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RESEARCH ARTICLE

EVALUATE THE ASSOCIATION OF ARBUSCULAR MYCORRHIZAL FUNGI IN SOME MEDICINAL PLANTS GROWN IN NOYAL RIVER BED, TIRUPPUR DISTRICT, TAMIL NADU

Venkatachalapathi, A.*, Abdul Kaffoor, H. and N. Nagarajan
Department of Botany, Kongunadu Arts and Science College (Autonomous), Coimbatore-641029, Tamil Nadu, India

ABSTRACT

To evaluate the rhizosphere soils and ten medicinal herbs polluted soils were tested for the association of arbuscular mycorrhizal fungi and determined the impact of the physico chemical factors in relation to the quantitative and qualitative assessment of AM fungi in polluted soils. Forty species of AMF belonging to five genera such as *Glomus, Acaulospora, Gigaspora, Sclerocystis* and *Scutellospora* were recorded and identified. *Glomus fistulosum* was noticed as the moist dominant in the polluted. In the non-polluted soils, all the plant species were colonized with AM fungi. Where as in polluted soils, eight herb species only were colonized and the percentage of root colonization was less.

Keywords: Arbuscular mycorrhizal fungi (AMF), Polluted soils, AMF root colonization, *Glomus fistulosum*

1. INTRODUCTION

Arbuscular mycorrhizal fungi are a natural constituent of the soil of most ecosystems. They interact with the root of more than 80 % of terrestrial plants and can be considered functional extensions of plant roots considerably enlarging the volume for nutrient up take. Arbuscular mycorrhizal (AM) fungi provide an attractive system to advance plant-based environmental cleanup. During symbiotic interaction the hyphal network functionally extends the root systems of their hosts. AM fungi occur in the soil of most ecosystems including polluted soils by acquiring phosphate micronutrients and water and delivering a proportion to their hosts they enhance the nutrition state of their hosts. Identifying the most sustainable disposal route an important issue in almost all industrialised countries due to a range of legislative, environmental and economic and social drivers (Awotoye, *et al.,* 2009).

Noyyal River is a seasonal river and it flows through the two urbanized and well known industrial cities namely Coimbatore and Tirupur before it reaches River Cauvery as a tributary. More than 6250 textile dyeing and bleaching units are situated in Tirupur region across the river basin release partially or untreated effluents into Noyyal River (Udayakumar *et al.,* 2011). Most of the industries dump their liquid waste in streams and river producing changes in physicochemical and biological conditions of water and soil. Major industrial pollution sources in the country are mills of textiles, leather, dyes, chemicals and number of other industries, in addition to municipal and domestic waste effluents. Textile industry in one of the foreign exchange earner in India. Total annual discharge of waste water is 9,420,000m^3 (Jogdand, 1995) and is disposed into river and on land. In order to find out the potential use of the tannery effluent, an experiment was conducted at polluted soils where the textile liquid wastes mixed with the Noyal river bed, Tirupur District, Tamil Nadu.

Heavy metals (HMs) occur naturally in the environment and constitute a potential hazard for waters, soils, plants and sediments. Numerous studies have indicated that agroecosystems receive inputs of HMs from the increased use of agrochemicals, the application of metalcontaining wastes such as sewage sludge, pig manure, coal and wood ashes to soils, and from atmospheric deposition (Mhatre and Pankhurst, 1997). Although some of these metals are essential plant micronutrients and are required or are beneficial for plant growth and development (Zn, Cu, Fe, Mn, Ni, Mo, Co), high contents and/or long-term presence of HMs, in soils, are generally considered a matter of concern to society as they may adversely affect the quality of soil and water, and compromise sustainable food production (Pandolfini *et al.,* 1997; Keller *et al.,* 2002; Voegelin *et al.,* 2003; Kabata-Pendias and Mukherjee, 2007). Arbuscular mycorrhizal fungi (AMF) are one of the important endophytic fungi living in the roots of most terrestrial plants. This symbiosis confers benefits directly to the host plant's growth and development through the acquisition of phosphorous and other mineral nutrients from the soil by the fungus. In addition, they may also enhance the plant's resistance to biotic and abiotic stresses (Harrier and Sawczak, 2000).

