VETIVERIA ZIZANIOIDES VIS-À-VIS REHABILITATION OF DEGRADED AND CONTAMINATED SOILS- SOME CASE STUDIES

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Environmental Degradation

- Increase in human and livestock population.
- Rapid industrialization and urbanization, and intensive agricultural practices.
- Production and release of sizeable amount of toxic waste in to the environment.

Concerns.....

A vast areas of soil are contaminated with

- ❖Persistent organic contaminants, mainly plant protectants,
- ❖Hydrocarbons,
- ❖Heavy metals,
- ❖Polycyclic aromatic hydrocarbons (PAH) etc.

Concerns…..

- Mitigation of environmental hazards,
- Restoration of soil ecology,
- Soil fertility and productivity are some of the concerns in recent years.
- It necessitates the researchers to develop a clean, cheap, effective and eco-friendly remediation strategy.

Remediation....

- Plant based technology called phytoremediation for mitigating soil toxicity and eco-restoration
- *Vetiveria zizanioides* is one of the few plants that has the potential to meet all the criteria required for phytoremediation.
- The crop has received a great attention and interest as an agent for phytoremediation of contaminated lands.
- Unique morphology, physiology and symbiotic association render vetiver capable of tolerating environmental extremities.

VETIVER AND REMEDIATION

- Vetiver is also helpful in controlling land degradation caused due to natural and anthropogic factors viz toxicity of recalcitrant persistent organic pollutants, soil sodicity and salinity.
- Control erosion, consequence of intensive cultivation, water-logging, deforestation, mining, overgrazing or any factors that adversely affect biological/agricultural productivity.

VETIVER VIS-VIS MARGINAL LANDS

- Vetiver oil is in high demand world-wide. However, in many developing countries including India, there is severe paucity of land
- Utilization of culturable-degraded lands can be one of the viable alternatives for the cultivation of non edible commercial crops.
- This strategy will have two-pronged benefits:
  - Enhancing production of vetiver oil, and
  - Rehabilitation of degraded lands including their phytoremediation.

Plant Based Remediation

- Remediation of soil fertility restoration of soil ecology and chemical and biological productivity are key concerns to crop scientist, ecologists and environmentalists: Clean and cheap technology
- Plant based technology, phytoremediation for mitigating pollutants from contaminated soils, particularly those affected by heavy metals is gaining importance day by day.
- Strategic advantage of phytoremediation over traditional engineering and chemical techniques is that, the former one is environmentally friendly, cheap and plant based and is expected to have significant economic, asthetic, and technical superiority

Advantage Vetiver.....

- Vetiver (*Vetiveria zizanioides*) is an essential oil bearing crop, the extensive root system of which upon hydro-distillation gives essential oil, which has high perfumery value.
- Vetiver grass is a tall, perennial tussock grass with strong ecological adaptability and large biomass.
- It is easy to cultivate and it grows in varying soil conditions starting from sandy soil to heavy soils, acidic to alkaline sodic and rainfed to water logged soil condition.

- Vetiver grass is native to South East Asia where it has been grown for centuries for roof thatching, fodder for livestock, as perfumery and cosmetic industries.
- Vetiver has initially been reported to be used for soil conservation and land stabilization purposes in Fiji since early 1950s, and promoted by world Bank for soil and water conservation in India in the 1980s.

- Besides, its perfumery value, the vetiver, essential oil can be used as a potential natural alternative for the control of termites.
- Due to its unique morphological, physiological and ecological characteristics such as its massive and deep root system, and its tolerance to a wide range of adverse climatic and edaphic conditions, including elevated levels of heavy metals and other xenobioties, the interest in this grass is increasing since couple of decades.

DIVERSE USAGE OF VETIVER

- Vetiver has also been successfully used to stabilize mining over burdens and highly saline, sodic and alkaline tailing of gold mines.

- In South Africa it was used effectively to stabilize waste and slime dams from platinum and gold mines.

- Similarly, in Australia, vetiver was used to stabilize landfill and industrial waste site contaminated with heavy metals such as As, Cd, Cr, Ni, Cu, Pb, and Hg.

- In Thailand vetiver is found widely distributed naturally in almost all part of the country. It has generally been used for erosion control and slope stabilization.
- Vetiver hedges played an important role in the process of captivity and decontamination of pesticides, preventing them from contaminating and accumulating in crops.
- There is a general opinion that vetiver, as compared to other crops, should be more efficient in absorbing heavy metals and chemicals due to voluminous deep root system and production of high biomass.

VETIVER SYSTEM FOR EROSION AND SEDIMENT CONTROL

- Effectiveness of vetiver hedges in soil and water conservation
- Flood erosion control
- Erosion control in acid sulphate soil
- Replacing contour banks

VETIVER FOR STEEP SLOPE STABILIZATION

- Tensile strength and shear strength of vetiver roots
- Slope stabilization

VETIVER FOR MINING STABILIZATION AND PHYTOREMEDIATION

- Tolerance high acidity aluminum and manganese toxicity
- Tolerance to high salinity and sodicity
- Tolerance to heavy metals

Truong and Loch (2004)

Garbage landfill

South China Institute of Botany, 1997 Vetiver grew quite well in the landfill better than other habitats .

Absorbed a lot of pollutants including nutrients

Guangzhou Datinshan Garbare landfill 2000-2001

- Stabilizing embankments of the landfill
- Preventing leachate from flowing out.
- Abating the concentration of pollutants in the leachate

Vetiver:Most promising in application of garbage landfill

Vetiver System for Land Reclamation

Xingning County, East Guangdong

Recovering a barren red soil slope "Red Skin Hill". In two year: 1991

Vetiver hedgegrows improved slope problems as compared to conventional garden

- ❖Nutrient (soil)content increased (except P)
- ❖Soil moisture increased (4-42%)
- ❖RH increased (4-5%)
- ❖Temperature decreased (summer) 1-3^{o}C

