

Plant Ecology and Environmental Science

1. Objectives

- Microbial degradation of oily sludge.
- Microbe-assisted phytoremediation of metals from fly ash.
- Biology of green house gas emission.
- Toxicity and tolerance responses of plants to metal and metalloid pollution.
- Phytoremediation of Geogenic, Urban and Industrial pollution in soil and water.
- Development of low grain arsenic rice cultivars (safe for human consumption) using molecular and chemical approaches.
- Identification and characterization of contrasting Arsenic accumulating rice lines

2. Goals:

- Development of microbial consortia for rapid degradation of oily sludge and oil contaminated soils.
- Development of bacterial consortia for enhancing phytoextraction of metals from fly ash.
- Mitigation of GHG emission from agricultural fields.
- Screening of sensitive and tolerant cultivars of selected crops suitable to be grown on metal and metalloid contaminated soil.
- Strategies for development of low grain arsenic accumulating rice cultivars.
- Phytostabilization and minimization studies of chromium containing tannery wastewater contaminated sites for safe agriculture
- Management of Ganga water pollution through development of constructed wetlands
- Biomonitoring and bioremediation of polluted soil and water resources.

3. Competencies :

- Biodegradation of oily sludge and oil contaminated sites.
- Microbe assisted phytoextraction of toxic metals.
- Attenuation of GHG emission from agricultural fields.
- To monitor, develop and recommend strategies for phytoremediation of metal/metalloid contaminated sites through tolerant plants/crops.

4. Facilities:

- HPLC-ICP-MS (coupled)
- HPLC
- Fluorescence spectrophotometer
- Gas Chromatograph
- Bioreactor
- LICOR photosynthesis system

5. Highlights of Current Research:

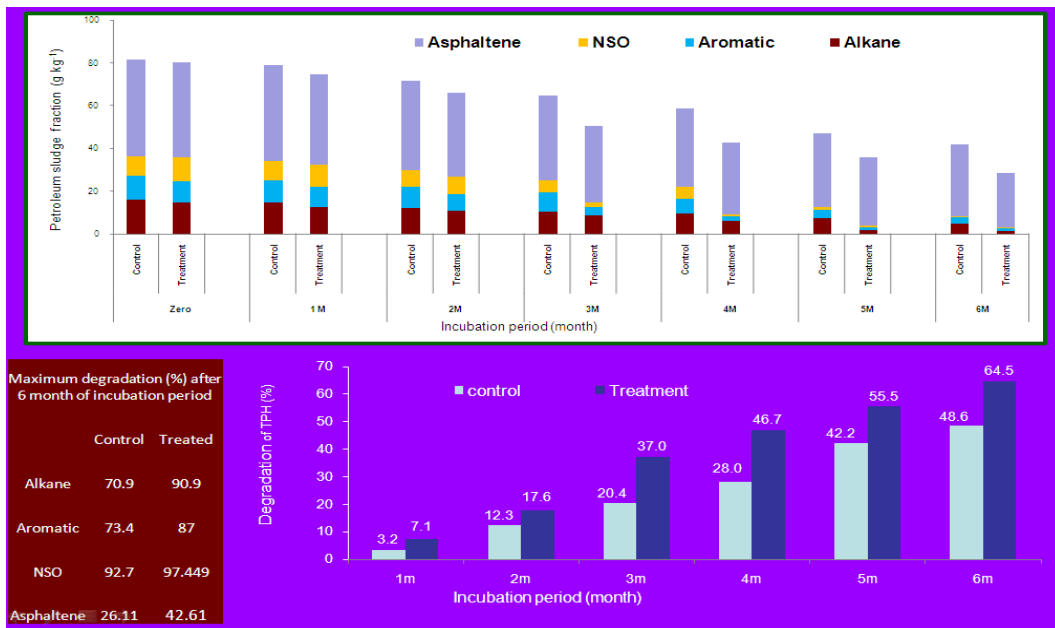


Fig 1: Degradation of different fractions of petroleum sludge in soil amended with vermicompost and bacterial consortium.

