Potentialities of Medicinal Indigenous taxa for accumulation of macro- and micro elements increasing nearby Abu-Tartur phosphate mining ore, Egypt

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Research Article

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Abstract

Background and Aims

Some wild taxa (*Astragalus vogalii*, *Sesbania sesban, Trigonella hamosa*, *Melilotus indicus*, *Senna italica*, *Bidens pilosa* and *Conyza bonariensis*) growing around Abu-Tartur phosphate mining ore in Egypt, were conducted to identify species accumulation of Fe, Mn, Zn, Cu, Mo, Se, B, Pb, Cr, Cd, Ni, Ag, Si and Na in plants and soils.

Methods

These metals levels were measured by atomic spectroscopy techniques, including flame-AAS, GF-AAS, and ICP-AES.

Results

The bioavailability of trace elements to plants was affected by soil factors such as soil pH, organic matter (OM) content. Soil considered alkali soil (pH range from 7.4- 8.6) with low organic contents (1.26-1.80 %). By comparing the soil content around the phosphate mining area in the Western Desert as part of the extremely dry deserts range with the ideal agricultural soil content of macronutrients, it was found that there were low contents of them. Bioconcentration Factor, Translocation Factor (TF), Biological Accumulation Coefficient (BAC) and element accumulation index (EAI) were calculated for the studied metals associated with phosphate mining process. BF and BAC for all metals are more than unity.

Conclusion

Our study showed that these native plants with a high BF and low (TF) and have the potential for phytostabilization and will be used in phytoremediation of the metallic pollutants in soils after further research in accumulation mechanism of phosphate mining spoils.

1. Introduction

A major economic deposit in Egypt is phosphate ore. The western desert between El-Karga and El-Dakhla Oases, the Nile valley close to Idfu, and the Red Sea between Safaga and Quesir are the three primary minefield locations in Egypt. Estimates place Egypt's total phosphate deposits at about 3 billion tones (**Notholt, 1985**). Concern for protecting the environment has increased during the past three decades. Sector in general, and the mining industry, are two of many such activities that have the potential to have serious negative effects on the environment. Despite the mine's location in the Western Desert, the extraction of ore from either an underground mine or a surface mine has several environmental effects that have an impact on people, agriculture, and natural resources (groundwater, wild plants and rare animals). These effects happen during mining operations, ore washing, loading and unloading, and other processes (**Coelho et al. 2011**). The physical and chemical characteristics of the soil in mining regions frequently impede microbial activity, plant growth, and soil-forming processes. The lack of topsoil, compaction, and a lack of vital nutrients are further detrimental concerns for vegetation in addition to high hazardous metal concentrations (**Anic et al., 2010; Shrivastava & Kumar, 2015**). Previous research demonstrated that some plants may thrive in these harsh settings and frequently could evolve into metal-tolerant ecotypes, particularly in the vicinity of mining operations (**Xiao et al., 2008; García-Lorenzo et al., 2009; Pérez-López et al., 2014; Rizwan et al., 2019; Heikal, et al., 2022; El-Esawi, et al., 2022**). The phytoremediation of mine tailings with high levels of heavy metals would benefit from the usage of these plant species. Exclusion, which involves avoiding excessive uptake and transport of metal ions, and accumulation and sequestration, which involves plants detoxifying free metals by compartmentalizing metals in vacuoles, are the two main coping mechanisms used by plants living in metal-enriched environments (**Sharma et al., 2016**).

Estimating the effect of soil factors on the bioavailability and uptake of metals by plants is crucial to reducing the harmful effects of metals and their transfer to food chains (**Zeng et al., 2011**). Valuable mathematical approaches and regression models can be applied to forecast specific dependent variables (e.g., metal concentrations within plant tissues) using variables independent of the soil (e.g., metal concentration, pH, and OM content) (**Chaudri et al., 2007; Zeng et al., 2011; Novotná et al., 2015; Li et al., 2022).**

Numerous geological, geochemical, and radiological studies and reports have examined the connections between the mining of phosphate and other metals associated with it (**El Maghraby, 2012; Hassan et al., 2016**; **Abou El-Anwar et al., 2017**), as well as vegetation, anatomical, and phytochemical analysis studies (**Abu Ziada et al., 2015; Abu Ziada et al., 2016b; El-Shamy, 2016**). There have also been reports about the uptake of phosphate-associated metals by various plants outside of Egypt (**Mkumbo et al., 2012; El Hasnaoui et al., 2020; El Berkaoui et al., 2021; Tibane & Mamba, 2022)**. There are no reports on the plant accumulators for heavy metals and the relationships between the soils in Egypt's extremely dry phosphate mining zones.

Metalliferous soils only let a small subset of the local flora's species to flourish. These plants exhibit physiological adaptations, such as metal tolerance, that set them apart from non-tolerant plants of the same species that grow in uncontaminated soils, according to various study cases **(Whiting et al., 2004; Bergmeier et al., 2009**). By immobilizing trace elements in the rhizosphere and stabilizing the soil, plants indigenous to toxic areas can restore metal-contaminated sites, lowering the risk of the spread of metalliferous dust through wind, water erosion, or downward water percolation from the root zone (Escarré et al., 2011).

Seven wild medicinal plant species indigenous to Abu-Tartur phosphate mining region: Astragalus vogelii *(Webb)* Borm., Sesbania sesban (L.) Merr., Trigonella hamosa L., Melilotus indicus (L.) All., Senna italica Mill. (Family: Fabaceae), Bidens pilosa Linn. And Conyza bonariensis (L.) Cronquist (Family: Asteraceae) were collected and examined for accumulation of macro- and trace- elements associated with mining operations around mining ore, Western Desert, Egypt.

The purpose of this work was: 1- to ascertain the relationship between the pH, organic content, macro, and trace elements of the soil samples associated with the studied sp., 2- to estimate macroelements, microelements concentrations accumulated by plants that are grown near mining areas. 3- to calculate

2. Materials And Methods

2.1. Study area

Abu Tartur phosphate deposit is one of the largest phosphates mining areas (1000 million tons and 200 million tons proved) in the Middle East. The mining area is in the western desert of Egypt, about 60 Km from El-Kharga City and 10 Km from the main road between El-Kharga and El-Dakhla Oases (Fig. 1). Abu Tartur phosphate mining area located at Latitude 25° 22' 50" north and Longitude 30° 5' 34" east (**El-Shamy, 2016**).

2.2. Soil and Plant Analysis

The technique of **Combs & Nathan (1998)** was used to calculate the level of organic matter (OM) content. Using a multi-parameter measuring device, electrical conductivity (EC) and pH (1:5 w/v soil water suspensions) were measured (**El Hasnaoui et al., 2020)**. To analyze the metal content (K, Ca, Mg, S, Fe, Mn, Zn, Cu, Mo, Se, B, Pb, Cr, Cd, Ni, Ag, Si, and Na), soil samples were dried at 72 ^{o}C to a constant weight before being digested with a solution that included 2 mL of concentrated HCl and 1 mL of concentrated HNO_3 according to **Temmingho & Houba (2004**). Plant samples were divided into shoots and roots and pulverized into powder after being dried at 72 ^{o}C for 48 hours. Then, plant samples were digested as **Temmingho & Houba (2004**). ICP-AES (inductively coupled plasma-atomic emission spectrometry; Ultima2 JY, Horiba Company, Edison, NJ, USA) was used to measure the concentrations of metal contents (**Ghosh et al., 2013)**. For plants and the corresponding soil samples, total N and P are quantified as according to **APHA (1998)**.

2.3. Biological Accumulation Coefficient, Bioconcentration Factor, Translocation Factor, and element accumulation index

To evaluate the metal enrichment characteristics of different plant species, three factors were calculated (**Gakwavu et al., 2012)**:

Biological accumulation coefficient (BAC) is defined as the concentration (conc.) of metals in plant shoots divided by metal conc. in rhizospheric soils.