Mined land

Phytoremediation and rehabilitation of mined land

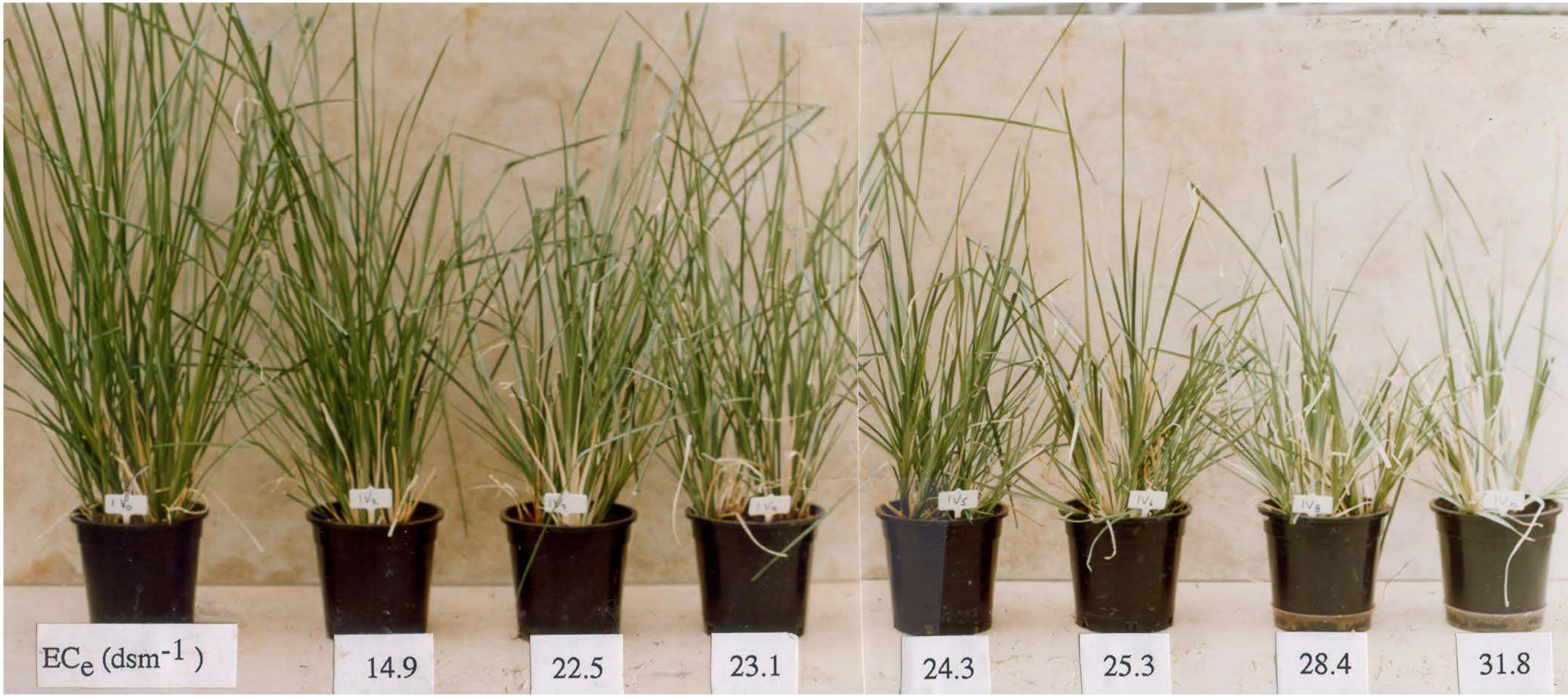
Metalliferous mining activities produce a large quality of waste materials

- Tailings
- Wastewater
- High concentrations of heavy metals
- Severe pollution problems
- Lots of land degradation

Effects of the vetiver system on soil loss and runoff in agricultural land

Country	Soil loss t ha^{-1}			Runoff (% of Rainfall)		
	Control	Conventional	VS	Control	Conventional	VS
Thailand	3.9	7.3	2.5	1.2	1.4	0.8
Venezuela	95.0	88.7	20.2	64.1	50.0	21.9
Venezuela (15%)*	16.8	12.0	1.1	88	76	72
Venezuela (30%)*	35.5	16.1	4.9	-	-	-
Vietnam	27.1	5.7	0.8	-	-	-
Bangladesh	-	42	6-11	-	-	-
India	-	2.5	2	-	-	-

*Land slope VS = Vetiver system (Rodriguez, 1993)



Truong *et al, 2002*

Response to varying levels of soil salinity

Salt tolerance level of vetiver grass as compared with some crop and pasture species grown in Australia.

Species	Soil ECse (dSm^{-1})	
	Saline Threshold	50% Yield Reduction
Bermuda Grass (*Cynodon dactylon)*	6.9	14.7
Rhodes Grass (cv Pioneer) (*Chloris guyana)*	7.0	22.5
Tall Wheat Grass (*Thynopyron elongatum)*	7.5	19.4
Cotton (*Gossypium hirsutum)*	7.7	17.3
Barley (*Hordeum vulgare)*	8.0	18.0
Vetiver (*Vetiveria zizanioides)*	8.0	20.0

Soil salinity levels corresponding to different species establishment.

Species	Profile Soil ECse (dSm^{-1})	
	0-5 cm	10-20 cm
Chloris guyana	4.83	9.59
Paspalum vaginatum	9.73	11.51
Vetiveria zizanioides	**18.27**	**18.06**
Bare ground	49.98	23.94

Relative tolerance of some medicinal and aromatic crops to soil salinity

Tolerant	Semi-tolerant	Sensitive
Rye for ergot (*Secale cereale*) Egyptian henbane (*Hyoscyamus muticus*) Plamarosa (*Cymbopogon martinii*) *Artemisia annua* Lemongrass (*Cymbopogon flexuosus*)	Vetiver (*Vetiveria zizanioides*) German chamomile (*Chamomilla recutita*) Jamarosa *Catharanthus roseus* *Mentha citrata* Isabgol (*Plantago ovata*) *Mentha piperita* *Mentha cardiaca*	Citronella java (*Cymbopogon winterianus*) *Mentha arvensis* *Chlorophytum borivilianum*