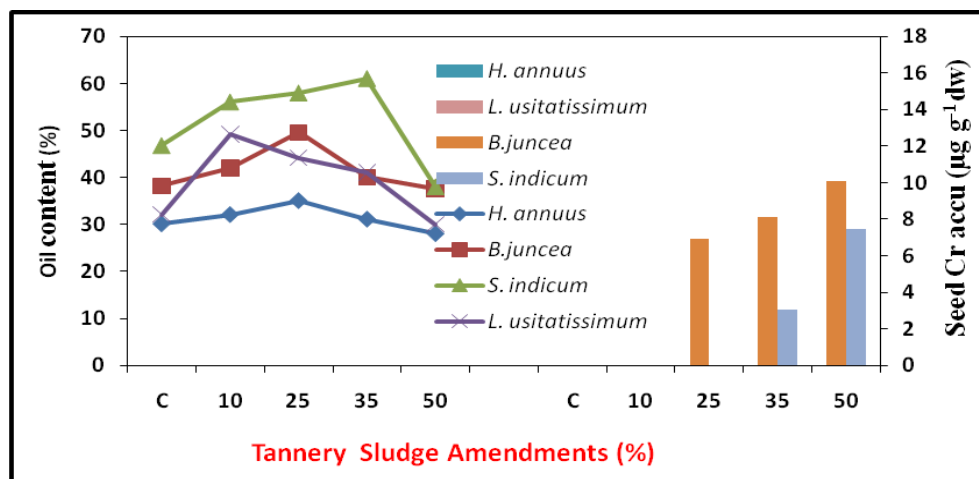


Fig. 2. Chromium accumulation in seeds and oil yield in the plants of *Helianthus annuus*, *Linum usitatissimum*, *Brassica juncea*, and *Sesamum indicum* grown on tannery waste contaminated soil.