*Correspondence: Venkatachalapathi, A., Department of Botany, Kongunadu Arts and Science College (Autonomous), Coimbatore-641029, Tamil Nadu, India Email: avenkatachalapathi61@gmail.com

Now a day, it has been shown that improvement of the interactions between beneficial

significantly lower the stress placed on plants by the presence of HMs, increase the availability of metal for plant uptake and subsequently are considered to be an important tool for phytoremediation technology (Glick, 2003, 2010).

2. MATERIALS AND METHODS

2.1. Study area

Tirupur is located at 11.1075°N 77.3398°E. It has an average elevation of 295 metres (967 feet). Tirupur is situated at the banks of Noyyal River, helping the textile business to grow well. As a textile city Tirupur is full of Dyings and Garments. Its location as a center of other cities like Erode, Coimbatore makes it easier to get cotton and other stuffs for the business to be done. The Noyyal River runs through the city and forms the southern boundary of corporation. The cities fast development leads to growth to its status as Tirupur district (Figure-1). The southern part of the city enjoys more rainfall Due to the surrounding of Western Ghats of the city. The mean maximum and minimum temperatures for Tirupur city during summer and winter vary between 35 to 22 °C (95 to 72 °F). The alternative perspective of historical geography is used to understand how Tirupur's industry is an outcome of processes liking work and investment across sectors in a form of regional industrialization based on small town.

Fig. 1. The map showing study area of Tirupur district.

2.2. Experimental soil

rhizosphere microorganisms and plants can

The physicochemical characteristics of the soil used for experiment were tested in Department Soil Science testing laboratories at Tamil Nadu Agricultural University, Coimbatore, Tamilnadu, India.

2.3. Rhizosphere effect in soil (Subbarao, 2000)

The quantitative rhizosphere effect of the plants was calculated using the formula:

$$R/S = \frac{\text{Number of microorganism per gram of rhizosphere soil}}{\text{Number of microorganism per gram of non-rhizosphere soil}}$$

2.4. Mycorrhizal status in plant roots

Results were processed using Phillips *et al.,* technique to study the percent of root colonization. Arbuscular mycorrhizal fungal spores were isolated by wet sieving and decanting method (Gerdemann and Nicolson, 1963).

2.5. Phosphorus content

The phosphorus content in the shoots was determined by the vanado-molybdate phosphoric acid yellow color method outlined by (Jackson, 1973).

3. RESULTS AND DISCUSSION

The contamination of nature compartments by heavy metals has become a serious environmental problem. The worldwide release of heavy metals has reached 1,350,000 tons Zn in 2002 (Singh *et al.,* 2003). This AMF-induced plant nutrient uptake is of more importance in alkaline and calcareous soils of arid semiarid regions in which the bioavailability of P and most of the cationic micronutrients is limited. Calcareous soils have also lower water holding capacity due to the presence of carbonates (Khodaverdiloo *et al.,* 2011). Furthermore, (Khodaverdiloo and Homaee, 2008 and Davari *et al.,* 2010) reported a significant reduction in plant transpiration with an increase in soil HM concentration. It has been suggested that heavy metals, such as Cd, can affect root hydraulic conductivity by multiple mechanisms operating on the apoplastic and the symplastic pathway (Shah *et al.,* 2010). Physico-chemical properties of soil samples of both the study sites were presented in (Table-1). Both the control and polluted soils of sandy clay loam and the pH of the non-polluted soil ranged from 7.3 - 7.2 while that of the polluted soils ranged from 6.2-5.4. Both study sites were deficient in phosphorus and nitrogen.

Phytoremediation cannot be done alone by the plant, just as there is always a close interaction between the microorganisms in the rhizosphere and the plant which leads to an increased activity related

to soil remediation (Compant *et al.,* 2010). Overall a searching for and application of hyper accumulating plants in combination with a beneficial rhizo- and endo-spheric microbial community holds great promise for low cost cleaning of contaminated sites. Arbuscular mycorrhizal fungi (AMF) are one of the important endophytic fungi living in the roots of most terrestrial plants. This symbiosis confers benefits directly to the host plant's growth and development through the acquisition of phosphorous and other mineral nutrients from the soil by the fungus. In addition, they may also enhance the plant's resistance to biotic and abiotic stresses (Harrier and Sawczak, 2000). Potential roles of AMF associations have repeatedly been demonstrated to alleviate metal stress of plants (Hildebrandt *et al.,* 2007).

