Comparative Evaluation of Phytoremediation Potential of Indian Mustard (Brassica juncea) Varieties Under Sewage Irrigated Sites

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Long-term application of sewage for crop production accumulates significant amount of heavy metals in soil. Some of these metals are carcinogenic and affect the soil, plant, animal and human health adversely. Phytoremediation with mustard is a well known and regularly adopted practice for metal removal from contaminated areas. However, genetic potential of mustard cultivars may have much influence on phytoremediation potential of mustard. For this, four prominent mustard crop varieties (NRC DR 2, NRC HB 101, RH 749 and RH 119) were grown at sewage contributed metal contaminated agriculture fields of Islamnagar and Bheropura villages. Results showed that all the mustard varieties removed significant amount of Cu, Cd, Pb, Cr, Ni, Zn and Mn from soil. Mean data of all three locations showed that maximum removal of Cu (479 mg plant⁻¹), Cd (2.80 mg plant⁻¹), Cr (38.1 mg plant⁻¹), Ni (9.96 mg plant⁻¹), Zn (26.6 mg plant⁻¹) and Mn (538 mg plant⁻¹) was in NRC HB 101 except for Pb uptake which was highest in NRC DR 2 (1.53 mg plant⁻¹). The NRC HB 101 showed higher phytoextraction potential compared to rest of the varieties. These results are very much useful for formulation of phytoremediation management strategies under metal contaminated agriculture areas.

Key words: Crop uptake, heavy metal, mustard cultivar, phytoremediation, soil health

Rising heavy metals pollution in agricultural ecosystem has become a serious concern worldwide (Saha et al. 2017). These metals persist in nature for long time and happen to be toxic in plants, animals and humans when these surpass specific threshold concentration levels. Metal contamination in agricultural fields are due to anthropogenic activities like industrial waste disposal, faulty agriculture management practices, use of municipal solid waste and industrial effluents, etc. Sewage irrigation for crop production is an alternative practice to meet water requirement of the crops particularly in peri-urban areas (Dotaniya et al. 2018a). Sewage water contains heavy loads of organic matter, nutrient elements, heavy metals and other contaminants. Long-term utilization of sewage can lead to accumulation trace metals in the soil that become toxic to plant, animal and human health (Dotaniya et al. 2018a). Therefore, removal of metals from contaminated sites is inevitable for sustaining crop production. Although, there are many approaches followed to remediate contaminated sites, phytoremediation is considered farmers-friendly, cost effective, non destructive and eco-friendly plant based approach for metal remediation (Van Ginneken et al. 2007; Ali et al. 2013; Meena et al. 2020).

Phytoremediation is a method of bioremediation for removal of pollutants from any natural system (soil, air and water) using different kinds of living plants. The processes involved are removal, transfer, stabilization, and/or destruction of contaminants in soil and water. Phytoremediation can be applied in polluted soil and water environment for removal of heavy metal contaminants under variable soil and climatic conditions (Dotaniya et al. 2020). This method is highly recommended as it usually does not have negative effect on the health of environment including soil ecosystem.

Phytosequestration or phytoextraction processes are more popular across the globe since the last 20-30
years (Grispen et al. 2006). The plants generally used for this purpose are called hyper accumulators. There is wide variability among plant species regarding accumulation of heavy metals from contaminated ecosystem. On the basis of different metal accumulation indices plants are categorized as low, medium and hyper accumulators. Mustard plants, alpine pennycress, hemp, and pigweed were identified as a hyper accumulator for remediation of metal from toxic waste sites (Rascio and Navari-Izzo 2011). Interestingly Indian mustard (Brassica juncea) was observed to serve as an efficient phytoremediator of some heavy metals (Rathore et al. 2019). Mustard plants have been widely used for removal of contamination particularly heavy metals from polluted sites (Rathore et al. 2019). Though there are many challenges, effective removal of metals by adoption of agronomic management practices had enhanced ability of crops to absorb and uptake of plant nutrient and concentrate heavy metals from contaminated soils (Rathore et al. 2019; Meena et al. 2020).

