pm 0.06$
	Stems	$0.06^{b} \pm 0.01$	$0.73^{a} \pm 0.18$	$0.01^{b} \pm 0.01$	$0.03^{b} \pm 0.03$
	Aboveground total	$\mathbf{0.34^{b} \pm 0.10}$	$\mathbf{0.91^{a} \pm 0.21}$	$\mathbf{0.15^{bc} \pm 0.04}$	$\mathbf{0.74^{a} \pm 0.11}$
	Roots	$0.06^{b} \pm 0.02$	$0.05^{b} \pm 0.03$	$0.02^{b} \pm 0.01$	$0.30^{a} \pm 0.05$
	Whole Plant	$\mathbf{0.40^{b} \pm 0.10}$	$\mathbf{0.95^{a} \pm 0.19}$	$\mathbf{0.17^{bc} \pm 0.04}$	$\mathbf{1.04^{a} \pm 0.14}$
Cu	Flowers	$0.50^{a} \pm 0.23$	$0.49^{a} \pm 0.10$	$0.65^{a} \pm 0.19$	$0.20^{b} \pm 0.05$
	Leaves	$0.50^{a} \pm 0.21$	$0.43^{a} \pm 0.17$	$0.46^{a} \pm 0.08$	$0.17^{b} \pm 0.03$
	Stems	$0.42^{a} \pm 0.17$	$0.42^{a} \pm 0.09$	$0.39^{a} \pm 0.05$	$0.29^{a} \pm 0.10$
	Aboveground total	$\mathbf{1.43^{a} \pm 0.32}$	$\mathbf{1.35^{a} \pm 0.24}$	$\mathbf{1.50^{a} \pm 0.16}$	$\mathbf{0.66^{b} \pm 0.13}$
	Roots	$0.47^{a} \pm 0.09$	$0.16^{b} \pm 0.05$	$0.35^{a} \pm 0.17$	$0.10^{b} \pm 0.03$
	Whole Plant	$\mathbf{1.90^{a} \pm 0.25}$	$\mathbf{1.51^{b} \pm 0.21}$	$\mathbf{1.85^{a} \pm 0.09}$	$\mathbf{0.76^{c} \pm 0.12}$
Mn	Flowers	$0.36^{b} \pm 0.10$	$0.79^{a} \pm 0.23$	$0.64^{ab} \pm 0.26$	$0.33^{b} \pm 0.02$
	Leaves	$1.17^{a} \pm 0.12$	$0.84^{ab} \pm 0.34$	$0.55^{b} \pm 0.21$	$0.33^{bc} \pm 0.08$
	Stems	$0.40^{b} \pm 0.12$	$0.68^{a} \pm 0.20$	$0.11^{c} \pm 0.04$	$0.46^{ab} \pm 0.16$
	Aboveground total	$\mathbf{1.92^{ab} \pm 0.17}$	$\mathbf{2.31^{a} \pm 0.61}$	$\mathbf{1.30^{b} \pm 0.26}$	$\mathbf{1.12^{bc} \pm 0.15}$
	Roots	$2.09^{a} \pm 0.87$	$1.53^{a} \pm 0.47$	$0.61^{b} \pm 0.23$	$0.19^{b} \pm 0.04$
	Whole Plant	$\mathbf{4.01^{a} \pm 0.89}$	$\mathbf{3.84^{a} \pm 0.40}$	$\mathbf{1.91^{b} \pm 0.19}$	$\mathbf{1.32^{b} \pm 0.14}$
Ni	Flowers	$0.73^{b} \pm 0.14$	$1.52^{a} \pm 0.53$	$0.59^{b} \pm 0.16$	$1.48^{a} \pm 0.25$