Microorganisms in the soil are responsible for nitrogen fixation, assimilation, and degradation of organic residues to release nutrients. When HMs is retained in the soil by repeated and uncontrolled additions, they interfere with these key biochemical processes which alter ecological balance. Toxic effects of HMs on microorganisms manifests in numerous ways such as decrease in litter decomposition and nitrogen fixation, less efficient nutrient cycling. The soil microbial community is thought to be a sensitive bioindicator of metal pollution effects on bioavailability and biogeochemical processes. It has been shown that HMs at certain concentrations can have long-term toxic effects within ecosystems and have a clear negative influence on biologically mediated soil processes (Lee *et al.,* 2002).

In all forty AM fungal species were observed in the rhizosphere soils of both non-polluted and polluted sites. The AM fungal species isolated from the study sites belonging to five genera viz., *Acaulospora, Glomus, Gigaspora, Sclerocystis,* and *Scutellospora* (Table-2). The number of AM spores in the root-zone soils ranged from 0-912. The non-polluted soils were rich both in AM spore number and species abundant whereas in polluted soils were less. This is an agreement with earlier findings of (Ramapulla Reddy and Manoharachary, 1990). There was an impact of season on the distribution of AM spores in polluted and non-polluted soil sites (Jagpal *et al.,* 1988). The numbers of AM spores were more in monsoon and summer. There was a certain degree of specificity among the different species in both non-polluted and polluted sites. There are previous reports of such specificity in root zone soils (Mosse, 1981) and the occurrence of forty species of AM fungi in polluted habitats in the present study is a report as (Gildon and Tinker, 1981) have isolated only one species of effluent tolerant AM fungi. In present study, *Glomus fistulosum* was noticed the most dominant effluent tolerant strain of AM fungi in polluted sites.

All the test plant species in non-polluted soil sites examined exhibited AM colonization whereas in soil polluted with effluent sites, eight plant species were positive for AM colonization and one plant species were nonmycorrhizal, results indicated that mycorrhizal condition is the rule and nonmycorrhizal condition is the exception and agrees with the widespread association of AM reported in natural ecosystem (John and Coleman, 1983). The presence of AM colonization in plants of industrially polluted habitats have earlier been reported (Gildon and Tinker, 1981). The percent root colonization was comparatively more in nonpolluted soil grasses than polluted soil plants (Table-2) and (Figure-2&3). The minimum and maximum per cent root colonization was observed in *Aerva lanata* (Amaranthaceae) (45%) and *Phyllanths amarus* (Euphorbiaceae) (76%) respectively in non-polluted sites and in polluted sites the minimum was in *Datura stromonium* (Solanaceae) (22%) and maximum in *Leucas aspera* (Lamiaceae) (96%) (Table-2). The percentage root colonization was high in summer season of plant species in polluted soil sites in the per cent study as supported by (Ramapulla Reddy and Manoharachary, 1990) in industrially polluted soil sites plant species (Table-2). The number of AM spores were more in monsoon and summer seasons in nonpolluted soils and less in polluted with effluents may be due to dilution of nutrients or accumulation of nutrients and optimum moisture level or water stress and increased level of carbon, zinc and iron were noticed in soil polluted with effluents may be caused reduction in the number of AM propagules, as supported by (Ramapulla Reddy and Manoharachary, 1990).

These results suggested that the variation in soil pH, temperature and effluent pollution seems to be the decisive factors in tropical soils influencing distribution of AM fungi. The physico-chemical data revealed that the polluted soil was acidic to neutral with more of carbon. Zinc, Iron and other nutrients in the present study. It can be concluded that tannery effluents significantly alter the occurrence of native AM fungi both quantitatively and qualitatively. The variation in spore population which was generally more or less in effluent site may be attributed to the season, soil edaphic characters particularly to the acidity, high moisture and organic carbon in soil.