Though there are many studies on heavy metal remediation using mustard species, an efficient cultivated variety of mustard for use as phytoextractor of heavy metals under lowly contaminated soils has not been identified. In the current study, metal uptake potential of four Indian mustard cultivars is investigated under farmers’ field condition in lands contaminated through long-term sewage water irrigation.

Material and Methods

Field locations

The field experiment was conducted in sewage irrigated areas near Bhopal city, India. Patranala (sewage carrying natural channel), is the major source of irrigation water in several surrounding villages. On the basis of survey on intensity of sewage utilization for crop cultivation, two experiments at Islamnagar village and one experiment at Bheropura village were conducted. Both the villages are having near proximity with Bhopal (about 15 km), the capital city of Madhya Pradesh.

Collection of soil and sewage

Geo-referenced sewage and soil samples were collected from three experimental locations prior to conduct the field experiments. Collected sewage samples were acidified with dilute acid for controlling microbial growth and for preventing heavy metal precipitation during storage. Another set of sewage samples were collected for other chemical parameters analysis. Surface soil (0-15 cm) samples were also collected from these locations demarcated for field experiments. Each sample was assigned unique identity number, processed and kept for further laboratory analysis.

Initial soil and sewage analysis

Soil physicochemical parameters were analyzed following the methods described in Jackson (1973) and the results are described in table 2. Collected sewage samplers were digested with di-acid mixture. For this 100 mL sewage water taken into conical flask and 5 mL of HNO₃ was added and kept for pre-digestion. After 2-3 h, 10 mL di-acid (HNO₃ and HClO₄ in 9:4 ratio) was added and digested on hot plates till the white fumes appeared. Then 50 mL of double distilled water was added and filtered, for heavy metals analysis. Similarly for soil analysis, 0.5 g sample was digested using di-acid mixture and the extractant was prepared. The DTPA extractable metal content was measured as per the method described by Lindsay and Norvell (1978). Metal contents in digested and/or extracted sewage and soil samples were measured with the help of inductively coupled plasma optical emission spectroscopy (ICP-OES) (Perkin Elmer Precisely Optima 2100 DV) for heavy metals.

Field experiment

Fields were prepared with one deep plough and two shallow ploughs to homogenize the root zone and mustard varieties were sown manually at 15 cm plant to plant and 45 cm row to row distance. Fertilizers were applied as per recommended doses (80:40:40 kg ha⁻¹ N: P₂O₅: K₂O, respectively) using urea, single super phosphate (SSP) and muriate of potash (MOP) sources. Five irrigations were applied during the crop period. Crop was raised in all the three locations following similar agronomic management practices. Crop varieties were harvested at full vegetative stage and were dried in oven at 70±2 °C. After drying samples were pulverized and kept for metal analysis in air tight plastic bags.

Mustard varieties and their characteristics

In the investigation, the phytoremediation trials were performed in different locations using four mustard varieties. The seeds of four mustard varieties namely, NRC DR 2, NRC HB 101, RH 749 and RH 119 were procured from ICAR-Directorate of Rapeseed-Mustard Research, Bharatpur, India. All
varieties are being widely cultivated by the farmers in India. The characteristic features of these varieties are mentioned in table 1.

**Metal analysis**

The processed plant samples (leaf+stalk) were digested with di-acid mixture as mentioned earlier (in initial soil and sewage water analysis). After that metal concentration in extractant from plant samples were measured with the help of ICP-OES. Metal uptake and metal transfer factor were calculated as per the formula given below:

\[
\text{Metal uptake (µg plant}^{-1}) = \frac{\text{Metal concentration in plant (µg g}^{-1}) \times \text{biomass (g plant}^{-1})}{\text{C Plant}}
\]

Metal transfer factors (TF) = \(\frac{C_{\text{Plant}}}{C_{\text{Soil}}}\)

where, \(C_{\text{Plant}}\) and \(C_{\text{Soil}}\) are the plant and soil concentrations of heavy metal, respectively.

**Statistical analysis**

Statistical analysis was done using randomized block design (RBD) with five replications at three locations. The analysis of variance was analyzed through statistical package WASP 2.0. The means were compared with the critical difference (CD) at 5.0% level of significance.