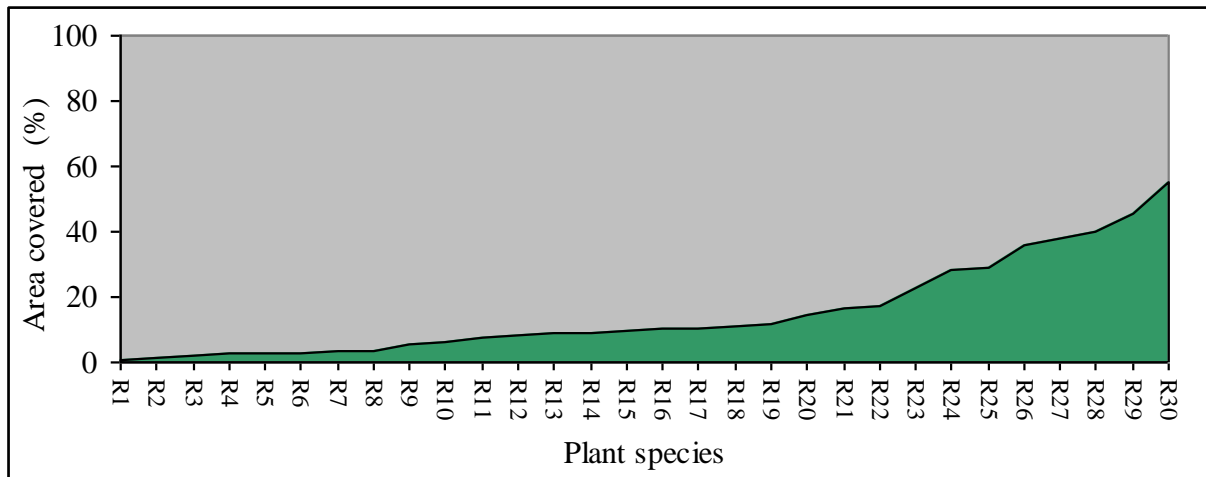


Fig. 3. Phytostabilization Technology for *in situ* plantation of economically important woody plants amended with metal tolerant bacterial strains, sand and cow dung manure for natural attenuation of vegetation on tannery sludge dump site at CETP, Unnao. R1= *Phicher lamcelata*, R2= *Launnea asplenifolia*, R3= *Cocenia grandis*, R4= *Dactyloctenium aegyptium*, R5= *Vernonia cinerea*, R6= *Launaca procumbens*, R7= *Medicago indica*, R8= *Borhavia diffusa*, R9= *Phyllanthus amanis*, R10= *Cynodon dictyolon*, R11= *Euphorbia hirta*, R12= *Oxalis corniculata*, R13= *Chenopodium album*, R14= *Ageratum haustorianum*, R15= *Croton tiglium*, R16= *Solanum nigrum*, R17= *Osimum salivam*, R18= *Amaranthus sp.*, R19= *Cyperus rotendus*, R20= *Cannabis sativa*, R21= *Leucina leucucephalla*, R22= *Sorghum tuberosum*, R23= *Calotropis prosera*, R24= *Nerium indicum*, R25 = *Dendrocalamus strictus*, R26 = *Terminalia arjuna*, R27 = *Eucalyptus terecticornis*, R28 = *Populus alba*, R29 = *Acassia nilotica*, R30= *Prosopis juliflora*