Patra et al,2000

Relative tolerance of selected medicinal and aromatic crops to soil sodicity

Tolerant	Semi-tolerant	Sensitive
Vetiver *(Vetiveria zizamioides)*	*Tagetes minuta*	*Mentha citrata*
German Chamomile *(Chamomilla recutita)*	*Tagetes patula*	*Mentha arvensis*
Jamarosa	*Tagetes erecta*	*Mentha cardiac*
Palmarosa *(Cymbopogon martini)*	Isabgol *(Plantago sp)*	Geranium *(Pelargonium sp.)*
Ocimum basilicum	Lemongrass *(Cymbopogon flexuosus)*	Kalmegh *(Andrographis paniculata)*
Ocimum sanctum		*Mentha piperita*
		Chlorophytum borivilianum

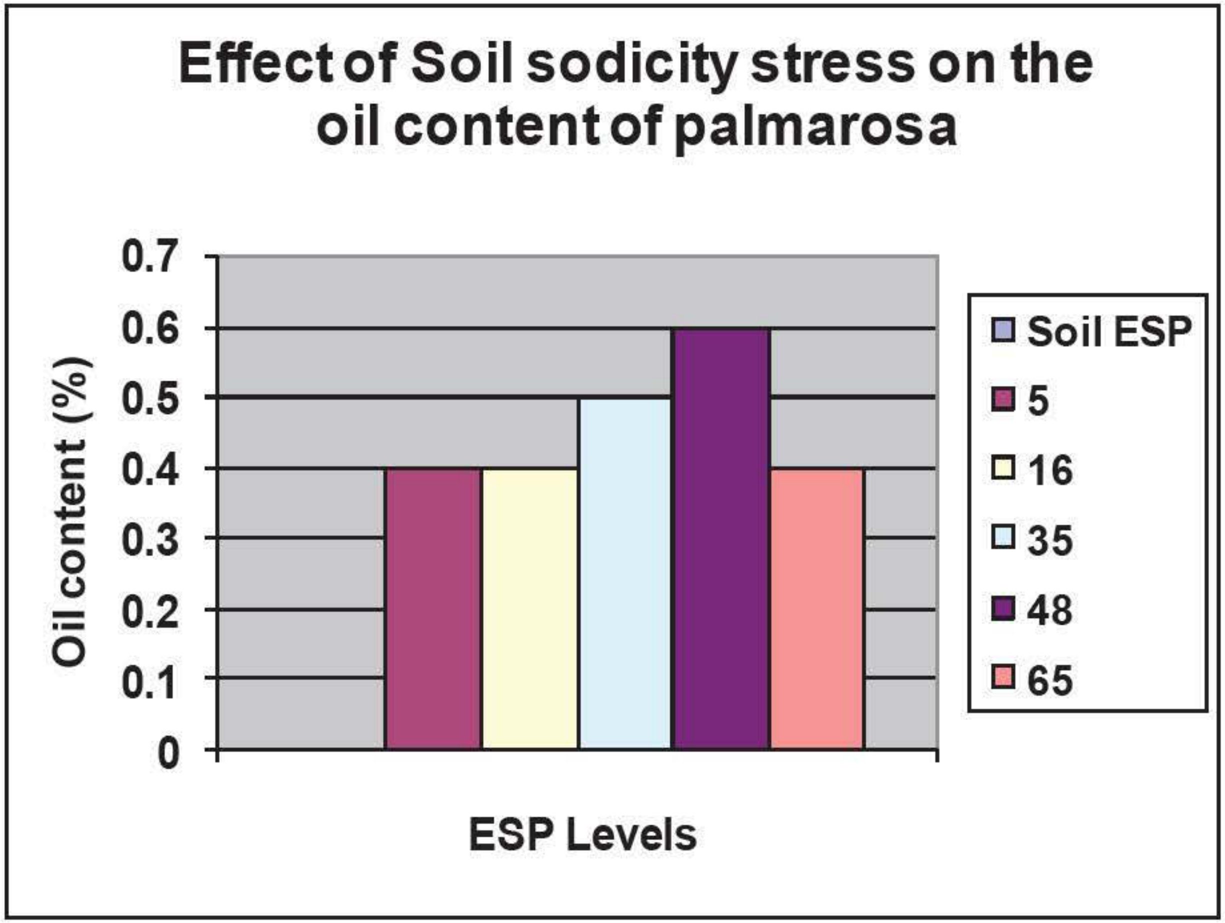
Threshold limits of salinity and sodicity for some important medicinal and aromatic crops

Crop	Salinity (dSm^{-1})	pH	Soil ESP
Aromatic			
Palmarosa	12.0(16.0)	9.5	55
Lemongrass	10.0(10.0)	9.0	50
Vetiver	12.0	10.5	55
Citronella	5.5	8.5	25
Medicinal			
Catharanthus	10.0(8.0)	9.5	-
Chamomile	12.0(8.0)	9.5	-
Isabgol	8.0	9.8	-
E.Henbane	8.0		
Wheat	2.0	8.5	10
Rice	4.0	9.5	15
Pulses	2.0	8.5	10

