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প্ৰথম সংস্কৰণ ঃ জানুৱাৰী ২০২২ চন

সম্পাদনা সমিতি

....

সম্পাদক

ড° সুব্ৰত বৰ্মন

পংকজ গোবিন্দ মেধি

উপদেষ্টা ঃ চিৰঞ্জীৱ জৈন

সভাপতি ঃ ড° বসন্ত কুমাৰ ভট্টাচাৰ্য

উপ সভাপতি ঃ ধ্ৰুৱজ্যোতি শৰ্মা

সদস্য ঃ ড° লীনা ডেকা, ড° ৰবীন দাস, ডাঃ ৰাতুল ভট্টাচাৰ্য, ড° দ্বীজেন দাস, হীৰেন্দ্ৰ কুমাৰ শৰ্মা, ড° কাকলি দত্ত, ড° ৰঞ্জনা ভট্টাচাৰ্য, ড° প্ৰদ্যুম্ন শৰ্মা, ড° দৰ্শনা গোস্বামী, অৰ্ণৱজ্যোতি আৰ্য, ধ্ৰুপৰাজ কৃষ্ণাত্ৰেয়, নুৰুল ইছলাম

প্ৰচ্ছদ : নিখিলেশ্বৰ শৰ্মা
অক্ষৰ বিন্যাস, অলংকৰণ : পংকজ গোবিন্দ মেধি
আদি পাঠ : হৰেকৃষ্ণ দাস
মূল্য : ২০০ টকা
ছপা : ভৱানী অফছেট এণ্ড ইমেজিং চিষ্টেমছ প্ৰাঃ লিঃ, গুৱাহাটী — ৭৮১০০৭

স্মাৰক-গ্ৰন্থ

নলবাৰী কলেজ মহাৰজত জয়ন্তী ১৯৪৫-২০২০

সম্পাদক:
সুব্ৰত বৰ্মন
পংকজ গোবিন্দ মেধি

চৰ্যাপদ আৰু মৈথিলী ভাষা ঃ এটি সাদৃশ্যমূলক আলোচনা

— ড° দীপামণি হালৈ মহন্ত

মহামহোপাধ্যায় হৰপ্ৰসাদ শাস্ত্ৰীয়ে নেপালৰ ৰাজদৰবাৰৰ পৰা উদ্ধাৰ কৰা চৰ্যাপদসমূহক মৈথিলী ভাষাৰো প্ৰাচীনতম লিখিত নিদৰ্শন বুলি কোৱা হয়। এই পদবোৰৰ মাজত খণ্ডিত ৰূপত হ'লেও মৈথিলী ভাষাৰ সৈতে সাদৃশ্যমূলক ধ্বনিতাত্ত্বিক, ৰূপতাত্ত্বিক বিশেষত্ব দেখা যায়। ইয়াৰ পূৰ্বে নৱম শতাব্দীত ৰচিত বাচস্পতি মিশ্ৰৰ 'ভামতী' গ্ৰন্থত সৰ্বপ্ৰথম 'হড়ী' বুলি মৈথিলী শব্দ এটাৰ প্ৰয়োগ পণ্ডিতসকলে চিনাক্ত কৰিছে।[১] এই শব্দটোৰ ভিত্তিত কিছুমান পণ্ডিতে মৈথিলী ভাষাটো খ্ৰীষ্টীয় নৱম শতিকাতে মাগধী প্ৰাকৃতৰ পৰা ফালৰি কাটি অহা বুলি ক'ব খোজে।[২] কিন্তু এটা শব্দৰ ওপৰত ভিত্তি কৰি ভাষা এটাই স্বকীয় ৰূপ লোৱা বোলা কথাটো গ্ৰহণযোগ্য নহয়। বৰং শব্দ প্ৰয়োগৰ দিশেৰে ১১ শতিকাৰ সৰ্বানন্দকৃত 'অমৰকোশ-টীকা'ৰ পৰাহে মৈথিলী ভাষাই অপভ্ৰংশৰ পৰা বিচ্ছিন্ন হৈ স্বকীয় ভাষাৰূপে গঢ় লোৱাৰ উপক্ৰম কৰা বুলি ক'ব পাৰি। সুভদ্ৰ ঝাৰ মতে গ্ৰন্থখনত এনে কিছুমান শব্দ পোৱা গৈছে, যিবোৰ কেৱল মৈথিলীত আছে।[৩] যেনে ঃ

সৰ্বানন্দ	আধুনিক মৈথিলী
অৰড়	অৰৰি
ওহালী	ওহাৰী
চিহড	চীৰ
শমিল	চীৰ
শমিল	সমেইল
হকাৰ	হকাৰ

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মঞ্জু দাস

প্ৰকাশক ঃ মানব পাব্লিকেশ্যনচ্
ফৰেষ্ট গেট, নাৰেংগী, গুৱাহাটী-৭৮১০২৬
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ভাষা-সাহিত্য সংস্কৃতিৰ সৰ্বেক্ষণ

সম্পাদক
ড° ৰুমী কলিতা দাস
মঞ্জু দাস

Prof. Arka Prokash Mazumdar

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(দ্বিতীয় খণ্ড)

প্ৰকাশক ঃ

নিতুল নেওগ

অসম বুক ট্ৰাষ্ট

যশোৱন্ত ৰোড, পাণবজাৰ

গুৱাহাটী- ১

প্ৰথম প্ৰকাশ ঃ নৱেম্বৰ, ২০২১

বেটুপাত ঃ অভিজিৎ বৰা

মূল্য ঃ ২৮০ টকা মাত্ৰ

মুদ্ৰণ ঃ

দ্ৰোণ অফছেট প্ৰিণ্টাৰ্ছ এণ্ড পাব্লিছাৰ,

জটীয়া, কাহিলিপাৰা পথ

গুৱাহাটী-৭৮১০১৯

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ASAMIYA ARU MAITHILI BHASHAR BIRODHMULAK BISLESHAN

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প্ৰথম প্ৰকাশ : ২০২১
প্ৰচ্ছদ : ড° সঞ্জীৱ বৰা
মূল্য : ৩০০.০০ টকা
পুথিভঁৰাল সংস্কৰণ : ৪৯০.০০ টকা

মুদ্ৰণ :
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ড° ভবেন্দ্ৰ নাথ শইকীয়া

('গতি অসমৰ জীৱনীমালা প্ৰকল্প-২০২১'ৰ অধীনস্থ জীৱনীগ্ৰন্থ)

সম্পাদনা সমিতি

উপদেষ্টা ঃ ড° অমৰজ্যোতি চৌধুৰী, শান্তনু তামুলী, বন্দিতা ফুকন, প্ৰভাত গোস্বামী, দেৱজিত হাজৰিকা, শশীপ্ৰভা দাস, সুকুমাৰ বৰঠাকুৰ, নীলিমা বৰা, অভিজিত শৰ্মা বৰুৱা

সভাপতি ঃ থানেশ্বৰ মালাকাৰ

সম্পাদক ঃ অনুভৱ পৰাশৰ

সদস্য ঃ ড° মামণি বৰঠাকুৰ, নৱজিত বৈশ্য, কল্পনা বৰুৱা, অনুৰাধা দাস, বৰ্ণালী তালুকদাৰ, ড° দীপামণি বৰুৱা দাস, ৰুমী শৰ্মা বৰঠাকুৰ, শশধৰ ডেকা, বিনীতা কলিতা, ভাৰ্গৱ কলিতা, ইনা লস্কৰ, লুকীমণি বৰুৱা ভূঞা, বন্দনা দত্ত হাজৰিকা, মহানন্দ শৰ্মা, খনীন্দ্ৰনাথ ডেকা

প্ৰকাশক ঃ সম্পাদক, গতি অসম, গুৱাহাটী-২৪

মুখ্য পৰিবেশক ঃ চিন্তামণি প্ৰকাশন
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ছপা-ব্যৱস্থাপনা ঃ প্ৰদীপ ডেকা
বেটুপাতৰ ফটো ঃ অনুভৱ পৰাশৰ
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মামণি ৰয়ছম গোস্বামীৰ 'দঁতাল হাতীৰ উঁয়ে খোৱা হাওদা' উপন্যাসৰ পটভূমি বিশ্লেষণ

ড° দীপামণি বৰুৱা দাস

মামণি ৰয়ছম গোস্বামীৰ উপন্যাসৰ পটভূমি বিশ্লেষণ প্ৰসংগত দুটি ভিন্ন ৰূপ পৰিলক্ষিত হয়। ইয়াৰে এটা হ'ল অসমৰ স্থানীয় পটভূমি আৰু আনটো হ'ল অসমৰ বাহিৰৰ পটভূমি।

অসমৰ স্থানীয় পটভূমিৰ ওপৰত এতিয়ালৈকে মামণি ৰয়ছম গোস্বামীৰ তিনিখন উপন্যাস প্ৰকাশ পাইছে। 'দতাঁল হাতীৰ উঁয়ে খোৱা হাওদা', 'সংস্কাৰ' আৰু 'উদয়ভানুৰ চৰিত্ৰ'। আনহাতে অসমৰ বাহিৰৰ পটভূমিত ৰচিত লেখিকাৰ আন আন উপন্যাসসমূহ হ'ল—'চেনাবৰ সোঁত', 'নীলকণ্ঠী ব্ৰজ', 'অহিৰণ', 'মামৰে ধৰা তৰোৱাল', 'নাঙঠ চহৰ', 'বুদ্ধসাগৰ ধূসৰ গাইসা আৰু মহম্মদ মুছা' আৰু 'জখমী যাত্ৰী'। ইয়াৰে অন্তিম দুখন ভাৰতৰ বাহিৰৰ পটভূমিত ৰচিত।

অসমৰ স্থানীয় পটভূমিৰ ওপৰত ৰচিত মামণি ৰয়ছম গোস্বামীৰ উপন্যাস ঃ

দতাঁল হাতীৰ উঁয়ে খোৱা হাওদা ঃ

মামণি ৰয়ছম গোস্বামীৰ সামাজিক বাস্তৱবাদী উপন্যাসসমূহৰ ভিতৰত 'দতাঁল হাতীৰ উঁয়ে খোৱা হাওদা' উপন্যাসখন এক অন্যতম সাৰ্থক সৃষ্টি। আশীৰ দশকৰ মাজভাগত সাহিত্য আলোচনী 'প্ৰকাশ'ত ধাৰাবাহিক-ভাৱে এই উপন্যাসখন প্ৰকাশ পাইছিল। মূলত সত্ৰীয়া গোঁসাই হিচাপে আৰ্থিক আৰু সামাজিক দুয়ো দিশতে সমাজৰ শীৰ্ষত থকা এটা পৰিয়ালৰ বাল বিধৱা এগৰাকীক ঘৰখনে সংস্কাৰ পৰৱশ হৈ তাইৰ যৌৱন ভোগ লিপ্সাৰ প্ৰতি চৰম নিষ্ঠুৰতাৰে তাইক আঁতৰাই ৰাখি, অমানৱীয় ক্লেশযুক্ত বৈধব্যৰ নীতি-নিয়মৰ বান্ধোনত সুমুৱাই ৰাখি মানৱতাৰ ওপৰত কিদৰে আঘাত সানিছে তাৰ এখন কৰুণ চিত্ৰ এই উপন্যাসখনত প্ৰতিফলিত হৈছে। এক আৱেদনশীল স্বপ্নীল

As per CBCS Syllabus

অসমীয়া চুটিগল্প আৰু উপন্যাস

গুৱাহাটী বিশ্ববিদ্যালয়ৰ স্নাতক মহলাৰ ষষ্ঠ ষাণ্মাসিকৰ সন্মান পাঠ্যক্ৰমৰ আধাৰত

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ড° ভনিতা নাথ

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শ্ৰীমন্ত শংকৰদেৱৰ সৃষ্টিত নাৰীৰ গুৰুত্ব ঃ এটি আলোচনা

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সংক্ষিপ্তসাৰ ঃ

অসমৰ সাংস্কৃতিক তথা জাতীয় জীৱনৰ সৰ্বোত্তম পুৰুষ শ্ৰীমন্ত শংকৰদেৱ। ধৰ্ম প্ৰচাৰৰ উদ্দেশ্যে কাব্য, নাট, গীত, পদ ইত্যাদি ৰচনা কৰা সংস্কৃতিৰ পূজাৰী শংকৰদেৱে অসমীয়া সাহিত্যক এক নিটোল ৰূপ প্ৰদান কৰিছে। তেখেতৰ সৃষ্টিৰাজি অধ্যয়ন কৰিলে নাৰীয়ে বিশেষ গুৰুত্ব পোৱা পৰিলক্ষিত হয়। বিশেষকৈ কাব্য নাটত উপস্থাপিত হোৱা নাৰীৰ এক সুকীয়া গুৰুত্ব আছে। মূলতঃ কৃষ্ণভক্তা নাৰীসকল মাতৃ ভগ্নী, পত্নী, সখী আদি বিভিন্ন ৰূপত ৰূপায়িত কৰোঁতে নাৰীৰ স্বভাৱসুলভ গুণ-দোষবোৰ ফুটি উঠিছে। আমাৰ অধ্যয়নটিত শংকৰদেৱৰ সৃষ্টিৰাজিত নাৰীয়ে কেনেধৰণৰ গুৰুত্ব পাইছে তাকে আলোচনা কৰিবলৈ বিচৰা হৈছে।

সূচক শব্দ ঃ নাট্য, কাব্য, নাৰী, সমাজ, ধৰ্ম।

পাতনি ঃ

অসমীয়া জাতি-সাহিত্য-সংস্কৃতিৰ নিৰ্মাতা শ্ৰীমন্ত শংকৰদেৱে অসমত বৈষ্ণৱ ধৰ্মৰ ভক্তি আন্দোলনৰ গুৰি ধৰিছিল। তেখেতৰ সৃষ্টিৰাজিয়ে অসমীয়া জাতীয় জীৱন তথা সমাজ-সংস্কৃতিক নানা প্ৰকাৰে সমৃদ্ধ কৰিছে। নৱবৈষ্ণৱ ধৰ্ম প্ৰচাৰৰ জৰিয়তে শংকৰদেৱে একত্ৰিত আৰু ঐক্যবদ্ধ কৰিলে। অসমীয়া তথা অসমীয়া সংস্কৃতিলৈ বিস্ময়কৰ অৱদান আগবঢ়োৱাৰ বাবেই শংকৰদেৱক মহাপুৰুষ আখ্যা দিয়া হৈছে। নামধৰ্ম প্ৰচাৰৰ লগতে বিভিন্ন কাব্য, পুৰাণ, নাট, গীত, পদ, ভক্তিমূলক গ্ৰন্থ ইত্যাদি ৰচনাৰে অসমীয়া সাহিত্যৰ বৰভেটি নিৰ্মাণ কৰি থৈ গৈছে।

