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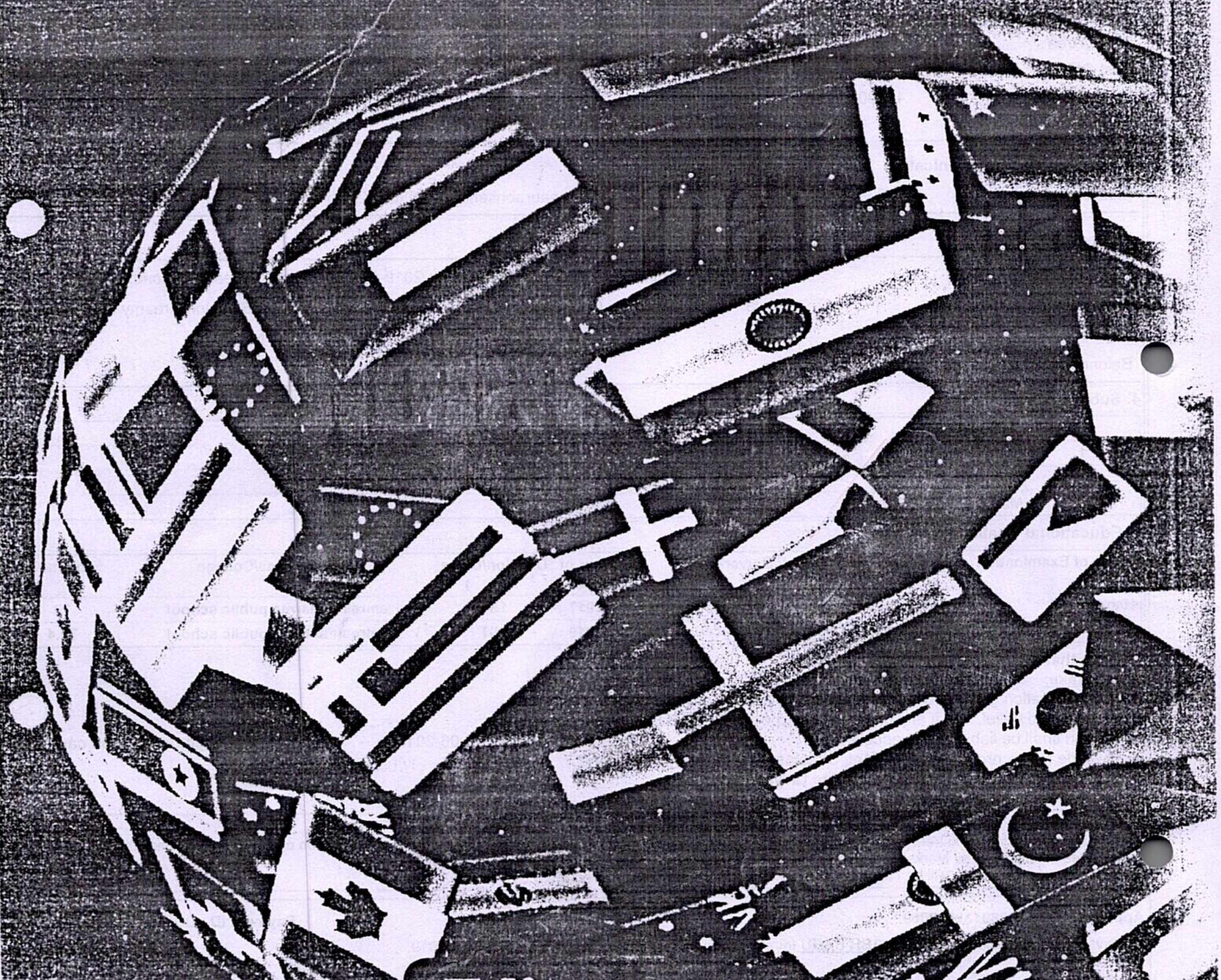

