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FULL PAPER

Evaluation of the heavy metal accumulation capacity of a Sahraria plant Aristida pungens L.

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In this work, we aimed at evaluating the xerophytic character by determining the content of seven heavy metals (Fe, Zn, Cu, Co, Cd, Ni, and Pb) in the different organs of a Sahrian plant Aristida pungens L. by atomic absorption spectrometry (SAA) and this to use this plant in to clean it up from contaminated soils. The xerophytic trait of Aristida pungens L. that allows it to accumulate metals has been confirmed. Aristida pungens L. has been shown to have a great capacity to accumulate heavy metals, particularly copper and lead. The contents of its heavy metals range in the threshold of toxic concentrations of fodder plants.

KEYWORDS

Aristida pungens L.; copper; lead; aqua regia; extraction.

Introduction

Besides the use of Aristida pungens L. as a windbreak to immobilize sand dunes [1], this species is used in several areas by nomads for healing wounds [2], as fodder for de many animals, and against rheumatic pain [3]. On the other hand, the seeds of Aristida pungens L. are ground to prepare pancake flour in the Algerian Sahara [4]. Published work on this plant has caught our interest for its antimicrobial, antibiotic, and antifungal activity [5].

The morphological adaptations and physiological regulations of plants in dry regions, particularly that of Aristida pungens L., are essential to tolerate changes in the external environment [6]. These adaptations tend to amplify the root uptake of these plants in dry soil, thus allowing metals to be tolerated and accumulated to potentially toxic levels.

Research on Aristida stolonifera taken in the vicinity of another copper mine has shown it to be hyper tolerant to copper [7]. Moreover, it has been discovered that corn and cereals are also very tolerant to heavy metals [8].

Soil pollution by heavy metals has become a significant problem worldwide, and this is due to industrial and urban activities [9].

Heavy metals cannot be biodegraded and therefore persist in the environment for long periods and is a daily hazard [10].

Among the methods of treating polluted soils used, we distinguish chemical treatment, biological treatment, and joint remediation [11].

Phytoremediation is used more and more and has many advantages. It is economically viable and compatible with environmental preservation policies. In addition, the process is more ecological, and its cost is lower. [12]. The search for a technique to naturally clean up the soil has led to the discovery of a variety of heavy metal hyperaccumulating plants that have been used to remove various heavy metals [13].

Among these plants, mention may be made of Glochidion cf. Sericeum is found to be very tolerant of nickel. Moreover, Jingtian has shown that it is hyperaccumulative to cadmium [14], while Pteris vittata can accumulate arsenic [15].

Medicinal plants can accumulate heavy metals from the soil, posing a significant problem relating to contamination in the food chain [16]. The accumulation of heavy metals such as Cd, Ni, As, Ag, Hg in the food chain will lead to risks that will not have carcinogenic consequences for health. [17].

The objective of this work is to determine the total contents of heavy metals (lead, zinc, cadmium, copper, nickel, cobalt, and iron) present in the various aerial parts (the stems, the knots, the sheaths, and the sheets) and roots of Aristida pungens L. by a set of acid extractants (HCl, HNO_3 and aqua regia) and this for the first time in this species. Quantification of heavy metals was done by atomic absorption spectroscopy. It opens up new perspectives for us. It is that of phytoremediation, which recommends the cultivation of Arisdida pungens L. in contaminated soils to remove them.

Experimental

Materials and methods

Plant: Samples of the plant (Aristida pungens L.) were taken in triplicate from the same field. The samples were washed using distilled water and then dried separately in the oven at 80 °C until a constant weight was reached. The samples were then ground separately through a steel mill, and the ground material was passed through a 2 mm sieve.

Dissolution of heavy metals

Elementary analysis techniques essentially consist of transforming plant constituents into disabled salts. Therefore, the dosage of these anions and cations concerns the mineral matter, that is to say, what remains after incineration.

Experimental Incineration Protocol

200 to 300 mg of vegetable powder was weighed in a porcelain capsule. The capsule is placed in a muffle furnace. The best results are obtained by keeping the oven at the temperature of 300 °C until the carbon stops glowing. The oven temperature then rose to 400-450 °C. The mineralization time was variable, and it depends on the nature of the material to obtain crumbly white ash as a product. The last traces of organic material are oxidation is then carried out by adding 1 to 2 mL of HNO_3 (1N) after cooling the capsule. It is evaporated to dryness on a hot plate or in a sand bath and returned to the oven at 400 °C for one hour.

Dissolution of heavy metals by acid attack

During this work, three acid solutions (aqua regia solution, concentrated nitric acid solution, and concentrated hydrochloric acid solution) were used to extract all of the heavy metals in the plant material.