Table 1. Physico-chemical characteristics of polluted and non-polluted soils of three different sites in polluted soils in Noyal river bed, Tirupur District, Tamil Nadu

S.No.	Study Sites	pH	Organic matter	N	P	K	Zn	Cu	Mn	Fe
Polluted sites										
1.	Site I	6.26±0.20	5.4±0.4	96.8±4.2	24.2±4.2	348±12.0	2.4±0.2	1.7±0.12	2.04±1.2	30.56±4.2
2.	Site II	5.93±1.24	4.6 ±0.2	89.0±4.6	26.4±2.4	293±10.0	2.98±0.4	1.8±0.12	1.92±1.2	21.58±4.2
3.	Site III	5.4±0.57	3.2±0.4	87.8±4.2	28.4±2.2	24.2±10.20	1.74±0.3	1.9±0.13	1.93±1.0	20.14±4.2
Non- Polluted sites										
1.	Site I	7.30±0.41	2.2±0.02	92.8±12.1	21.3±12.1	121.0±17.0	2.4±0.2	2.1±0.1	5.6±1.2	1.2±0.1
2.	Site II	6.56±0.57	2.8 ±0.2	89.4±14.0	28.4±11.4	135.4±15.2	2.7±0.1	1.9±0.2	5.4 ±1.3	1.2±0.1
3.	Site III	7.21±0.58	2.4±0.02	77.4±12.0	34.0±10.4	140.0±26.0	2.1±0.4	1.8±0.1	4.2 ±1.1	1.3±0.1

NPS-Non-Polluted Soil. **PS**-Polluted soil.

General nutrient Status of the soil.	**N**	**P_2O_3**	**K_2O**
Low :	<140	<24.2	<140.7
Medium:	141-280	24.3-32.2	140.8-281.6
High :	>280	>32.3	>281.6

Table. 2. Precent root colonization spore count and AM fungal species associated in the root zone soil it plants in polluted and non-polluted sites at Noyal river

S.No.	Family and Botanical name.	Study Sites	% of root Colonization		AMF Spores Population/100g Soil		AMF Spores Associated	
			PS	NPS	PS	NPS	PS	NPS
1.	Amaranthaceae *Aerva lanata* L.	S I	45	66	224	534	*Acaulospora sporocarpa* *Glomus fasciculatum* *Glomus delhiense*	*Glomus citricola* *Glomus fistulosum* *Glomus multicaulis*
		S II	32	45	135	463	*Glomus hoi* *Glomus canadense* *Glomus austral*	*Glomus occultum* *Glomus multisubtensum* *Glomus segmentatum* *Aculospora denticulatam*
		S III	25	33	334	765	*Acaulospora denticulatum* *Aculospora thomii* *Scutellospora scutata*	*Glomus multisubtensum* *Glomus microcarpum* *Glomus mososporum*
2.	Solanaceae *Datura stromonium* L.	S I	33	69	210	345	*Glomus fistulosum* *Glomus multicaulis* *Acaulospora denticulatum* *Aculospora thomii*	*Scutellispora heterograma* *Acaulospora thomii* *Glomus claroids*
		S II	22	53	325	657	*Glomus fistulosum* *Aculospora denticulatam* *Glomus pansihalos*	*Acaulospora apendicula* *Glomus clarum* *Glomus claroids*
		S III	33	79	132	432	*Glomus segmentatum* *Aculospora denticulatam* *Scutellospora scutata*	*Glomus flavisporum* *Glomus fistulosum* *Glomus etunicatum*
3.	Lamiaceae *Leucas aspera* L.	S I	56	89	215	765	*Glomus hoi* *Glomus muticaulis* *Scutellospora verrucosa* *Sclerocystis paecaulis*	*Glomus geosporum* *Acaulospora apendicula* *Glomus segmentatum* *Glomus fasciculatum*
		S II	26	78	453	876	*Glomus pansihalos* *Glomus claroids* *Glomus citricola* *Gl.hoi*	*Aculospora thomii* *Scutellospora scutata* *Glomus fistulosum*
		S III	41	95	312	675	*Glomus fistulosum* *Single spore of dimorphicum* *Glomus manihot*	*Glomus austral* *Glomus muticaulis* *Acaulospora rehmii*
4.	Euphorbiaceae	S I	38	73	343	745	*Glomus pansihalos*	*Acaulospora thomii*