**Result and discussion**

**Effect of locations on metal dynamics**

**Physicochemical properties of soil and sewage**

Organic carbon (OC) and available nutrients (N, P, K, S and B) contents in soil of Bheropura were higher as compared to soils of Islamnagar-II and Islamnagar-I (Table 2). Concentrations of different heavy metals in the irrigation water (sewage) in three locations were more or less similar and in the sub ppm range. These values were within permissible limits for irrigation water (Ayers and Westcot 1976). Total heavy metal content of soils of the three locations were more or less in the similar range (Table 3). As compared to the contents in groundwater irrigated area in the same city reported elsewhere (Saha et al. 2014), concentrations of Cd, Cr, Cu, Ni and Pb in the experimental soils were 4.6 to 7.2, 3.44 to 4.37, 2.02 to 2.18, 7.65-8.78 and 7.21 to 8.39 times more than metal concentration of IISS field, respectively.

**Biomass production of mustard varieties**

There were significant difference among the varieties with respect to dry matter production. The highest mean dry biomass was recorded in mustard variety NRC HB 101 with 44.7 g plant\(^{-1}\). The mean biomass of other mustard varieties produced was 42.8, 38.0 and 34.1 g plant\(^{-1}\) by RH 749, RH 119 and NRC DR 2, respectively (Fig. 1). Observed difference in biomass production among the varieties might be due to differences in their genetic potential. The similar findings of yield difference among the cultivars of different crops are well established and reported by different researchers (Qdir et al. 2004). Nutrient acquisition capacity of cultivars by releasing of chelating agents, ion specific transporters helps in plant growth promotion and production of higher

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**Table 1.** Potential yield and genetic characteristics of the mustard varieties used in the experiment

<table>
<thead>
<tr>
<th>Variety</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>NRC DR 2</td>
<td>It is suitable for timely sown irrigated conditions of Haryana, Punjab, Jammu, parts of Rajasthan and Delhi; The average yield 2.21 t ha(^{-1}) with 143 days maturity.</td>
</tr>
<tr>
<td>NRC HB 101</td>
<td>It is suitable for late sown irrigated conditions of Madhya Pradesh, Uttar Pradesh, Uttarakhand and Eastern Rajasthan. The average yield 1.38 to 1.49 t ha(^{-1}) with 105-135 days maturity.</td>
</tr>
<tr>
<td>RH 749</td>
<td>Timely sown conditions in rainfed areas of Haryana, Punjab, Delhi and parts of Rajasthan. The average yield 2.60-2.80 t ha(^{-1}) with 146-148 days maturity.</td>
</tr>
<tr>
<td>RH 119</td>
<td>Timely sown conditions in rainfed areas of Haryana state. Average yield 1.80-2.00 t ha(^{-1}) with 145-150 days maturity.</td>
</tr>
</tbody>
</table>

**Table 2.** Physicochemical properties of experiment field

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Location</th>
<th>Location</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Islamnagar I</td>
<td>Islamnagar II</td>
<td>Bheropura</td>
</tr>
<tr>
<td>pH</td>
<td>8.16</td>
<td>8.12</td>
<td>8.21</td>
</tr>
<tr>
<td>EC (dS m(^{-1}))</td>
<td>0.36</td>
<td>0.33</td>
<td>0.42</td>
</tr>
<tr>
<td>OC (%)</td>
<td>0.89</td>
<td>0.96</td>
<td>1.13</td>
</tr>
<tr>
<td>Avail N (kg ha(^{-1}))</td>
<td>489</td>
<td>502</td>
<td>527</td>
</tr>
<tr>
<td>Avail P (kg ha(^{-1}))</td>
<td>14.6</td>
<td>18.9</td>
<td>23.5</td>
</tr>
<tr>
<td>Avail K (kg ha(^{-1}))</td>
<td>590</td>
<td>612</td>
<td>678</td>
</tr>
<tr>
<td>Avail S (kg ha(^{-1}))</td>
<td>46.2</td>
<td>36.9</td>
<td>48.7</td>
</tr>
<tr>
<td>Avail B (mg kg(^{-1}))</td>
<td>0.40</td>
<td>0.59</td>
<td>0.68</td>
</tr>
</tbody>
</table>
Table 3. Heavy metal in soil and sewage samples