Dissolution of heavy metals by aqua regia

Amount of 1 g of ash was introduced into an Erlenmeyer flask where the attack was carried out with 10 mL of aqua regia (HCl / HNO_3 (1: 3)). The ashes are moistened with a few drops of water, and then 2 mL of HCl are added. It was evaporated to dryness on a hot plate. After adding 3 mL of HCl + 1 mL of HNO_3, the mixture was left in contact for 10 minutes, and the filter was carried out in 25 mL volumetric flasks. After adjusting to the gauge line and then homogenized by manual stirring, the solutions are transferred into cups rinsed beforehand with the solution and on which the sample was numbered.

Dissolution of heavy metals with nitric acid (HNO_3)

An amount of 0.5 g of powder was placed in an Erlenmeyer flask, and a volume of 5 mL of concentrated nitric acid (60% HNO_3) was added. After closing the Erlen, the reaction was left at room temperature for 16 h. under agitation. Then the reaction was brought to 70 °C in a water bath followed by stirring for 8 h.

After cooling, filtration was carried out with rinsing with distilled water. The final solution was calibrated to 50 mL.

Dissolution of heavy metals by HCl

An amount of 0.5 g of ash was introduced into an Erlenmeyer flask, with a volume of 5mL of concentrated hydrochloric acid (37% HCl). After closing the Erlen, the reaction was heated at a temperature in the range of 40-60 °C for 8 h with stirring. After cooling, filtration was carried out with rinsing with distilled water. The final solution was calibrated to 25 mL.

Dosage of solutions or metal analysis

The concentrations of metals Cd, Pb, Ni, Co, Cu, Zn, and Fe in both plants (Aristida pungens L.) were determined using the atomic absorption spectrometry (Aurora Instruments Ltd-AI 1200).

Results and discussion

Treatment of plant material

The content of mineral elements (%) in the various organs of Aristida pungens L. studied, previously, calcined was determined using the following formula: % = MC / MS

Where Mc is the mass of the dry matter after calcination and Ms is the mass of the dry matter before calcination. The obtained results are presented in Table 1.

The results mentioned in the Tables (2-4), obtained by the three extractants are different. We compared our results with normal [18] and critical levels of heavy metals in plants [19].

TABLE 1 Percentage of mineral matter in the different organs From Aristida pungens L.

Organs	The mineral part (%)
The stems (T)	5.74
The knots (N)	1.21
The sheaths (G)	5.94
The sheets (F)	5.19

TABLE 2 The concentrations of heavy metals (mg/kg of dry matter) in the various organs of Aristida pungens L. (extraction with HNO_3)

	Cu	Co	Ni	Pb	Cd	Zn	Fe
The stems	81.07	5.37	43.50	9.99	1.72	95.00	305.19
The knots	74.29	0	94.12	0	20.49	124.33	394.10
The sheaths	31.59	5.13	40.47	0	0.59	60.13	160.88
The sheets	25.53	3.57	35.24	8.85	0	9.11	6.62

TABLE 3 The concentrations of heavy metals (in mg/kg of dry matter) in the various organs of Aristida pungens L. (extraction with HCl)

	Cu	Co	Ni	Pb	Cd	Zn	Fe
The stems	84.72	6.75	43.64	7.29	5.04	84.72	292.32
The knots	51.31	18.80	86.36	2.06	28.20	12.13	60.28
The sheaths	24.31	5.22	41.92	0	1.78	17.81	22.30
The sheets	20.14	17.60	38.45	12.58	2.17	10.35	51.60

TABLE 4 The concentrations of heavy metals (in mg/kg of dry matter) in the various organs of Aristida pungens L. (extraction with aqua regia)

	Cu	Co	Ni	Pb	Cd	Zn	Fe
The stems	52.18	10.93	22.71	52.72	0.34	42.87	205.42
The knots	59.37	0	44.63	16.49	2.42	34.63	784.20
The sheaths	32.21	0	18.70	28.77	0.47	18.38	84.86
The sheets	16.18	0	0	28.09	0.23	17.14	300.62

The results mentioned in the tables above, obtained by the three extractants, are different. It can be deduced that the used extractants were not allowed to extract all of the metal from the organ studied, hence an unstable estimate of the content. To achieve a truly total content, all available forms of the element must be dissolved. However, despite these uncertainties, it was possible to evaluate the extraction power of each acid solution used for each metal dosed.

The extraction results of each metal by the three acid solutions are shown as histograms 1-7.

