

A Comprehensive Study on Phytoextractive Potential of Sri Lankan Mustard (*Brassica Juncea* (L.) Czern. & Coss) Genotypes

S. Somaratne and S. R. Weerakoon

Abstract—Heavy metal pollution is an environmental concern. Phytoremediation is a low-cost, environmental-friendly approach to solve this problem. Mustard has the potential in reducing heavy metal contents in soils. Among mustard (*Brassica juncea* (L.) Czern & Coss) genotypes in Sri Lanka, accessions 7788, 8831 and 5088 give significantly a high yield. Therefore, present study was conducted to quantify the phytoextractive potential among these local mustard accessions and to assess the interaction of heavy metals, Pb, Co, Mn on phytoextraction. A pot experiment was designed with acid washed sand (quartz) and a series of heavy metal solutions of 0, 25, 50, 75 and 100 µg/g. Experiment was carried out with factorial experimental design. Mustard accessions were tolerant to heavy metals and could be successfully used in removal of Pb, Co and Mn and they are capable of accumulating significant quantities of heavy metals in vegetative and reproductive organs. The order of the accumulative potential of Pb, Co and Mn in mustard accessions is, root > shoot > seed.

Keywords—*Brassica juncea*, heavy metal hyper-accumulation, phytoremediation

I. INTRODUCTION

THE use of plants as a remedial measure for extraction of contaminants from the environment or for lowering of their toxicity is defined as phytoremediation [1]. Metal hyperaccumulator plant species are able to accumulate at least 0.1% of the leaf dry weight in a heavy metal [2]. This is a low cost and eco-friendly means of reclaiming heavy metal contaminated soils [3]. As biological processes are ultimately solar-driven, phytoremediation is on average ten-fold cheaper than engineering-based remediation methods [4]. As with vegetation; they have to produce a large biomass and to have the ability to accumulate significant quantities of heavy metals in their stems [5, 6, 7, 8]. However, there are evidences that ca. 400 hyperaccumulative plants are capable of extracting contaminants [1]. Most of them are unsuitable for phytoremediation, because they have a slow growth rate and small size.

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Therefore, numbers of the technologies based on the use of plants, the success of the phytoremediation is dependent on their proper selection.

The plants used for phytoremediation must have a short period of researchers are focusing their studies on the accumulative plants with higher growth rates with a bulky biomass, which includes the crops used in the agricultural practice, in order to determine their ability to tolerate and accumulate heavy metals in their stems [9, 10].

In Sri Lanka and other regions in South Asia, the heavy metal and organic pollutant contamination already pose a severe threat to human and ecosystem health [11]. There are only a few published reports available on the nature of soil and water contamination in Sri Lanka [12, 13]. However, large areas of soil and water contain high levels of heavy metals such as Cd, Cu, Co, Cr, Ni, Pb and Zn and other pollutants due to various human actions [14]. Industrial effluents, agriculture residues, e-waste, domestic waste water and solid waste have contributed largely to heavy metal contamination on land and in both surface and ground water resources [12]. Cadmium is available in considerable amounts in soils, water, plant and animal biomass in the dry zone of Sri Lanka [15].

The members of the family Brassicaceae are prominent for their ability in accumulating the heavy metals in an extremely high degree [16]. Due to the fact that, significant attention is paid to the members of the Brassicaceae family, which are well-known as plants having significant biomass and capacity to accumulate high quantities of heavy metals [5, 17]. It was found that plants with higher growth rates from the Brassicaceae family in their ability to tolerate and accumulate the metals, including *Brassica juncea* (L.), *Brassica nigra* Koch, *Brassica campestris* L., *Brassica napus* L., and *Brassica oleracea* L [5]. Despite the fact that all of the examined crops from the Brassicaceae family do accumulate the metals, *B. juncea* shows the highest ability to accumulate and transport Cu, Cr, Cd, Ni, Pb, and Zn towards their stems. However, all of the species of the Brassicaceae family shows equal ability to accumulate and transport the heavy metals towards their stems [18].