<table>
<thead>
<tr>
<th>Location</th>
<th>Cu</th>
<th>Cd</th>
<th>Pb</th>
<th>Cr</th>
<th>Ni</th>
<th>Zn</th>
<th>Mn</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Metal in sewage</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Islamnagar I</td>
<td>0.008</td>
<td>0.002</td>
<td>0.014</td>
<td>0.007</td>
<td>0.018</td>
<td>0.017</td>
<td>0.011</td>
</tr>
<tr>
<td>Islamnagar II</td>
<td>0.006</td>
<td>0.001</td>
<td>0.013</td>
<td>0.006</td>
<td>0.011</td>
<td>0.029</td>
<td>0.009</td>
</tr>
<tr>
<td>Bheropura</td>
<td>0.011</td>
<td>0.001</td>
<td>0.014</td>
<td>0.008</td>
<td>0.004</td>
<td>0.033</td>
<td>0.013</td>
</tr>
<tr>
<td><strong>Total metal in soil</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Islamnagar I</td>
<td>82.9</td>
<td>2.9</td>
<td>122.6</td>
<td>110.2</td>
<td>562</td>
<td>72.3</td>
<td>45.6</td>
</tr>
<tr>
<td>Islamnagar II</td>
<td>86.3</td>
<td>3.6</td>
<td>126.8</td>
<td>96.3</td>
<td>489</td>
<td>68.9</td>
<td>56.3</td>
</tr>
<tr>
<td>Bheropura</td>
<td>89.5</td>
<td>2.3</td>
<td>142.7</td>
<td>122.4</td>
<td>511</td>
<td>89.3</td>
<td>42.9</td>
</tr>
<tr>
<td><strong>DTPA- extractable metal in soil</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Islamnagar I</td>
<td>4.89</td>
<td>0.05</td>
<td>1.52</td>
<td>0.02</td>
<td>0.03</td>
<td>1.12</td>
<td>0.09</td>
</tr>
<tr>
<td>Islamnagar II</td>
<td>3.58</td>
<td>0.04</td>
<td>1.46</td>
<td>0.01</td>
<td>0.01</td>
<td>1.24</td>
<td>1.02</td>
</tr>
<tr>
<td>Bheropura</td>
<td>3.41</td>
<td>0.05</td>
<td>1.58</td>
<td>0.03</td>
<td>0.07</td>
<td>1.33</td>
<td>1.03</td>
</tr>
</tbody>
</table>

The different letter in the same column represents statistically significant differences between treatments ($p<0.05$).

Metal concentration and metal uptake

In all the three locations, the mustard variety NRC HB 101 had the highest Cu and Mn concentrations in biomass. Cadmium concentration in NRC DR2, NRC HB 101 and RH 119 varieties in all the locations was similar and these were significantly higher as compared to RH 749 variety (Table 4). The RH 749 variety had significantly highest Pb concentration in Islamnagar-I and II; and NRC HB 101 had significantly highest Pb concentration in Bheropura location. The varieties NRC HB 101 in Islamnagar-I and Bheropura locations and NRC DR2 in Islamnagar-II had significantly higher concentration of Cr when compared to other varieties. Whereas, the highest concentration of Ni was found in RH 749 at Islamnagar-I, in RH 119 at Islamnagar-II and in NRC HB 101 at Bheropura (Table 4). The variety RH 119 had the highest Zn concentration in Islamnagar-I and RH 749 in Islamnagar-II and Bheropura.

Table 4. Effect of locations on metal concentration in different mustard cultivars