BAC = [Metal] shoot / [Metal] soil

The biological factor (BF) is found by dividing the plant root metal conc. by the metal conc. in rhizospheric soils. This factor shows the accumulation ability for root from the soil.

BF = [Metal] root / [Metal] soil

Translocation factor (TF) is the metal ratio transfer capacity from root to shoots.

TF = [Metal] shoot / [Metal] root

The element accumulation index (EAI) was used to assess the overall performance of trace elements accumulation in plants **(Liu et al. 2007)**:

EAI $= \left(\frac{1}{N}\right)\sum_{j=1}^{N}\mathrm{Ij};\mathrm{I}j = x/\delta x$

Where N is the total number of the analyzed elements and Ij is the sub-index for an element j, obtained by dividing the mean conc. of an element (x) by its standard deviation (dx).

2.4. Data analysis

The significant differences between means among seven plant species were identified using Tukey HSD (honest significant difference) test at $P < 0.05$. Values in the figures and table are mean values of three independent replicates.

After testing the data for normality, the differences in the soil and plant tissues were tested using one-way analysis of variance (ANOVA) according to SPSS software. The differences in soil chemical properties, metal concentrations, macro-nutrients, and variations in trace metals conc. in shoots and roots of studied taxa were analyzed by one-way ANOVA using Tukey analysis. Also, EAI data for seven plant species were subjected to a one-way analysis to test the differences in trace elements conc. between shoots and roots. The comparisons of means for trace elements and macronutrients concentrations in shoot and roots of studied taxa were performed using principal component analysis (PCA-Biplot). Macro- and micro- nutrients data for plant species were subjected to an ANOVA-2 to identify the interactions in the independent variables (species and tissues).

3. Results

3.1 Soil properties

By comparing the soil content around the phosphate mining area in the Western Desert as part of the extremely dry deserts range with the ideal agricultural soil content of macronutrients, it was found that there were low contents of N, K, Ca and Mg **(Table 1)** showed that, ***Astragalus vogelii*** had the highest values of soil pH (8.6) and E.C (944.00 mmohs cm^{-1}).The analysis of soil underlying the studied species indicated that between twenty investigated macro and micro- elements, N, Mg, Cu, Pb and Ni were no significantly difference. Also, pH, E.C and organic contents of different soil samples had significant difference at different sites of studied species. The highest concentrations of K, Mn, Pb, Cd, Si and Na (173, 1.2, 0.94, 2.21, 0.23 and 1.59 mg/Kg) recorded in soil supporting***A. vogelii***, *Ni (0.207 mg/Kg) for soil of* ***S. sesban***, Ca, Fe and Cr (24.91, 0.53 and 0.202 mg/Kg)*, respectively, for soil of* ***T. hamosa*** Se, Ag (0.80 and 1.33mg / Kg) for soil of ***M. indicus*** N, P, Mo and B (46.88, 17.29, 1.83 and 0.98 mg/Kg) recorded in soil of ***S. italica*** Mill, Mg (14.81 mg/Kg) for soil of ***B. pilosa***, S and Zn (37.58 and 0.146 mg/Kg) for soil of ***C. bonariensis***.

3.2 Plant Macronutrients and trace elements

Regarding the studied species, conc. of all macro- elements (N, P, K, Ca, Mg, S) were significantly affected by mining site, plant species and plant tissues (**Table 2**). Comparing with different studied sp., the highest conc. of N (3.75 %), P (0.9254%) and Ca (3.509 %) were recorded in ***B. pilosa***, K (5.796%) and S (1513.5 mg/ kg) in ***S. sesban*** and Mg (1.889%) in tissues of ***A. vogelii***.

Considering the seven plant species, conc. of micro elements were significantly affected by mining site (**Table 3**). Most micro elements conc. in both roots and shoots (Mn, Zn, Mo, Se, B, Cr, Ag, Si and Na) were significantly high between different studied species around the mining site, while, Fe, Cu, Pb, Cd and Ni concentrations were non-significant.

Concerning to ***A. vogelii***, the micro elements conc. in its shoots had the following sequence: Fe > Zn > Na > Cu > Mo > Cd >Se > Pb > Mn >Ag > B > Ni >Si > Cr, while in the roots the sequence was: Fe >Na > Cu > Zn > Cd > Pb> Se > Mn > B>Ag > Mo> Ni >Si > Cr. The accumulation of these elements was higher in shoots of ***A. vogelii*** except Na.

For ***S. sesban*** shoots the sequence was: Fe >Na >Cu >Mo> Cd> Pb >Mn >Zn >Ag >Si >Mo >Se > Ni >Cr, while the sequence for its roots was: Fe >Ag >Na > Cu> Cd> Pb> Si> Mn> Zn> Mo> B> Se > Ni>Cr. The higher conc. of Mn, Zn, Mo, Se, B, Cr and Cd documented at the shoots of ***S. sesban***.

In case of ***T. hamosa*** *shoots,* the sequence was*:* Fe >Na >Cu >Mo >Cd >Zn >Pb >Se >Ag >Mn >B >Ni >Cr >Si, whereas the sequence of elements in roots was: Fe >Na >Cu >Cd >Pb >Mn >Se >B >Ag >Ni >Zn >Cr >Mo >Si. The higher accumulation of Fe, Zn, Mo, Se, B, Cd and Ag documented at the shoots.

Considering to the trace elements conc. in the shoots of ***M. indicus****, the sequence was: Fe* >Ag >Na >Cu >Cd >Mn >Pb >Zn >B >Mn >Se >Ni >Si >Cr, and for their roots was: Fe >Ag >Na >Cu >Cd >Mo >Pb >B >Mn >Se >Zn >Ni >Cr >Si. In case of ***M. indicus***, the higher accumulation of Fe, Mn, Zn, Se, B, Pb and Ni was in shoots.

In case of ***S. italica*** shoots, the graduation of elements conc. was Fe >Na >Cu >Mo >Cd >Pb >B >Zn >Ag >Se >Mn >Ni >Cr >Si, while the graduation in roots was Fe >Na >Cu >Ag >Cd >Pb >Mo >Mn >Se >B >Ni >Zn >Cr >Si. The more accumulation of most elements was in shoots of ***S. italica*** (Fe, Zn, Cu, Mo, B, Pb, Cr, Cd, Ni and Si).

The graduation of elements conc. in ***B. pilosa*** shoots was as follow: Fe >Na >Cu >Cd >Pb >B >Mo >Ag >Mn >Se >Ni >Cr >Si >Zn, and in roots was Fe >Mo >Na >Cu >Cd >Pb >Ag >B >Mn >Se >Zn >Ni >Cr >Si. The more accumulation of most elements was in roots of ***B. pilosa*** (Mn, Zn, Mo, Se, Pb, Cr, Cd, Ag and Na).

Finally, *the sequence* of trace elements in the shoots of ***C. bonariensis****, was* Fe >Na >Cu >Mo >Cd >Pb >B >Se >Mn >Ni >Cr >Zn >Ag >Si, whereas *the sequence* in roots was: Fe >Na >Cu >Zn >Cd >Pb >B >Mn >Se >Mo> Ni> Ag >Cr >Si (**Table 3**).

3.3 Plant strategies

As general view, as shown in **table 3**, higher accumulation of elements in different species shoots: Fe was accumulated in shoots of all studied species (except ***S. sesban***), Zn was accumulated more in shoots (except ***B. pilosa*** *and* ***C. bonariensis***) and Se was recorded in higher concentration of species shoots (except ***S. italica*** and ***B. pilosa***). For roots of studies sp.: Ag was accumulated more in roots of all studied taxa (except ***A. vogelii*** and ***T. hamosa***) and Na was accumulated in roots of all studied sp. (except ***S. sesban***). Two-way ANOVA of the studied plant species showed that, the concentrations of all heavy metals were significantly affected by mining site, plant species and plant tissues (**Table 4**). As a summary, the highest concentrations of Fe, Zn, Se were recorded in ***A. vogelii***; Mn, Si, Na in ***S. sesban***, Mo, B, Ni in ***B. pilosa***, and Pb, Cr, Cd in ***C. bonariensis*** Cu in ***S. italica*** and Ag in ***M. indicus***.