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It was shown that *B. juncea* indicates excellent ability in eliminating Pb from the soil solution and to accumulating [19, 20]. In contrary, based on several research [15, 7] findings it was possible to conclude that *B. juncea* (L.) possesses the capacity to absorb and accumulate significant quantities of heavy metals, as Cd, Cu, Ni, Zn, Pb and Se and has a very high potential for phytoremediation of heavy metals [7, 21, 22, 23]. The available statistics indicate that *B. juncea* (L.) has an ability of removing 1.1550 kg Pb from an acre [24]. Certain crops like *B. oleracea* L. are able to accumulate significant quantities of heavy metals [25], which may lead to a risk for the health of the people.

Sri Lanka has genetically diverse mustard (*B. juncea* (L.) Czern) germplasm of over sixty accessions, which is stored in the gene bank of Plant Genetic Resource Centre (PGRC) [26]. Molecular studies with AFLP fluorescent markers on the genetic diversity of these mustard accessions showed the presence of highly diverse genetic variation among mustard germplasm in Sri Lanka [27]. Since humans consume mustard seeds and oil and seed itself as a condiment, it is useful to assess the extent of heavy metal accumulation in seeds as well. A study on the impact of seasonal variations on seed yields of mustard (*Brassica juncea* (L.) Czern & Coss) genotypes in Sri Lanka [28] revealed that mustard accessions 7788, 8831 and 5088 were having a significantly high yield among the similar ten accessions tested before. Further, a preliminary study conducted on phytoextractive potential among mustard (*Brassica juncea* (L.) Czern & Coss) genotypes in Sri Lanka have revealed that a comprehensive study on the mustard germplasm in Sri Lanka is useful to identify highly potential heavy metal accumulators [29].

Therefore, purpose of the present study was to conducted a study on the quantities and the depots of accumulation of Pb, Co, and Mn in the vegetative and reproductive organs of *B. juncea* accessions and their use in the purposes of phytoremediation and suitability for human consumption. Two-fold objectives were formulated and attempts were made to achieve them: a) Quantification of phytoextractive capacity among the Sri Lankan mustard (*Brassica juncea* (L.) Czern & Coss) genotypes (accessions) and b) Assessment of the interaction of heavy metals, Pb, Co, Mn on phytoextraction potential of different mustard genotypes.

II. MATERIALS AND METHODS

The common soil heavy metals Pb, Co and Mn, which were included in the study, were chosen by considering their

abundance in soils of different eco-climatic zones of the island. The selection of mustard accessions was based on the results of a previous study [29] and three mustard accessions were included in the present study (Accession No. 5088, 7788 and 8831) for the laboratory experiment.

A set of pot experiments was made with acid washed sand (quartz) and a series of heavy metal solutions of (Pb (NO₃)₂, Co (NO₃) and Mn (NO₃)₃) with concentrations of 0, 25, 50, 75 and 100 µg g⁻¹ were used. Acid washed sands were filled into black polythene bags up to 2/3 (16 cm height and 8 cm diameter) and in each bag six seeds of the selected mustard accessions were allowed to germinate and three healthy seedlings were kept in each bag by removing the weaker ones. The healthy seedlings were used for the experiment. Equal amounts of 5% Albert solution was added to each bag periodically to provide the essential nutrients. These pots were treated with heavy metals solutions with varying concentrations. The pot experiment was carried out with factorial experimental design with three replicate.

At the commercial maturity stage, seeds, shoots and roots were collected. The collected samples were oven-dried at 70 °C to constant weight followed by acid-digestion according to AOAC method [30] using HNO₃ and HClO₄ (25:10 ml). The clear digested liquid was filtered through 0.45 µm and acid resistant filter paper and the metal content in the filtrate was determined using Graphite Furnace Atomic Absorption (GFAAS), GBC, Australia. Data analysis was carried out using SAS Ver. 9 [31].

III. RESULT AND DISCUSSION

The results given in TABLE 01 showed that with increasing the substrate heavy metal concentration exhibited tendency for increasing total contents of heavy metals in the root, shoot and seed biomass of the mustard accessions studied. The seed heavy metal content in mustard accessions vary along the concentration gradient. The higher seed content occur in accession No.1099 and 5088 with increasing concentration in relation to increase substrate concentrations (Fig. 01). The Pb content of the seed samples obtained from the accession 1099 was higher (15.96 µg/g) than the rest of the accessions. However, it is less than the permissible concentration (80 mg/kg). Comparatively lower Pb content was found in the seed samples of the accession No. 8831. Meanwhile, samples of the accession 5088 contained more or less similar amounts of Pb and Co. The Co content of the seed samples of accession 8831 indicates its specificity for hyper-accumulation of Co in seeds. Comparatively, the Pb contents in the seeds of accession 1099 were more or less twice the substrate Pb content. There is a tendency in doubling the seed Pb and Co content with increasing substrate concentrations. The seed Mn contents among the accession numbers were lower than that of the Pb and Co contents in the seeds and ranged from the minimum in the seeds of accession No. 1099 (5.15 µg/g) and the highest in the samples of accession 5088 (14.50 µg/g).