<table>
<thead>
<tr>
<th>Location</th>
<th>Variety</th>
<th>Cu (µg g$^{-1}$)</th>
<th>Cd</th>
<th>Pb</th>
<th>Cr</th>
<th>Ni</th>
<th>Zn</th>
<th>Mn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Islamnagar I</td>
<td>NRC DR2</td>
<td>4.70c</td>
<td>0.40a</td>
<td>3.57c</td>
<td>4.90c</td>
<td>0.47c</td>
<td>8.80b</td>
<td>9.53c</td>
</tr>
<tr>
<td></td>
<td>NRC HB 101</td>
<td>12.77a</td>
<td>0.30ab</td>
<td>4.23b</td>
<td>5.87a</td>
<td>1.43ab</td>
<td>19.27a</td>
<td>14.70a</td>
</tr>
<tr>
<td></td>
<td>RH 749</td>
<td>6.33b</td>
<td>0.10c</td>
<td>5.33a</td>
<td>5.43b</td>
<td>1.57a</td>
<td>6.23c</td>
<td>13.20b</td>
</tr>
<tr>
<td></td>
<td>RH 119</td>
<td>12.47a</td>
<td>0.17bc</td>
<td>5.67a</td>
<td>5.57ab</td>
<td>1.27b</td>
<td>19.67a</td>
<td>2.77d</td>
</tr>
<tr>
<td>Islamnagar II</td>
<td>NRC DR2</td>
<td>4.67c</td>
<td>0.33a</td>
<td>5.13b</td>
<td>6.63a</td>
<td>0.60c</td>
<td>13.67c</td>
<td>20.70b</td>
</tr>
<tr>
<td></td>
<td>NRC HB 101</td>
<td>9.80a</td>
<td>0.23a</td>
<td>2.37d</td>
<td>2.73c</td>
<td>0.77b</td>
<td>20.53b</td>
<td>36.47a</td>
</tr>
<tr>
<td></td>
<td>RH 749</td>
<td>9.23b</td>
<td>0.10b</td>
<td>6.80a</td>
<td>2.43d</td>
<td>0.47d</td>
<td>30.43a</td>
<td>19.43c</td>
</tr>
<tr>
<td></td>
<td>RH 119</td>
<td>2.70d</td>
<td>0.23a</td>
<td>4.60c</td>
<td>5.63b</td>
<td>1.33a</td>
<td>9.53d</td>
<td>13.83d</td>
</tr>
<tr>
<td>Bheropura</td>
<td>NRC DR2</td>
<td>4.37d</td>
<td>0.27a</td>
<td>5.37c</td>
<td>3.97c</td>
<td>0.57b</td>
<td>7.91b</td>
<td>14.27b</td>
</tr>
<tr>
<td></td>
<td>NRC HB 101</td>
<td>9.77a</td>
<td>0.23a</td>
<td>8.17a</td>
<td>10.77a</td>
<td>1.80a</td>
<td>20.37a</td>
<td>28.57a</td>
</tr>
<tr>
<td></td>
<td>RH 749</td>
<td>8.33b</td>
<td>0.10b</td>
<td>4.77d</td>
<td>1.57d</td>
<td>0.27c</td>
<td>21.67a</td>
<td>26.71a</td>
</tr>
<tr>
<td></td>
<td>RH 119</td>
<td>6.77c</td>
<td>0.23a</td>
<td>5.73b</td>
<td>5.83b</td>
<td>0.70b</td>
<td>11.33b</td>
<td>10.83b</td>
</tr>
</tbody>
</table>
The metal uptake pattern of mustard cultivars had showed almost identical trend in all the three locations during the study. In Islamnagar-I location, maximum Cu (548 µg plant⁻¹), Cd (3.83 µg plant⁻¹), Zn (27.6 µg plant⁻¹) and Mn (283 µg plant⁻¹) was recorded in NRC DR 101, whereas maximum Pb was accumulated in NRC DR 2 (1.45 µg plant⁻¹). The highest Cr uptake was noted in RH 119 (31.5 µg plant⁻¹) and the maximum Ni uptake was found in RH 749 (8.52 µg plant⁻¹) (Table 5). In case of Islamnagar-II location, the maximum uptake of metals were found in the cultivars NRC HB 101 for (441 µg plant⁻¹), Cd (2.29 µg plant⁻¹), Zn (15.7 µg plant⁻¹) and Mn (34.0 µg plant⁻¹); NRC DR2 for Pb (1.71 µg plant⁻¹) and Cr (34.0 µg plant⁻¹); and RH 119 for Ni (7.51 µg plant⁻¹). In case of Bheropura location NRC HB 101 had the highest metals uptake when compared to other varieties (Table 5). Among the three locations, total metal removed by the mustard cultivars were in the pattern of Islamnagar-I > Bheropura > Islamnagar-II for Cu, Cd and Zn; Bheropura > Islamnagar-I > Islamnagar-II for Cr, Pb and Ni; Islamnagar-II > Bheropura > Islamnagar-I for Mn.