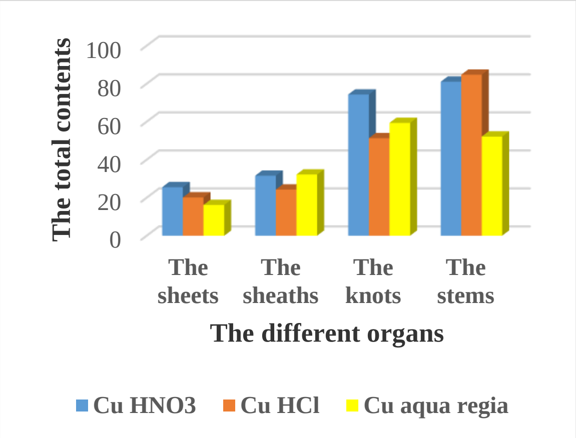

FIGURE 1 Histogram illustrating the copper contents (mg/kg of dry matter) in the different organs (extraction by HNO_3, HCl, and aqua regia)

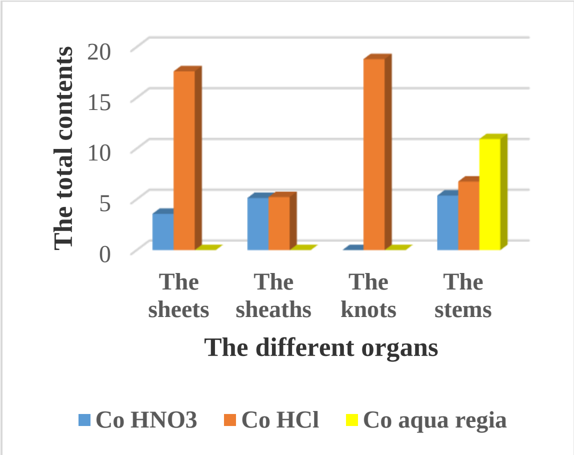

FIGURE 2 Histogram illustrating the cobalt contents (mg/kg of dry matter) in the different organs (extraction by HNO_3, HCl, and aqua regia)

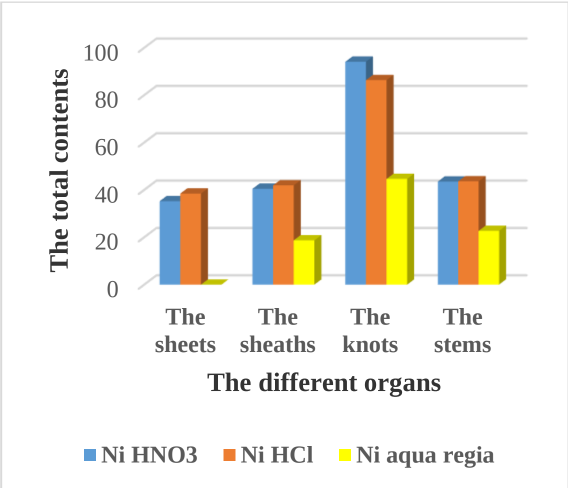

FIGURE 3 Histogram illustrating the nickel contents (mg/kg of dry matter) in the different organs (extraction by HNO_3, HCl, and aqua regia)

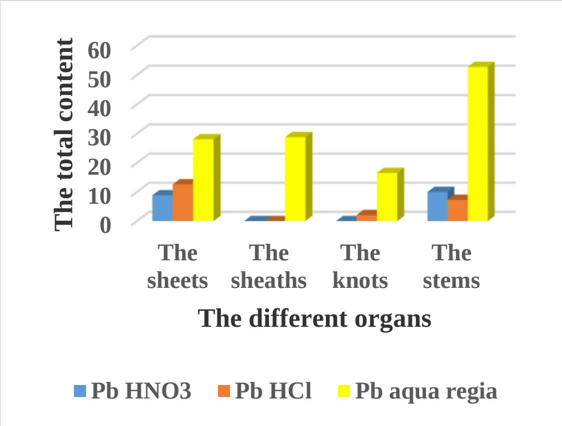

FIGURE 4 Histogram illustrating the lead contents (mg/kg of dry matter) in the different organs (extraction by HNO_3, HCl, and aqua regia)

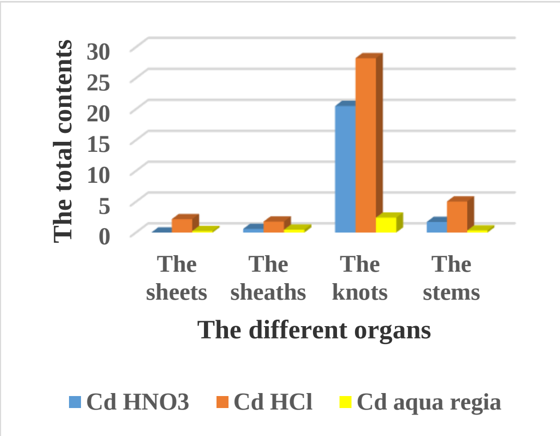

FIGURE 5 Histogram illustrating the cadmium contents (mg/kg of dry matter) in the different organs (extraction by HNO_3, HCl, and aqua regia)

After treatment and extraction of the different organs of the plant studied respectively with HCl, HNO_3, and aqua regia, the heavy metal contents obtained show that the nature of the acid used and the type of organ subjected to our investigation plays an essential role in the ease of extraction of the metal. This is because the metals Cd, Ni, Co, and Cu are best extracted by hydrochloric acid concentrated in the stems, leaves, and sheaths.