The heavy metal accumulation in the shoot system also varies with the accession numbers (TABLE I). The shoot Pb contents in the accession No. 1099 were higher than in the rest of accession numbers (Fig. 02). The shoot heavy metal distribution also indicated the similar trend, which was observed for seed heavy metal accumulation among the mustard accessions, 7788, 8831 and 5088. However, the magnitude of the heavy metal contents is greater than the seed contents.

TABLE I

DISTRIBUTION OF HEAVY METALS IN SEEDS, ABOVE GROUND AND BELOW GROUND BIOMASS OF MUSTARD ACCESIONS, 7788, 8831 AND 5088. TABLE INCLUDES MEAN AND STANDARD DEVIATION WITHIN PARENTHESIS. DIFFERENT LETTERS INDICATES SIGNIFICANT DIFFERENT AT $P \geq 0.05$

Accession Number	Heavy metal	Seed ($\mu\text{g/g}$)	Shoot ($\mu\text{g/g}$)	Root ($\mu\text{g/g}$)
1099	Co	13.01 (1.69)a	15.87 (2.09)a	18.00 (2.66)a
	Mn	5.15 (0.95)b	6.38 (1.18)b	7.36 (1.18)b
	Pb	15.96 (3.23)a	19.68 (4.00)a	20.34 (4.00)a
5088	Co	15.38 (2.98)a	19.04 (3.69)a	20.10 (3.60)a
	Mn	14.50 (2.75)b	17.05 (3.41)a	18.25 (3.49)a
	Pb	7.31 (1.30)a	11.82 (2.97)a	9.79 (1.61)b
8831	Co	14.17 (2.80)a	17.54 (3.47)a	18.25 (3.59)a
	Mn	5.22 (1.51)b	6.47 (1.50)b	7.54 (1.48)b
	Pb	8.52 (1.52)b	10.54 (1.87)a	11.26 (1.85)a

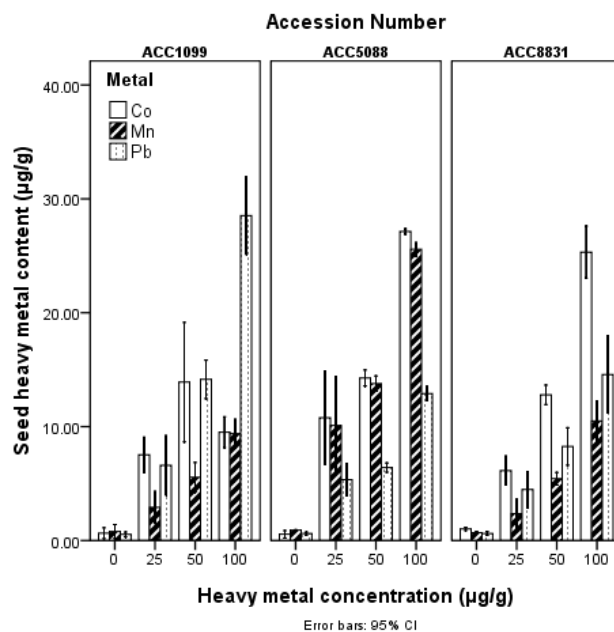


Fig. 2 Heavy metal accumulation in above ground biomass of different mustard accessions, 7788, 8831 and 5088 of Sri Lanka