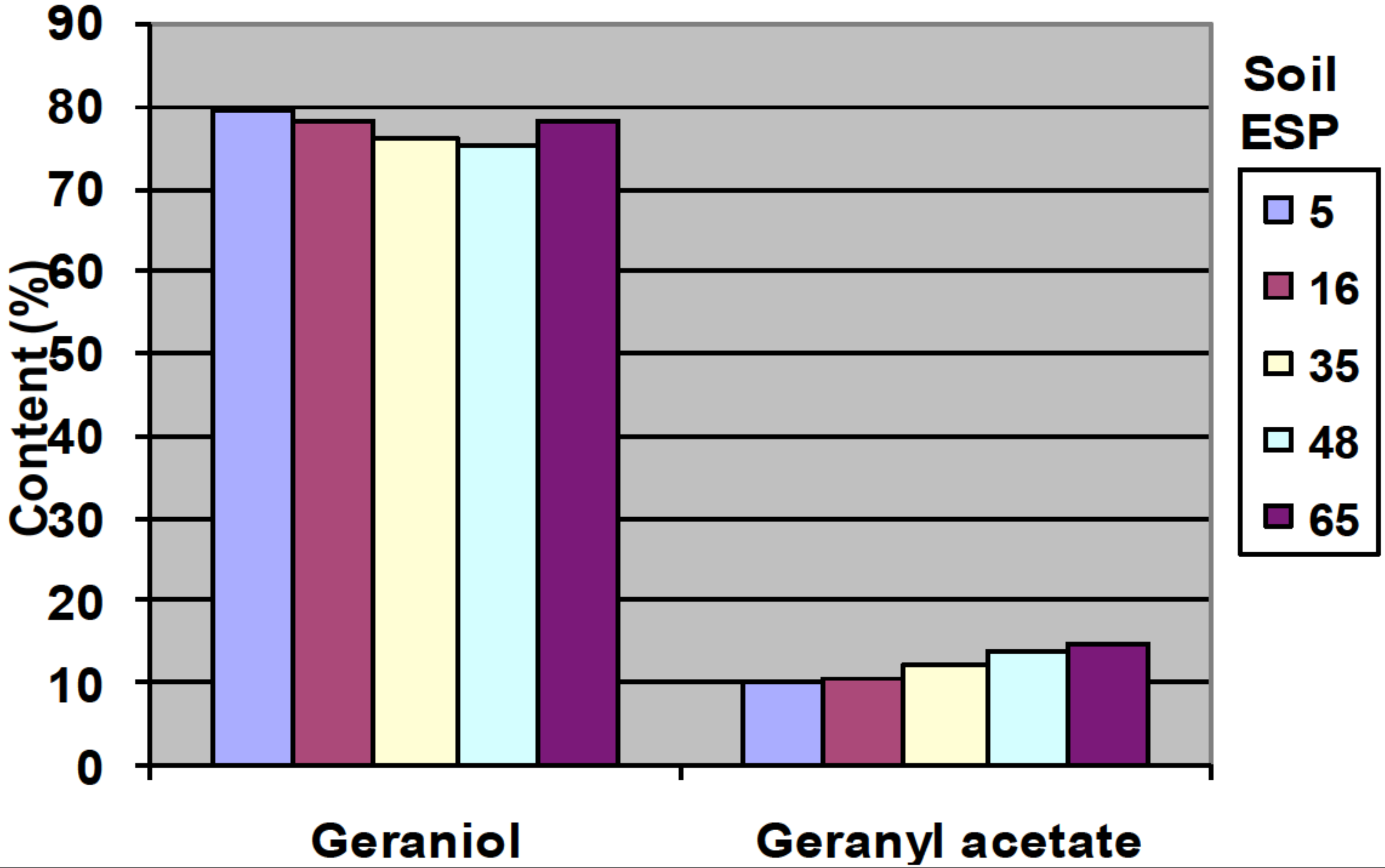
Patra et al,2000

Effects of Salinity and Sodicity Stress on the Quality of Medicinal and Aromatic Crops

Soil salinity and sodicity stress may affect the biosynthesis of secondary metabolites which determine the quality of medicinal and aromatic crops



Effect of soil sodicity stress on the chemical composition of essential oil of palmarosa



SODIC SOIL IN NATURAL CONDITION

HIGHLY SODIC SOIL

SODIC SOIL UNDER MOIST CONDITION

LUXURIANT GROWTH OF VETIVER

Possibility of intercropping of mint (*Mentha arvensis*) in the inter row spacing of vetiver, in farmers' field

- Vetiver (cv. Dharani, Gulabi) were transplanted in farmers field at Raebareily districts, in a plant to plant and row to row distance of 1x1 m.
- Since during the early six month the growth of vetiver is slow, the interspaces of vetiver rows were planted with plantlets of menthol mint (cv. Kosi)

- Intercropped mint had a higher biomass and oil yield as compared mint grown alone.
- This allows optimum utilization of natural resources (water, fertilizer).
- Weed infestation drastically decreased due to intercropping.
- Root biomass and total dry matters of vetiver were not affected due to mint.

Chemical analyses of a coal mine overburden

Properties	Value	Properties	Value
Soil pH (1:5)	9.6	Calcium ($mgkg^{-1}$)	1200
EC dSm^{-1}	0.36	Magnesium ($mgkg^{-1}$)	2400
Chloride $mgkg^{-1}$	256	Sodium ($mgkg^{-1}$)	2760
Nitrate $mgkg^{-1}$	1.3	Potassium ($mgkg^{-1}$)	168
Phosphate $mgkg^{-1}$	13	ESP* (%)	33
Sulphate $mgkg^{-1}$	6.1		

* ESP = Exchangeable sodium percentage

TOLERANCE TO HIGH ALKALINITY AND HIGH SODICITY

- Soil with ESP (Exchangeable Sodium Percentage) higher than 15 is considered to be strongly sodic.

- Vetiver established and grew vigorously on Bentonite tailings with ESP of at least 48.

- Moreover, the sodicity of some overburden is further exacerbated by the very high level of magnesium (2400 $mgkg^{-1}$) compared to calcium (1200 $mgkg^{-1}$).

Soil and water conservation in agricultural lands in Queensland

- Vetiver grass has been used for soil and water conservation in orchards, cropping and grazing lands instead of contour banks .
- Due to its high level of salinity tolerance vetiver is particularly effective in gully erosion control in sodic and salt affected soils.
- When planted on contour lines vetiver hedge
- Acts as a porous barrier, spreading and slowing down runoff water,
- Trapping sediment and increasing water infiltration thus conserving soil moisture on sloping land

Saline mine tailings in Queensland

- Several trials has been set up to select the most suitable species for the rehabilitation of a 23ha coal tailings dam.
- The substrate was saline, highly sodic and extremely low in nitrogen and phosphorus.
- The substrate contained high levels of soluble sulfur, magnesium and calcium. Plant available copper, zinc, magnesium and iron were also high.
- Five salt tolerant species were used:
- Vetiver (Vetiveria zizanioides), marine couch (*Sporobolus virginicus), common reed grass (Phragmites australis), cumbungi* (*Typha domingensis) and Sarcocornia spp. Complete mortality was recorded after 210 days for* all species except vetiver and marine couch.