	Leaves	$0.81^{a} \pm 0.20$	$0.99^{a} \pm 0.35$	$0.39^{b} \pm 0.08$	$0.37^{b} \pm 0.07$
	Stems	$0.68^{b} \pm 0.10$	$0.98^{a} \pm 0.21$	$0.50^{b} \pm 0.14$	$0.10^{c} \pm 0.04$
	Aboveground total	$\mathbf{2.22^{b} \pm 0.27}$	$\mathbf{3.49^{a} \pm 0.55}$	$\mathbf{1.48^{c} \pm 0.15}$	$\mathbf{1.95^{bc} \pm 0.23}$
	Roots	$0.60^{b} \pm 0.23$	$0.55^{b} \pm 0.15$	$1.40^{a} \pm 0.34$	$0.41^{b} \pm 0.07$
	Whole Plant	$\mathbf{2.82^{b} \pm 0.38}$	$\mathbf{4.04^{a} \pm 0.49}$	$\mathbf{2.88^{b} \pm 0.28}$	$\mathbf{2.36^{b} \pm 0.24}$
Pb	Flowers	$1.42^{b} \pm 0.66$	$0.97^{bc} \pm 0.33$	$2.83^{a} \pm 0.62$	$0.22^{c} \pm 0.04$
	Leaves	$0.92^{c} \pm 0.17$	$1.11^{ab} \pm 0.17$	$1.45^{a} \pm 0.36$	$0.29^{c} \pm 0.08$
	Stems	$2.34^{a} \pm 0.45$	$0.92^{b} \pm 0.14$	$1.09^{b} \pm 0.38$	$0.30^{c} \pm 0.09$
	Aboveground total	$\mathbf{4.68^{a} \pm 0.43}$	$\mathbf{3.00^{b} \pm 0.16}$	$\mathbf{5.37^{a} \pm 0.83}$	$\mathbf{0.81^{c} \pm 0.15}$
	Roots	$1.50^{a} \pm 0.48$	$0.23^{c} \pm 0.06$	$0.74^{b} \pm 0.20$	$0.33^{bc} \pm 0.08$
	Whole Plant	$\mathbf{6.17^{a} \pm 0.77}$	$\mathbf{3.23^{b} \pm 0.11}$	$\mathbf{6.11^{a} \pm 0.81}$	$\mathbf{1.14^{c} \pm 0.11}$
Zn	Flowers	$0.63^{a} \pm 0.29$	$0.61^{a} \pm 0.12$	$0.67^{a} \pm 0.17$	$0.36^{a} \pm 0.03$
	Leaves	$0.63^{a} \pm 0.27$	$0.54^{a} \pm 0.21$	$0.57^{a} \pm 0.11$	$0.19^{b} \pm 0.03$
	Stems	$0.56^{a} \pm 0.17$	$0.47^{a} \pm 0.18$	$0.36^{ab} \pm 0.13$	$0.17^{b} \pm 0.04$
	Aboveground total	$\mathbf{1.82^{a} \pm 0.39}$	$\mathbf{1.62^{a} \pm 0.24}$	$\mathbf{1.60^{a} \pm 0.13}$	$\mathbf{0.72^{b} \pm 0.07}$
	Roots	$0.59^{a} \pm 0.11$	$0.22^{bc} \pm 0.07$	$0.35^{b} \pm 0.20$	$0.13^{c} \pm 0.03$
	Whole Plant	$\mathbf{2.41^{a} \pm 0.31}$	$\mathbf{1.84^{b} \pm 0.20}$	$\mathbf{1.95^{b} \pm 0.32}$	$\mathbf{0.84^{c} \pm 0.06}$