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ছমহীয়া গৱেষণা গ্ৰন্থ

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মে', ২০২২

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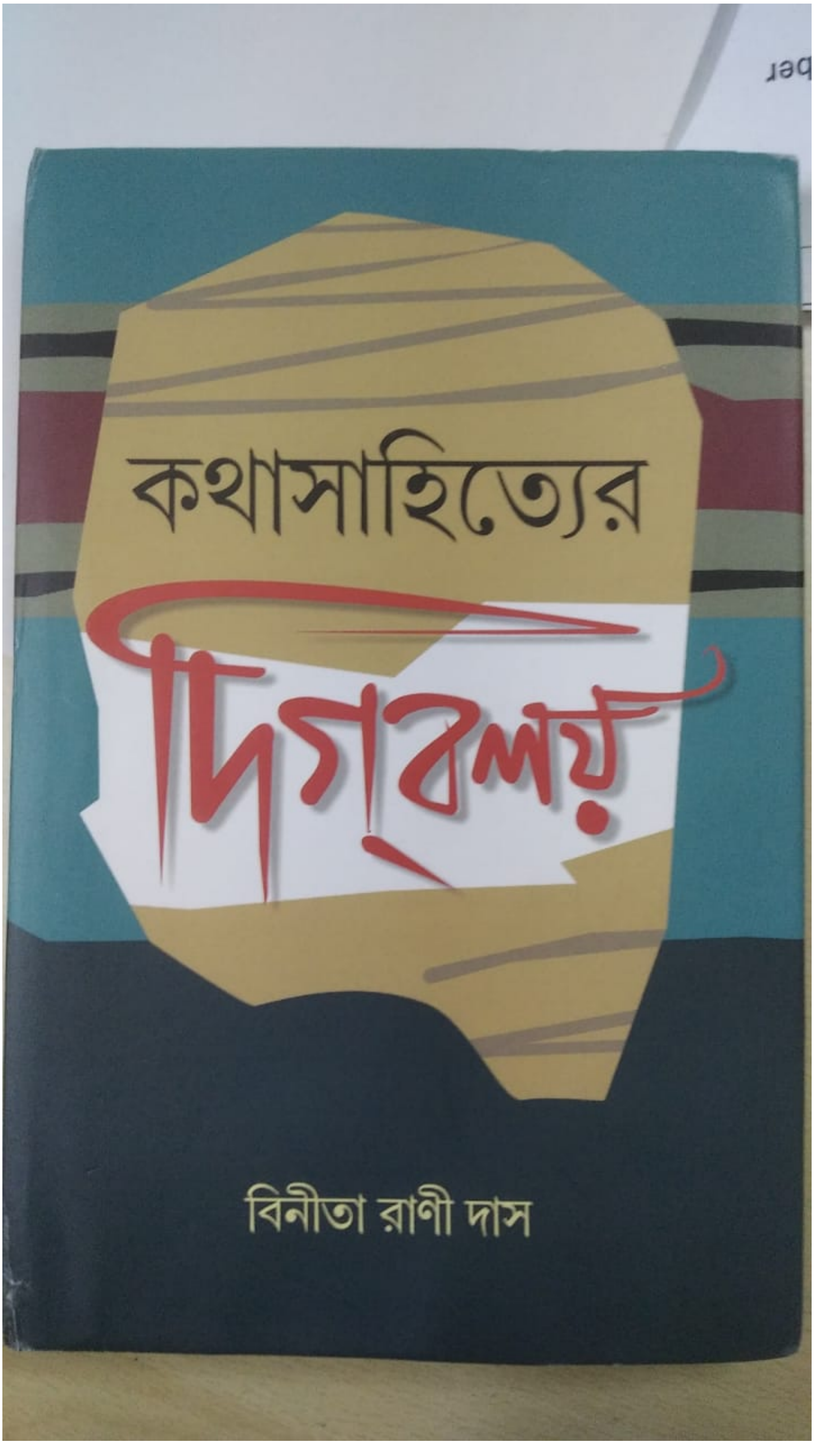
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বিনীতা রাণী দাস

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কলকাতা : ৭০০০০৯

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An Approach to

PRACTICAL ARABIC GRAMMAR

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(AWARD OF DEGREE OF DOCTOR OF PHILOSOPHY)

The under mentioned candidate is declared to have qualified for the award of Degree of Doctor of Philosophy (Ph.D.) as per Vice-Chancellor's approval dated 31.08.2021. The degree will be conferred to them at the next Convocation of the University.

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2	[illegible]	Arts	Assamese	Karishma Hazarika, Registration no.0122528 of 2007-2008	Prof. Dipti Phukan Patgiri, G.U	Abibhakta Nagan Jilar Sthanabasak Sabda: Eti Adhyayan	Done	Prof. Kailash Pattanaik, Viswa-Bharati Santiniketan	Prof. Ajit Kumar Baishya, Assam University	Prof. Ajit Kumar Baishya, Assam University
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4	6960	Arts	Assamese	Kukila Goswami, Registration no.006560 of 2006-07	Prof. Bimal Mazumdar, G.U	Lakshminandan Borarr Upanyasar Patabhumi: Eti Bisleshanatamak Adhyayan.	Done	Prof. Biplab Chakravarty, Burdwman University	Dr. Satyakam Borthakur, Dibrugarh University	Dr. Ratnottama Das, Delhi University
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An Approach to

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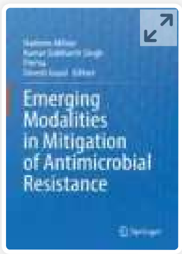

Emerging Modalities in Mitigation of Antimicrobial Resistance pp 489–511

Role of Gold Nanoparticles Against Multidrug Resistance (MDR) Bacteria: An Emerging Therapeutic Revolution

Kaushik Kumar Bharadwaj, Bijuli Rabha, Bhabesh Kumar Choudhury, Aditi Das, Lydia Islary, Dorothy Bhattacharjya, Monoswi Chakraborty, Debabrat Baishya & Arabinda Ghosh

Chapter | First Online: 31 January 2022

Abstract

Multidrug resistance (MDR) due to ext
use of antibiotics exhibits as an emerg
human health toward diagnosis and tr
Various antimicrobial strategies were i
alternative to the conventional antibio
fight against multidrug- resistant bact

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can develop their defense mechanism resistant to antimicrobial agents by altering target site or enzyme, increasing efflux, formation of biofilm, etc. Metallic nanoparticles, precisely use of gold nanoparticles paved a new horizon intimidating antibiotic resistance due to their unique physicochemical properties and targeting ability. Employments of gold nanostructures like gold nanoparticles (AuNPs), gold nanorod (AuNR), gold nanocluster (AuNC), gold nanostar (AuNS), gold nanocage (AuNCG), etc., nanoparticlulate systems exhibit antimicrobial activity and circumvent resistance mechanism by inhibiting biofilm formation. Apart from that, these can cargo antimicrobial agents, aid in the delivery of novel drugs or antibiotics that possess antimicrobial activity. These nanoparticles can be combined with other antimicrobial agents to control the problems related to solubility, stability, toxicity, and showed combinatorial effect in inhibiting efflux pump, biofilm formation, and other resistance mechanism. In addition to this, gold nanoparticles in combination with new techniques like bacteriophage particles in therapy, nano-photothermal therapy, showed promising results in MDR. This chapter summarizes drug resistance by bacteria, antibacterial mechanism of gold nanoparticles, pharmacokinetic and pharmacodynamic characteristics of AuNPs, and current research on gold nanoparticles/nanomaterials to combat MDR. Newer strategies like phage therapy,

antimicrobial peptide delivery, combined photothermal therapy, photodynamic therapy, combination therapy, clinical status and current challenges, and future perspectives in MDR are also discussed.

Keywords

Gold nanoparticles **Multidrug resistance**

Bacteria **Antimicrobial agents** **Therapy**

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2

Leaf Architectural patterns of a Few species of *Phlogacanthus* Nees in Assam, India

Barnali Dutta
Namita Nath

Abstract

The genus *Phlogacanthus* Nees (Acanthaceae) of Assam has a few species bearing medicinal properties. It is confined to a few South-East Asian countries *viz*., Bangladesh, Bhutan, China, India, Indonesia, Myanmar and Vietnam. An investigation based on leaf characters and venation patterns were carried out in a few collected species. The leaves are simple, opposite decussate and unlobed. They were further categorized into Blade class i.e Megaphylls and Macrophylls. Various other laminar characters like shape, symmetry, base, apex, margin and texture along with the petiole features were found out. Obovate leaves are recorded in *Phlogacanthus curviflorus* var. *curviflorus* and *P. curviflorus* var. *menchanensis* while elliptic lanceolate leaves are found in *P. gomezii*, *P. jenkinsii*, *P. parviflorus*, *P. pubinervius*, *P. thyrsiflorus*, *P. tubiflorus* and *P. quadrangularis*. *Phlogacanthus. curviflorus* var. *curviflorus* has largest leaf, while *P. quadrangularis* has the smallest leaf. The quantitative characters of the venation patterns were recorded which showed the presence of 1°- 4° venation in all species except *P. jenkinsii* that showed the presence of 1° - 5°. The areolation were moderately developed in a few and well developed in others. As a few leaf characters are similar in most of the species so this study will help in delimitation of the taxa upto infraspecific category.

Keywords: *Phlogacanthus, Venation patterns, Leaf characters, Assam, India.*

Introduction

The family Acanthaceae has about 220 genera and *ca.* 4000 species distributed in the pantropical, subtropical and temperate regions of the world (Hu *et al.* 2011). The members of the genus are shrubs, under shrubs or small trees with opposite, petiolated, ovate to oblanceolate leaves and a large lamina. Inflorescences are either terminal or axillary with presence or absence of small bracts and bracteoles. The presence of staminode is a very rare feature as only a few species bears staminode. The most common English name of the genus is "Flame flower". The genus is confined to a few South-East Asian countries *viz.* Bangladesh, Bhutan, China, India, Indonesia, Myanmar and Vietnam. The distribution of species in the SE Asia is about 35 (Scotland 1992; Scotland and Vollesen 2000; Mabberley 2008; McDade *et al.* 2008); 15 species in mainland Asia; two species in China (Hu *et al.* 2011). In India there are 10 species viz. *Phlogacanthus curviflorus, P. wallichii, P. tubiflorus, P. parviflorus, P. thyrsiflorus, P. asperulus, P. guttatus, P. elongates, P. pubinervius* and *P. jenkinsii* and one variety *P. curviflorus* var. *brevicalyx* most of which are confined to the North Eastern region (Hooker, 1884). Assam is represented by 8 species (Kanjilal *et al.* 1939). The tribe under which *Phlogacanthus* falls is Andrographideae (Endlicher, 1839).

Phlogacanthus is a well known medicinal plant with bitter flowers. The juice of the inflorescence of *Phlogacanthus tubiflorus* has long been used by the Karbi ethnic community of Karbi Anglong to get rid of intestinal worm (Kar and Borthakur, 2008) and the Barman community of Cachar uses the decoction of the leaves to cure cough (Das *et al.* 2008). Mukherjee *et al.* (2009) reported the analgesic activity of *Phlogacanthus thyrsiflorus*. It is commonly used as vegetable througout the state of Assam for its high medical properties.

Besides other morpholigical characters the leaf characters like the general sizes, shape, margin, base, apex and texture contributes towards specific and infraspecific delimitations. The arrangement of leaves is important in deliminating the genera. Opposite decussate, exstipulate conditions is common in this family. *Phlogacanthus* have opposite decussate leaves.

In plant taxonomy the importance of leaf architecture was emphasised by Esau, 1965; Foster, 1950; Varghese, 1969; Hickey, 1973; Hicky and Wolfe, 1975; Melville, 1976; Frank, 1979; Mohan and Inamder, 1983. The size of areoles and vein endings are also used as an important taxonomic significance (Dickison *et al.* 1987). The leaf venation pattern of the genus *Phlogacanthus* has not been studied yet, so the present study was carried out to bridge the gap.

Chapter 13

Dissecting the Molecular Basis of Drought-Induced Oxidative Stress Tolerance in Rice

Amit K. Pradhan, Sabnoor Y. Jyoti, Zina M. Shandilya, Mehzabin Rehman, Debanjali Saikia, Junu Poudel, Jyotirmay Kalita, Kongkona Borborah, Uma K. Chowra, Jnandabhiram Chutia ... See all authors

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Summary

Drought is one of the major abiotic stresses that limit rice productivity worldwide. An in-depth understanding of the mechanisms involved against drought stress is vital for determining the process of tolerance. Rice plants undergo various morpho-physiological changes under drought, but the major factor associated with it is the increase in the level of reactive oxygen species (ROS), that leads to oxidative stress. To cope with drought-induced oxidative stress, rice plants have developed various mechanisms of tolerance, such as osmotic-adjustment or increase in antioxidant activity leading to structural rearrangements. The mechanisms often vary among species that result in variation of drought-tolerance capacity. Recent developments of various high-throughput technologies like RNA-Seq, genome-wide SNP analysis, and different "OMICS" technologies, such as functional genomics, transcriptomics, metabolomics, have opened up new ways to identify the mechanisms possessed by tolerant genotypes. The identification of candidate gene or metabolites against drought tolerance has promoted the development of drought-tolerant cultivars with increased quality and yield. In this chapter, we describe the effects and regulatory molecular network associated with drought-induced oxidative-stress tolerance in rice.