After the application of pattern recognition technique using unsupervised Principal Components Analysis (PCA) on the all-analytical variables including macro- and micro elements for shoots and roots of the studied taxa (**Fig. 2 a &b)**.

Fig. 2a showed roots accumulated ability along the first component the cluster of variables (**a**): Ni, Mn were connected with ***C. bonariensis***; Zn, Mg, N, Fe connected with ***A. vogelii***; along the second component other two clusters of the variables (**b**) Se, Ca, B for ***T. hamosa*** and Cr for ***B. pilosa****;* (**c**):P, K, Si, Na, S, Ag, Cu connected with ***S. sesban*** *and (***d***) Mo, Pb, Cd connected with* ***S. italica*** and ***M. indicus***.

Figure 2b showed plant shoots accumulated ability in which ***A. vogelii*** was located in the cluster of variables **(a)** (**Fig. 2b**), it was accumulated Mg, Se, Zn, Mn well; ***M. indicus*** *and* ***T. hamosa*** *were accumulated Ag at the same sector;* ***B. pilosa*** was located in the cluster of variables***(b)*** *with Pb, Ni, Fe, Cu;* ***S. sesban*** was located in the cluster of variables (**c**) which accumulate K, Si, S, Na; ***C. bonariensis*** *(connected with N, Ca, Cr, Cd)* and ***S. italica*** (accumulate P) were located in the cluster of variables (**d**).

3.4 Biological Accumulation Coefficient (BAC), Bioconcentration Factor (BF), Translocation Factor (TF) and element accumulation index (EAI) of trace elements:

BAC, BF **(Fig. 3)**, TF **(table 5)** and EAI **(Fig. 4)** were calculated for the studied metals associated with phosphate mining process. Results in **Figure 3** showed that **BAC** and **BF** for all trace elements of the studied species were than more unity, **whereas** TFs values differ from elements to another and from one species to the other. Generally, TFs of Fe, Mn, Cu, B, Cd, Ni, Si, Na, Se (except TF for ***A. vogelii***) and Zn (excluded TF of ***M. indicus***) are less than unity for all studied species (were accumulated in roots) although it's displayed high BCAs. TFs 1 for Zn, Mo, Se, Ag in ***A. vogelii***, Mo, Cr in ***S. sesban****; Zn, Mo, Ag in* ***T. hamosa****; Zn,* *Mo, Cr in S.* ***italica***; B, Si in ***B. pilosa****; Mo, Cr* in ***C. bonariensis*** and Zn only in ***M. indicus***. However, the translocation ability was not consistent with accumulation, and each species was selective for heavy metals (**Fig. 3**).

Regarding to element accumulation index (EAI), (Fig 4) their values of roots for all species were non-significant in all plant species as compared to their shoots. The shoot of species with the highest EAI were ***T. hamosa*** (22.15), followed by ***C.bonariensis*** (22.03), while that with the lowest EAI was ***S. sesban*** (19.28). Moreover, ***B. pilosa*** (22.04) had the highest EAI of roots, while ***M. indicus*** (20.12) had the lowest value.

4. Discussion

In areas near mining and smelting operations, heavy metal pollution of the soil is frequent. Mineral waste left over from both historic and contemporary ore extraction and processing activities serves as the foundation for soil development in the mine sites under study. (**Adnan et al., 2022)**.

The pH of the soil is a crucial factor of the elements in the soil that are available for plant absorption **(Jackson & Meetei, 2018; Adamczyk-Szabela & Wolf, 2022)**. Metals are chemisorbed to sesquioxide and variable-charged clays in acidic circumstances **(Solly et al., 2022**). Low pH also results in a reduced retention of metals to soil organic matter, making more metals readily available in the soil solution for root absorption. Low pH (below 5.5) increases the availability and solubility of many metal cations in the soil solution **(Blaylock and Huang, 2000)**. The presence and buildup of Cd, Cu, Ni, Pb, and Zn, as well as how they relate to soil pH, organic matter, inorganic nitrogen, total nitrogen, and readily accessible phosphorus **(Wei et al., 2020)**. When compared to mining sites with low pH, the Abu- Tartur phosphate mining site in Western Desert, Egypt, has moderate alkali, which results in less readily available metal in the soil solution, **El-Shamy, 2016.**

Application of phosphate rock as fertilizer is well recognized. In contrast to commercial P fertilizers, phosphate rock looks to be a very appealing phosphate fertilizer despite its comparatively sluggish release of soluble P. Farmers in Egypt's Qena Governorate, Deshna, and surrounding villages are used to using cretaceous phosphate rocks as P fertilizer that they obtain from local hills **(Hellal et al., 2019)**. Considering this, it is important to note that (a) Egyptian agricultural land has a pH range of 7.8 to 8.2, making it difficult to apply phosphate rock, which requires an acidic pH. P precipitates with calcium (Ca) ions when the pH is higher than 7. For mineral soils, pH 6.5 maximizes the availability of phosphorus (**Johan et al., 2021**). Additionally, there are sizable farms adjacent to the Abu-Tartur phosphate mining site that employ some of the cretaceous phosphate rocks found in the nearby hills, as we observed during our field trips. In general, the soils near mining sites, where wild plants thrive, are low in macro-nutrient levels, except for phosphorus, which worked in conjunction with calcium (**Penn & Camberato 2019**), Sulphur, potassium, and other micro-elements as indicated in the current data. Most of the other phosphate mining in other nations differs in terms of the abiotic conditions and the vegetation it uses (**Xiao et al., 2008; Kratz et al., 2016; Mghazli et al., 2021**). Numerous mining nations, including South Africa, Spain, Morocco, Mexico, and Ghana, are seeing a decline in soil quality because of trace metal poisoning from mine tailing dumps that have not been remedied **(Lu et al., 2019; Cao et al., 2022**; **Tibane & Mamba, 2022**).