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CONTENT

Chapter - 6

INDIA'S RELATIONS WITH ITS NEIGHBOURS

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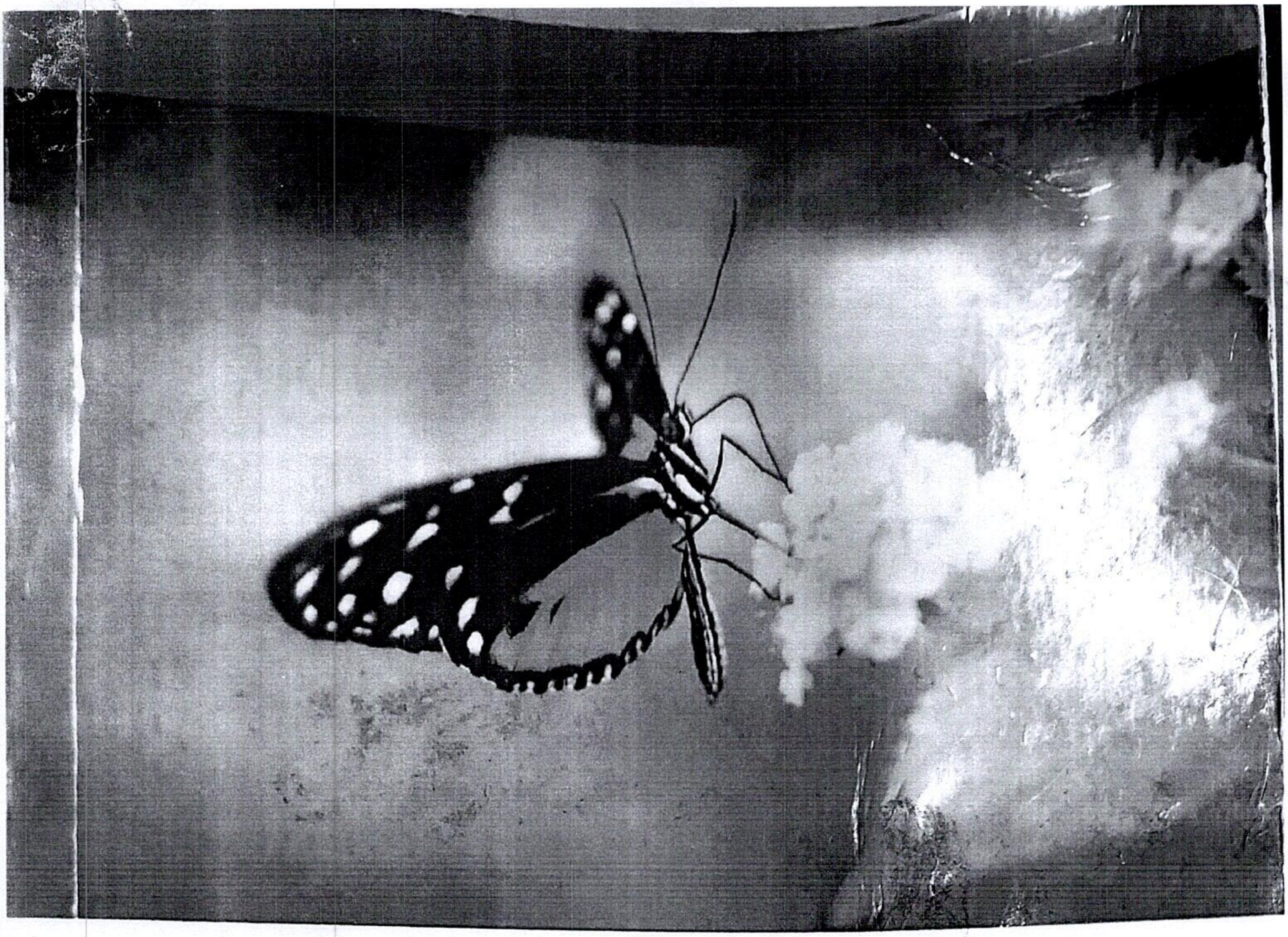
ABSTRACT

This chapter examines the relations of India with its neighbouring countrie. economic, cultural and diplomatic arenas and how these relations have evolved o the years. India's immediate neighborhood consists of nine nations that are not onl close proximity but also share historical, religious, ethnic, economic, security cultural ties. Post-independence, India's foreign policy focused mainly on forging relationships with other nations for mutual benefits& development. The developm projects of India in its neighborhood focusing basically on capacity buildi development of media & information technology, upgradation of educational facili and human resource development have been discussed. Initiatives taken to strengt the relations through high level exchanges, signing of various agreements, increa connectivity and promotion of people-to-people ties are highlighted. It also gives account of the manner in which the partnerships among the neighbors have progres and what were the areas of conflict & discord between them.