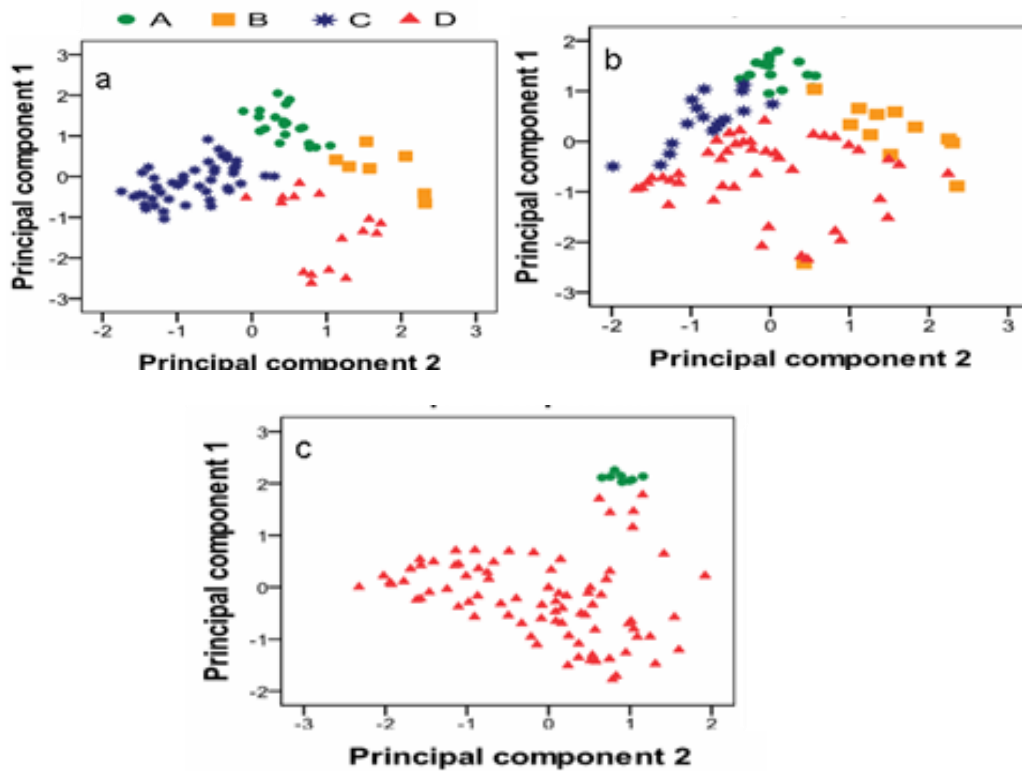


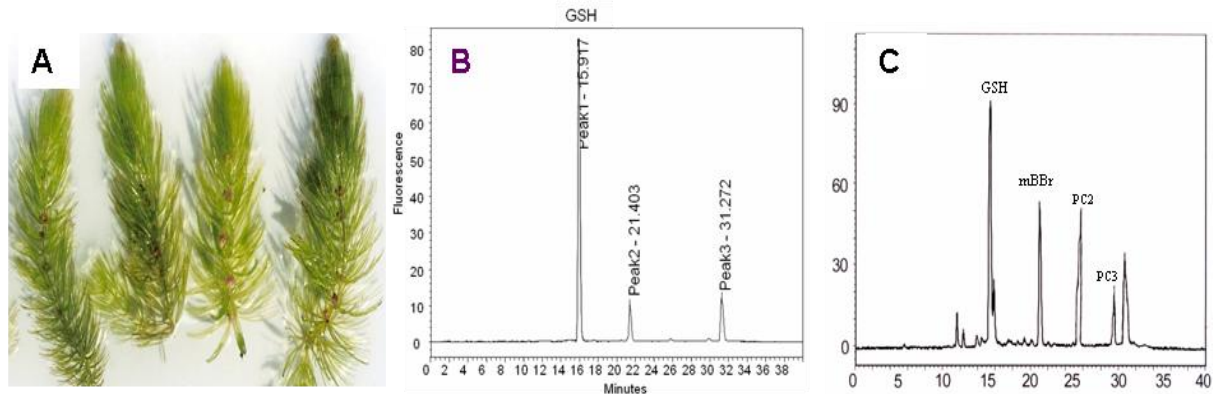
Figure 4 (a-c): Principal component analysis of the 89 rice cultivars cultivated at the three arsenic contaminated sites Chinsurah (a), Purbosthali (b) and Birnagar (c) in West Bengal, grouped according to:

Type A: Sufficient-Se and low-As accumulating cultivars (>0.183 Se, <0.25 As)

Type B: Sufficient-Se and high-As accumulating cultivars (>0.183 Se, >0.25 As)

Type C: Insufficient-Se and low-As accumulating cultivars (<0.183 Se, <0.25 As)

Type D: Insufficient-Se and high-As accumulating cultivars (<0.183 Se, >0.25 As)



(D)

MAIAGLYKRVLP**C**PPAVEFSSGEGRQLF**C**EALKDGTMEGFFKLI SYFQTQSEPAY**C**GLASISV
 VLNALSIDPGRTWKGPWRWFDE SMLD**C**CE SLEKVKAKGITFGKVV**C**LAR**C**SGAKVEAFLTNQS
 TTNDFRKHVI**T**CASSDD**C**HLIASYHRSILKQTGTGFHFSPIGGYHAGRDMVLILDVARFKYPH
 WVPLPLLWEAMDTVDI VTGHPRGFMLISKLQVPSLLYTLS**C**KHTDWINSAKFLVDDLPKLLNS
 KDINSIEDILSIL**C**TSLNSNVLDFIKWVAEVRSESGISSLSIEEKGRLSAKEDVLR TARETE
 LFKYVTEWLYSSNS**C**YKNFSNAGSTSLSIIGTNV**C**CQGAELLSGRLGNG**C**RF**C**SEI**C**IKYVK
 DDIDYPKTI VSGSVQLDGNNDVDAL IPTSPVYSK**C**GPSTND**C**SEM**C**PGDSDILTMLLLTLP
 PHTW**C**AIENEKLLTKVQALVSTESLPMLLQEEVLHLRNQLNLLVRFQKNKEDDDYL RPTT

Figure 5 (A-D): Fluorescence HPLC chromatograms of mBBr-labeled extracts of As accumulating *Ceratophyllum demersum* (A) showing glutathione and phytochelatins in: (B) Control and (C) 100 mM As exposed plants. (D) Deduced amino acid sequence of phytochelatin synthase from *Ceratophyllum demersum*. 22-cystein {C} residues present in the amino acid sequence has been shown in red color.