Different locations were irrigated with sewage water and had difference in soil physicochemical properties (Gurjar and Yadav 2013). So, there were differences in heavy metal uptake by the mustard cultivars in different locations. The results showed that the influence of different locations on metal concentration in mustard cultivars. The concentration in the plant tissues might have been influenced by many factors like heavy metals content and interactions, soil and sewage properties, frequency of sewage water application, other management practices, etc. (Yadav et al. 2002). Apart from the genetic potential of the plant, environmental and management factors influencing metal concentration in plant tissues had been reported (Prasad and Freitas 2003). The amount of metal absorbed by plants was affected by pH, organic matter, and phosphorus content of soil. The soil properties like particle size, soil mineralogy, pH, organic matter and cation exchange capacity (CEC) and kind of metal fractions and forms could influence the soil-metal interactions and availability of metals (Dermont et al. 2008).

Further, Clemente et al. (2005) reported that addition of organic amendments improved the phytoextraction potential of B. juncea at a multi-metal contaminated site. The sewage also had large amount of organic matter can build up SOC which in turn augmented phytoextraction potential of the mustard cultivars. In the current investigation, Bheropura experimental site with high SOC and soil available nutrient showed better performance of remediation than the other sites. Addition of organic matter and fertilizers was also one of the options to augment the phytoremediation process (Dotaniya et al. 2019).

Effect of varieties on metal uptake

Different varieties had performed differently regarding metal uptake (Table 6). Mean data of all the three locations showed that the maximum Cu (479 µg plant⁻¹), Cd (2.80 µg plant⁻¹), Cr (38.1 µg plant⁻¹), Ni (9.96 µg plant⁻¹), Zn (26.6 µg plant⁻¹) and Mn (538 µg plant⁻¹) uptakes were found in NRC HB 101, except maximum Pb uptake in NRC DR 2 (1.53 µg plant⁻¹). The pattern of Cu uptake was NRC HB 101 (479 µg plant⁻¹) > RH 749 (340 µg plant⁻¹) > RH 119 (276 µg plant⁻¹) and NRC DR 2 (155 µg plant⁻¹). In case of Cd uptake, the pattern was NRC HB 101 >