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13

Phytochemical and Pharmacological aspects of the Medicinal herb *Lindernia crustacea* (L.) F. Muell. A Review

Jinti Moni Das
Barsha Sarma
Namita Nath
Mridul Kr. Borthakur

Abstract

Plant diversity has tremendous contribution in advancement of noble drug. There has been always a curiosity amongst researchers to explore more about the plant's abundance in medicinal as well as nutritive properties.

Lindernia crustacea (L.) F. Muell. is such an herbaceous plant depicting essential medicinal properties and has been an integral part of folklore system in different continents and sub-continents.A variety of bioactive compounds are being reported and isolated from *Lindernia crustacea* (L.)

There is necessity to carry out proper phytochemical analysis or other scientific evaluation of the herbal plants used by the rich traditional knowledge based communities of Lower Assam part. This particularly holds good for the plants used against diabetes, high blood pressure and jaundice. The destruction of habitats, uncontrolled use of chemical fertilizers, pesticides, and herbicides all these are effecting negatively not only on the diversed flora but also on the entire living kingdom as a whole. From the study it can be concluded that further study about the uses as well as the scientific evaluation of traditional herbal practices need to be carried out extensively along with the conservational aspects of the herbal species and traditional knowledge. Then it will lead to a new dimension in both medicinal and taxonomic fields in the near future.

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12

Plants in Traditional Medicines among the Mishing Tribe of Sadiya sub-division, Tinsukia District, Assam

Pranati Gogoi
Namita Nath

Abstract

The traditional knowledge on the uses of medicinal plants by the Mishing tribe in Sadiya region was carried out from February 2018 to February 2019 through several field trips in five villages (Borgora gaon, Mising tiniali, Shantipur-2, Shantipur-5, Chapakhowa). The vernacular names of the plants were collected with the help of local people. The collected plants were identified with the help of literature, consulting various Flora, comparing the specimens with GUBH (Assam). Ethnobotanical data were collected through questionnaire, interviews and discussions among the local healers and practitioners of Mishing tribe in local language. The data obtained during field work were scrutinized using relevant literature. Ethnomedicinal values of plants were ascertained in consultation with village people. The relative importance of plant species was captured by calculation of use values (UV); the dominant use-categories were also determined. A total of 67 medicinal plant species in 66 genera and 39 families were recorded in the five villages. The most important species of medicinal plants were *Ficus auriculata* Lour, *Ficus racemosa* L., *Cheilocostus speciosus* (J.Konig) C. Specht, *Scoparia dulcis* L. and *Sida acuta* Burm.f. which had UV's of 0.56, 0.56, 0.52, 0.5, 0.5 respectively. In this work an attempt has been made to determine the various medicinally

Sarma, P., Sarma, A., Kashyap, D., Mahanta and Medahi, (2014). Nutraceutical properties of *Stelleria media* and *Persicaria chinensis* under Brahmaputra valley agro-climatic condition. *Annals of Plant Science*. 1: 799-82.

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8

Taxonomic overview of the genus Premna L.

Rantumoni Sharma
Namita Nath
Mohan Chandra Kalita

Abstract

The genus Premna L. was first described by Linnaeus in 1771 with two species, *Premna integrifolia* L. and *Premna serratifolia* L. The generic name '*Premna*' was derived from the Greek word '*premnon*', meaning 'tree stump'. The genus Premna consists of *c.a.* 200 species, widely distributed in the tropical and subtropical regions of Australia, Africa and Asia. 25 species of *Premna* has been reported from India. 31 species and 6 varieties of *Premna*, recognised after the taxonomic revision was done on the family Verbenaceae from India by Rajendran and Daniel (2002). The genus *Premna* was earlier included in the family Verbenaceae, but now based on the molecular data (A.P.G. 2009) it has been transferred to the family Lamiaceae.

Keywords: *Premna, Premnon, Verbenaceae, Lamiaceae, Distribution.*

Introduction

The genus Premna was first reported in 1771 was under the confused category due to its indistinguishable taxonomic characters and diverse morphological features. Presently, it is one of the largest genera of the family

11

Use of some common Herbs in various Traditional Medicines: A Case study in different localities of Lower Assam

Barnali Das
Sukanya Kalita
Pooja Moni Baruah
Namita Nath

Abstract

Plants are the sole source of survival of this living world. The North East India is blessed with full of diversed greenery as well as fauna. People have been using plants in many aspects from ancient period of time. From the vigorous trees to the tiny herbs, every plant has its own impact on the mankind. The North East region is rich in its culture and tradition due to the presence of diversified tribes and communities. In this present work, emphasis is given to document the medicinal herbs used by different communities of Lower Assam region. From the survey carried out during 2018-2019, 80 herbaceous plants have been reported which belong to 39 families. Out of them 30 are Dicotyledonous and 9 are of Monocotyledonous families. For documentation, field studies were done repeatedly and group discussions were arranged with the local people to gather knowledge about the uses of the collected samples. The voucher specimens were identified by comparing them at GUBH (Assam) and consulting relevant taxonomic literatures. The destruction of habitats, uncontrolled use of chemical fertilizers, pesticides, and herbicides all these are effecting negatively not only on the diversed flora but also on the entire

living kingdom as a whole. From the study it can be concluded that further study about the uses as well as scientific evaluation of traditional herbal practices should be carried out extensively along with the conservational aspects of the herbal species and traditional knowledge.

Keywords: *Assam; Conservation; Ethno medicinal; Herbs, North East.*

Introduction

The NE region of India is one of the most flora rich regions of the country. The region is botanically very interesting due to the occurrence of various floristic elements. It contains many valuable trees, shrubs, climbers, bamboos and numerous medicinal herbaceous species. Traditional medicinal plants have played a major role in the enhancement of health care in developing countries around the world (Desta Ejeta, 2019). The rural people of different countries of the world have firsthand knowledge on benefits provide by the plant community. Since the ancient times, different plants have been used for curing various diseases and now those practices are still performed by the rural or tribal people due to less medical facilities in the remote areas. Medicinal herbs are important parts of the traditional appliance for curing and resisting many common diseases .These herbaceous plants also have aromatic and other economic values. But many of them still with no scientific identity due to their small size for which they are not noticeable by the explorers. Exploration of newer areas and addition as well as revision of data to the earlier published works will provide complete and updated knowledge of the plant wealth of NE region as well as India.

Materials and Methods

A survey was done for documenting the herbaceous specimens. Specimens were collected weekly from various sites of study area. Frequent focus group studies were arranged with the local people for collecting the information about the uses of the collected herbs.

Herbarium specimens were prepared by following standard herbarium techniques as described by Jain & Rao (1977). Identification was done by comparing them at GUBH (Assam) and also was confirmed by consulting various relevant taxonomic literatures.

Results

From the present study, a total species of 80 under 39 families were recorded. Out of the total species, dicotyledons comprise of 58 species under 30

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From K. Goswami
Dy. Finance & Accounts Officer
ASTE Council

To The Registrar
Gauahti University
Jalukbari, Guwahati - 14

SUB : **Research & Development Project** – Inventorization of wild edible fruits of Assam with special reference to their sustainable utilization for livelihood generation.

Ref.: Your letter No. GU/UGC/ASTEC/Prof/Botany/Prof. N. Devi/2018/1832 Dt. 13/10/2018

Sir,

With reference to the subject and letter mentioned above, Director, ASTE Council is pleased to sanction a sum of Rs. 5,00,000.00 (Rupees five lakhs) only for the research project Inventorization of wild edible fruits of Assam with special reference to their sustainable utilization for livelihood generation submitted by Dr. Namita Nath , Associate Professor, Botany Department , Gauhati University ,Jalukbari, Guwahati

In this regard, you are requested to note the following points.

(i) Out of the total sanctioned amount a sum of Rs.3,50,000.00 (Rupees three lakh fifty thousand) only will be released as first installment .

(ii) The second installment of Rs.1,50,000.00 (Rupees one lakh fifty thousand) only will be released after submission of satisfactory progress reports of the work done with photographs and Utilization Certificate & Expenditure Statement along with supporting vouchers in original of the first installment.

(iii) **A BOND FOR ACCEPTING GRANT** is enclosed herewith, which is to be submitted signed with seal by the head of the institution and P.I. of the project for necessary action at our end.

Yours sincerely,

(K. Goswami)

Encl: as stated above

Copy to Dr. Namita Nath , Associate Professor
Botany Department , Gauhati University
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Wild Edible Bioresources of North East India

Editors

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Namita Nath
Mohan Chandra Kalita

Rantumoni Sharma, Namita Nath & Mohan Chandra Kalita
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20

Morpho-anatomical impact assessment on some copious herb species of crude oil contaminated soil

Supriya Patgiri
Partha Pratim Baruah

Abstract

Crude oil contaminated sites lack true soil characteristics along with low biological activity, and records an acidic pH resulting in visible effect on morpho-anatomy of the plants growing in those areas. The present endeavour was therefore, made to study the impact of crude on morpho-anatomical characters of *Chromolaena odorata, Lantana camara, Melastoma malabathricum* growing in the contaminated sites taking a few plants growing in non-contaminated sites as references. Investigation revealed that morphology and anatomy of the plants underwent structural deformations. Cortical parenchymatous cells were wider in the plants growing in polluted areas whereas xylem vessels showed constricted growth in the plants of polluted areas than that of the non-contaminated site.

Keywords: *Morphological modifications, hydrocarbon pollution, anatomical structural deformations*

Introduction

Petroleum as a source of energy has gained tremendous importance in the world economy (Achuba, 2006). Exploration, use of modern technologies for production, processing, maintenance, transportation, storage, and unbridled use

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PLANT ECOLOGY AND PHYTOGEOGRAPHY

(Core Course IV of Gauhati University, Dibrugarh University and Bodoland University)

For Fourth Semester Botany (Honours)

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Hemen Deka

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Bioremediation

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Contents

Chapter 6

Contents

6

Heavy Metals (HMs) pollution in NE India: Current Research and Future Direction

Glory Borah
Hemen Deka

Abstract

Heavy metals (HMs) are considered as major pollutants of environmental concern. HMs are toxic, carcinogenic, non-biodegradable and therefore very difficult to remove from environment more particularly from soil systems. HMs can even stay more than half lives within the biological tissues. HMs such as lead (Pb), chromium (Cr), arsenic (As), zinc (Zn), cadmium (Cd), copper (Cu), mercury (Hg) and Nickel (Ni) has been proved to show severe effects on living organisms including human beings (Zhang et al. 2019). HMs are one of the principal pollutants present in crude oil. In NE India more particularly in Assam HMs associated crude oil pollution is a severe problem in the adjacent agro-ecosystems of the oil fields because of their capability for bioaccumulation and food chain contaminations. It has been reported that extensive HMs contaminations in the paddy fields of NE India has altered the physico-chemical composition of soils thereby reducing the productive lands (Basumatary et al. 2012). In this chapter, overview of research literature pertaining to occurrence and behavior of HMs, its adverse effect on the ecosystem, hyper accumulation in plants, various remediation techniques including physical, chemical and biological and their limitations has been presented. Besides, the chapter has also highlight about the works carried out in NE India and possible research gaps in HMs bioremediation.

Chapter 9

Contents

9

Plant-Bacteria Associations for Remediation of Crude Oil Pollutants with a Special Emphasis on Application Potential of Plant Growth Promoting Rhizobacteria (PGPRs)

Paramita Chakravarty
Hemen Deka

Abstract

Crude oil pollution is a major and severe problem in several countries round the globe. Crude oil contains several pollutants such as hydrocarbons (HCs) including polycyclic aromatic hydrocarbons (PAHs), heavy metals (HMs) and others. Some of the HCs are comparatively more stable in the environment and natural biodegradation of these compounds is very slow and even difficult. The remediation techniques involving both plant and bacteria more particularly plant growth-promoting rhizobacteria (PGPRs) is an efficient, cheap and economically viable options for the removal of HCs from the contaminated habitats. The combined use of plants and the associated microbes/bacteria for remediation of crude oil pollutants has been considered as the new and most relevant concept in the field of bioremediation. Plants and their associated PGPRs interact with each other where plant supplies carbon as special food source to the bacteria that can stimulate the bacteria to degrade hydrocarbon pollutants in the growth matrix. In return, PGPRs synthesize chemicals/enzymes to stimulate plant growth and promote nutrients uptake and thereby enhancing the capacity of plants against contaminated-induced stress, lowering of both phytotoxicity and evapotranspiration of volatile hydrocarbons. This chapter is attempted to highlight about the works carried out on effective and potential use of plant-bacteria associations for remediation of crude oil pollutants from contaminated habitats besides addressing the limitations and research gaps.

Chapter 11

Contents

11

Crude Oil Associated Abiotic Stresses on Herbaceous Plants

Tridip Boruah
Hemen Deka

Abstract

Crude oil is an intricate composition of both aliphatic and aromatic hydrocarbons, asphaltenes, resin and many organic as well as organometallic compounds. Crude oil contaminations negatively affect the biological activity and productivity of ecosystem by changing the dynamics of soil parameters such as pH, electrical conductivity, moisture content, aeration, water holding capacity and nutrients compositions. Being one of the principal producers of the ecosystem the herbaceous plant communities plays a vital role in the establishment of homeostasis of the ecosystem. The growth, structure and phenology of herbaceous plant communities are severely influenced by ecological, anthropogenic, climatic and biogeochemical processes on the earth. The herbaceous plant species must have some adaptive advantages and possess certain mechanisms of stress tolerance which make them suitable for fast acclimatization in crude oil polluted environment. The entry of pollutants cause the injury to biological membrane by accumulating reactive oxygen species, inhibits photosynthesis as well as transpiration and finally lead to the death of plants. Reduction of growth, senescence, abnormal root and shoot development, light receptor destruction, reduction of photosynthetic efficiency, rate of absorption, stomatal movement, flowering response, water conducting system are significantly affected by crude oil associated abiotic stresses. This chapter is attempted to focus the impact of crude oil contaminations on herbaceous plant communities, their potential defense mechanism against hydrocarbons associated stresses besides highlighting the research gap in the north east India including Assam.