	Phyllanths amarus L.						*Glomus geosporum* *Scutellispora heterograma*	*Acaulosopora gdanskensis* *Single spore of dimorphicum*
		S II	25	55	225	564	*Acaulospora thomii* *Glomus magnicaule* *Glomus citricola*	*Glomus microaggregatum* *Glomus versiforme* *Scutellispora heterograma*
		S III	22	76	143	688	*Glomus delhiense* *Glomus monosporum* *Acaulospora sporocarpa*	*Aculospora denticulatam* *Glomus pansihalos* *Glomus geosporum*
5.	Euphorbiaceae *Phyllanths madraspatensis* L.	S I	31	66	233	543	*Acaulospora apendicula* *Glomus clarum* *Glomus claroids*	*Scutellispora heterograma* *Acaulospora thomii* *Glomus claroids*
		S II	45	75	153	456	*Glomus claroids* *Glomus canadense* *Glomus austral*	*Glomus intraradix* *Glomus clarum*
		S III	32	56	122	698	*Glomus austral* *Glomus muticaulis* *Acaulospora rehmii*	*Glomus pansihalos* *Glomus claroids* *Glomus citricola*
6.	Malvaceae *Sida acuta* Burm.	S I	25	65	211	534	*Glomus multisubtensum* *Glomus microcarpum* *Glomus mososporum*	*Glomus geosporum* *Acaulospora apendicula* *Glomus clarum*
		S II	36	78	143	546	*Acaulospora sporocarpa* *Glomus fasciculatum* *Glomus delhiense*	*Glomus delhiense* *Glomus monosporum* *Acaulospora sporocarpa*
		S III	41	58	241	789	*Acaulospora denticulatum* *Aculospora thomii* *Glomus fistulosum* *Scutellospora scutata*	*Glomus fistulosum* *Aculospora denticulatam* *Glomus pansihalos*
7.	Tiliaceae *Corchorus aestuans* L.	S I	42	81	314	543	*Glomus citricola* *Glomus multicaulis*	*Glomus canadense* *Acaulospora thomii*
		S II	21	78	110	876	*Glomus manihot* *Glomus arborense*	*Acaulosopora gdanskensis*
		S III	43	69	143	765	*Scutellispora heterograma* *Glomus claroids*	*Glomus flavisporum* *Glomus fistulosum*

8.	Oxalidaceae *Oxalis carniculata* L.	S I	55	93	322	869	*Glomus austral* *Glomus muticaulis* *Acaulospora rehmii* *Sclerocystis paecaulis*	*Glomus dimorphicum* *Glomus fistulosum* *Glomus microcarpum*
		S II	46	88	309	896	*Glomus etunicatum* *Acaulosopora gdanskensis* *Glomus magnicaule* *Acaulospora thomii*	*Glomus citricola* *Glomus fistulosum* *Acaulospora apendicula* *Glomus rubiformis* *Sclerocystis paecaulis*
		S III	43	80	259	798	*Acaulospora thomii* *Acaulosopora gdanskensis* *Glomus magnicaule*	*Acaulospora sporocarpa* *Glomus fasciculatum* *Glomus delhiense*
9.	Fabaceae *Cassia occidentalis* L.	S I	12	66	103	659	*Glomus geosporum* *Scutellispora heterograma*	*Scutellispora heterograma* *Acaulospora thomii*
		S II	44	83	215	765	*Glomus maculosum*	*Acaulospora thomii*
		S III	23	78	453	876	*Acaulospora apendicula* *Glomus rubiformis*	*Acaulospora denticulatum* *Aculospora thomii* *Scutellospora scutata*
10.	Mimosaceae *Mimosa pudica* L.	S I	36	87	312	675	*Glomus fistulosum* *Glomus canadense* *Glomus invermeyanum* *Glomus manihot* *Glomus arborense* *Glomus macrocarpum*	*Glomus pansihalos* *Glomus geosporum* *Scutellispora heterograma* *Glomus magnicaule* *Glomus radiatum* *Glomus magnicaule* *Glomus citricola*
		S II	45	66	343	745	*Glomus delhiense* *Glomus monosporum* *Acaulospora sporocarpa* *Acaulosopora gdanskensis* *Acaulospora thomii*	*Glomus etunicatum* *Entrospora infrequens* *Acaulosopora gdanskensis* *Acaulospora apendicula* *Glomus magnicaule* *Acaulospora thomii*
		S III	32	45	233	543	*Glomus citricola* *Glomus fistulosum* *Glomus multicaulis* *Acaulospora apendicula*	*Glomus austral* *Glomus muticaulis* *Acaulospora rehmii*

NPS-Non-Polluted Soil. **PS**-Polluted soil.