TABLE 3 - Heavy metal average bioconcentration factor (BF) and translocation factor (TF) of *A. aestivus* Brot. (*n*= 20, Means ± Standard Deviation]

Elements	BCF [metal shoot/ metal soil (mg/kg^{-1})]			TF [metal shoot/ metal soil (mg/kg^{-1})]		
Cd	3.59	±	2.02	3.33	±	2.15
Cr	1.66	±	1.48	8.05	±	5.56
Cu	2.82	±	1.35	5.78	±	3.47
Mn	0.28	±	0.16	2.89	±	2.37
Ni	1.12	±	0.62	4.02	±	2.14
Pb	2.57	±	2.23	6.64	±	5.19
Zn	0.16	±	0.08	5.73	±	2.81

ground total cadmium contents (Table 2). But the dominancy was not detected among above ground plant parts in regarding to Cd accumulation.

In our study, soil chromium levels varying between 0.78 ± 0.37 mg/kg dry weight and 0.19 ± 0.03 mg/kg dry weight (Table 1) showed that the soils of *A. aestivus* around Bursa (Turkey) were not contaminated by Cr, because these values were below than the average Cr range in the soils (5-1000 mg/kg dry weight) [34]. The mean Cr contents in *A. aestivus* plant varied between 1.04 ± 0.14 mg/kg dry weight and 0.17 ± 0.04 mg/kg dry weight and, the highest Cr accumulation was determined in the plant samples taken from Site IV. By comparing these values with the average Cr range in plant tissues (0.2-1 mg/kg dry weight) [34], the Cr levels of *A. aestivus* are similar to Cr levels of a normal plant. So, it can be said that Cd was not accumulated by these plants. But, Allen (1989) [35] reported that the chromium level above 0.5 mg/kg dry weight was toxic to plants. For this reason the highest Cr level in plant samples taken from Site IV may reflect the Cr accumulation capacity of Asphodel plant. The average BF and TF values (1.66 ± 1.48 and 8.05 ± 5.56; respectively) also supported this result (Table 3). But we could not determine a clear Cr distribution model among plant parts.

Our results suggest that the copper, manganese and zinc did not cause heavy metal pollution in destroyed areas of Mediterranean environment around the Bursa City. For instance, the average Cu range in soils is 2 - 60 mg/kg dry weight [34] but the highest mean Cu contents in the soils of *A. aestivus* varied between 0.83 ± 0.20 mg/kg dry weight and 0.18 ± 0.04 mg/kg dry weight. Similar results can be found for Mn and Zn (Table 1). Also, we determined low Cu, Mn and Zn contents in the total phytomass of Asphodel plants. Maestri et al. (2010) [34] reported that the average ranges in plant tissues for Cu, Mn and Zn are 2 - 20 mg/kg dry weight, 1-700 mg/kg dry weight and 15-150 mg/kg dry weight, respectively. The mean contents of three heavy metals were below these ranges. For example, the mean Cu contents 0.76 ± 0.12 mg/kg dry weight and 1.90 ± 0.25 mg/kg dry weight in total phytomass of this species were under the average Cu range in plant tissues (Table 2). Similarly, the Mn and Zn contents did not exceed the reported limits. Even if the Mn content of this species reached up to 4.01 ± 0.89 mg/kg dry weight, this value is much lower than that of a normal plant (200 mg/kg dry weight) [36]. Due to low Cu, Mn and Zn concentrations, we can conclude that these heavy metals cannot be accumulated by *A. aestivus*. Although the low Cu contents of plant samples may indicate a low Cu accumulation capacity of this species, the high BF and TF factors (Table 3) may point to the accumulation and translocation capability of this heavy metal. The significant positive correlation ($P < 0.05$) (Table 4) between copper contents of soils and aboveground parts may support the Cu accumulation capacity of *A. aestivus.*

Soil Pb contents of sample sites varied between 0.67 ± 0.16 mg/kg dry weight and 3.38 ± 1.00 mg/kg dry weight. These values were lower than the upper Pb limits of non-polluted sites reported in literature (50 mg/kg dry weight, 10-150 mg/kg dry weight) [34, 37]. Although the soil Pb contents were low, the mean Pb contents of plants taken from all sample sites were higher than the normal Pb composition (1.0 mg/kg dry weight) [36]. The mean Pb content of aboveground parts of plant samples taken from Site III reached up to 5.37 ± 0.83 mg/kg dry weight (Table 2). The mean Pb content of total phytomass of these plants was 6.11 ± 0.81 mg/kg dry weight. These values were also above the average Pb range in plant tissues reported by Maestri et al. (2010) [34] (0.1- 5 mg/kg dry weight). So, they can indicate the Pb accumulating capacity of Asphodel plant. In addition to high BF and TF values determined for this heavy metal (Table 3), the significant positive correlations ($P<0.05$) between Pb content of soils and leaf, flowers and aboveground parts support this result.