Tidal creek bank stabilization in Queensland

- ❖Vetiver has been used successfully for stream bank stabilization of tidal creeks and canals in southern Queensland.
- ❖At a site on the Gold Coast, two years after vetiver was planted to stabilise a tidal creek bank, mangrove seedlings were found growing among vetiver rows.

A two-year-old vetiver row at Swan Hill planted to control saline seepage from sloping orchard plot

Changes in physico-chemical characteristics of soil (0-15 cm) after growing of medicinal and aromatic crops on sodic soils

Aromatic crops	Soil pH (1:2.5)		Soil EC (dSm^{-1})		Soil ESP	
	Initial	After harvest	Initial	After harvest	Initial	After harvest
Palmarosa (2 years)	10.6	9.4	4.8	0.64	93.0	43.8
Lemongrass	9.8	8.95	1.25	1.35	60.0	52.8
Vetiver	10.5	9.5	1.38	1.42	82.0	62.8
Vetiver	9.5	9.0	1.35	1.58	56.5	43.2
Isabgol	10.0	9.7	1.25	0.81	60.0	48.4

Phytoremediation of heavy metals

- Soil heavy metal cleanup is traditionally done via soil removal for off-site disposal, which is expensive and environmentally unsafe.
- *In situ* remediation techniques such as chemical and biological methods have become popular in recent years.
- Phytoremediation has emerged as an attractive option for clean up of contaminated soils; the technique is environment friendly, inexpensive and visually unobtrusive.

Heavy metal uptake : Enigma

- In general, a large portion of the heavy metal contaminants are not available for root uptake by plants because they are either bound to organic and inorganic soil constituents, or alternately as insoluble precipitants
- Some high biomass plants have been used in phytoremediation. Most important among them are plants belonging to Brassicaceae (mustard) family, which are metals hyperaccumulators.
- Some other plants, having higher biomass producing characteristics viz. corn, peas, sunflowers, goldenrods etc. has successfully been used in phytoextraction

Heavy metal uptake: Enigma

- Root system of many of the high biomass plants are mainly located in the surface of the soil and very few root systems of these plants can penetrate to deeper soil layers.
- Root systems of these plants are unable to explore and absorb the heavy metals that may possibly have leached in the soil profile.

The solubility of heavy metals in soil tends to be low due

- **Complexation** with organic matter
- **Adsorption** on clays and oxide
- **Precipitation** as carbonates, hydroxides and phosphates

Addition of chelates and organic legands enhance metal activity in soil

Increased availability for higher uptake

Facilitate metal movement to plant roots

Chemical/ synthetic chelates are not biodegradable and alternative methods are required

Synthetic chelates

EDTA-Ethylene dinirilo tetra acetic acid

HEDTA-Hydroxy ethylene diamine triacetic acid

CDTA-Trans-1, 2 cyclohexylene dinitro tera-acetic acid

EGTA-Ethylenebis (oxyethylene trinitro) tetra acetic acid

Synthetic chelates in soil contaminated with multiple metals represents challenge for chemical enhancement of the phytoextraction by plants grown on contaminated sites.

Lead accumulation in vetiver plant tissues, grown in different location in USA and exposed to two chelants at four concentrations

Location	Chelant	Chelant conc (m mol kg^{-1} soil)	Plant Pb mg kg^{-1} Plant tissue DW	
			Root	Shoot
Baltinore	Control	0	292	22
	EDTA	5	1059	185
		10	2420	270
		15	4456	476
	EDDS	5	858	116
		10	1915	284
		15	3016	493

Andra *et al* (2011)

Hydroponic set up (Andra *et al*, USA)

Accumulation of Pb by vetiver ($mg\ kg^{-1}$ dw)

Roots	**19800 ± 2400**
Shoots	**3350 ± 66**

No phytotoxic symptoms like growth retardation or chlorosis

Under natural soil condition, majority heavy metals were bound to soil minerals and organic matter, and were not available for plant uptake.

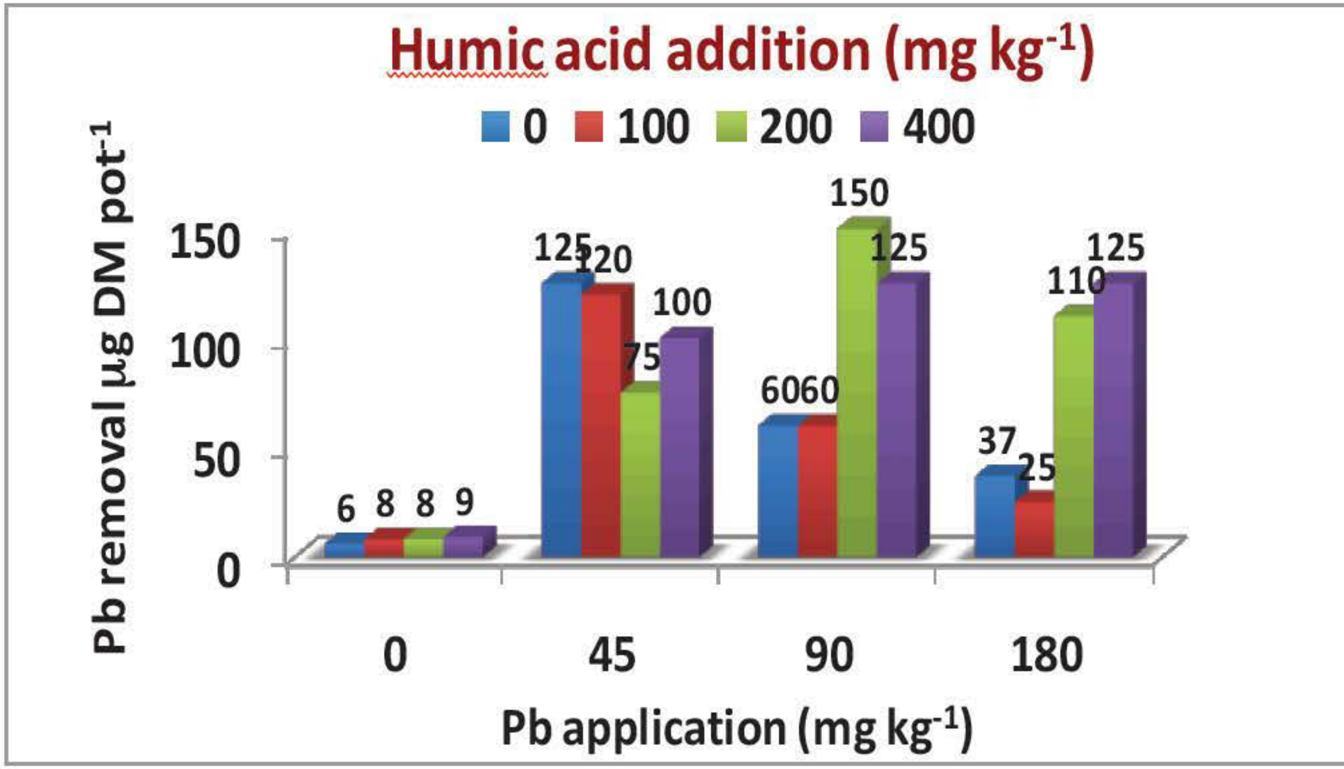
It is essential to mobilize metals in soil pool favouring phytoextraction