The concentrations of macro- and micro-elements, pH, EC, and OC values in the soils collected at the Abu-Tartur phosphate mining site worked together in a way that most likely had no impact on the mobility of trace metals in the soil and their bioavailability to local plants. The accumulation of micro-elements by studied plants has not reached the critical value of hyper-accumulation plants, but it has far exceeded that of common plants and these results agree with many previous results (**Kratz et al., 2016; Bouzekri et al., 2019; Bianchi et al., 2022).** Although some metals, such as Fe, S, Cu, Mn, Cr, Zn, Ni, Co, P, and Mo, are naturally occurring important micronutrients when found in tiny quantities, they can be poisonous when present in higher than permitted concentrations, posing a severe threat to the environment (**Chetty and Pillay, 2019).** The Fabaceae genus Astragalus is the most representative because it contains 25 species that can absorb and withstand high concentrations of selenium **(Shrift, 1969)**. In comparison to nonaccumulators, hyperaccumulators have endogenous Se contents that are 10- to 100-fold higher and a higher Se: S ratio (**Barillas et al., 2011**). A Se hyperaccumulator is Astragalus bisulcatus (Barillas et al., 2012; Kolbert et al., 2018). Astragalus vogelii accumulates Se higher than the other investigated species, but only in limited levels, in accordance with earlier findings because Se is one of the components that work with phosphorus mining **(Favorito et al., 2020)** and this matched with present results. Sesbania drummondi is **Pb** (**Sharma et al., 2004**), **Cd** (**Israr et al., 2006**) and **Cu** accumulator (**Sharma et al., 2005; Sahi et al., 2007**). The Sesbania plants' efficient antioxidative defense mechanisms allowed them to withstand stress brought on by Hg **(Israr et al., 2006**) Sesbania cannabina has demonstrated a substantial metal accumulation (Fe, Mn, Zn, Cu, Pb and Ni) when it grows on various fly ash (FA) amendments, (**Sinha & Gupta, 2005**). S. sesban has the capacity to accumulate and stabilize most of the examined elements in the current study, except for Cr and Mo, which are transmitted more to their shoots. Potential plant options for improving the Cd phytoextraction process include Cassia alata (**Raza et al., 2020**). According to the study of **Aloud et al., 2022**; Cassia Italica considered phytoaccumulator for Cd and Cr comparing with other studied species in an Industrial Environment, Saudi Arabia. Cassia italic*a* (Senna italica) was efficient in accumulation of **Cu, Co** and **Pb** (**Macnicol & Beckett, 1985; Badr et al., 2012**), also our results show the potentiality of Senna italica for accumulation of the studied micro-elements. Trigonella foenum -graecum can be used for phytoremediation of Cd **(Menon et al., 2022**), also in the present results Trigonella hamosa can accumulate many trace elements associated with phosphate in their roots and shoots. **Steliga and Kluk (2021**) mentioned the suitability of Melilotus officinalis for Phytoremediation of Soil Contaminated with Petroleum Hydrocarbons, Zn, Pb and Cd. Also, **Ghazaryan et al. (2021**) estimated the phytoextraction potential of Melilotus officinalis growing on Cu and Mo-polluted soils. Melilotus indicus was reported to be effective in phyto-stabilizing Cd in Hayat Abad Industrial Estate located in Peshawar, Pakistan (**Naz et al., 2022**) and these results agree with the present study. that The accumulation features of Bidens pilosa as a potential Cd-hyperaccumulator was revealed by **Sun et al. (2008) and Dai et al. (2021)**. **Salazar et al. (2020)** indicate the Pb accumulator profile of Bidens pilosa, and both the previous results decide with our data. Conyza sumatrensis was tested in the field and shown to considerably reduce the amount **Cd (Khaokaew & Landrot, 2015**). According to **Rizwan et al. (2019)**, these findings with the most recent data support the idea that C. bonariensis plants could be used as a successful tool for phytoremediation of toxic trace elements (TEs) in polluted areas.

In the current study, near the phosphate mining site, when TF is less than unity as many metals accumulate in root systems while the BF and BAC are greater than unity for all metals. TF for Fe, Mn, Cu, B, Cd Ni, Si, Na, Se (except for Astragalus, **TF** 1) and Zn (excluding Melilotus, TF 1) are totally less than unity for all studied taxa, and these results agree with many previous research (**Navarro et al., 2008; Bonanno, 2013; Mghazli et al., 2021**; **Tibane & Mamba, 2022**). The potentiality for phytostabilization exists in plants with high BF and low translocation factors (TF). Most of the examined species exhibit potential for phytostabilization and phytoextraction, according to BCAs, BFs, and TFs values.

Regarding to element accumulation index (EAI), the highest EAI values of shoots recorded in T. hamosa and C. bonariensis. The results are closely related among the different studied species; show their ability to accumulate many elements associated with phosphate mining.

Furthermore, metal-tolerant plants with an exclusion strategy can be utilized in a phytostabilization process to lessen the mobility of heavy metals in soils, according to **Xiao et al. (2008**). **El Berkaoui et al. (2021)** conducted research on six species at the defunct Kettara pyrrhotite mine, which is close to Marrakech, Morocco which is an acid mine drainage producer site. The previous species are suitable candidates for phytostabilization of the phosphate cover because they have bioconcentration factors larger than 1 and weak translocation factors. In the process of phytostabilization, plants can absorb and accumulate heavy metals in their roots (**Yan et al.,2020**). So, phytostabilization lowers metal bioavailability for entrance into the food chain and decreases metal mobility and leaching into groundwater **(Kafle et al., 2022**). The effect of phytoextraction-improving compounds on soil health must also be considered (**Sladkovska et al., 2022)**.

Our research demonstrated the potential for phytoremediation among native plant species growing around Abu- Tartur mining site. These plants are significant from a patrimonial standpoint because of their potential use in phytoremediation of habitats contaminated with hazardous metals. It is vital to rehabilitate land in the mining area that has been affected by excessive amounts of heavy metals. The goal of vegetation reconstruction is to identify tolerant plants that can adapt to the local soil and environment.

5. Conclusion

Remediation options now available focus on lowering heavy metal concentrations in soil and the food chain. The amazing capacity of hyperaccumulator plants to absorb, convert, and accumulate high quantities of heavy metals without phytotoxicity makes them significant. It is important to remember that phytoremediation is a sustainable method. Prioritizing control measures can help authorities create more efficient exposure reduction and management strategies and inspire creative remediation techniques for future studies.

The highest EAI values of shoots were found in *T. hamosa* and *C. bonariensis*, but *S. sesban* growing in a phosphate mining site had the lowest EAI values. This suggests that these plants are better able to accumulate heavy metals and are hence more suitable for phytoremediation.

The accumulation of studied of macro and micro elements by wild ingenious plants has not reached the critical value of hyper-accumulation plants, but it has far exceeded that of common plants. The bio-concentration factors of *studied species* to various heavy metals are all greater than 1, and the coverage rate was relatively high, showing good enrichment ability and remediation potential of heavy metal contaminated soil. which can be used as a pioneer species for ecological restoration in this area and similar areas.

Abbreviations

Fe (iron), Mn (manganese), Zn (Zinc), Cu (copper), Mo (molybdenum), Se (selenium), B(boron), Pb (lead), Cr (chrome), Cd(cadmium), Ni(nickel), Ag(silver), Si(silicon), Na (sodium). N (nitrogen), P (phosphorous), K (potassium), Ca (calcium), Mg (magnesium) and S (Sulphur), Enrichment Accumulation coefficients (BAC), Bioaccumulation factor (BF), translocation factor (TF), element accumulation index (EAI), Principal Components Analysis (PCA).

Declarations

Authors contribution

M.M.E. and S.M.R. carried out the field trips for Mining site at Western Desert of Egypt about 800 Km away from Mansoura University. M.M.E., S. Al-Balawi and S.M.R. cooperate in experimental work in labs and carried out all analysis of the experimental work. All authors have analyzed the data, wrote the manuscript, and approved the final version of the manuscript.

Data Availability statement

All data generated or analyzed during this study are included in this published article.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Tables

Table 1: Mean ± Standard Error of Chemical Characteristics for soil Samples associated with studied plant. Mean ± standard error (n = 3) of soil Chemical characteristics for where the present study was carried out.