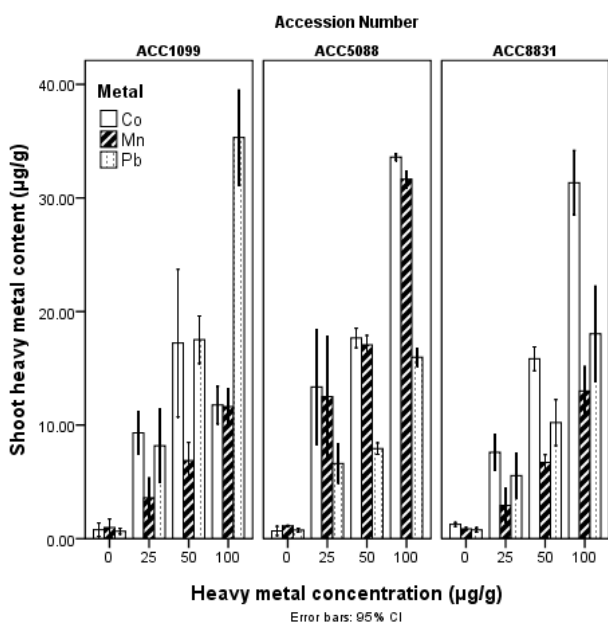


Fig. 1 Heavy metal accumulation in seeds of mustard accessions, 7788, 8831 and 5088 of Sri Lanka

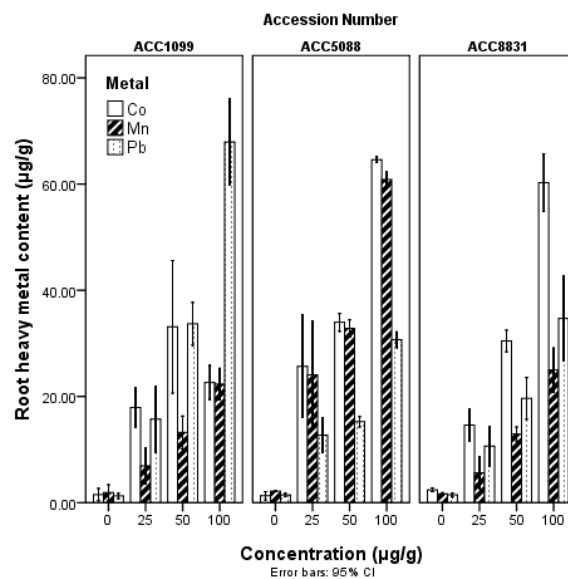


Fig. 3 Heavy metal accumulation in root biomass of the mustard accessions, 7788, 8831 and 5088 of Sri Lanka

The variation of heavy metal contents in root biomass is depicted in Fig. 03. The Pb content in the root biomass of accession 1099 ($20.34 \mu\text{g/g}$) and Co content ($20.10 \mu\text{g/g}$) in the accession 5088 were higher compared to the accession 8831 ($11.26 \mu\text{g/g}$ for Pb and $18.25 \mu\text{g/g}$ for Co) (TABLE I).

Therefore, a comparison was made with the results obtained from the present study with those obtained for the other members of the Brassicaceae family. A study carried out [32] for *Brassica alba* has shown that accumulation of Pb, Cd

and Zn is higher in the roots than the stems of *B. juncea* vary from 6.2 mg/kg to 28.6 mg/kg. However, the present study values are higher than those reported [9], in an examination of different species of the Brassicaceae family for the heavy metal accumulation capability. There is a scarcity of reports on the seed heavy metal content of different mustard accession locally or internationally.

Due to the lack of scientific literature on the studies on the heavy metal accumulation of different mustard accessions in Sri Lanka, there is no information about the ability of these mustard accessions in accumulating heavy metals.

The results reported in the present study indicate that the contents of heavy metals in the roots of the Sri Lankan mustard accessions are higher. Further, it was clear from the results that the mustard accessions studied have the ability to transport Pb, Mn and Co from their roots to the above ground biomass in case of their growing in soil with a low concentration of heavy metals. At higher substrate concentration of heavy metals, the capacity of their conduction system is exceeded and possibly accumulates in roots.

The contents of the heavy metals in the seeds of the mustard accession studied are lower compared to those in the shoot and root. The accumulation of heavy metals in the seeds is taken place mainly through the conduction system. The content of Pb in the seeds of the mustard accession No. 1099 grown in higher concentrations reaches up to 15.96 µg/g. The distribution of the heavy metals studied in the organs of the mustard accession when grown in a laboratory conditions, were in the order of roots > shoot > seeds. The results of the study show that the mustard accessions possess differential potential for phytoremediation of soils contaminated by heavy metals.

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