### Table 5. Effect of locations on metal uptake dynamics

<table>
<thead>
<tr>
<th>Location</th>
<th>Variety</th>
<th>Cu</th>
<th>Cd</th>
<th>Pb</th>
<th>Cr</th>
<th>Ni</th>
<th>Zn</th>
<th>Mn</th>
<th>Total metal uptake</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NRC DR 2</td>
<td>150d</td>
<td>1.89b</td>
<td>1.45a</td>
<td>17.4c</td>
<td>2.26c</td>
<td>4.06d</td>
<td>84b</td>
<td>261</td>
</tr>
<tr>
<td></td>
<td>NRC HB 101</td>
<td>548a</td>
<td>3.83a</td>
<td>1.27a</td>
<td>24.8b</td>
<td>8.41a</td>
<td>27.61a</td>
<td>283a</td>
<td>898</td>
</tr>
<tr>
<td></td>
<td>RH 749</td>
<td>266c</td>
<td>0.63b</td>
<td>0.53a</td>
<td>28.9a</td>
<td>8.52a</td>
<td>9.76c</td>
<td>82b</td>
<td>396</td>
</tr>
<tr>
<td></td>
<td>RH 119</td>
<td>473b</td>
<td>2.08b</td>
<td>0.97b</td>
<td>31.5a</td>
<td>7.06b</td>
<td>24.90b</td>
<td>54c</td>
<td>594</td>
</tr>
<tr>
<td>Islamnagar II</td>
<td>NRC DR 2</td>
<td>158c</td>
<td>1.56b</td>
<td>1.71a</td>
<td>34.0a</td>
<td>3.98b</td>
<td>8.20c</td>
<td>282c</td>
<td>491</td>
</tr>
<tr>
<td></td>
<td>NRC HB 101</td>
<td>441a</td>
<td>2.29a</td>
<td>0.13d</td>
<td>1.5d</td>
<td>2.09c</td>
<td>15.74a</td>
<td>748a</td>
<td>1211</td>
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<tr>
<td></td>
<td>RH 749</td>
<td>397b</td>
<td>0.92c</td>
<td>0.68c</td>
<td>16.5c</td>
<td>1.13d</td>
<td>14.20ab</td>
<td>591b</td>
<td>1021</td>
</tr>
<tr>
<td></td>
<td>RH 119</td>
<td>105d</td>
<td>0.63c</td>
<td>1.07b</td>
<td>25.9b</td>
<td>7.51a</td>
<td>12.72b</td>
<td>131d</td>
<td>285</td>
</tr>
<tr>
<td>Bheropura</td>
<td>NRC DR 2</td>
<td>157d</td>
<td>1.16b</td>
<td>1.43a</td>
<td>21.2c</td>
<td>2.24c</td>
<td>4.71b</td>
<td>113b</td>
<td>301</td>
</tr>
<tr>
<td></td>
<td>NRC HB 101</td>
<td>449a</td>
<td>2.27a</td>
<td>1.90a</td>
<td>87.9a</td>
<td>19.39a</td>
<td>36.67a</td>
<td>582a</td>
<td>1180</td>
</tr>
<tr>
<td></td>
<td>RH 749</td>
<td>358b</td>
<td>0.83c</td>
<td>0.48b</td>
<td>7.4d</td>
<td>0.42d</td>
<td>5.78b</td>
<td>578a</td>
<td>951</td>
</tr>
<tr>
<td></td>
<td>RH 119</td>
<td>250c</td>
<td>1.57b</td>
<td>1.33a</td>
<td>33.4b</td>
<td>4.08b</td>
<td>7.95b</td>
<td>122b</td>
<td>421</td>
</tr>
</tbody>
</table>

The different letter in the same column represents statistically significant differences between treatments (p< 0.05)
NRC DR 2 > RH 119 = RH 749. The Pb uptake was NRC DR 2 > RH 119 > NRC HB 101 = RH 749. The Cr uptake pattern was NRC HB 101 > RH 119 > NRC DR 2 > RH 749 (Table 6). The Mn uptake of mustard varieties were followed the sequence of NRC HB 101 (538 µg plant⁻¹) > RH 749 (417 µg plant⁻¹) > NRC DR 2 (160 µg plant⁻¹) > RH 119 (103 µg plant⁻¹).

This showed the preference of each cultivar towards metal uptake as controlled by genetic factor of the cultivars (Dotaniya et al. 2018b; Kozminiska et al. 2018). Plants with high affinity for heavy metals had been recommended to restore degraded soils. The uptake of metals or any compound could be influenced by plant species or varietal characteristics (Burken and Schnoor 1996). Grispen et al. (2006) observed that metal uptake variability within the B. napus species of different varieties and accessions. Qadir et al. (2004) assessed ten cultivars of B. juncea for their Cd extraction potential and some cultivars showed higher Cd tolerance than others. Similarly, Gill et al. (2015) also studied the Cr uptake potential in four cultivars of B. napus. Plants could affect the soil by lowering the pH, which affects the availability of the metals; and increasing the bio-availability of heavy metals by chelating agents (Van Ginneken et al. 2007). The dry matter yield must also played a major role in accumulation of large quantity of metals as evidenced from the result of maximum uptake of metals by cultivar NRC HB 101 with the highest dry matter yield. The similar concept of hyperaccumulating plants that produce large amounts of biomass using established crop production and management practices to be selected for successful phyto remediation had been envisaged. Further, plant varieties with better remediation properties had to be selected for remediation purpose (Prasad and Freitas 2003). The heterogeneous distribution of metals as that of current study were real and mostly happen in many contaminated sites depicted the clear picture than the homogeneous conditions (Podar et al. 2004). Release of enzymes, chelating agents and metal transporters were the most important mechanisms of phyto remediation of metal contaminated sites (Mourato et al. 2015). Though the current study comparatively assessed the four Indian mustard varieties actual mechanism involved and exhibited by each cultivars was not known and need to be studied using advanced technologies like genomics, transcriptomics, proteomics and metabolomics to establish the genome, transcript, protein and metabolite levels involved in heavy metal stress, which was beyond the scope of the current study. However, among the cultivar used NRC HB 101 performed better in all the three locations, and could be recommended for remediation of multi-metal contaminated sites.