Fig. 2. Showing the common herb plants collected in Noyal river bed.
A- *Aerva lanata,* B- *Datura stromonium,* C- *Leucas aspera,* D- *Phyllanths amarus,* E- *Corchorus aestuans,* F- *Mimosa pudica*

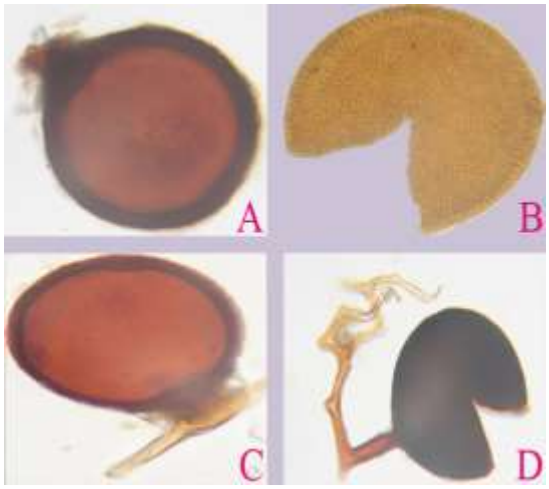

Fig. 3. AM fungal spores/100g soil in both polluted and non-polluted soils of Noyal river
A - *Acaulospora sporocarpa,* B- *Acaulospora denticulatum,* C-*Gigaspora species,* D- *Glomus multicaulis*

4. CONCLUSION

The indigenous AM fungi associated with the dominant plant species growing on the polluted sites, may have assisted plants tirupur in soils that were substantially polluted with toxic metals. In order to utilize native plants for revegetation of metal polluted soils, more detailed investigations are needed to improve our understanding of plant adaptation. It is also essential to identify the potential role of indigenous AM fungi in phytostabilization of toxic metals in contaminated environments, and also in stimulating plant growth so that optimum use can be made of both the plant and fungal symbionts for successful revegetation.

REFERENCES

1. Awotoye, O., M.B. Adewole, A.O. Salamiz and M.O. Ohiembor, (2009). Arbuscular mycorrhiza contribution to the growth performance and heavy metal update of *Helianthus annuus* LINN inpot culture. *African Journal of Environmental Science and Technology* **3**(6):157-163.
2. Compant, S., B. Clement and A. Sessitsch, (2010). Plant growth-promoting bacteria in the rhizo and endosphere of plants: their role, colonization, mechanisms involved and prospects for utilization. *Soil Biology Biochemistry* **42**: 669-678.
3. Davari, M., M. Homaee and H. Khodaverdiloo, (2010). Modeling Phytoremediation of Ni and Cd from Contaminated Soils Using Macroscopic Transpiration Reduction Functions. *Journal of Science and Technology of Agriculture and Natural Resources* **14**(52): 75-85.
4. Gerdemann, J.W. and T.H. Nicolson, (1963). Spores of mycorrhizal Endogones species extracted by wet-seiving and decanting. *Transactions of the British Mycological Society* **46**: 235-244.
5. Gildon, A. and P.B. Tinker, (1981). A heavy metal tolerant strains of VA mycorrhizal fungus. *Transactions of the British Mycological Society* **77**: 648-649.
6. Glick, B.R. (2003). Phytoremediation: Synergisticuse of plants and bacteria to clean up the environment. *Biotechnology Advances* **21**: 383-393.
7. Glick, B.R. (2010). Using soil bacteria to facilitate phytoremediation. *Biotechnology Advances* **28**: 367-374.
8. Harrier, L.A. and J. Sawczak, (2000) Detection of the 3 phosphoglycerate kinase protein of *Glomus mosseae* (Nicol. & Gerd.) Gerdemann & Trappe. *Mycorrhiza* **10**: 81-86.