Chapter 15

Contents

15

Nanomaterials for Removal of Polycyclic Aromatic Compounds (PACs) and Heavy Metals (HMs)

Shaleh Akram
Hemen Deka

Abstract

The challenging task of this century is to clean up the contaminants by eco-friendly, sustainable and economically viable technologies. Polycyclic aromatic hydrocarbons (PAHs) and heavy metals (HMs) are the major contaminants of environment that shows detrimental affects on living organisms including human beings. Nanomaterials are more reactive and have large surface area than its bulk phase, so it has a wide range of applications including bioremediation. For the unique property of nanomaterials, it can also be applied to clean up PAHs and HMs contaminated sites. For remoal of contaminants/pollutants nanomaterials can be applied in two ways. The first one is direct application for the removal of contaminants and the second one is the removal of contaminants through adsorption or chemical modification. Nanomaterials enhance remediation of contaminants by microorganisms either by increasing the microbial growth or stabilizing the remediating agents or through induced production of remediating microbial enzymes. Besides, nanoparticles also reduce the hydrophobicity and create a conductive environment in the contaminated sites and also enhance the microbial degradation process. In this chapter application potential of various nanomaterials for remediation of PAHs and HMs has been discussed besides the brief highlights about their limitations.

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Chapter 7

Heavy Metals (HMs) Dynamics During Vermicomposting of Organic Wastes: Current Understanding and Future Prospects

Tridip Boruah and Hemen Deka*

Department of Botany, Ecology and Environmental Remediation Laboratory, Gauhati University, Guwahati-14, Assam, India

Keywords

Earthworms; Vermiremediation; Ecotoxicity; Bioaccumulation

Abstract

Vermicomposting is a mesophilic process that involves the combined interaction of earthworms and microbes resulting in efficient stabilization of large quantities of organic waste. The end product of the vermicomposting process is a well-known commodity for not only increasing the soil fertility but also amplifying the biomass of beneficial microbial populations while reducing the unwanted harmful microbes. Heavy metal toxicity is one of the major growing concerns in the vermicomposting systems because not only it has an adverse effect on plants but it also destabilizes the microbial community responsible for plant growth and development. Therefore it is necessary to understand the distribution, mobility, transport, bioavailability, uptake and the ultimate fate of heavy metals in the vermicomposting system to gain further knowledge about the ecotoxicity of vermicompost. This chapter will focus on the heavy metals (HMs) toxicity of vermicompost to understand the mechanism of heavy metal dynamics in the vermicomposting system following the degradation pathways of HMs in the vermicomposting systems; along with that the role of microbes and earthworms in the detoxification of heavy metals.

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Polymer Science

Bio-Based Polymers and Composites

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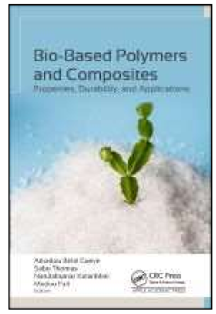

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This volume, **Bio-Based Polymers and Composites: Properties, Durability, and Applications,** takes its inspiration from Nature as the source of innumerable and priceless resources. When applying human ingenuity and experience to natural resources and processes, scientists and researchers can maximize the potential of nature for human benefit. In that vein, this new volume explores the latest breakthroughs in natural biopolymers, green composites, and green nanocomposites, a field that is rapidly expanding.

This book consolidates information on the synthesis and applications of biopolymers, green composites, and green nanocomposites for various applications with detailed characterization, mechanical approaches, and theoretical consideration. Recent development in advanced devices using nanostructured materials are covered. This book provides fundamentals and advanced concepts for developing nanostructured materials based on biopolymers and their composites.

The volume also looks at bio-based polymers and composites for environmental sustainability, such as in bioremediation and for wastewater treatment. It discusses natural polymers from waste products. It considers the use of bio-based polymers and composites in fertilization in horticulture as well as in industry and construction, for recycling of concrete, for gas sensing applications for safety, for fiber-reinforced epoxy composites, etc. In medicine, a study shows the use of biopolymers and green composites for measuring the blood glucose concentration of a patient.

Over the past 20 years, the size and sophistication of natural polymers and biomaterials have significantly increased due to advances in science, technology, and business. The circumstance has compelled academic and industrial researchers to do substantial research in these fields. Academicians (undergraduate to doctoral students and researchers) and professionals will be interested in this volume.

CONTENTS:

CHAPTER

11

c0011 [AU3]

Instrumental characterization of matured vermicompost produced from organic waste

[AU4]

W James Singha and Hemen Deka

Ecology and Environmental Remediation Laboratory, Department of Botany, Gauhati University, Guwahati, Assam, India

s0010

1. Introduction

p0010 Fertilization is one of the most effective ways to increase the efficiency of obtaining better return products in the agricultural sector (Klimczyk et al., 2021). However, the rampant utilization of chemical fertilizers to meet food demands in recent decades has raised serious concern due to its association with pollution in water, air, and soil, increased emission of greenhouse gases, and reduction of soil fertility in the distant future (Nadarajan and Sukumaran, 2021; Kumar et al., 2019; Pahalvi et al., 2021; Srivastav, 2020). With the advent of science and an increase in understanding of the environment, there is a rising demand for adopting organic fertilizer as an alternative to replace or minimize the usage of chemical fertilizers (Nosheen et al., 2021). Organic fertilizers are derived from the residues of plants, vegetables, industrial waste, animal matter, and excreta (Diacono et al., 2019). They improve soil texture, nutrient profile, water-holding capacity, aeration, and beneficial microbial population, resulting in a higher output of agricultural crops (Lim and Wu, 2015). Besides, organic fertilizers are superior in the context of environmental management, quality of the product, and recycling of bio-waste (Verma et al., 2020). The population explosion in recent decades has resulted in sizable growth of bio-waste originating from agriculture, households, and [AU5] industries (Bhat et al., 2018a,b; Mirabella et al., 2014). Without adequate treatment, the disposal of these wastes might have harmful repercussions on human health and the sur- [AU6] rounding environment (Bhat et al., 2017a,b). Therefore, the conversion of this waste to a useful resource through nature-friendly methods is a rising interest in the issue of waste management (Taiwo, 2011).

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Plant Stress: Challenges and Management in the New Decade

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Naturally Growing Native Plants of Wastelands: Their Stress Management Strategies and Prospects in Changing Climate

Nabanita Bhattacharyya

Abstract

Industrial and mining waste dumping is among the most concerning anthropogenic causes of the formation of stress-laden wastelands, which are characterized by loss of plant cover and subsequent land degradation. Under the pressure of changing climate, the revival of the degraded wastelands into productive lands becomes a sustainable option to meet the basic survival demands of the increasing human population. Restoration of vegetation cover is a widely accepted eco-friendly approach for remediation of degraded wastelands over physical or chemical strategies. However, the successful establishment of plants in wastelands is a difficult process due to the phytotoxic nature of the wasteland soils. Therefore, the use of naturally growing native plants, which thrive well in the adverse soil properties of degraded lands with little or no agronomical effort, is an effective option. Some of these plants might have phytoremediation potential, which is a sustainable technology for the remediation of contaminants including heavy metals from soil and water by using plants. Documentation of such stress-tolerant naturally growing plants of various wastelands and studying their mechanism of tolerance are among the major emerging areas of research in recent times. Such efforts may help in finding novel plant species that are more stress-tolerant with greater potential of creating vegetation cover on degraded wastelands. Therefore, for the benefit of interested researchers and policymakers, an attempt has been made to review and comprehensively document the discrete information, from available sources, on naturally growing native plants of various industrial and mining wastelands, their stress management strategies and phytoremediation prospects in changing climate.

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Keywords

Dumpsites • Heavy metal • Native plants • Phytoremediation • Stress • Wastelands

Abbreviations

IPCS	International Programme on Chemical Safety
WHO	World Health Organization

1 Introduction

Wastelands are the landmasses that are degraded due to various natural or anthropogenic factors and are lying underutilized as non-productive land due to lack of appropriate water and soil management practices (Sarma 2006; Singh et al. 2003). Industrial and mining waste dumping are the two most concerning anthropogenic causes of wasteland formation post-industrialization era. Millions of hectares of land have been turned into wastelands in developed and developing countries due to gross mismanagement and unsustainable practices over the landmasses as a result of the indiscriminate scale of industrialization and mining activities (Zhu et al. 2018). Industrial and mining waste dumping areas are notorious sources of pollution and contamination that add various pollutants of organic and inorganic nature including toxic heavy metals to the environment. There is increasing evidence that heavy metal pollution of industrial and mined areas causes health damage to the local inhabitants (Lei et al. 2015; Shen et al. 2017; Xiao et al. 2017; Santucci et al. 2018). Therefore, rehabilitation of such wastelands should be a priority concern to be addressed for the respective governments, as public health and shortage of cultivable lands are among the burning problems of recent times. The most significant impact of dumping exercise is the loss of plant cover that leads to land degradation. Area of arable land is depleting fast with the increase in human

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population due to increase in agriculture, industrialization and urbanization and hence, remediation of degraded wastelands is the much-talked need of the hour to meet the requirements of the increasing population (Bhattacharyya 2012).

The various abiotic stresses encountered by the plants in wastelands are water stress (flood and drought), temperature stress (high and low temperature), nutrient deficiency or overburden, heavy metal contamination, salt stress etc. (Das et al. 2021; Franzaring et al. 2018). The consequences of land degradation in wastelands are soil erosion, depletion of natural resources, lower productivity, groundwater depletion, shortage of drinking water, reduction in species diversity etc. Most of the potential productive lands have turned into wastelands due to gross mismanagement and unsustainable exploitation of its biosphere (Bhattacharyya 2012). Available physical or chemical strategies for remediation of degraded wastelands are temporary with multiple limitations, such as the threat of irreversible changes in soil properties, disturbance in native soil microflora, chances of secondary pollution as well as high cost of the processes (Jutsz and Gnida 2015). Therefore, sustainable biological methods like the restoration of vegetation cover on degraded sites are widely accepted as eco-friendly approaches (Wong 2003). Phytoremediation is a solar-driven, eco-friendly, sustainable and inexpensive technology with impressive public acceptance, where plants are used for the remediation of various contaminations including toxic heavy metals from soil and water (Marrugo-Negrete et al. 2016; Maharet al. 2016; Ali et al. 2013). Having great biomass with considerable metal tolerance capacity are among the important criteria to be the perfect plant species for phytoremediation (McGrath et al. 2002; McGrath and Zhao 2003). However, the successful establishment of plants in wastelands is a difficult process due to the stressful and phytotoxic nature of the wasteland soils (Bradshaw 1997). Moreover, restoration of natural dynamics of ecological succession in degraded soil of wastelands is required for systematic conversion into arable land and thoughtful and logical selection of plants is crucial for that purpose.

In this regard, the use of naturally growing native plants with inherent capabilities to adapt and withstand the adverse environment, soil properties and toxicity level of degraded lands can prove to be an effective option and information about such plant species from various wastelands may be beneficial in creating vegetation cover successfully in degraded sites (Yoon et al. 2006; Das et al. 2021). Several studies reveal the presence of numerous plant species growing naturally on industrial and mining wastelands, which can be prospected for their capabilities to clean up the environment by proper research-based approach and management. Therefore, realizing the discrete nature of such information, an attempt has been made to review and comprehensively document the available information on naturally growing native plants of various degraded wastelands including pulp and paper mill dumpsites, fly ash dumpsite of the thermal power plant as well as various metal mine tailing areas along with their stress management strategies and prospects in changing climate, for the better benefit of interested researchers, environmentalists and policymakers.

2 Pulp and Paper Mill Waste Dumpsite

Designated as one of the most notorious environment degraders, pulp and paper industries are the sources of a variety of wastes that are discharged into the environment in solid, liquid and gaseous forms (Buyukkamaci and Koken 2010). The most important solid wastes generated by a paper mill are the lime sludges, which are often disposed to nearby low-lying areas to form barren dumpsites without vegetation that are prone to be turned into degraded lands (Phukan and Bhattacharyya 2003). Analyses of various stress indices in established bio-monitor plants like *Ricinus communis* L. (Euphorbiaceae) as well as investigation of soil physico-chemical properties and nutrition status confirmed the stress burden and phytotoxicity of such degraded dumpsites (Das et al. 2021). However, despite of the unfavorable and harsh condition for vegetation growth, a few species of plants, with ethnomedicinal and economic importance, were reported to be grown naturally in paper mill dumpsite (Table 1), some of which had also been reported from mining and industrial dumpsites as tolerant natural vegetation (Das et al. 2021). These plants possibly have inherent capabilities to withstand stress and hence can be prospected to create vegetation cover by following proper management practices with minimal effort, in an attempt to recover paper mill dumpsites into arable lands in course of time.

3 Copper Mine Tailings

Finely ground wastes produced after copper are extracted from the ores and during the beneficiation process is called the copper tailings. High concentrations of toxic heavy metals like lead (Pb), zinc (Zn), arsenic (As) and cadmium (Cd) were found to be present in such copper mine tailings, from which several plant species were reported despite of metal overburdens (Table 2). It was suggested that the plants like *Imperata cylindrica, Cynodon dactylon* and *Paspalum distichum* that were dominant among all other species could have phytoremediation potentials for future revegetation programs in copper mine tailing sites (Chen et al. 2005; Zhan and Sun 2012).