Studied species		*Astragalus voglii*	*Sesbania sesban*	*Trigonella hamosa*	*Melilotus indicus*	*Senna italica*	*Bidens pilosa*	*Conyza bonariensis*	*F- value*
pH		8.60± 0.25 ^{b}	8.00±0.28 ^{ab}	7.90±0.27 ^{ab}	8.40±0.29 ^{ab}	7.40±0.21 ^{c}	7.50±0.17 ^{ab}	7.70±0.22 ^{ab}	3.31*
EC		944.00±21.80 ^{a}	884.00±25.52^{ab}	771.00±17.81^{cd}	780.00±22.52^{bc}	668.00±23.10^{d}	673.00±23.31^{d}	707.00±16.33^{cd}	23.7***
OC %		1.56±0.03 ^{bc}	1.38±0.04 ^{cde}	1.80±0.04 ^{a}	1.74±0.06 ^{ab}	1.50±0.04 ^{cd}	1.26±0.03 ^{e}	1.32±0.03 ^{de}	25.41***
N	mg/Kg	44.88±1.29 ^{b}	44.01±1.02 ^{b}	42.77±0.99 ^{b}	42.61±1.23 ^{b}	46.88±1.62 ^{b}	44.71±1.29 ^{b}	43.14±1.00 ^{b}	1.51^{ns}
P		14.32±0.41 ^{b}	16.83±0.39 ^{a}	16.99±0.39 ^{a}	16.90±0.49 ^{a}	17.29±0.40 ^{a}	17.04±0.49 ^{a}	16.21±0.56 ^{ab}	5.12**
K		173.00±4.99 ^{a}	163.84±3.78 ^{a}	87.36±2.01 ^{b}	88.92±2.57 ^{b}	162.76±5.64 ^{a}	83.60±2.41 ^{b}	78.32±1.81 ^{b}	149.70**
Ca		21.05±0.61 ^{c}	24.19±0.56 ^{bc}	24.91±0.86 ^{b}	22.48±0.78 ^{bc}	23.32±0.68 ^{bc}	23.25±0.67 ^{bc}	22.78±0.79 ^{bc}	3.02*
Mg		14.07±0.40 ^{b}	13.24±0.31 ^{b}	14.79±0.51 ^{b}	14.77±0.34 ^{b}	13.36±0.39 ^{b}	14.81±0.43 ^{b}	14.79±0.51 ^{b}	2.85^{ns}
S		9.79±0.28 ^{de}	9.89±0.23 ^{de}	18.07±0.63 ^{c}	5.73±0.13 ^{f}	8.39±0.24 ^{e}	11.94±0.34 ^{d}	37.58±0.87 ^{b}	561.87**
Fe		0.36±0.01 ^{d}	0.39±0.01 ^{cd}	0.53±0.02 ^{a}	0.51±0.01 ^{ab}	0.45±0.01 ^{b}	0.49±0.02 ^{ab}	0.51±0.02 ^{ab}	19.22***
Mn		1.20±0.03 ^{a}	0.57±0.02 ^{c}	0.48±0.01 ^{cd}	0.56±0.01 ^{c}	0.41±0.01 ^{d}	0.83±0.02 ^{b}	0.49±0.01^{cd}	190.53**
Zn		0.04±0.00 ^{c}	0.04±0.00 ^{c}	0.05±0.00 ^{c}	0.07±0.00 ^{b}	0.01±0.00 ^{d}	0.04±0.00 ^{c}	0.15±0.00 ^{a}	390.44**
Cu		1.36±0.04 ^{a}	1.36±0.03 ^{a}	1.36±0.03 ^{a}	1.37±0.05 ^{a}	1.37±0.04 ^{a}	1.37±0.05 ^{a}	1.36±0.05 ^{a}	0.02^{ns}
Mo		1.37±0.03 ^{b}	0.10±0.00 ^{d}	0.53^{c}±0.01	0.66±0.02 ^{c}	1.83±0.05 ^{a}	0.10±0.01 ^{d}	1.49±0.05 ^{b}	471.05**
Se		0.66±0.02 ^{b}	0.44±0.02 ^{d}	0.640.02 ^{b}	0.80±0.02 ^{a}	0.40±0.01 ^{d}	0.54±0.02 ^{c}	0.68±0.02 ^{b}	56.07***
B		0.92±0.03 ^{a}	0.88±0.02 ^{a}	0.57±0.02 ^{c}	0.58±0.01 ^{bc}	0.98±0.03 ^{a}	0.68±0.02 ^{b}	0.63±0.02 ^{bc}	55.93***
Pb		0.94±0.03 ^{a}	0.93±0.03 ^{a}	0.92±0.03 ^{a}	0.92±0.03 ^{a}	0.93±0.03 ^{a}	0.90±0.03 ^{a}	0.92±0.03 ^{a}	0.22^{ns}
Cr		0.02±0.00 ^{d}	0.15±0.01^{b}	0.20±0.01^{a}	0.01±0.00^{d}	0.09±0.00 ^{c}	0.16±0.01^{b}	0.18±0.00 ^{a}	339.95**
Cd		2.21±0.06 ^{a}	1.58±0.05 ^{b}	1.48±0.04 ^{b}	1.56±0.05^{b}	1.42±0.05 ^{b}	1.28±0.27 ^{b}	1.17±0.16 ^{b}	6.72**
Ni		0.19±0.01 ^{a}	0.21±0.01 ^{a}	0.20±0.01 ^{a}	0.19±0.01 ^{a}	0.20±0.01 ^{a}	0.21±0.01^{a}	0.20±0.01^{a}	1.44^{ns}
Ag		0.06±0.00 ^{d}	1.30±0.05 ^{a}	0.78±0.03 ^{b}	1.33±0.03 ^{a}	0.77±0.03 ^{b}	0.47±0.01 ^{c}	0.85±0.02 ^{b}	269.28**
Si		0.23± 0.01 ^{a}	0.08±0.00 ^{b}	0.06±0.00 ^{c}	0.06±0.00 ^{bc}	0.06±0.00 ^{c}	0.07±0.00 ^{bc}	0.06±0.00 ^{bc}	316.29**
Na		1.59±0.05 ^{a}	1.58±0.04 ^{ab}	1.40±0.05 ^{ab}	1.41±0.05 ^{ab}	1.49±0.03 ^{ab}	1.42±0.04 ^{ab}	1.39±0.03 ^{b}	4.29*

Table 2: Results of one-way ANOVA (F-values) of macronutrients in shoots and roots of the studied sp.

			Astragalus vogelii	*Sesbania sesban*	*Trigonella hamosa*	*Melilotus indicus*	*Senna italica*	*Bidens pilosa*	*Conyza*
%	N	shoot	1.49±0.043^{ab}	1.28±0.030^{a}	1.42±0.033^{a}	1.50±0.035^{ab}	1.70±0.049^{b}	2.33±0.081^{c}	1.43±0.050^{a}
		root	1.96±0.057^{c}	1.28±0.044^{a}	1.48±0.051^{ab}	1.35±0.031^{ab}	1.37±0.040^{ab}	1.42±0.049^{ab}	1.53±0.053^{b}
	P	shoot	0.44±0.013^{ab}	0.44±0.010^{ab}	0.39±0.009^{a}	0.40±0.009^{ab}	0.43±0.012^{ab}	0.45±0.010^{b}	0.44±0.015^{ab}
		root	0.43±0.012^{ab}	0.45±0.010^{ab}	0.40±0.014^{a}	0.43±0.015^{ab}	0.42±0.012^{ab}	0.48±0.011^{b}	0.42±0.010^{ab}
	K	shoot	2.55±0.074^{b}	2.95±0.068^{c}	2.26±0.078^{ab}	2.33±0.081^{ab}	2.22±0.064^{ab}	2.01±0.070^{a}	2.11±0.049^{a}
		root	2.84±0.082^{b}	2.85±0.066^{b}	2.18±0.050^{a}	2.25±0.052^{a}	2.35±0.068^{a}	2.35±0.082^{a}	2.04±0.047^{a}
	Ca	shoot	1.38±0.040^{a}	1.37±0.032^{a}	1.42±0.049^{a}	1.54±0.035^{a}	2.05±0.059^{b}	1.96±0.045^{b}	1.47±0.051^{a}
		root	1.26±0.036^{b}	1.00±0.023^{a}	0.96±0.022^{a}	1.44±0.041^{c}	1.22±0.035^{b}	1.55±0.036^{c}	1.57±0.036^{c}
	Mg	shoot	0.97±0.028^{d}	0.15±0.005^{a}	0.38±0.013^{c}	0.24±0.007^{b}	0.17±0.005^{a}	0.38±0.013^{c}	0.18±0.004^{ab}
		root	0.92±0.027^{e}	0.09±0.003^{b}	0.32±0.007^{c}	0.02±0.002^{a}	0.03±0.001^{a}	0.38±0.009^{d}	0.03±0.001^{a}
mg/Kg	S	shoot	209.90±6.059^{ab}	890.60±20.568^{d}	309.90±7.157^{c}	202.60±5.849^{ab}	193.40±5.583^{ab}	213.60±4.933^{b}	165.10±5.719^{a}
		root	330.10±9.529^{c}	622.90±14.385^{e}	244.50±5.646^{b}	172.60±4.983^{a}	635.00±21.997^{e}	241.80±5.584^{b}	430.70±9.947^{d}

Table 3: Mean ± SE of trace elements in shoots and roots of the studied sp.