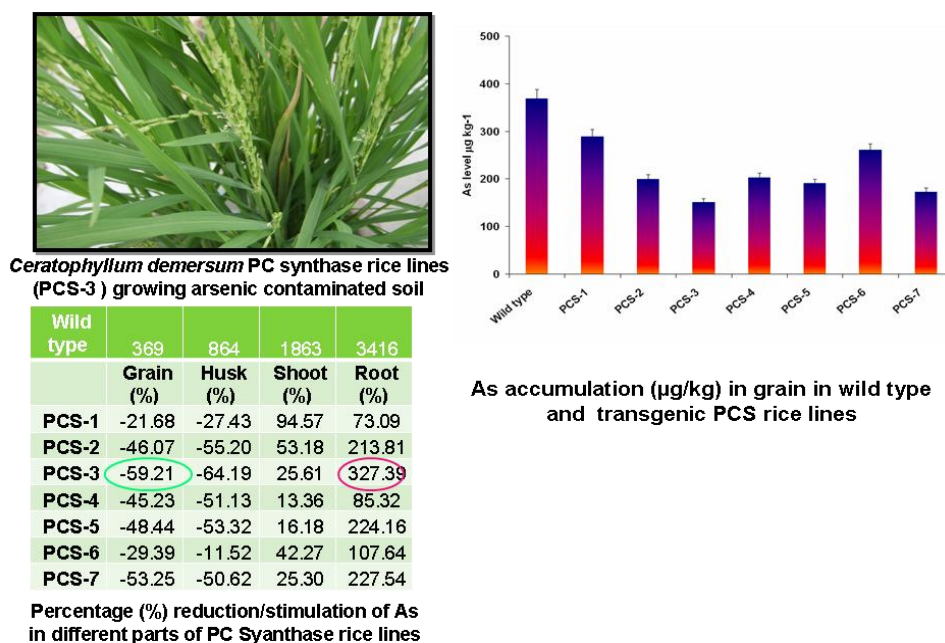


Figure 6: Evaluation of transgenic plant for arsenic detoxification and accumulation in plants. Transgenic rice cultivars with low grain arsenic for safe rice consumption by humans.

6. List of Ongoing projects:

- I. Biodegradation of petroleum sludge (CSIR Network project) till March,2012 (email: drsn_s@rediffmail.com)
- II. Studies on speciation of arsenic in contrasting lines low and high As accumulation of rice: minimization of the translocation of As in the upper parts using phosphate, selenium and iron. DST (Govt. of India) till Sept., 2013, Dr. Sarita Sinha (E mail : sinha_sarita52@yahoo.com)
- III. Plant-based management of Ganga water pollution: Plantation along the Bank and development of constructed wetland for sewage and waste treatment : phase-I Uttaranchal funded by Ministry of Environment & Forests., Govt. of India, New Delhi Till Dec. 2013, Dr.U.N.Rai (Email: rai_un@rediffmail.com).
- IV. Role of thiol and nitric oxide metabolism mediated pathways in arsenic stress in higher plants. (Indo-Spanish Joint research project). DST, Govt of India; till September, 2012; Dr. R D. Tripathi (tripathi_rd@rediffmail.com).
- V. Plant based screening technologies for biomonitoring and assessment of heavy metal/metalloid pollution (CSIR Network project) till March, 2012, Dr. R D. Tripathi (tripathi_rd@rediffmail.com).
- VI. Development of transgenic rice and hyperaccumulator species for arsenic contaminated (CSIR Network project). March,2012 (tripathi_rd@rediffmail.com).