Table 1 Native plants of paper mill dumpsite (Das et al. 2021)

Sl. no	Name of plant	Family	Type of stress tolerated
1	*Calotropis gigantea* (L.) Dryand.	Asclepiadaceae	Nutrient overburden, toxic trace elements, excess amount of calcium
2	*Chromolaena odorata* (L.) R. M. King & H Rob.	Asteraceae	
3	*Mikania scandens* (L.) Willd.	Asteraceae	
4	*Ricinus communis* L.	Euphorbiaceae	
5	*Rotheca serrata* (L.) Steane & Mabb.	Lamiaceae	
6	*Senna* sophera (L.) Roxb.	Fabaceae	
7	*Solanum myriacanthum* Dunal.	Solanaceae	

Table 2 Native plants of copper mine tailings (Chen et al. 2005; Llerena et al. 2021; Zhan and Sun 2012)

Sl no	Name of plant	Family	Type of stress tolerated
1	*Imperata cylindrica* var. major (Nees) C.E. Hubb	Poaceae	Heavy metals like Pb, Zn, As, Cd, Cu and Cr contamination
2	*Cynodon dactylon* (L.) Per.	Poaceae	
3	*Setaria viridis* (L.) Beauv.	Poaceae	
4	*Coreopsis drummondii* Torr. Et Gray	Asteraceae	
5	*Inula ensifolia* L.	Asteraceae	
6	*Erigeron acris* L.	Asteraceae	
7	*Kummerowia striata* (Thunb.) Schindl.	Leguminosae	
8	*Cyperus rotundus* L.	Cyperaceae	
9	*Pteris cretica* L.	Pteridaceae	
10	*Pteris vittata* L.	Pteridaceae	
11	*Miscanthus floridulus* (Labill.) Warb	Poaceae	
12	*Saussurea japoinca* (Thunb.) Dc.	Asteraceae	
13	*Paspalum distichum* L.	Poaceae	
14	*Phragmites communis* Trin.	Poaceae	
15	Miscanthus sinensis	Poaceae	
16	Zoysia sinica	Poaceae	
17	*Hippochaete debilis* (Roxb. ex Vaucher) Ching	Equisetaceae	

4 Antimony Mine Area

Antimony mine areas are contaminated with multiple heavy metals including a very high amount of antimony (Sb), As, Cd, as well as comparable concentrations of copper (Cu), Pb and Zn to the corresponding background values of study areas (Long et al. 2018). There were reports on several native plant species growing naturally in those areas (Table 3) and heavy metals were accumulated mainly on the aerial parts of those plants revealing their phytostabilization potential against multi-heavy metal pollution. Among all the colonized plants, *Bidens bipinnata* L. (Family: Asteraceae) was found to be the most suitable species in the antimony mine area considering the metal accumulation level and growing abundance of the plant.

Table 3 Native plants of antimony mine area (Long et al. 2018)

Sl no	Name of plant	Family	Type of stress tolerated
1	*Boehmeria nivea* (L.) Gaudich.	Urticaceae	Heavy metals like Sb, As, Pb, Cd, Cu and Zn contamination
2	*Symphyotrichum subulatum* (Michx.) G.L.Nesom	Asteraceae	
3	*Bidens bipinnata* L.	Asteraceae	
4	*Miscanthus sinensis* Andersson	Poaceae	
5	*Erigeron Canadensis* L.	Asteraceae	
6	*Artemisia umbrosa* (Besser) Turcz. ex Verl.	Asteraceae	

5 Gold Mine Area

Mercury (Hg) is used in the amalgamation process for the recovery of the gold during the Artisanal and small-scale gold mining (ASGM) process and therefore gold mines are considered as one of the major sources of Hg pollution in the environment (Marrugo et al. 2007). Improper handling of Hg has led to the contamination of different sections of the environment, threatening human health in surrounding areas (Olivero and Johnson 2002). There were reports on several native herbs and sub-shrubs that grow naturally on gold mine areas as promising plants for Hg remediation (Table 4) among which *Jatropha curcas* L., *Capsicum annuum* L., *Piper marginatum* Jacq. and *Stecherus bifidus* Willd. were found to be highly potential to be used in phytoremediation (Marrugo-Negrete et al. 2016).

6 Mercury Mining Area

Highly toxic inorganic and organic forms of Hg are accumulated and biomagnified at various trophic levels through food chains (Lindberg et al. 2007; Xia et al. 2010). Methylmercury (MMHg), an organic form of Hg, is the most toxic form of Hg (WHO and IPCS 1990) that poses a serious health risk to both humans and wildlife. One of the worst instances of Hg contamination in higher trophic levels is the Minamata disease that occurred in Japan after consumption of fish and other seafood contaminated with MMHg. The most prevalent anthropogenic sources of Hg are the mercury mining and retorting of cinnabar ores that release elemental Hg into the surrounding environment and generate numerous wastelands of Hg-rich mine tailings (Gray et al. 2004; Qiu et al. 2005, 2013). Therefore, there were attempts to identify native plant species from Hg mining areas that could effectively accumulate both organic and inorganic Hg as promising candidates for phytoremediation of Hg-contaminated soil. A total of 49 species under 29 families of plants (Table 5) were reported from heavily Hg-contaminated wastelands of the mercury mining area of cinnabar ore mine tailings (calcines) in the Wanshan region of southwestern China (Qian et al. 2018), out of which *Eremochloa ciliaris* (L.) Merr., *Buddleja lindleyana* Fortune, *Equisetum giganteum* L., *Artemisia herba-alba* Asso, *Plantago asiatica* L., and *Sonchus oleraceus* L. were proved to be the most Hg-tolerant species. Considering the accumulation of total Hg in aerial and underground parts, *E. ciliaris* and *A. hispidus* had been suggested as potential hyperaccumulators and candidates for phytostabilization respectively, in abandoned Hg mining sites.

7 Lead–Zinc (Pb/Zn) Mining Area

There were reports of erosion of unstable Pb/Zn mine tailings from the dumping sites and the spread of contaminants from mining wastes into the nearby farmlands and water bodies. Soils in these mining wastelands turn acidic and polluted with toxic heavy metals like Cd, Pb and Zn, which are serious health hazards. Several plant species, mostly herbaceous plants, were reported to be growing naturally on Pb/Zn mine tailings with heavy metal accumulation potential above the standard phytotoxic level in Thailand, China and Morocco (Hasnaoui et al. 2020; Rotkittikhun et al. 2007; Shu et al. 2002; Xiao et al. 2018; Zhu et al. 2018). In Pb/Zn mining areas, the contents of Cd, Pb and Zn in the most analyzed plants exceed the normal ranges and the phytotoxic level. Various plant species including *Crassocephalum crepidioides, Solanum nigrum*, *Bidens pilosa*, *Erigeron canadensis*, *Ageratum conyzoides*, *Crepidiastrum denticulatum* and *Echinochloa crus-galli* showed strong capability in accumulation and transport of Cd and they could be used as good candidates for Cd-phytoextraction (Table 6). Among all the species, *C. crepidioides* demonstrated the basic characteristics of a Cd-hyperaccumulator, as Cd concentration in the aerial part of this species exceeded the threshold of Cd-hyperaccumulator. The lower translocation ratios for Cd, Cu, Zn and Pb in *Pteris vittata* and *Carex chinensis* make them suitable for phytostabilization in the study area (Zhu et al. 2018).

Table 4 Native plants of gold mining area (Marrugo-Negrete et al. 2016)

Sl no	Name of plant	Family	Type of stress tolerated
1	*Tabebuia rosea* (Bertol.) Bertero ex A.DC.	Bignoniaceae	High level of Hg contamination
2	*Cecropia peltata* L.	Utricaceae	
3	*Cyperus ferax* Rich.	Cyperaceae	
4	*Cyperus luzulae* (L.) Retz.	Cyperaceae	
5	*Eleocharis interstincta* (Vahl) Roem. & Schult.	Cyperaceae	
6	*Cyperus blepharoleptos* Steud.	Cyperaceae	
7	*Jatropha curcas* L.	Euphorbiaceae	
8	*Phyllanthus niruri* L.	Phyllanthaceae	
9	*Ricinus communis* L.	Euphorbiaceae	
10	*Senna alata* (L.) Roxb.	Fabaceae	
11	*Stecherus bifidus* Willd.	Gleicheniaceae	
12	*Ceiba pentandra* (L.) Gaertn.	Malvaceae	
13	*Guazuma ulmifolia* Lam.	Malvaceae	
14	*Thalia geniculata* L.	Marantaceae	
15	*Calathea lutea* (Aubl.) E.Mey. ex Schult.	Marantaceae	
16	*Muntingia calabura* L.	Muntingiaceae	
17	*Psidium guajava* L.	Myrtaceae	
18	*Ludwigia octovalvis* (Jacq.) P.H.Raven	Onagraceae	
19	*Piper marginatum* Jacq.	Piperaceae	
20	*Pityrogramma calomelanos* (L.) Link	Pteridaceae	
21	*Capsicum annuum* L.	Solanaceae	

8 Coal Mine Dumpsites

Coal mine overburden dumps, produced during coal mining, create devastated landscapes with degraded soil that cannot support the natural growth of vegetation (Arshi 2017). Nevertheless, in a few elaborative studies, a total of 114 and 102 plant species were recorded from coal mine dumpsites of West Bengal (WB) and Jharkhand (JK), India, respectively (Table 7). Nine species from WB, namely, *Cassia fistula* L., *Emblica officinalis* Gaertn., *Dalbergia sissoo* Roxb., *Azadirachta indica* A.Juss., *Pongamia glabra* Vent., *Albizia lebbeck* (L.) Benth, *Holoptelea integrifolia* (Roxb.) Planch., *Acacia auriculiformis* Benth. and *Swietenia macrophylla* King were tested for their phytoremediation potential against various stresses including heavy metals Cd and Hg (Kar and Palit 2019). These plants could grow well with an increase in biomass and could change the soil conditions by reducing the heavy metal content of degraded wasteland into a favorable condition for plant growth. Studies suggest the potential of these nine plants for revegetation of wastelands. A total of ten species namely *Vachellia farnesiana* (L.) Wight & Arn., *Alternanthera sessilis* (L.) R.Br. ex DC., *Croton bonplandianus* Baill., *Chrysopogon lancearius* (Hook.f.) Haines, *Cynodon dactylon* (L.) Pers., *Lantana camara* L., *Launaea nudicaulis* (L.) Hook.f., *Phyllanthus niruri* L., *Saccharum spontaneum* L. and *Xanthium strumarium* L. were found to be growing naturally in the core mining area of coal mine in JK, which indicated their better adaptation to more adverse environmental conditions (Arshi 2017). However, more than a hundred other reported plants from coal mine areas are yet to be tested for their phytoremediation capabilities with potential research endeavors.

9 Dumpsite of Thermal Power Plants

With the increase in urbanization, coal-based thermal power plants have been increased in considerable numbers to meet the increased demand for energy. As a result, bulk generation of solid wastes in the form of fly ashes is creating havoc in the surrounding environment. Fly ashes are considered as serious pollutants of soil, air and water as they contain toxic metals like Cr, Cd, Zn, Pb and nickel (Ni) as well as create other stresses for vegetation growth like alkaline pH, less nitrogen and organic carbon in the dumping sites (Pandey et al. 2016). Therefore, management of fly ash dumpsite by removal or stabilization of heavy metals with eco-friendly approaches like phytoremediation practices has gained much

Table 5 Native plants of Hg mining area (Qian et al. 2018)

Sl no	Plant	Family	Type of stress tolerated
1	*Allium tuberosum* Rottler ex Spreng.	Amaryllidaceae	High level of Hg contamination
2	*Arthraxon hispidus* (Thunb.) Makino	Poaceae	
3	*Aster ageratoides* Turcz.	Asteraceae	
4	*Symphyotrichum subulatum* (Michx.) G.L.Nesom	Asteraceae	
5	*Brassica rapa* L.	Brassicaceae	
6	*Buddleja lindleyana* Fortune	Scrophulariaceae	
7	*Buddleja officinalis* Maxim.	Scrophulariaceae	
8	*Campylotropis trigonoclada* (Franch.) Schindl.	Fabaceae	
9	*Chamaecrista nomame* (Makino) H.Ohashi	Fabaceae	
10	*Oxybasis glauca* (L.) S.Fuentes, Uotila & Borsch	Amaranthaceae	
11	*Chromolaena odorata* (L.) R.M.King & H.Rob.	Asteraceae	
12	*Cibotium barometz* (L.) J.Sm.	Cyatheaceae	
13	*Cirsium japonicum* DC.	Asteraceae	
14	*Clerodendrum bungei* Steud.	Lamiaceae	
15	*Erigeron canadensis* L.	Asteraceae	
16	*Coriaria nepalensis* Wall.	Coriariaceae	
17	*Corydalis edulis* Maxim.	Papaveraceae	
18	*Thelypteris acuminata* (Houtt.) C.V.Morton	Aspleniaceae	
19	*Debregeasia orientalis* C.J.Chen	Urticaceae	
20	*Puhuaea sequax* (Wall.) H.Ohashi & K.Ohashi	Fabaceae	
21	*Equisetum giganteum* L.	Equisetaceae	
22	*Eremochloa ciliaris* (L.) Merr.	Poaceae	
23	*Euphorbia esula* L.	Euphorbiaceae	
24	*Reynoutria multiflora* (Thunb.) Moldenke	Polygonaceae	
25	*Gynura bicolor* (Roxb. ex Willd.) DC.	Asteraceae	
26	*Artemisia herba-alba* Asso	Asteraceae	
27	*Bidens bipinnata* L.	Asteraceae	
28	*Houttuynia cordata* Thunb.	Saururaceae	
29	*Imperata cylindrica* (L.) P.Beauv.	Poaceae	
30	*Crepidiastrum sonchifolium* (Bunge) Pak & Kawano	Asteraceae	
31	*Macleaya cordata* (Willd.) R.Br.	Papaveraceae	
32	*Mentha canadensis* L.	Lamiaceae	
33	*Neyraudia reynaudiana* (Kunth) Keng ex	Poaceae	
34	*Oenanthe javanica* (Blume) DC.	Apiaceae	
35	*Oenothera glazioviana* Micheli	Onagraceae	
36	*Sonchus brachyotus* DC.	Asteraceae	
37	*Plantago asiatica* L.	Plantaginaceae	
38	*Portulaca oleracea* L.	Portulacaceae	
39	*Lobelia nummularia* Lam.	Campanulaceae	
40	*Primula sikkimensis* Hook.	Primulaceae	
41	*Rumex acetosa* L.	Polygonaceae	
42	*Rumex japonicas* Houtt.	Polygonaceae	
43	*Sedum bulbiferum* Makino	Crassulaceae	
44	*Sedum emarginatum* Migo	Crassulaceae	
45	*Pseudogynoxys chenopodioides* (Kunth) Cabrera	Asteraceae	
46	*Sonchus oleraceus* L.	Asteraceae	
47	*Swertia bimaculata* (Siebold & Zucc.) Hook.f. & Thomson ex C.B.Clarke	Gentianaceae	
48	*Telosma cordata* (Burm.f.) Merr.	Apocynaceae	
49	*Xanthium strumarium* L.	Asteraceae	