The average nickel ranges in soil and plant tissues were given as 2 - 200 mg/kg dry weight and 0.4 – 4.0 mg/kg dry weight by Maestri et al. (2010) [34]. If we compare the mean Ni contents of *A. aestivus* and its soils with these values, we can say that Ni was not accumulated in the soil tissues of *A. aestivus* from degraded Mediterranean environment. Because the highest Ni contents determined in the soils taken from Site III (5.24 ± 0.72 mg/kg dry weight) were not above the upper limits of this range (Table 2). The highest Ni content in Asphodel plants (4.04 ± 0.49 mg/kg dry weight) was also not above the upper limits of reported range. In contrast, Markert et al. (1994) [36] reported the Ni content of a normal plant was 1.5 mg/kg dry weight. The mean Ni contents of Asphodel plants taken from all samples were higher than that of a normal plant.

TABLE 4 - Simple Correlation Coefficients (r^2), significant levels (Possibility, *P*) and linear regression equations ($Y = a + bx$) between the acid-soluble contents of elements in soil and different organs (mg/kg DW) of *A. aestivus* Brot. (*n* = 20, *P* < 0.05 significant correlation)

Parameters	r^2	*P*	$Y = a + bx$
Soil-Cd			
Root-Cd	0.201	**0.048**	Root-Cd = 0.030108 + 0.7234 *x Soil-Cd*
Stem-Cd	0.017	0.587	Stem-Cd = 0.045960 + 0.1429 *x Soil-Cd*
Leaf-Cd	0.032	0.450	Leaf-Cd = 0.104982 - 0.3126 *x Soil-Cd*
Flower-Cd	0.110	0.152	Flower-Cd = 0.140411 - 0.6100 *x Soil-Cd*
Aboveground-Cd	0.051	0.337	Aboveground-Cd = 0.291352 – 0.7796 *x Soil-Cd*
Whole plant-Cd	0.000	0.949	Whole plant-Cd = 0.321460 – 0.0563 *x Soil-Cd*
Soil-Cr			
Root-Cr	0.311	**0.011**	Root-Cr = 0.221210 - 0.2318 *x Soil-Cr*
Stem-Cr	0.550	**0.000**	Stem-Cr = -0.168133 + 0.8250 *x Soil-Cr*
Leaf-Cr	0.142	0.101	Leaf-Cr = 0.224807 - 0.1366 *x Soil-Cr*
Flower-Cr	0.254	**0.024**	Flower-Cr = 0.296741 - 0.2912 *x Soil-Cr*
Aboveground-Cr	0.119	0.137	Aboveground-Cr = 0.33414 – 0.3972 *x Soil-Cr*
Whole plant-Cr	0.015	0.612	Whole plant-Cr = 0.564624 + 0.1654 *x Soil-Cr*
Soil-Cu			
Root-Cu	0.085	0.212	Root-Cu = 0.181803 + 0.1623 *x Soil-Cu*
Stem-Cu	0.135	0.111	Stem-Cu = 0.305770 + 0.1363 *x Soil-Cu*
Leaf-Cu	0.193	**0.052**	Leaf-Cu = 0.247429 + 0.2575 *x Soil-Cu*
Flower -Cu	0.100	0.174	Flower-Cu = 0.334516 + 0.2236 *x Soil-Cu*
Aboveground-Cu	0.238	**0.029**	Aboveground-Cu = 0.887716 + 0.6174 *x Soil-Cu*
Whole plant-Cd	0.249	**0.025**	Whole plant-Cu = 1.069519 + 0.7797 *x Soil-Cu*
Soil-Mn			
Root-Mn	0.473	**0.001**	Root-Mn = 3.383622 - 0.3365 *x Soil-Mn*
Stem-Mn	0.107	0.159	Stem-Mn = 0.709482 - 0.0440 *x Soil-Mn*