		Astragalus vogelii	*Sesbania sesban*	*Trigonella hamosa*	*Melilotus indicus*	*Senna italica*	*Bidens pilosa*	*Conyza bonariensis*	F- value
Fe	Shoot	80.97±1.870^{a}	75.33±2.175^{a}	76.88±1.775^{a}	74.46±1.720^{a}	78.06±2.253^{a}	74.46±2.150^{a}	78.68±2.725^{a}	1.31^{ns}
	Root	78.12±2.255^{a}	78.18±1.806^{a}	71.86±2.489^{a}	73.84±2.132^{a}	75.70±1.748^{a}	74.15±2.569^{a}	78.55±1.814^{a}	1.48^{ns}
Mn	Shoot	17.17±0.397^{d}	17.97±0.519^{d}	14.29±0.330^{c}	14.12±0.489^{c}	8.95±0.258^{ab}	10.54±0.304^{b}	7.56±0.175^{a}	117.40***
	Root	14.36±0.415^{bc}	13.67±0.316^{b}	15.96±0.553^{c}	10.48±0.303^{a}	15.75±0.364^{c}	14.22±0.410^{bc}	13.04±0.452^{b}	20.34***
Zn	Shoot	39.45±1.367^{e}	16.39±0.473^{c}	24.90±0.575^{d}	22.96±0.663^{d}	12.50±0.289^{b}	0.11±0.004^{a}	2.48±0.072^{a}	442.41***
	Root	25.98±0.750^{e}	13.04±0.452^{d}	4.42±0.153^{ab}	6.79±0.157^{bc}	4.10±0.118^{a}	9.16±0.212^{c}	28.35±0.982^{e}	387.31***
Cu	Shoot	34.15±1.183^{a}	34.07±0.984^{a}	33.95±0.784^{a}	34.05±1.180^{a}	34.19±0.790^{a}	34.12±0.985^{a}	34.22±0.790^{a}	0.01^{ns}
	Root	34.04±0.983^{a}	34.18±1.184^{a}	33.95±0.784^{a}	34.20±0.987^{a}	34.14±1.183^{a}	34.08±0.787^{a}	33.95±0.980^{a}	0.01^{ns}
Mo	Shoot	26.42±0.610^{ab}	31.13±0.899^{de}	27.47±0.952^{cd}	23.48±0.813^{b}	30.03±0.867^{cde}	13.64±0.473^{a}	33.48±0.966^{e}	64.67***
	Root	7.52±0.217^{b}	10.51±0.364^{c}	1.56±0.036^{a}	23.51±0.679^{e}	19.76±0.456^{d}	52.38±1.210^{f}	8.60±0.248^{bc}	854.51***
Se	Shoot	24.62±0.569^{f}	7.79±0.270^{a}	17.03±0.393^{e}	9.53±0.220^{b}	11.37±0.328^{c}	10.42±0.3016^{bc}	13.10±0.303^{d}	260.65***
	Root	16.22±0.468^{d}	7.67±0.266^{a}	15.67±0.543^{d}	8.45±0.242^{ab}	15.61±0.543^{d}	12.75±0.294^{c}	10.22±0.295^{b}	82.39***
B	Shoot	13.80±0.479^{a}	13.73±0.475^{a}	14.18±0.328^{a}	15.35±0.531^{a}	20.50±0.593^{b}	19.64±0.455^{b}	14.72±0.340^{a}	37.55***
	Root	12.59±0.364^{b}	10.02±0.231^{a}	9.60±0.334^{a}	14.37±0.415^{c}	12.18±0.282^{b}	15.45±0.445^{c}	15.70±0.363^{c}	48.14***
Pb	Shoot	23.56±0.543^{a}	22.94±0.530^{a}	23.00±0.664^{a}	23.32±0.808^{a}	23.13±0.669^{a}	23.12±0.533^{a}	23.40±0.809^{a}	0.12^{ns}
	Root	22.50±0.651^{a}	22.97±0.796^{a}	23.27±0.537^{a}	22.90±0.660^{a}	22.91±0.792^{a}	23.24±0.670^{a}	23.03±0.532^{a}	0.15^{ns}
Cr	Shoot	1.37±0.030^{a}	2.19±0.063^{b}	2.05±0.070^{b}	1.07±0.024^{a}	3.42±0.098^{c}	2.16±0.051^{b}	4.27±0.098^{d}	273.19***
	Root	1.25±0.045^{a}	1.43±0.034^{ab}	3.73±0.109^{d}	3.49±0.121^{d}	1.60±0.057^{ab}	2.25±0.064^{c}	1.75±0.059^{b}	174.97***
Cd	Shoot	25.15±0.727^{a}	25.19±0.872^{a}	25.19±0.872^{a}	25.18±0.727^{a}	25.19±0.582^{a}	25.17±0.582^{a}	25.20±0.727^{a}	0.001^{ns}
	Root	25.14±0.582^{a}	25.18±0.727^{a}	25.18±0.582^{a}	25.18±0.582^{a}	25.18±0.727^{a}	25.18±0.872^{a}	25.20±0.583^{a}	0.001^{ns}
Ni	Shoot	5.07±0.146^{a}	4.94±0.171^{a}	5.06±0.146^{a}	5.07±0.117^{a}	5.12±0.177^{a}	5.11±0.118^{a}	4.98±0.144^{a}	0.20^{ns}
	Root	5.02±0.145^{a}	5.02±0.174^{a}	5.10±0.177^{a}	4.92±0.170^{a}	4.68±0.135^{a}	5.01±0.116^{a}	5.08±0.176^{a}	0.82^{ns}
Ag	Shoot	14.62±0.506^{cd}	14.57±0.505^{cd}	16.39±0.379^{d}	39.39±0.910^{e}	11.46±0.265^{b}	12.34±0.356^{bc}	2.36±0.055^{a}	534.90***
	Root	9.52±0.275^{b}	57.33±1.324^{f}	7.04±0.163^{ab}	47.12±1.632^{e}	31.55±0.911^{d}	18.92±0.437^{c}	3.33±0.096^{a}	556.36***
Si	Shoot	4.78±0.138^{b}	14.55±0.336^{c}	1.30±0.030^{a}	1.11±0.032^{a}	1.34±0.031^{a}	1.46±0.034^{a}	1.24±0.029^{a}	1262.21***
	Root	3.82±0.087^{b}	14.90±0.429^{c}	1.34±0.030^{a}	1.35±0.031^{a}	1.32±0.030^{a}	1.17±0.034^{a}	1.24±0.029^{a}	919.60***
Na	Shoot	35.95±1.038^{a}	51.37±1.780^{b}	34.59±0.999^{a}	34.61±0.799^{a}	34.81±1.005^{a}	35.10±0.811^{a}	34.83±1.005^{a}	31.56***
	Root	36.42±1.051^{a}	51.05±1.768^{b}	35.02±1.213^{a}	35.01±1.213^{a}	35.13±1.014^{a}	35.77±0.826^{a}	35.87±1.035^{a}	24.36***

Table 5: Results of one-way ANOVA (F-values) of Translocation factors (TFs) for micro-elements of native studied plant species around Abu-Tartur mining site., Western Desert, Egypt.