### Metal transfer factor

Transfer of a metal concentration from the soil to plant parts can be calculated by metal transfer factor. In this experiment, we have computed the phytoextraction capacity of different mustard varieties (Fig. 2). Experimental results showed that most of the varieties extract most of the metals from sewage irrigated soils. Among mustard varieties, NRC HB 101 showed higher accumulation potential (more than one) as compared to rest of the varieties at all the locations except Islammagar I. If we compared the individual phytoextraction potential of all the varieties, it was less than one, which showed most of the varieties are not performed as a higher accumulator for a particular metal at all the locations. The RH 749 also showed phytoextraction potential after NRC HB 101 at Islammagar II and Bheropura location, whereas NRC DR 2 better performed at Islammagar I. The transfer of metal from soil to plant part much affected by genetic and the soil properties like SOM, pH, other metal ions and also by the humus-metal complex formed in rhizospheric zone of the soil. Sewage irrigated soils are having higher

### Table 6. Effect of mustard varieties on metal uptake

<table>
<thead>
<tr>
<th>Variety</th>
<th>Cu (µg plant⁻¹)</th>
<th>Cd (µg plant⁻¹)</th>
<th>Pb (µg plant⁻¹)</th>
<th>Cr (µg plant⁻¹)</th>
<th>Ni (µg plant⁻¹)</th>
<th>Zn (µg plant⁻¹)</th>
<th>Mn (µg plant⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NRC DR2</td>
<td>155±4.4d</td>
<td>1.54±0.42b</td>
<td>1.53±0.22a</td>
<td>24.2±8.7c</td>
<td>2.83±1.01d</td>
<td>5.66±2.23d</td>
<td>160±10c</td>
</tr>
<tr>
<td>NRC HB 101</td>
<td>479±60a</td>
<td>2.80±0.90a</td>
<td>1.10±0.82b</td>
<td>38.1±4.7a</td>
<td>9.96±3.22a</td>
<td>26.67±9.44a</td>
<td>538±180a</td>
</tr>
<tr>
<td>RH 749</td>
<td>340±63b</td>
<td>0.80±0.15c</td>
<td>0.56±0.12c</td>
<td>17.6±4.4d</td>
<td>3.36±0.82c</td>
<td>9.91±2.31c</td>
<td>417±186b</td>
</tr>
<tr>
<td>RH 119</td>
<td>276±107c</td>
<td>1.42±0.65b</td>
<td>1.12±0.15b</td>
<td>30.2±3.9b</td>
<td>6.22±1.87b</td>
<td>15.19±5.92b</td>
<td>103±28d</td>
</tr>
</tbody>
</table>

*Mean data of all locations; the different letter in the same column represents statistically significant differences between treatments (p< 0.05)
amount of SOM and convert the metal concentration in organic matter bound form and reduced active concentration level in soil solution (Mourato et al. 2015).

Conclusions

Sewage irrigation is much popular among the peri-urban areas for agricultural production. Most of the agricultural fields located on the banks of sewage channel are irrigated using sewage water by willingly or to meet the scarcity of fresh water. Sewage waters contain significant amount of plant nutrients and organic matter which reduce the use of chemical fertilizers. They also contain meager amount of heavy metals which impact the soil and plant health and productivity. Long-term application of sewage for irrigation accumulates significant amount of metals in crop fields. Indian mustard is well known for remediation of contaminated areas and is largely adopted across the globe. Experimental results showed that among the four mustard varieties raised in the study, the cultivar NRC HB 101 has recorded the maximum uptake of Cu, Cd, Cr, Ni, Zn and Mn and also performed as a metal accumulator, whereas variety NRC DR 2 has accumulated the highest amount of Pb from soils. These kinds of information are very much useful for formulation of metal remediation strategies in sewage or industrial irrigated metal contaminated areas.

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References