Table 6 Native plants of lead–zinc mining area (Hasnaoui et al. 2020; Rotkittikhun et al. 2007; Shu et al. 2002; Xiao et al. 2018; Zhu et al. 2018)

Sl no	Plant	Family	Type of stress tolerated
1	*Thysanolaena latifolia* (Roxb. ex Hornem.) Honda	Poaceae	Heavy metals like Cd, Pb, Zn contamination
2	*Chenopodium album* L.	Amaranthaceae	
3	*Cirsium arvense* (L.) Scop.	Asteraceae	
4	*Setaria viridis* (L.) P.Beauv.	Poaceae	
5	*Silybum marianum* (L.) Gaertn.	Asteraceae	
6	*Tagetes erecta* L.	Asteraceae	
7	*Paspalum distichum* L.	Poaceae	
8	*Cynodon dactylon* (L.) Pers.	Poaceae	
9	*Erigeron canadensis* L.	Asteraceae	
10	*Artemisia lavandulaefolia* DC.	Asteraceae	
11	*Crassocephalum crepidioides* (Benth.) S.Moore	Asteraceae	
12	*Crepidiastrum denticulatum* (Houtt.) Pak & Kawano	Asteraceae	
13	*Pseudogynoxys chenopodioides* (Kunth) Cabrera	Asteraceae	
14	*Ageratum conyzoides* L.	Asteraceae	
15	*Taraxacum mongolicum* Hand.-Mazz.	Asteraceae	
16	*Bidens pilosa* L.	Asteraceae	
17	*Pteris vittata* L.	Pteridaceae	
	Pteridium revolutum (Blume) Nakai	Dennstaedtiaceae	
18	*Echinochloa crus-galli* (L.) P.Beauv.	Poaceae	
19	*Centella asiatica* (L.) Urb.	Apiaceae	
20	*Buddleja davidii* Franch.	Scrophulariaceae	
21	*Solanum nigrum* L.	Solanaceae	
22	*Carex chinensis* Retz.	Cyperaceae	
23	*Dysphania ambrosioides* (L.) Mosyakin & Clemants	Amaranthaceae	
24	*Reseda alba* L.	Resedaceae	
25	*Convolvulus althaeoides* L.	Convolvulaceae	
26	*Sulla spinosissima* (L.) B.H.Choi & H.Ohashi	Fabaceae	
27	*Phragmites australis* (Cav.) Trin. ex Steud.	Poaceae	
28	*Lotus corniculatus* L.	Fabaceae	
29	*Capsella bursa-pastoris* (L.) Medik.	Brassicaceae	
30	*Scolymus hispanicus* L.	Asteraceae	
31	*Rapistrum rugosum* (L.) All.	Brassicaceae	
32	*Cistus libanotis* L.	Cistaceae	
33	*Agathophora alopecuroides* (Delile) Fenzl ex Bunge	Amaranthaceae	
34	*Hirschfeldia incana* (L.) Lagr.-Foss.	Brassicaceae	
35	*Macrochloa tenacissima* (L.) Kunth	Poaceae	
36	*Artemisia herba-alba* Asso	Asteraceae	
37	*Capsella bursa-pastoris* (L.) Medik.	Brassicaceae	

Table 7 Native plants of coal mine dumpsite (Arshi 2017; Kar and Palit 2019)

Sl no	Plant	Family	Type of stress tolerated
1	*Andrographis echioides* Nees	Acanthaceae	Loose soil particles to support plant roots, challenges like soil erosion, dust, water pollution, heavy metal toxicity, deficiency in major nutrients and microbial activities in the soil system
2	*Andrographis paniculata* Nees	Acanthaceae	
3	*Hygrophila auriculata* (Schumach.) Heine	Acanthaceae	
4	*Rostellularia diffusa* (Willd.) Nees	Acanthaceae	
5	*Ruellia tuberosa* L.	Acanthaceae	
6	*Rungia pectinata* (L.) Nees	Acanthaceae	
7	*Agave sisalana* Perrine	Agavaceae	
8	*Trianthema portulacastrum* L.	Aizoaceae	
9	*Alangium lamarckii* Thwaites	Alangiaceae	
10	*Alternanthera paronychioides* A.St.-Hil.	Amaranthaceae	
11	*Alternanthera pungens* Kunth	Amaranthaceae	
12	*Alternanthera sessilis* (L.) R.Br. ex DC.	Amaranthaceae	
13	*Alternanthera tenella* Colla	Amaranthaceae	
14	*Amaranthus spinosus* L.	Amaranthaceae	
15	*Amaranthus viridis* L.	Amaranthaceae	
16	*Gomphrena celosioides* Mart.	Amaranthaceae	
17	*Ouret sanguinolenta* (L.) Kuntze	Amaranthaceae	
18	*Mangifera indica* L.	Anacardiaceae	
19	*Semecarpus anacardium* L.f.	Anacardiaceae	
20	*Annona reticulata* L.	Annonaceae	
21	*Annona squamosa* L.	Annonaceae	
22	*Alstonia scholaris* (L.) R.Br.	Apocynaceae	
23	*Catharanthus roseus* (L.) G. Don	Apocynaceae	
24	*Holarrhena pubescens* Wall. ex. G. Don	Apocynaceae	
25	*Thevetia neriifolia* Juss. ex Steud.	Apocynaceae	
26	*Borassus flabellifer* L.	Arecaceae	
27	*Phoenix sylvestris* (L.) Roxb.	Arecaceae	
28	*Calotropis gigantea* (L.) W.T. Aiton	Asclepiadaceae	
29	*Calotropis procera* W.T.Aiton	Asclepiadaceae	
30	*Hemidesmus indicus* (L.) R.Br. ex Schult.	Asclepiadaceae	
31	*Pergularia daemia* (Forssk.) Chiov.	Asclepiadaceae	
32	*Blumea axillaris* (Lam.) DC.	Asteraceae	
33	*Blumea lacera* (Burm.f.) DC.	Asteraceae	
34	*Cnicus wallichii* Hook.f.	Asteraceae	
35	*Eclipta alba* (L.) Hassk.	Asteraceae	
36	*Launaea nudicaulis* (L.) Hook. f.	Asteraceae	
37	*Mikania scandens* (L.) Willd.	Asteraceae	
38	*Spilanthes paniculata* Wall.	Asteraceae	
39	*Tridax procumbens* L.	Asteraceae	
40	*Vernonia cinerea* (L.) Less.	Asteraceae	
41	*Vicoa indica* (L.) DC.	Asteraceae	
42	*Xanthium strumarium* L.	Asteraceae	

(continued)

Table 7 (continued)

Sl no	Plant	Family	Type of stress tolerated
43	*Chromolaena odorata* (L.) R. M.King & H.Rob.	Asteraceae	
44	*Cleome gynandra* L.	Capparaceae	
45	*Cleome viscosa* L.	Capparaceae	
46	*Siphonodon celastrineus* Griff.	Celastraceae	
47	*Terminalia arjuna* (Roxb. ex DC.) Wight & Arn.	Combretaceae	
48	*Terminalia bellirica* (Gaertn.) Roxb.	Combretaceae	
49	*Terminalia elliptica* Willd.	Combretaceae	
50	*Commelina benghalensis* Forssk.	Commelinaceae	
51	*Evolvulus alsinoides* (L.) L.	Convolvulaceae	
52	*Ipomoea cairica* (L.) Sweet	Convolvulaceae	
53	*Ipomoea maxima* (L.f.) Sweet	Convolvulaceae	
54	*Ipomoea pes-tigridis* L.	Convolvulaceae	
55	*Ipomoea pinnata* Hochst. ex Choisy	Convolvulaceae	
56	*Hellenia speciosa* (J.Koenig) S. R.Dutta	*Costaceae* Nakai	
57	*Coccinia cordifolia* Cogn.	Cucurbitaceae	
58	*Trichosanthes cucumerina* L.	Cucurbitaceae	
59	*Cyperus rotundus* L.	Cyperaceae	
60	*Kyllinga monocephala* Muhl.	Cyperaceae	
61	*Schoenoplectiella articulata* (L.) Lye	Cyperaceae	
62	*Tacca leontopetaloides* (L.) Kuntze	Dioscoreaceae	
63	*Shorea robusta* C.F.Gaertn.	Dipterocarpaceae	
64	*Acalypha indica* L.	Euphorbiaceae	
65	*Croton bonplandianus* Baill.	Euphorbiaceae	
66	*Emblica officinalis* Gaertn.	Euphorbiaceae	
67	*Euphorbia antiquorum* L.	Euphorbiaceae	
68	*Euphorbia hirta* L.	Euphorbiaceae	
69	*Euphorbia prostrata* Aiton	Euphorbiaceae	
70	*Jatropha curcas* L.	Euphorbiaceae	
71	*Jatropha gossypiifolia* L.	Euphorbiaceae	
72	*Phyllanthus amarus* Schumach. & Thonn.	Euphorbiaceae	
73	*Tragia involucrata* L.	Euphorbiaceae	
74	*Acacia auriculiformis* A.Cunn. ex Benth.	Fabaceae	
75	*Acacia floribunda* (Vent.) Willd.	Fabaceae	
76	*Atylosia scarabaeoides* (L.) Benth.	Fabaceae	
77	*Bauhinia variegata* L.	Fabaceae	
78	*Butea monosperma* (Lam.) Kuntze	Fabaceae	
79	*Cajanus scarabaeoides* (L.) Thouars	Fabaceae	
80	*Cassia alata* L.	Fabaceae	
81	*Cassia fistula* L.	Fabaceae	
82	*Cassia obtusifolia* L.	Fabaceae	
83	*Cassia siamea* Lam.	Fabaceae	
84	*Cassia sophera* L.	Fabaceae	
85	*Cassia tora* L.	Fabaceae	
86	*Crotalaria juncea* L.	Fabaceae	
87	*Crotalaria linifolia* L.f.	Fabaceae	

(continued)

Table 7 (continued)

Sl no	Plant	Family	Type of stress tolerated
88	*Dalbergia sissoo* Roxb. ex DC.	Fabaceae	
89	*Desmodium gangeticum* (L.) DC.	Fabaceae	
90	*Entada gigas* (L.) Fawc. & Rendle	Fabaceae	
91	*Grona triflora* (L.) H.Ohashi & K.Ohashi	Fabaceae	
92	*Indigofera latifolia* Micheli	Fabaceae	
93	*Pithecellobium dulce* (Roxb.) Benth.	Fabaceae	
94	*Pongamia pinnata* (L.) Pierre	Fabaceae	
95	*Senna hirsuta* (L.) H.S.Irwin & Barneby	Fabaceae	
96	*Senna occidentalis* (L.) Link	Fabaceae	
97	*Tephrosia purpurea* (L.) Pers.	Fabaceae	
98	*Tephrosia villosa* (L.) Pers.	Fabaceae	
99	*Teramnus labialis* (L.f.) Spreng.	Fabaceae	
100	*Vachellia farnesiana* (L.) Wight & Arn.	Fabaceae	
101	*Vachellia nilotica* (L.) P.J.H. Hurter & Mabb.	Fabaceae	
102	*Flacourtia indica* (Burm.f.) Merr.	Flacourtiaceae	
103	*Clerodendrum viscosum* Vent.	Lamiaceae	
104	*Gmelina arborea* Roxb.	Lamiaceae	
105	*Hyptis suaveolens* (L.) Poit	Lamiaceae	
106	*Leonurus sibiricus* L.	Lamiaceae	
107	*Leucas aspera* (Willd.) Link	Lamiaceae	
108	*Leucas cephalotes* (Roth) Spreng.	Lamiaceae	
109	*Ocimum canescens* A.J.Paton	Lamiaceae	
110	*Tectona grandis* L.f.	Lamiaceae	
111	*Vitex negundo* L.	Lamiaceae	
112	*Abutilon indicum* (L.) Sweet	Malvaceae	
113	*Bombax ceiba* L.	Malvaceae	
114	*Sida acuta* Burm.f.	Malvaceae	
115	*Sida cordata* (Burm.f.) Borss. Waalk.	Malvaceae	
116	*Sida cordifolia* L.	Malvaceae	
117	*Sterculia urens* Roxb.	Malvaceae	
118	*Urena lobata* L.	Malvaceae	
119	*Azadirachta indica* A.Juss.	Meliaceae	
120	*Melia azedarach* L.	Meliaceae	
121	*Swietenia macrophylla* King	Meliaceae	
122	*Stephania japonica* (Thunb.) Miers	Menispermaceae	
123	*Albizia lebbeck* (L.) Benth.	Mimosaceae	
124	*Trigastrotheca pentaphylla* (L.) Thulin	Molluginaceae	
125	*Artocarpus heterophyllus* Lam.	Moraceae	
126	*Artocarpus lacucha* Buch.-Ham.	Moraceae	
127	*Ficus benghalensis* L.	Moraceae	
128	*Ficus cunea* Steud	Moraceae	
129	*Ficus racemosa* L.	Moraceae	
130	*Ficus religiosa* L.	Moraceae	
131	*Streblus asper* Lour.	Moraceae	
132	*Syzygium cumini* (L.) Skeels	Myrtaceae	
133	*Boerhavia diffusa* L.	Nyctaginaceae	

(continued)

Table 7 (continued)