		Astragalus vogelii	*Sesbania sesban*	*Trigonella hamosa*	*Melilotus indicus*	*Senna italica*	*Bidens pilosa*	*Conyza bonariensis*	F-value
TF	Fe	1.04±0.036[a]	0.96±0.033[a]	1.07±0.031[a]	1.07±0.031[a]	1.03±0.036[a]	1.00±0.029[a]	1.00±0.023[a]	1.54[ns]
	Mn	1.04±0.030[a]	0.96±0.033[a]	1.07±0.031[a]	1.01±0.029[a]	1.03±0.024[a]	1.00±0.023[a]	1.00±0.035[a]	1.28[ns]
	Zn	1.52±0.044[b]	1.26±0.044[b]	5.63±0.130[d]	3.38±0.117[c]	3.05±0.106[c]	0.01±0.000[a]	0.09±0.003[a]	624.69***
	Cu	1.00±0.029[a]	0.99±0.035[a]	1.00±0.023[a]	0.99±0.034[a]	1.00±0.035[a]	1.00±0.035[a]	1.01±0.029[a]	0.01[ns]
	Mo	3.51±0.081[c]	2.96±0.085[c]	17.61±0.610[d]	0.99±0.023[ab]	1.52±0.044[b]	0.26±0.009[a]	3.89±0.113[c]	623.55***
	Se	1.52±0.053[d]	1.02±0.035[b]	1.09±0.031[b]	1.13±0.039[bc]	0.73±0.017[a]	0.82±0.024[a]	1.28±0.037[c]	57.60***
	B	1.10±0.038[ab]	1.37±0.040[cd]	1.48±0.051[d]	1.07±0.031[a]	1.68±0.039[e]	1.27±0.044[bc]	0.94±0.027[a]	43.93***
	Pb	1.37±0.169[ab]	0.50±0.248[a]	1.88±0.454[b]	0.90±0.067[ab]	0.58±0.216[a]	0.77±0.115[a]	0.81±0.105[ab]	4.51***
	Cr	1.10±0.038[c]	1.53±0.044[d]	0.55±0.019[b]	0.31±0.009[a]	2.14±0.074[e]	0.96±0.022[c]	2.44±0.070[f]	296.57***
	Cd	1.00±0.035[a]	1.00±0.029[a]	1.00±0.035[a]	1.00±0.029[a]	1.00±0.035[a]	1.00±0.023[a]	1.00±0.023[a]	0.00[ns]
	Ni	1.01±0.023[a]	0.98±0.028[a]	0.99±0.034[a]	1.03±0.030[a]	1.09±0.025[a]	1.02±0.029[a]	0.98±0.034[a]	1.77[ns]
	Ag	1.54±0.045[d]	0.25±0.008[a]	2.33±0.054[e]	0.84±0.024[c]	0.36±0.010[a]	0.65±0.019[b]	0.73± 0.018[bc]	572.22***
	Si	1.25±0.043[c]	0.98±0.034[ab]	0.97±0.028[ab]	0.82±0.029[a]	1.02±0.029[b]	1.25±0.029[c]	1.00±0.029[b]	23.86***
	Na	0.99 ± 0.028[a]	1.01±0.023[a]	0.99±0.029[a]	0.99±0.034[a]	0.99±0.029[a]	0.98±0.023[a]	0.97±0.028[a]	0.14[ns]

Table 4 is available in the Supplementary Files section.

Figures

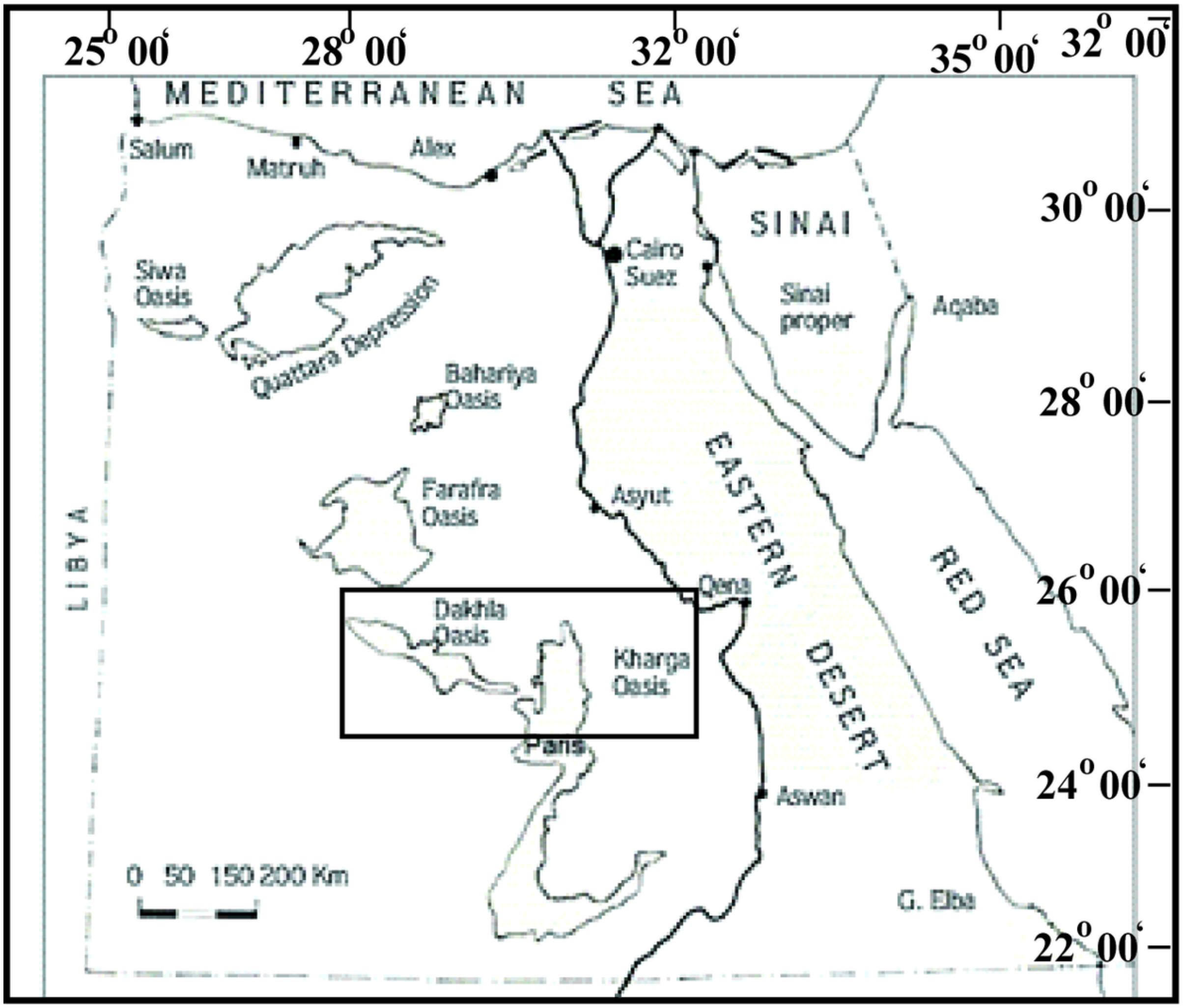

Figure 1

Map of phosphate Mining region of Abu-Tartur, Western Desert, Egypt (according to El- Shamy, 2016)