7. Significant achievements:

- Development of microbial consortia for enhanced degradation of oily sludge and oil contaminated sites.
- A bacterial consortium was developed to enhance the phytoextraction of metals from fly ash.

- Several options were worked out to mitigate GHG emission from agricultural fields.
- Identification of oil yielding crop having lowest accumulation of chromium in its seeds and lesser effect on the oil yield (Fig. 1).
- Demonstration of aquatic macrophyte treatment system for tannery wastewater
- Identified crop/vegetables safe for growing in chromium contaminated sites.
- Phytostabilization of tannery sludge dumps in order to reduce leaching by woody plants and microbial inoculation (Fig 2).
- Stabilization and transformation of chromium during composting of phytoremediated biomass.
- Demonstration of amelioration of toxic metal uptake by essential nutrient.
- PCA analysis of the results of Se & As in grains revealed a site specific affinity of various cultivars to categories of safety. On Chinsurah (a), the safest category A, while at Birnagar (b) except for 8 cultivars all were found grouped as category D; the most unsafe category (Fig. 3 A-C).
- *Ceratophyllum demersum*, a high accumulator of As synthesized significant amount of metal binding peptides (poly γ -EC) G, the phytochelatin (PCs), catalyzed by phytochelatin synthase. PC synthase gene has been cloned and characterized from *C. demersum*. (Fig 4).
- Rice plants (IR-64) were transformed using *C. demersum* PCS for developments of transgenic plant with low grain As accumulation. The lowest grain As level was found in PCS-3 rice line. Over expression of PC Synthase gene reduced the grain As concentration upto 59 % than control (41% in the grain) in PCS-3 rice line, in which most of arsenic (327%) was sequestered in root when grown on arsenic laded soils (12 mg/kg) (Fig. 5).

8. Recent Publications:

1. Tiwari S., Kumari B and Singh S. N. (2008) Evaluation of metal mobility/immobility in fly ash induced by bacteria strains isolated from the rhizospheric zone of *Typha latifolia* growing on fly ash dumps. *Bioresource Technology* 99(5):1305-1310
2. Tiwari S., Kumari B and Singh S. N. (2008) Microbe-induced changes in metal extractability from fly ash. *Chemosphere* 71(7):1284-1294
3. Tyagi, L., Kumari, B. and Singh, S. N. (2010) Water management –A tool for methane mitigation from irrigated paddy fields. *STOTEN* 408: 1085-1090
4. Kumari, B. and Singh, S.N. (2011) Phytoremediation of metals from fly ash through bacterial augmentation *Ecotoxicology* 20:166-176.
5. Kumar S, Upadhyay SK, Kumari B, Tiwari S, Singh SN, Singh PK (2011) – In vitro degradation of fluoranthene by bacteria isolated from petroleum sludge. *Bioresource Technol.* 102: 3709-3715.
6. Sinha, S., Gupta, A. K., Bhatt, K., Pandey, K. Rai, U. N. and Singh, K. P. (2006) Distribution of metals in the edible plants grown at Jajmau, Kanpur (India) receiving treated tannery wastewater : relation with physico-chemical properties of the soil. *Environ. Monit. Assess.* 115 (1-3) : 1-22.
7. Sinha S. and Saxena R. (2006) Effect of iron on lipid peroxidation, and enzymatic and non-enzymatic antioxidants and bacoside-A content in medicinal plant *Bacopa monnieri* L. *Chemosphere* 62: 1340-1350.