In addition, it was easier to separate Ni, Cu, and Zn by treating the nodes and leaves respectively with concentrated nitric acid. On the other hand, aqua regia extracts Pb, Ni, and Cu from the sheaths and nodes. These results do not allow an estimate of the total content of an element.

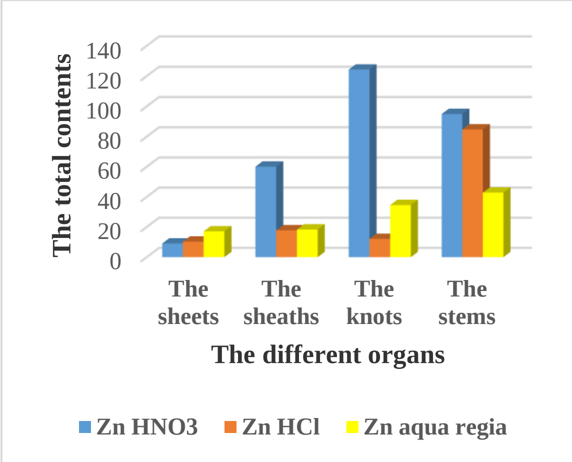

FIGURE 6 Histogram illustrating the zinc contents (mg/kg of dry matter) in the different organs (extraction by HNO_3, HCl, and aqua regia)

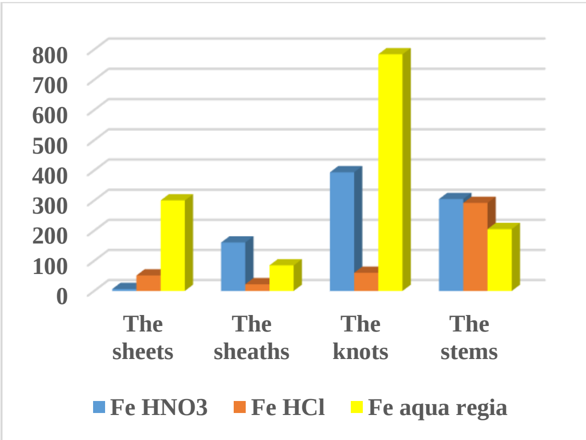

FIGURE 7 Histogram illustrating the iron contents (mg/kg of dry matter) in the different organs (extraction by HNO_3, HCl, and aqua regia)

This due to the fact that the extractants used are probably not able to extract all of the metal from the organ studied, which makes it difficult to estimate the phytoavailability of heavy metals in our plant.

To obtain a truly total content, it is imperative to dissolve all assimilable forms of the element. Plants mainly take up trace elements through the roots via the soil solution. This root sample is taken in ionic form (Cd, Zn), in the form of anionic complexes

(Cd), and also in the form of organic complexes (Pb, Fe) [20, 21]. The quantification of these assimilable forms requires speciation studies in solution. However, from these results, it can be seen that the concentration of heavy metals varies from organ to organ in the plant. It should be noted that the heavy metals Zn, Ni, Cu, Pb, and Co are distributed uniformLy throughout the plant but are concentrated more in the nodes (Zn, Ni, and Cu) and the stems (Cu, Zn, and Pb).

Besides, Co was found throughout the plant while Cd was concentrated more mainly in the nodes. We also noticed the metals Cu and Pb accumulation in the stems and Cu, Ni, and Cd in the knots.

The Cu and Pb contents very much exceed the phytotoxicity threshold. At the same time, the Cd contents greatly exceed the minimum value of phytotoxicity. On the other hand, the Ni contents are very close to the maximum value of phytotoxicity. As for the Co contentssignifican greatly exceeded the abnormal threshold and approached the minimum value of phytotoxicity.

Conclusion

This study showed that Aristida pungens L. is a plant hyperaccumulator with heavy metals, including copper and lead. This interesting result represents a novelty and is reported for the first time in this species. The analyses carried out by atomic adsorption show that the plant studied accumulates heavy metals, sometimes in quantities far exceeding the toxicity threshold. This finding poses a significant problem relating to contamination in the food chain.

Faced with these qualities of a tolerant plant and hyperaccumulator of heavy metals, we recommend cultivating Aristida pungens L. in contaminated soils to clean them up.

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Conflict of interest

"The authors declare that there are no conflicts of interest regarding the publication of this manuscript."

Abbreviations

Not applicable in this section.

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