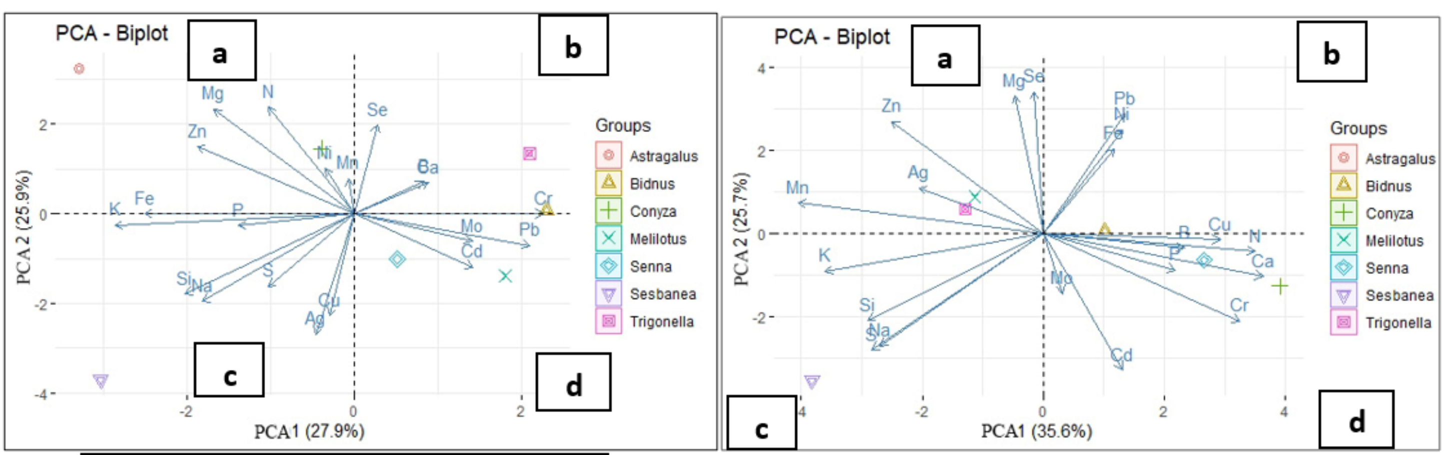

Fig. 2a: PCA-Ordination plot of roots of studied

Fig. 2b: Ordination plot of shoots of studied plants.

Figure 2

PCA – Biplot showing the relations between maco- and microelements concentrations in root (Fig 2a) and relation of these elements in shoots (Fig. 2b) of studied species (concentrations on the component plane).

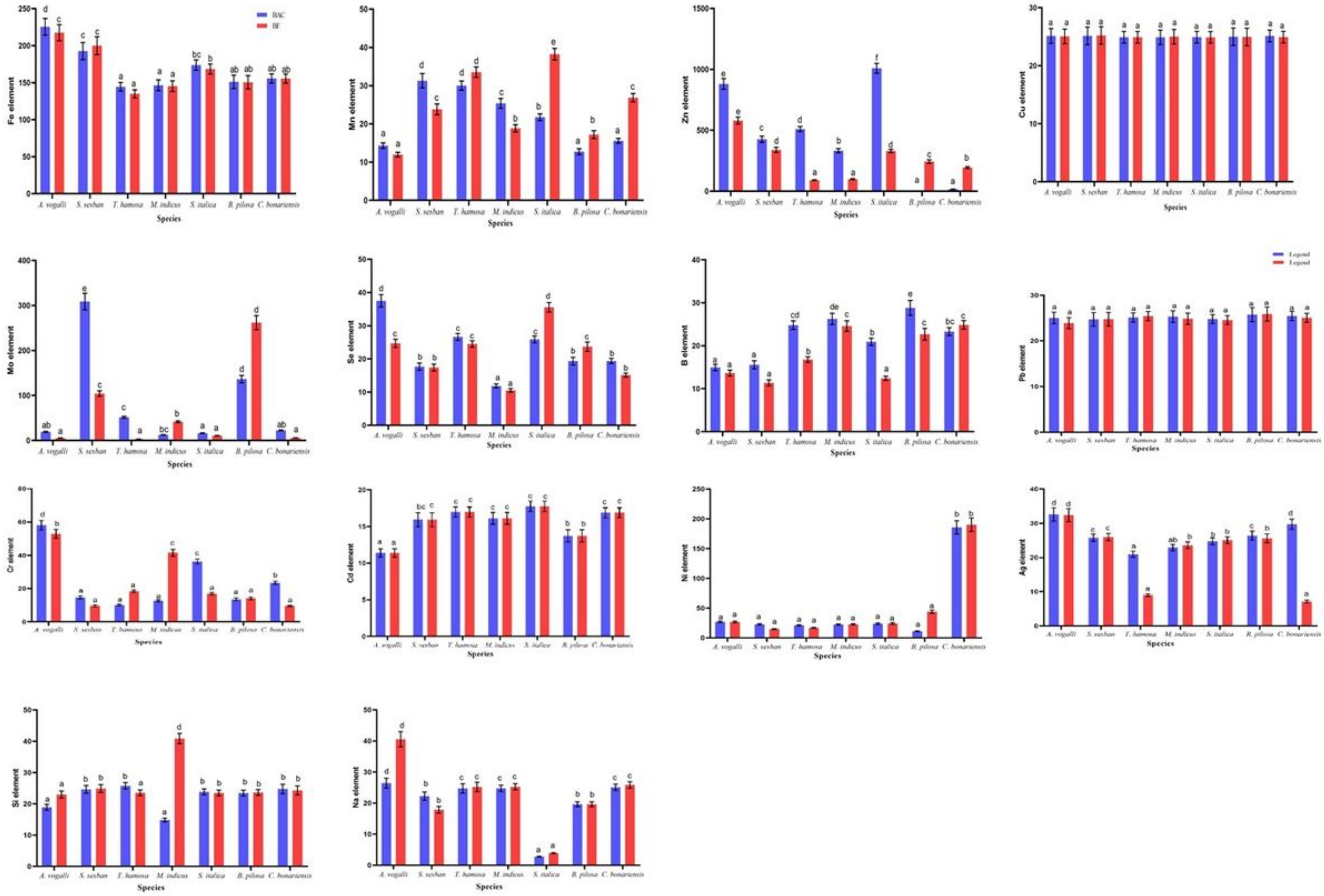

Figure 3

Mean (n = 3) of translocation factors (BAC) (blue column) from soil to shoot tissues and Mean (n = 3) of bioaccumulation factors (BFs) (red column) from soil to roots tissues of micro-elements in seven native plant species that grown around Abu-Tartur mining site.

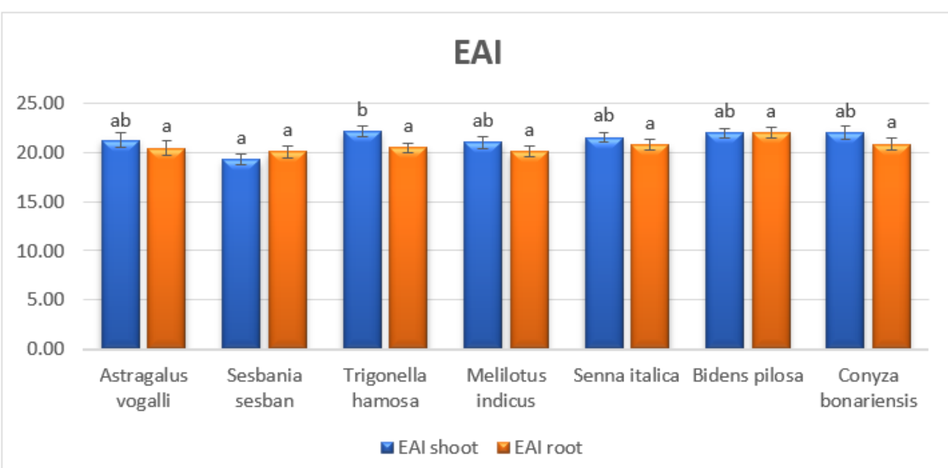

Figure 4

Element accumulation index (EAI) values of roots and shoots for all studied plant species grown around phosphate Abu-Tartur mining site, Western Desert, Egypt. Means followed by different letters are significantly different at P < 0.05 according to Tukey HSD test.

Supplementary Files

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- Table4.docx