Leaf-Mn	0.548	**0.000**	Leaf-Mn = 1.752317 - 0.1524 *x Soil-Mn*
Flower-Mn	0.032	0.447	Flower-Mn = 0.702362 - 0.0254 *x Soil-Mn*
Aboveground-Mn	0.485	**0.001**	Aboveground-Mn = 3.164161 - 0.2219 *x Soil-Mn*
Whole plant-Mn	0.625	**0.000**	Whole plant-Mn = 6.547783 – 0.5583 *x Soil-Mn*
Soil-Ni			
Root-Ni	0.591	**0.000**	Root-Ni = 0.158589 + 0. 2087 *x Soil-Ni*
Stem-Ni	0.070	0.259	Stem-Ni = 0.405943 + 0. 0565 *x Soil-Ni*
Leaf-Ni	0.029	0.471	Leaf-Ni = 0.736594 + 0. 0348 *x Soil-Ni*
Flower-Ni	0.233	**0.031**	Flower-Ni = 1.504671 - 0.1528 *x Soil-Ni*
Aboveground-Ni	0.068	0.267	Aboveground-Ni = 2.647207- 0.1311 *x Soil-Ni*
Whole plant-Ni	0.031	0.454	Whole plant-Ni = 2.805796 + 0.7755 *x Soil-Ni*
Soil-Pb			
Root-Pb	0.060	0.300	Root-Pb = 0.889372 - 0.0997 *x Soil-Pb*
Stem-Pb	0.010	0.672	Stem-Pb = 1.274743 - 0.0591 *x Soil-Pb*
Leaf-Pb	0.595	**0.000**	Leaf-Pb = 0.438547 + 0.2640 *x Soil-Pb*
Flower-Pb	0.349	**0.006**	Flower-Pb = 0.489519 + 0.4567 *x Soil-Pb*
Aboveground-Pb	0.244	**0.027**	Aboveground-Pb = 2.202809 + 0.6616 *x Soil-Pb*
Whole plant-Pb	0.122	0.131	Whole plant-Pb = 3.092181 + 0.5618 *x Soil-Pb*
Soil-Zn			
Root-Zn	0.005	0.773	Root-Zn = 0.379857 - 0. 0062 *x Soil-Zn*
Stem-Zn	0.104	0.166	Stem-Zn = 0.129164 + 0.2695 *x Soil-Zn*
Leaf-Zn	0.119	0.136	Leaf-Zn = 0.136010 + 0.0355 *x Soil-Zn*
Flower-Zn	0.066	0.274	Flower-Zn = 0.3447 + 0.0227 *x Soil-Zn*
Aboveground-Zn	0.166	**0.075**	Aboveground-Zn = 0.609900 + 0.0852 *x Soil-Zn*
Whole plant-Zn	0.087	0.208	Whole plant-Zn = 0.98978 + 0.0791 *x Soil-Zn*

Also, we found significantly high positive correlation between Ni content of soils and roots (P<0.05) (Table 4). These findings may suggest the Ni accumulation capacity of this species.

4. CONCLUSION

In this study, we determined that the Cd, Cr, Cu, Mn, Ni, Pb and Zn did not cause heavy metal pollution in the soils of *A. aestivus* spread on degraded areas from Medi-

terranean environment. Also, it was found that *A. aestivus* generally has no effective heavy metal accumulating capacity. But if we compare the Cd, Cr, Ni and Pb levels with the reported values of these heavy metals in literature, our results imply the possible accumulation capacity of this species. For this reason, this study contains a basic knowledge about the heavy metal accumulation capacity of *A. aestivus* and the contribution of this property in the dominancy of species on degraded areas from Mediterranean environment. But there is a requirement to know the response of asphodel plant's growing under the heavy metal abundance.

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