Humic acids (HA) contain acidic groups (COOH, OH functional groups)

Provide organic macromolecules with important role in

- Transport
- Bio-availability
- Solubility

Lower solubility constant compared to synthetic chelates prevents the possible movement of heavy metal-humic acid complexes across the profile



Effect of humic acid (HA) application on uptake of Pb in above ground (harvestable) biomass at different levels of Pb contamination

HA could not enhance Pb removal in control
HA addition was effective in enhancing Pb only at higher conc of Pb

Mycorrhizo-remediation: Phytoremediation

Metal (Pb and Zn distribution in roots and shoots of *vetiveria zizanioides* due to mycorrhizal association

Metal Conc. (mg kg^{-1})	Mycorrhizal fungus	Pb (mg kg^{-1})	
		Root	Shoot
0	Control *Glomus mosseae* *G. intraradices*	19.4 23.8 55.1	6.98 4.84 1.21
10	Control *G mosseae* *G. intraradices*	48.8 29.5 78.8	7.50 5.84 2.73
100	Control *G mosseae* *G. intraradices*	66.3 56.2 79.4	11.10 5.35 9.10
1000	Control *G mosseae* *G. intraradices*	449 117 213	17.40 12.90 29.40

(Wong *et al*, 2007)

- ❖ Inoculation with AMF protects host from the metal toxicity.
- ❖ The degree of protection varies according to the fungus.
- ❖ Phytoremediation does not increase with AMF.
- ❖ It offers a protective effect

Vetiver can be considered a hyperaccumulator of Pb and Zn; heavy metal accumulation high in roots than in shoot

The design of a phytoremediation system varies

- ❖ Among contaminants
- ❖ The condition at the site
- ❖ The level of clean up required
- ❖ The plant species used

Heavy metal– mediated toxicity :LEAD

Exerts oxidative stress in plants resulting in formation of (Reactive Oxidation Stress)ROS

- **Protein degradation**
- **DNA damage**
- **Lipid peroxidation**
- **Cell death**

Antioxidant defense minimize oxidative damage of Pb to cellular components in tolerant plants

Important oxidative enzymes in reducing free radical stress:

- **Superoxide dismutase (SOD):** O_2^- $H_2O_2 \rightarrow$
- **Catalase**
- **Glutathione peroxidase (GPx)** H_2O_2 $H_2O \rightarrow$

Lead accumulation in roots and shoots of *Vetiveria zizanioides* (12 week field simulation study: Thailand)

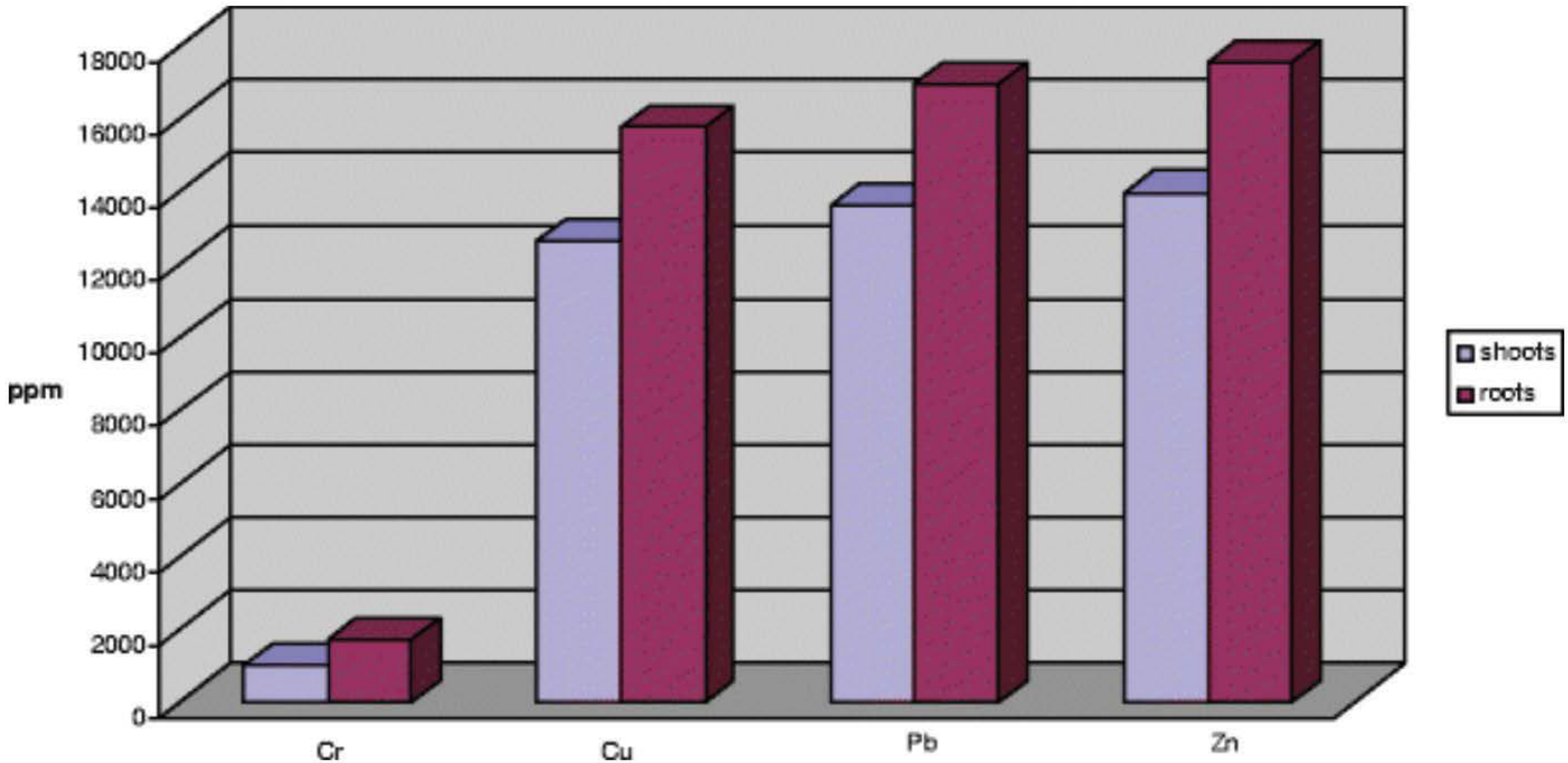
Lead conc. (gL^{-1})	Shoot uptake (mg kg^{-1})	Root accumulation (mg kg^{-1})	Root: shoot ratio
0	-	-	-
5.0	408	720	1.76
7.0	485	2000	4.12
9.0	560	2350	4.19
11.0	640	2840	4.43