Sl no	Plant	Family	Type of stress tolerated
134	*Mirabilis jalapa* L.	Nyctaginaceae	
135	*Argemone mexicana* L.	Papaveraceae	
136	*Pedalium murex* L.	Pedaliaceae	
137	*Phyllanthus urinaria* L.	Phyllanthaceae	
138	*Phyllanthus virgatus* G.Forst	Phyllanthaceae	
139	*Mecardonia procumbens* (Mill.) Small.	Plantaginaceae	
140	*Andropogon pumilus* Roxb.	Poaceae	
141	*Aristida adscensionis* L.	Poaceae	
142	*Chloris barbata* Sw.	Poaceae	
143	*Chrysopogon aciculatus* (Retz.) Trin.	Poaceae	
144	*Chrysopogon lancearius* (Hook. f.) Haines	Poaceae	
145	*Cynodon dactylon* (L.) Pers.	Poaceae	
146	*Eragrostis coarctata* Stapf	Poaceae	
147	*Eulaliopsis binata* (Retz.) C.E. Hubb.	Poaceae	
148	*Heteropogon contortus* Beauv. ex Roem. & Schult.	Poaceae	
149	*Oplismenus compositus* P. Beauv.	Poaceae	
150	*Panicum maximum* Jacq.	Poaceae	
151	*Poa annua* L.	Poaceae	
152	*Saccharum munja* Roxb.	Poaceae	
153	*Saccharum spontaneum* L.	Poaceae	
154	*Sporobolus indicus* (L.) R.Br.	Poaceae	
155	*Polygonum barbatum* L.	Polygonaceae	
156	*Ziziphus mauritiana* Lam.	Rhamnaceae	
157	*Ziziphus oenoplia* (L.) Mill.	Rhamnaceae	
158	*Dentella repens* J.R.Forst. & G. Forst.	Rubiaceae	
159	*Spermacoce hispida* L.	Rubiaceae	
160	*Scoparia dulcis* L.	Plantaginaceae	
161	*Aegle marmelos* (L.) Corrêa	Rutaceae	
162	*Atalantia monophylla* DC.	Rutaceae	
163	*Madhuca longifolia* (J.Koenig ex L.) J.F.Macbr.	Sapotaceae	
164	*Ailanthus excelsa* Roxb.	Simaroubaceae	
165	*Datura metel* L.	Solanaceae	
166	*Physalis minima* L.	Solanaceae	
167	*Solanum nigrum* L.	Solanaceae	
168	*Solanum sisymbriifolium* Lam	Solanaceae	
169	*Solanum surattense* Burm.f.	Solanaceae	
170	*Solanum virginianum* L.	Solanaceae	
171	*Triumfetta rhomboidea* Jacq.	Tiliaceae	
172	*Holoptelea integrifolia* (Roxb.) Planch.	Ulmaceae	
173	*Lantana camara* L.	Verbenaceae	
174	*Phyla nodiflora* (L.) Greene	Verbenaceae	
175	*Cayratia trifolia* (L.) Domin	Vitaceae	
176	*Tribulus terrestris* L.	Zygophyllaceae	

importance in recent times. Several plants have been reported (Table 8) to be growing naturally in fly ash dumpsites of thermal power plants of Bihar and Jharkhand, India, which are worth to be prospected for their phytoremediation potentials (Kumari et al. 2011, 2016; Pandey et al. 2016). *Ipomoea carnea* Jacq., *Lantana camara* L. and *Solanum virginianum* L. were the three most abundant species found in the fly ash dump sites of Patratu thermal power plant, Jharkhand, India (Pandey et al. 2016). *Pteris vittata* L., growing in fly ash dumpsites of a thermal power

Table 8 Native plants of fly ash dumpsite of thermal power plant (Kumari et al. 2011, 2016; Pandey et al. 2016)

Sl. no	Plant	Family	Type of stress tolerated
1	*Azolla pinnata* R.Br	Salviniaceae	Alkaline pH, less nitrogen and organic carbon; rich in heavy metals like Cr, Cd, Zn, Pb, Al, Si, As, Fe and Ni
2	*Ceratopteris thalictroides* (L.) Brongn	Pteridaceae	
3	*Hydrilla verticillata* (L.f.) Royle	Hydrocharitaceae	
4	*Marsilea minuta* L.	Marsileaceae	
5	*Typha latifolia* L.	Typhaceae	
6	*Achyranthes aspera* L.	Amaranthaceae	
7	*Argemone mexicana* L.	Papaveraceae	
8	*Amaranthus spinosus* L.	Amaranthaceae	
9	*Thelypteris prolifera* (Retz.) C.F.Reed	Aspleniaceae	
10	*Chenopodium album* L.	Amaranthaceae	
11	*Cannabis sativa* L.	Cannabaceae	
12	*Senna tora* (L.) Roxb	Fabaceae	
13	*Calotropis procera* (Aiton) W.T.Aiton	Apocynaceae	
14	*Croton bonplandianus* Baill	Euphorbiaceae	
15	*Cynodon dactylon* (L.) Pers	Poaceae	
16	*Datura metel* L.	Solanaceae	
17	*Diplazium esculentum* (Retz.) Sw	Aspleniaceae	
18	*Eclipta prostrata* (L.) L.	Asteraceae	
19	*Erigeron annuus* (L.) Desf	Asteraceae	
20	*Ipomoea carnea* Jacq	Convolvulaceae	
21	*Lantana camara* L.	Verbenaceae	
22	*Linum usitatissimum* L.	Linaceae	
23	*Momordica charantia* L.	Cucurbitaceae	
24	*Parthenium hysterophorus* L.	Asteraceae	
25	*Phyllanthus urinaria* L.	Phyllanthaceae	
26	*Plumbago zeylanica* L.	Plumbaginaceae	
27	*Persicaria hydropiper* (L.) Delarbre	Polygonaceae	
28	*Pteris vittata* L.	Pteridaceae	
29	*Tripidium bengalense* (Retz.) H. Scholz	Poaceae	
30	*Stellaria media* (L.) Vill	Caryophyllaceae	
31	*Solanum virginianum* L.	Solanaceae	

plant of Bihar, significantly accumulated toxic heavy metals like As, Cu and Cr in its above-ground parts, which revealed its potential as a suitable species for phytoremediation of metal contamination (Kumari et al. 2011). *Typha latifolia* L. and *Azolla pinnata* R.Br. were found to be the most efficient metal hyper-accumulator aquatic species and *Croton bonplandianus* Baill. was suggested to be the best metal accumulator terrestrial species for various heavy metals of thermal power plant dumpsites in Bihar (Kumari et al. 2016). As evidenced by better translocation of metals from below ground to above-ground parts *I. carnea* and *L. camara* were suggested to be promising species for phytoextraction. On the other hand, *S. virginianum* was considered as a better candidate for phytostabilization of metals in fly ash dumpsites, as metals were mostly found in the below-ground parts of the plant (Pandey et al. 2016).

10 Stress Management Strategies

In order to thrive in stress conditions, plants implement various mechanisms and adaptation strategies, such as enhancement of water-absorbing capacity by promoting root growth, increase in water-holding capacity through stomatal regulation, improvement in osmotic regulation by accumulation of osmoprotectants as well as reduction in oxidative damages by regulation of enzymatic and non-enzymatic antioxidant defense systems. In a broad sense, plants deploy two mechanisms as strategies for stress management, which include (i) mechanism of stress avoidance and (ii) mechanism of stress tolerance (Fig. 1).

10.1 Mechanism of Stress Avoidance

Stress avoidance strategy is one of the adaptive mechanisms acquired by plants to survive environmental stresses in course of evolution. Activation of avoidance mechanisms such as reduced physiological function like absorption and transport of water and minerals, reduced vegetative growth, early flowering, leaf shedding, accelerated senescence, as well as loss of biomass or yield, allow plants to escape the potentially detrimental effects of stressful conditions (Maggio et al. 2018). In most of the cases naturally occurring plant species of mine tailings have possibly developed the mechanism of avoidance to endure the stress of high levels of metal contaminations, as evidenced by relatively low metal concentrations found in the aerial parts in comparison to very high concentrations in underground parts (Chen et al. 2005). Plants in stress conditions can avoid stress by the synthesis of

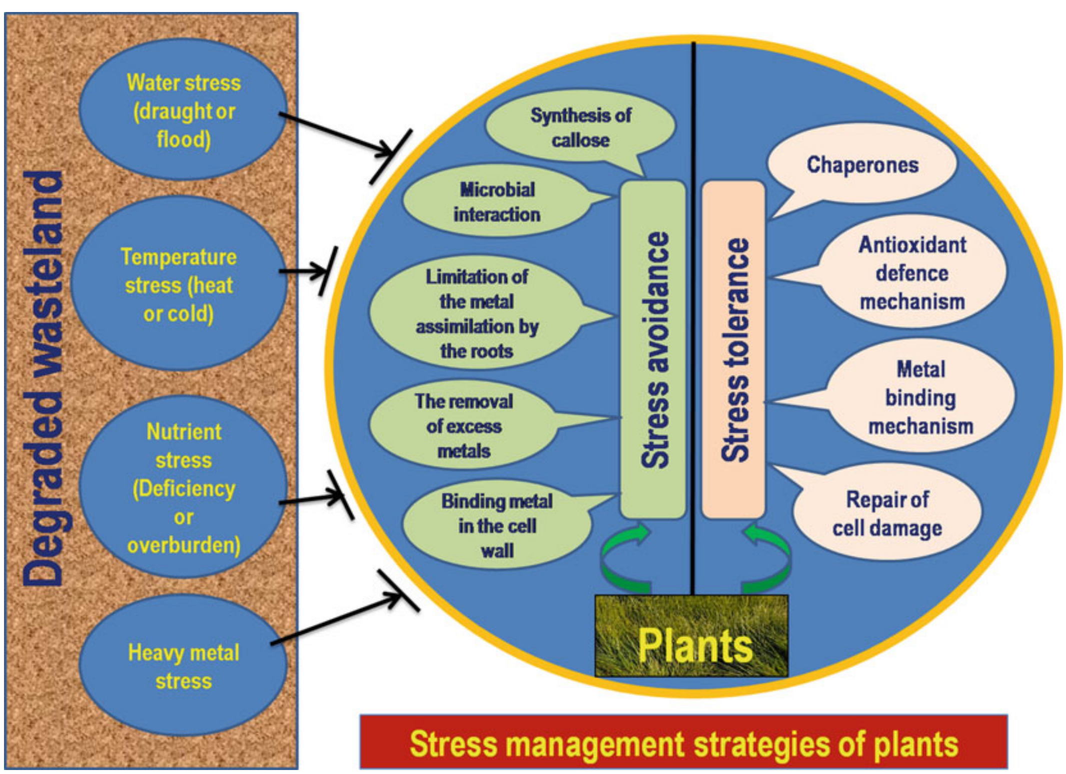

Fig. 1 Strategies for the management of stress in plants

callose, microbial interaction, limitation of the metal assimilation by the roots, the removal of excess metals as well as by binding metal in the cell wall (Jutsz and Gnida 2015).

10.1.1 Synthesis of Callose

Callose (β-1, 3 glucans) is a polysaccharide that is synthesized in a plant cell by the action of enzyme β-1, 3-glucan synthetase and is deposited on the outer side of the cell membrane. This polysaccharide reduces the diffusion of metal ions into the cell and thus serves as the earliest defense strategy in the presence of stress including heavy metal (Jutsz and Gnida 2015).

10.1.2 Microbial Interaction

Mycorrhizal Association

Mycorrhiza is the symbiotic relationship between non-pathogenic fungi and higher plant roots. Mycorrhizal fungi reduce the penetration of metals like Zn, Pb, Cu, Cd, Ni, Mn, Fe etc. into the plant cells by secreting metal chelating agents, such as organic acids, phenolic compounds, siderophores and phosphate ions forming insoluble metal salts. Metals are adsorbed on the surface of mycorrhizal fungal cells with the help of precipitated sulfides and hydrated iron oxides. Another strategy is the accumulation and immobilization of metal ions in the arbuscules, vesicles and hyphae of mycorrhizal fungi as well as metal detoxification by binding with metallothionein and vacuole polyphosphates within the fungal cells (Jutsz and Gnida 2015).

The Arbuscular mycorrhizal (AM) symbioses enhance the antioxidant defense system, improve water absorption, nutrient uptake, photosynthetic efficiency and maintain nutrient balance under stress conditions (Estrada et al. 2013; Santander et al. 2017, 2020). In several cases, metal (Zn, Cu etc.) contaminated wastelands are first colonized by non-mycorrhizal plant species followed by mycorrhizal species in course of ecological succession (Chen et al. 2005; Gucwa-Przepiora and Turnau 2001; Turnau 1998). Mycorrhizal colonization increases the tolerance capacity of plants to toxic heavy metal contamination making the mycorrhizal association a better application for remediation purposes than the application of either non-mycorrhizal plants or free-living micro-organisms alone (Haselwandter and Bowen 1996; Leyval et al. 1997). There is a need for more information on the role of the mycorrhizal association in the stabilization and remediation of contaminants for better planning and management of wastelands with the help of native tolerant plants.

Rhizospheric and Non-rhizospheric Microbial Interaction

Studies involving the PCR-DGGE approach to sequence nifH genes from environmental DNA extracted from tailing samples revealed the presence of considerable diversity of free-living nitrogen-fixing microbial communities in rhizosphere and non-rhizosphere of native plants growing on wastelands of copper mine tailings. Less than 90% sequence identity with bacteria in the available databases suggested the presence of novel nitrogen fixers in copper mine tailings that were possibly capable of modifying the degraded mining sites into a favorable site for plant growth (Zhan and Sun 2012).

Endophytic Microbiota

There are evidences that endophytic microbiota, that colonize a plant's internal tissues without causing any apparent harm to the host plant, confer resistance and tolerance to various abiotic stresses by increasing the levels of antioxidants or by the production of phytohormones, like indoleacetic acid (IAA) and cytokinin, that are responsible for plant growth as well as disease suppression in stress-laden ecosystems (Baltruschat et al. 2008; Brígido et al. 2019; Lata et al. 2018; Orozco-Mosqueda et al. 2018; Rajkumar et al. 2009; Rashid et al. 2012; Rho et al. 2018). Therefore, systematic study on the diversity of endophytic microbiota of native plants of wastelands can provide beneficial information on the possible mechanism of stress tolerance in these plants.

10.1.3 Limitation of the Metal Assimilation by the Roots

As another avoidance strategy in a stressed condition, especially in a heavy metal contaminated environment, roots exude some substances including organic acids, simple sugars, phenols, amino acids, polysaccharide gels etc. which bind metal ions and thus limit their assimilation by plants. Sometimes roots change the pH of the rhizosphere causing a reduction in metal availability. In some cases, roots produce an oxidizing zone around them resulting in the formation of oxidized forms of metals, which are less soluble and thus less available to plants (Meier et al. 2012; Miransari 2011).