8. Gupta, A. K. and Sinha, S. (2007). Phytoextraction capacity of the plants growing on tannery sludge dumping sites. *Biores. Tech.* 98 : 1788-1794
9. Gupta, A. and Sinha, S. (2009) Antioxidant response in sesame plants grown on industrially contaminated soil : effect on oil yield and tolerance to lipid peroxidation. *Biores. Technol.* 100, 179-185.
10. Mallick, S., Sinam, G., Mishra, R. K. and Sinha, S. (2010) Interactive effects of Cr and Fe treatments on plants growth, nutrition and oxidative status in *Zea mays* L. *Ecotoxicology and Environmental Safety* 73 (2010) 987–995
11. Sinha, S., Sinam, G., Mishra, R. K., Mallick, S. (2010). Metal accumulation, growth, antioxidants and oil yield of *Brassica juncea* L. exposed to different metals. *Ecotoxicol. Environ Safety* 73 : 1352-1361
12. Rai, U.N., Pandey, K., Sinha, S., Singh, A., Saxena, R. and Gupta, D.K. (2004). Revegetating fly-ash landfills with *Prosopis juliflora* L.: Impact of different amendments and *Rhizobium* inoculation. *Environmental International.* 30: 293-300.
13. Rai, U. N., Dwivedi, S., Tripathi, R. D., Shukla, O.P. and Singh, N. K. (2005). Algal biomass: an economical method for removal of chromium from tannery effluent. *Bull. Environ. Contam. Toxicol.* 75: 297-303.
14. Tewari A., Singh, R., Singh, N. K., Rai. U. N. (2008). Amelioration of municipal sludge by *Pistia stratiotes* L.: Role of antioxidant enzymes in detoxification of metals. *Bioresource Technology* 99: 87158721
15. Rai, U. N., Dubey, S., Shukla, O. P., Dwivedi, S. and Tripathi, R. D. (2008). Screening and identification of early warning algal species for metal contamination in fresh water bodies polluted from point and non-point sources. *Environ. Monit. Assess.* 144: 469-481.
16. Shukla, O. P., Rai, U. N. and Dubey, S. (2009). Involvement and interaction of microbial communities in the transformation and stabilization of chromium during the composting of tannery effluent treated biomass of *Vallisneria spiralis* L. *Bioresource Technology* 100 : 2198-2203.
17. S. Dwivedi, R. D. Tripathi, P. Tripathi, A. Kumar, R. Dave, S. Mishra, R. Singh, D. Sharma, U.N. Rai, D. Chakrabarty, P.K. Trivedi, B. Adhikari, M.K. Bag, O. P. Dhankher and R. Tuli (2010). Arsenate Exposure Affects Amino Acids, Mineral Nutrient Status and Antioxidants in Rice (*Oryza sativa* L.) Genotypes. *Environ. Scien. Technol.* 44, 9542–9549.
18. Rai A., Tripathi P., Dwivedi S., Dubey S., Shri M., Kumar S., Tripathi P. K., Dave R., Kumar A., Singh R., Adhikari B., Bag M., Tripathi R. D., Trivedi P. K., Chakrabarty D., Tuli R. (2010). Arsenic tolerances in rice (*Oryza sativa*) have a predominant role in transcriptional regulation of a set of genes including sulphur assimilation pathway and antioxidant system, *Chemosphere*, 82, 986–995.
19. Mishra, M., Tripathi, R.D., Srivastava, S., Dwivedi, S., Trivedi, P. K., Dhankher, O. P., Khare, A. (2009): Thiol metabolism play significant role during cadmium detoxification by *Ceratophyllum demersum* L. *Bioresou. Technol.*, 100, 2155-2161.
20. Tripathi, RD, Srivastava, S, Mishra, S, Singh, N, Tuli, R, Gupta, DK, Maathuis, FJM (2007). Arsenic hazards: strategies for tolerance and remediation by plants. *Trend. Biotech.*, 25, 158-165.
21. Srivastava, S, Mishra, S, Tripathi, RD, Dwivedi, S, Trivedi, PK, Tandon, (2007). Phytochelatins and antioxidant systems respond differentially during arsenite and arsenate stress in *Hydrilla verticillata* (L.f.) Royle. *Environ. Scien. Tech.*, 41, 2930-2936.

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