Chantochon *et al* (2004)

Comparison of vetiver (*V. zizanioides*) and bahia (*Paspalum nofatum*) with regard to ability to absorb heavy metals when grown in Pb-Zn mine tailing for 130 days

Species	Pb		Zn	
	Shoot	Root	Shoot	Root
Vetiver	46.3	309	105	380
Bahia	95.7	218	172	332
P (0.01)	7.6	24.8	10.2	18.1

Truong & Loch, 2004



Antiochia *et al* (2007)

Comparison between the heavy metal accumulation in shoots and roots in bioremediation experiments (30 days: Italy)

Plant tolerance to heavy metals results from:

- Enhanced production of antioxidant enzymes
- Enzymes detoxify the free reactive oxygen species (ROS) (produced in response to heavy metal stress) and or
- Complexation of the metal with peptides (phytochelatins) or

Other low molecular mass thiol compounds

↓

Transport

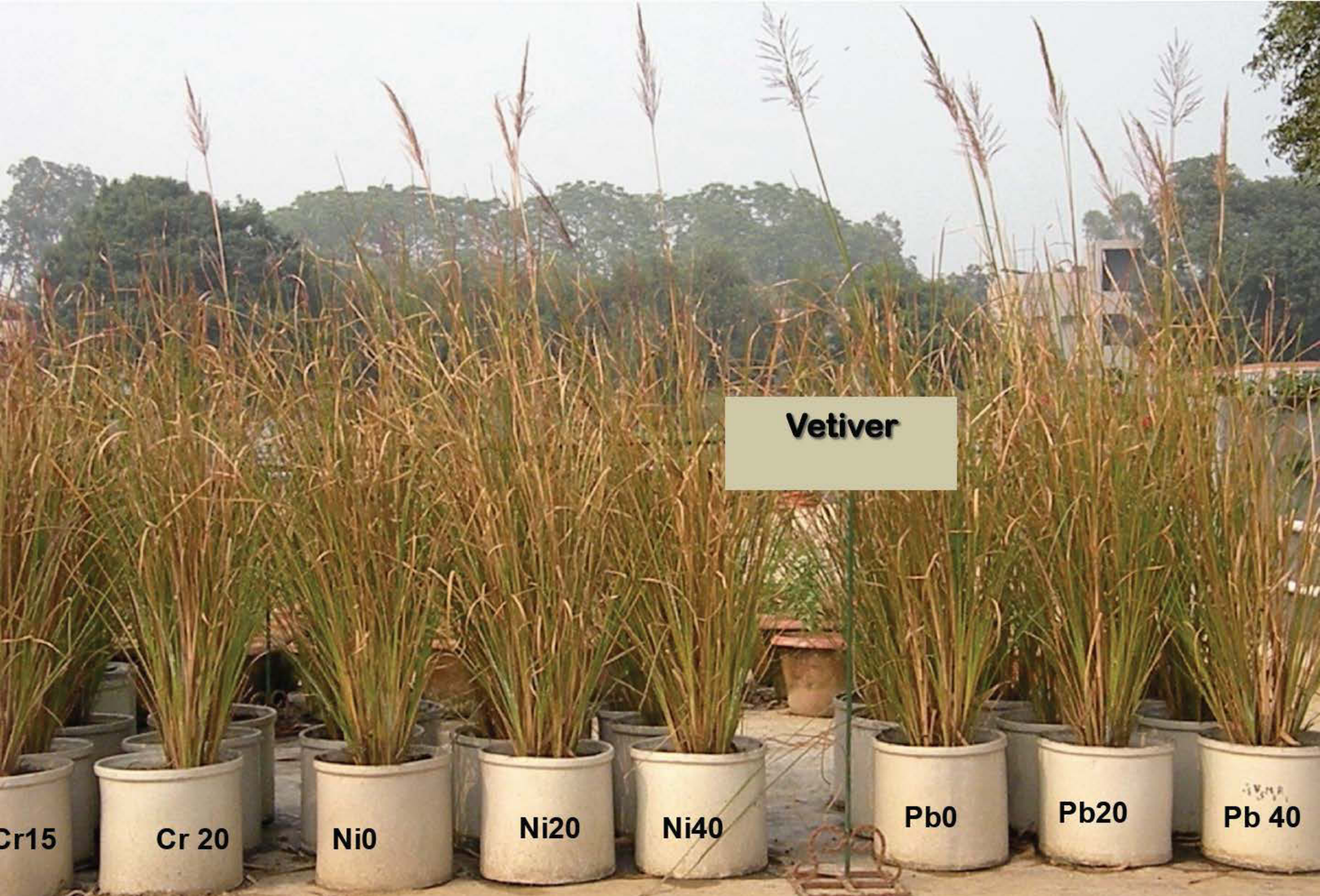
↓

Sequestration of theses complexes in vacuoles

Threshold limits of heavy metals to vetiver growth *vis-à-vis* other species

Metals	In soil ($mg kg^{-1}$)		In plants ($mg kg^{-1}$)	
	Vetiver	Other plants	Vetiver	Other plants
Armenic	100-250	2.0	21-72	1-10
Cadmium	20-60	1.5	45-48	5-20
Copper	50-100	-	13-15	15
Chromium	200-600	-	5-18	0.02-0.20
Lead	<1500	-	778	-
Mercury	<6	-	70.12	-
Nickel	100	7-10	347	10-30
Selenium	<74	2-14	711	-
Zinc	<750	-	880	-