9. Hildebrandt, U., M. Regvar and H. Bothe, (2007). Arbuscular mycorrhiza and heavy metal tolerance. *Phytochemistry* **68**: 139-146.
10. Jagpal, R., P.D. Sharma and K.G. Mukerji, (1988). Effect of VAM fungi in relation to pollution, pp.*48-49*. In: Mycorrhizae for Green Asia (Eds. Mahadevan, A., N. Raman and K. Natarajan), University of Madras, Madras - 600 025.
11. Jog Dand, S.N. (1995). Tannery Industry and biotechnology: *Environmental Biotechnology* 161- 168.
12. Kabata-Pendias, A. and A.B. Mukherjee, (2007). Trace elements from soil to human. Springer, Berlin/Heidelberg, Germany / New York. Springer-Verlag, Heidelberg, Germany. p. 550.
13. Keller, C., S.P. McGrath and S.J. Dunham, (2002). Trace metal leaching through a soil-grassland system after sewage sludge application. *Journal of Environmental Quality* **31**: 1550–1560.
14. Khodaverdiloo, H. and M. Homaee, (2008). Modeling of Cadmium and Lead Phytoextraction from Contaminated Soils. *Soil Science* **41**(2): 149-162.
15. Khodaverdiloo, H. and A. Samadi, (2011). Batch equilibrium study on sorption, desorption, and immobilization of cadmium in some semiarid-zone soils as affected by soil properties. *Soil Research* 49(5):10-15.
16. Lee, I.S., O.K. Kim, Y.Y. Chang, B. Bae, H.H. Kim and K.H. Baek, (2002). Heavy metal concentrations and enzyme activities in soil from a contaminated Korean shooting range. *Journal of Bioscience and Bioengineering* **94**(5): 406-411.
17. Mhatre, G.N. and C.E. Pankhurst, (1997). Bioindicators to detect contamination of soils with special reference to heavy metals, In C.E. Pankhurst, B.M. Doube, V.V.S.R. Gupta (Eds.), *Biological indicators of soil health.* CAB International, New York. pp. 349-369.
18. Mosse, B. (1981). Vesicular arbuscular mycorrhizal research for tropical agriculture. The Research Bulletin, 194. College of Tropical Agriculture and Human Resources, University of Hawai, Hawai, pp. 82.
19. Pandolfini, T., P. Gremigni and R. Gabbrielli, (1997). Biomonitoring of soil health by plants, In C.E. Pankhurst, B.M. Doube, V.V.S.R. Gupta (Eds.), *Biological indicators of soil health*. CAB International, New York. pp. 325-347.
20. Ramapulla Reddy, P. and C. Manoharachary, (1990). Occurrence and distribution of Vesicular - arbuscular mycorrhizal fungi in soils polluted with sewage and industrial effluents. *Pp.51-52.In:* Mycorrhizal symbiosis and plant Growth (Ed.by Bagyaraj DJ and Manjunath A.) University of Agricultural, GKVK Campus, Bangalore.
21. Shah, F.R., N. Ahmad, K.R. Masood, J.R. Peralta-Videa and F.D. Ahmad, (2010). Heavy Metal Toxicity in Plants. In: Plant Adaptation and Phytoremediation. (M. Ashraf · M. Ozturk · M.S.A. Ahmad, Eds.). Springer Dordrecht Heidelberg London New York. pp. 71-98.
22. Singh, O.V., S. Labana, G. Pandey and R. Budhirahja, (2003). Phytoremediation: an overview of metallic ion decontamination from soil. *Applied Microbiology and Biotechnology* **61**: 405-412.
23. St. John, T.V. and D.C. Coleman, (1983). The Role of mycorrhizal in plant ecology. *Canadian Journal of Botany* **61**: 1005-1014.
24. Subbarao, N.S. (2000). Soil microbiology. Oxford and IBH publications. Pp. 82-87.
25. Udayakumar, P., S. Dhanakumar and M. Lekshmanaswamy, (2011). Impact of Textile Dyeing and Bleaching Effluents on Surface Water Quality of River Noyyal at Tirupur, Tirupur Dist, Tamil Nadu, India. *Indian Journal of Natural Sciences* **9**: 604-720.
26. Voegelin, A., K. Barmettler and R. Kretzschmar, (2003). Heavy metal release from contaminated soils: Comparison of column leaching and batch extraction results. *Journal of Environmental Quality* **32**: 865-875.

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