10.1.4 Removal of Excess Metals

Plants can remove excess metals such as copper, nickel, zinc, iron and manganese by forming crystals with the involvement of salt glands present on leaf epidermis as well as through hydathodes and ectoderms. Another strategy is to avoid metal stress is by transporting them to the aging leaves and subsequent removal of the leaves. Sometimes heavy metals are accumulated and sequestrated in fibers and idioblasts to get rid of their harmful effects (Olko 2009).

10.1.5 Binding Metal in the Cell Wall

Immobilization of toxic metal ions in the cell wall is another stress avoidance mechanism. Dissociation of cell wall components like cellulose, hemicelluloses and pectins lead to the production of negatively charged groups that are eventually saturated with calcium. In the case of the heavy metal contaminated environment, calcium ions are competitively replaced by metal cations, and thereby heavy metals are immobilized in the cell wall. Sometimes, the cell wall becomes highly lignified or suberized in the presence of heavy metals, by the increase in transverse bonds among cell wall components like phenols, proteins and saccharides making the wall more compact, stiffer and hence less permeable to heavy metals (Miransari 2011).

10.2 Mechanism of Stress Tolerance

When contaminants or stress factors such as metal ions overcome the plant protective barriers and penetrate their cells by evading all the strategies of stress avoidance, plants deploy a second set of strategies for detoxifying the stress factors and tolerating stress effects. Rapid and effective detoxification of stressors including heavy metals is crucial for the survival of a particular plant species in a stressed condition. Plants install a bunch of mechanisms for stress tolerance, for instance, activation of molecular chaperons, antioxidant defense systems, metal binding with chelators like phytochelatins, metallothioneins, organic acids and amino acids and subsequent transportation and accumulation of metals in vacuoles as well as induction of quick cell repair system (Miransari 2011).

10.2.1 Chaperones

Chaperones are also referred to as heat shock proteins (HSPs), which are accumulated in cytoplasm and all cellular compartments of all kinds of living organisms to protect other proteins from being degraded and to re-establish cellular homeostasis under various stresses including temperature stress, water stress, salinity stress, osmotic and oxidative stress (Wang et al. 2004; Singh et al. 2019). Various stresses affect the proper folding of proteins and thus affect the protein functions. The molecular chaperones bind to the nascent polypeptide chain and stabilize unfolded and partially folded polypeptides by minimizing the protein aggregation and thus facilitate proper folding and errorless transportation of proteins to various subcellular locations (Roy et al. 2019). Some of the chaperones are assisted by certain co-chaperones, such as the HSP70-HSP90 organizing protein (HOP), during protein folding (Toribio et al. 2020). Elaborative investigation on cellular chaperones and co-chaperons in native plants of industrial and mining wastelands can unfold significant information about the stress tolerance mechanisms of plants for crop improvement programs.

10.2.2 Antioxidant Defense Mechanisms

Excessive exposure of plants to abiotic stresses, like salinity, drought, cold, heavy metals, UV irradiation etc., increases the production of reactive oxygen species (ROS), such as singlet oxygen, superoxide radical, hydroxyl radical and hydrogen peroxide in different cellular compartments including primarily the chloroplast, mitochondria and peroxisome as well as in some secondary sites like plasma membrane, endoplasmic reticulum, cell wall and the apoplast (Das and Roychoudhury 2014). Production of ROS by various cellular metabolic pathways results in lipid peroxidation and oxidative damage to pigments, carbohydrates, proteins and nucleic acids that eventually lead to plant cell death (Foyer 2018). The balance between ROS production and elimination is essential for normal cellular homeostasis and under environmental stress conditions, this delicate balance is disturbed (Miller et al. 2010). Plants modulate various stresses by changing the enzymatic and non-enzymatic antioxidant systems for scavenging ROS, which reduce oxidative damage and thereby enhance the plant tolerance to various stresses and sustain growth. Enzymatic ROS scavenging components involve the actions of superoxide dismutase (SOD), catalase (CAT), ascorbate peroxidase (APX), guaiacol peroxidase (GPX), glutathione reductase (GR), mono dehydroascorbate reductase (MDHAR) and dehydroascorbate reductase (DHAR), whereas non-enzymatic antioxidants include mainly the osmolyte proline as well as other biomolecules like ascorbic acid (AA), reduced glutathione (GSH), α-tocopherol, carotenoids and flavonoids (Das and Roychoudhury 2014; Santander et al. 2020).

It was found that *Ricinus communis* plants that were naturally growing in a phytotoxic paper mill dumpsite showed a significantly higher level of proline and ascorbic acid than control, indicating induction of non-enzymatic antioxidant system as stress mitigation strategy (Das et al. 2021). In another study, a decrease in the lipid peroxidation as indicated by decreased malondialdehyde content with the increase in activities of antioxidant enzymes such as catalase and superoxide dismutase was observed in two native, metal hyperaccumulator plant species (*Baccharis salicina* and *Chenopodiastrum murale*) of a Cu mine wasteland (Llerena et al. 2021). Detailed investigation on antioxidant defense mechanisms of potential native plants of wastelands can be a game-changer in crop improvement challenges in coming ages of changing climate.

10.2.3 Metal-Binding Mechanism

Cells contain certain metal-binding molecules such as phytochelatins, different amino acids, glutathione, organic acids like malic acid, citric acid and oxalic acid. In the cytoplasm, metal ions are transported to the vacuole by attaching to the thiol groups of glutathione. Inside the vacuole, the complex undergoes decomposition and resulting metal ions subsequently bind to phosphates which are a more immobilized form of metals (Miransari 2011). Similarly, metals like iron and nickel can be transported to the vacuole and through the xylem vessels by associating with the carboxyl group (COOH) of organic acids like malic acid and citric acid. Amino acid histidine also forms complex with metals like nickel, zinc and copper in hyper-accumulator plants e.g. *Alyssum lesbiacum*, as evidenced by a manifold increase in histidine concentration in xylem after exposure to the metal. Similarly, another amino acid, nicotinamide, can chelate some metals including iron, copper and zinc (Singla-Pareek et al. 2006).

Some proteins known as metallothionein and phytochelatins are also involved in heavy metal tolerance and accumulation. Metallothioneins and phytochelatins help in the chelation of metal ions in the cytosol with subsequent compartmentalization of metals in the vacuoles. These proteins repair the stress-damaged proteins as well as remove and degrade proteins that fail to attain their native conformations (Hasan et al. 2017). Metallothioneins (MTs) are low molecular weight, cysteine-rich proteins that are involved in the detoxification of metals from the cytoplasm by binding metal ions like Cu, Cd and Zn ions with thiol groups. Correlation between MT RNA levels and differences in tolerance to heavy metals could be observed in *Arabidopsis* ecotypes that revealed their role in protection against abiotic stress (Murphy and Taiz 1995). Studies revealed that the native plants growing in copper (Cu) contaminated areas of a Cu mine in Arequipa, Peru, developed tolerance mechanisms, by enhanced MT production along with other stress-related physiological responses like changes in photosynthetic pigments, sugar contents, malondialdehyde contents and antioxidant enzyme activities (Llerena et al. 2021).

Phytochelatins (PCs) are small cysteine-rich peptides and products of the biosynthetic pathway, which are synthesized from reduced glutathione by enzyme phytochelatin synthetase in response to metal-induced stress. They can detoxify heavy metals, particularly cadmium by the mechanism of chelation and subsequent transportation from the cytoplasm to the vacuole. These peptides are important for maintaining metal homeostasis in cells as metals can be released from the immobilized complex whenever required for other uses, for instance, to produce metalloenzymes (Ahmad et al. 2019; Guo et al. 2008; Hasan et al. 2017; Liu et al. 2015; Pochodylo and Aristilde 2017).

During the process of ameliorating metal toxicity, besides the binding of metal ions by peptides like MTs and PCs, transportation of arrested metal ions from the cytosol to the vacuole for sequestration is equally crucial which involves the transporter proteins like ATP-dependent vacuolar pumps (V-ATPase and VPPase) and a bunch of other tonoplast transporters (Sharma et al. 2016). Isolation and characterization of MTs, PCs and transporter proteins in native plants of various wastelands can unravel the understanding of their stress management mechanisms in the stressed environment.

10.2.4 Repair of Cell Damage

Prompt and effective repair of stress-caused damages of cell components is an important strategy of plants for stress tolerance. Heat shock proteins (HSPs), which are expressed in plant cells exposed to stress conditions including high temperatures, heavy metal stress and others, help in the repair process (Singla-Pareek et al. 2006).

11 Climate Change, Land Degradation and the Prospect of Native Plants

Climate change affects adversely and intensifies severely the effects of abiotic stresses on crop production as plants experience multifactorial abiotic stresses including an elevated concentration of CO_2, temperature (low and high), waterlogging, drought, sunshine intensity as well as chemical factors like pH and heavy metals, in course of changing climate along with global warming and environmental pollution (Onyekachi et al. 2019; Pareek et al. 2020; Zandalinas et al. 2021). It has been predicted that in the coming years, climate change will bring about unavoidable ecological damages as well as widespread and severe crop yield losses which will threaten the food security of the growing global population (Ferguson 2019). Although most of the plants adapt to individual stress by various mechanisms, an increase in the number of different co-occurring multifactorial stress factors affect physiological processes of plants related to growth and survival, as well as the microbiome diversity that plants depend on. Therefore, it is important to the development of elite crop varieties with enhanced tolerance to multifactorial stress combinations that are conferred by changing climate, to meet the demands of a growing population. In this respect, biotechnological and breeding efforts to exploit the physiological and biochemical mechanisms of stress management are critical (Ferguson 2019). Advanced methods of biotechnology and genetic engineering tools can be used for developing stress-tolerant crops by introgression of the genes that are involved in stress management in naturally tolerant plants (Bhatnagar-Mathur et al. 2008; Ahanger et al. 2017). In this context, to ensure the viability of crop improvement efforts under the context of a dynamically changing environment, native plant species from stress-laden wastelands can be exploited on a priority basis to harness the stress-tolerant gene resources for better stress management.

Climate change and land degradation are two interdependent phenomena, cyclically affecting each other. Climate change is one of the major factors that lead to land degradation and affect subsequent sustainable development (Kumar and Das 2014). An increase in dry climates and decrease in polar climates result in shifts of climate zones, which have direct consequences on respective ecosystems and thereby on land fertility. Crop productivity, irrigation needs and management practices determine the land use pattern. Changes in land use and land cover due to loss of vegetation productivity are the two major impacts of global warming. On the other hand, land use changes alter the chemical composition, air quality, temperature, humidity and dynamics like the strength of winds of the atmosphere, which can amplify the consequences of climate change (Jia et al. 2019). Therefore, under the apparent pressure of changing climate and increasing human population, there remain no other options than reviving the degraded wastelands into productive lands to meet the subsequent increasing demands of basic survival needs like food, medicine and many other essential commodities. This is because the total arable land is not going to increase with the growing need for food grains for the expanding population which is projected to be doubled by 2050 (Bhattacharyya 2012). Therefore, emphasis has been put to remediate and utilize wastelands, which have the adequate potential to support the majority of the underprivileged population in solving basic problems like hunger and malnutrition in near future. By implementing scientific management techniques, wastelands can be transformed to produce fuel, fodder, forage, essential oil, medicine or vegetation cover to check further soil degradation. Hence, naturally growing native plants of wastelands can serve in two ways: (i) by providing genetic resources that are the molecular basis of the physiological and biochemical mechanism of stress management strategies for crop improvement programs to produce elite climate-resilient crops; and (ii) by remediating stress-laden wastelands into productive lands by creating vegetation cover with little effort.

12 Conclusion

Although wastelands like industrial and mining dumpsites are characterized by adverse physicochemical and biological properties of soil, still numerous plant species have been reported to thrive well in stressful conditions with little or no agronomical effort. Herbaceous and shrub species usually adapt faster to these conditions than other plant species because of their shorter life cycles, which allow them to produce various genotypes in a shorter time. Documentation of such stress-tolerant naturally growing native plants of various wastelands and studying their mechanisms of tolerance are two major emerging areas of research in recent times. Such efforts may help in finding novel plant species that are more stress-tolerant with greater potential of creating vegetation cover. However, more comprehensive investigations with modern multi-omics approaches are required to understand the underlying mechanisms of stress tolerance in those species, which will help improve the adaptation of economically important species of interest in stress-laden wastelands. Discovering important tolerance pathways, functions of antioxidant enzymes, osmolyte accumulation, membrane-bound transporters involved in efficient compartmentation of harmful ions and accumulation of toxic heavy metals as well as resistance mechanisms against pests and pathogens by the native plants of wastelands are some of the vital areas for future research-based study.

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Contents

Chapter 6

Contents

6

Heavy Metals (HMs) pollution in NE India: Current Research and Future Direction

Glory Borah
Hemen Deka

Abstract

Heavy metals (HMs) are considered as major pollutants of environmental concern. HMs are toxic, carcinogenic, non-biodegradable and therefore very difficult to remove from environment more particularly from soil systems. HMs can even stay more than half lives within the biological tissues. HMs such as lead (Pb), chromium (Cr), arsenic (As), zinc (Zn), cadmium (Cd), copper (Cu), mercury (Hg) and Nickel (Ni) has been proved to show severe effects on living organisms including human beings (Zhang et al. 2019). HMs are one of the principal pollutants present in crude oil. In NE India more particularly in Assam HMs associated crude oil pollution is a severe problem in the adjacent agro-ecosystems of the oil fields because of their capability for bioaccumulation and food chain contaminations. It has been reported that extensive HMs contaminations in the paddy fields of NE India has altered the physico-chemical composition of soils thereby reducing the productive lands (Basumatary et al. 2012). In this chapter, overview of research literature pertaining to occurrence and behavior of HMs, its adverse effect on the ecosystem, hyper accumulation in plants, various remediation techniques including physical, chemical and biological and their limitations has been presented. Besides, the chapter has also highlight about the works carried out in NE India and possible research gaps in HMs bioremediation.