Truong & Loch, 2004



Influence of Cr, Ni and Pb on growth of vetiver (*Vetiveria zizanioides*)

Relations between tissue Pb and antioxidant enzyme activities in vetiver grown in Pb-paint contaminated rosidential soils and treated with chelating agent

Location	Vetiver tissue	Chelant treatm-ents	Pb Conc. (m mol kg^{-1} soil)	Antioxidant enzymes n kat-g^{-1} FW		
				SOD	CAT	GPx
Baltinore	Root	Control	292	64	17	112
		EDTA	2645	36	13	86
		EDDS	1929	31	11	64
	Shoot	Control	22	6	2	7
		EDTA	310	21	2	5
		EDDS	297	2	2	4

- The oxidative stress by Pb in vetiver was higher in absence of chelating agent
- Higher antioxidant enzyme activities in control treatments
- Lower antioxidant enzyme activities with chelating agent is due to uptake of chelated or bound form of Pb

Phytoremediation- Tolerance, Accumulation-Translocation

- Plant should be able to transport the contaminants
- Removal from the contaminated sites

Distribution of heavy metals in vetiver plant (Truong, 1999)

- Very little of As, Cd, Cr and Hg absorbed and trans-located to shoots (1-5%)
- A moderate proportion of Cu, Pb, Ni and Se translocated to shoots (16-33%)
- Zn evenly distributed between shoot & roots (40%)

General view is that vetiver root accumulates higher heavy metals than shoot

Environmental perspectives of *Vetiveria zizanioides*

- **Metal removal from soil**

  Assisted – phytoremediation ⟨ Chelant / Microbe

- **Water treatment**

  Cations and anions

  Radionuclides

  Protective barricading – reducing pollution level

  Soil erosion (slopes and water ways)

  - **Removal of xenobiotics**

  Pesticides

  Hydrocarbons

  TNT

  - **Removal of Pathogen from water (Enterobacteriaceae)**

Vetiver demonstrates ability to absorb TNT in aqueous media

- Large scale 2, 4, 6-trinitrotoluene (TNT) production and use (USA)
- Soil and ground water pollution
- TNT can be highly resistant to volatilization, biodegradation and hydrohytic processes.
- Potent mutagen and is classified as group C human carcinogen.
- Exposure causes rashes, skin hemorrhages, mucus and blood disorder.
- Soil contamination occurs at open-burning, and incinator sites

TNT – contaminated soils *vis-à-vis* vetiver

- ❖ Vetiver can be one potential candidate for phyto-remediation.
- ❖ High affinity to both organic and inorganic chemcials.
- ○ Xerophyte as well as hydrophyle
- ○ Not affected by drought or flood
- ○ Tolerant to frost, heat sodic and saline condition
- ○ Wide adoptability to pH (3-II)
- ○ Dense root system

Accumulation of TNT by vetiver *vis-à-vis* other plant species: Hydroponic system

Species	Maximum initial TNT Conc (mm)	Maximum TNT accumul-ation (mg g^{-1})	Reference
Vetiveria zizanioides	0.18	1.03	Makris *et al*, 2007
Glycine max	0.10	0.21	Admia *et al*, 2006
Zea mays	0.10	0.09	Admia *et al*, 2006
Myriophyllum spicatum	0.35	1.60	Hughes *et al*, 1997

Chemically catalyzed uptake of 2, 4, 6 TNT by vetiver with urea as a chaotropic agent

Chaotropic agents are specific anions (SCN^-) or polar carbamide derivatives (urea) for increasing solubility of hydrophobic compounds (TNT).

TNT uptake significantly enhanced by urea

Major TNT metabolites were detected in roots (1, 3-5-trinitrobenzene, 4-amino 2,6, diniltrotoluene and 2 amino 4, 6 dinitrotoluene)

TNT degradation by vetiver (roots)

No translocation of TNT metabolites from root to shoot

Thousands of users have applied Vetiver Grass Technology (VGT) as a solution to a wide range of environmental problems.

- ❖Significant impact in improving soil and water conservation,
- ❖stabilizing manmade (engineered) slopes,
- ❖rehabilitating land, including mines, wasteland and ravines,
- ❖ preventing floods and recharging groundwater.

- Vetiver grass technology (VGT) has been used for hundreds of years by farmers in India where it was used for soil erosion control and for the demarcation of farm boundaries (Gundalpet, Karnataka).
- In other parts of India it was used for stabilizing rice bunds and inter-field channels (Orissa).
- In other countries such as the Philippines and Thailand VGT has been used traditionally for the stabilization of rice field bunds.
- Historically, vetiver grass was well known in many tropical countries for its aromatic and medicinal properties. Thus, as a practical farmer-based technology, it was not difficult to introduce it on a wide scale for an extended range of applications.

Khus (*Vetiveria*)biovillage

Effect of chemical (phosphogypsum) and biological (vermicompost and green mannuring) amendmends on vetiver grown in sodic soils

- An experiment was initiated in a typical sodic soil existing in the Regional Research Station,CSSRI, Shivari (Kanpur Road): Collaborative Study.
- To investigate the relative performance of the cultivars of vetiver developed at CIMAP (KS-1, Gulabi, Dharani and Keshari) to soil sodicity with and without addition of amendment.

- Phosphogypsum application.


Thanks