INTRODUCTION

India has always given due consideration & importance to its neighborho Principles of non-interference & non-alignment have dominated India's foreign po apart from having a blend of security, economic & moral imperatives. After adopt economic reforms in the 1990s, India's approach shifted from idealism to pragmati It preferred the route of soft power diplomacy wherein it emphasized culture, value people centric policies rather than coercion or military force.

Two policies, namely 'Neighborhood First' & 'Act East' of the central governm prioritize the need for exploiting strategic opportunities and strengthening India's relat



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CONTENTS

Diversity of Actinomycetes in India: a review based on Past Decade

M G Roymon and Priyambnda Singh

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1. Introduction

Biological diversity or biodiversity is that part of nature which includes the differences in genes among the individuals of a species; the variety and richness of all organisms at different scales in space – locally, in a region, in the country and the world; and the types of ecosystem, both terrestrial and aquatic, within a defined area. The diversity of life on earth is so great that if we use it sustainably we can go on developing new products for many generations. A large variety of ecosystem exists on earth, each with their own complement of distinctive interlinked species based on differences in the habitat. Distinctive ecosystems include landscapes like forest, grasslands, deserts and mountains as well as aquatic ecosystem like rivers, lakes and seas (Bharucha, 2013).

Microorganisms are important component of biosphere and play important role in maintaining the ecological balance. The development of molecular biology techniques has increased the researches on microbial diversity from morphological or protein level to molecular level (Li and Zhang, 2012). Microbial diversity is represented by genotype frequency of whole genome pool of a microbial community. Among all living organisms, the complexity and diversity of microbial population is highest and their ecological roles are being explored in soil, water, on plants and in animals and extreme environments such as arctic deep sea vents or hyper saline lakes (Liao and Huang, 2012). Study of biodiversity is important for those biological species that are screened specifically for their value as producers of organic compounds known as secondary metabolites. Not even 10% of microbial diversity has been tapped because of the fact that early 99% of bacteria have eluded culture by traditional techniques (Lal, 2007).

Actinomycetes are prokaryotic spore forming gram positive bacteria with a high G + C content in their DNA ranging from 51% in *Corynebacteria* to more than 70% in *Streptomyces* and *Frankia* (Ventura *et al*., 2007). They are free living, saprophytic bacteria and due to their filamentous nature, branching pattern and conidia formation as similar as fungi they are also known as ray fungi (Balakrishna *et al*, 2011). They are most widely distributed group of microorganisms in nature and due to their

diversity and ability for the production of most of the discovered bioactive secondary metabolites, mainly antibiotics (Dasari *et al*, 2011; Singh *et al*, 2012). Enzymes (Lam kin, 2006). Enzyme inhibitors (Sathiyaseelan and Stella, 2012). Immunosuppressive agents (Berdy, 2005). holds a prominent position as targets in screening programs. The class Actinobacteria includes some of the resilient species which can easily adapt in various conditions making them capable of growing in extreme, hostile and polluted environment (Ballav *et al*, 2012). Over 22, 00 bioactive microbial compounds (including antibiotics) were published on the scientific and patent literature and about a half of them were produced by Actinomycetes (Jiang *et al*, 2013). About 150 antibiotics are in direct practical use in human therapy and most of them were derived from Actinomycetes species (Berdy, 2005). And from these common Actinomycetes the rate of discovery of new compounds has declined, therefore improved methodologies for isolating the uncommon and rare Actinomycetes from the diverse habitats is required to avoid the re isolation of same strains that produce known bioactive compounds and to improve the quality of natural products screened (Takahashi and Omura, 2003; Berdy, 2005).

The Phylum Actinobacteria is large and very complex; it contains one class (Actinobacteria), 5 subclasses, 6 orders 14 suborders and 44 families. Most of the genera reported in the following review are in the subclass *Actinobacteridae* and order *Actinomycetales*, that is divided into 10 suborders.

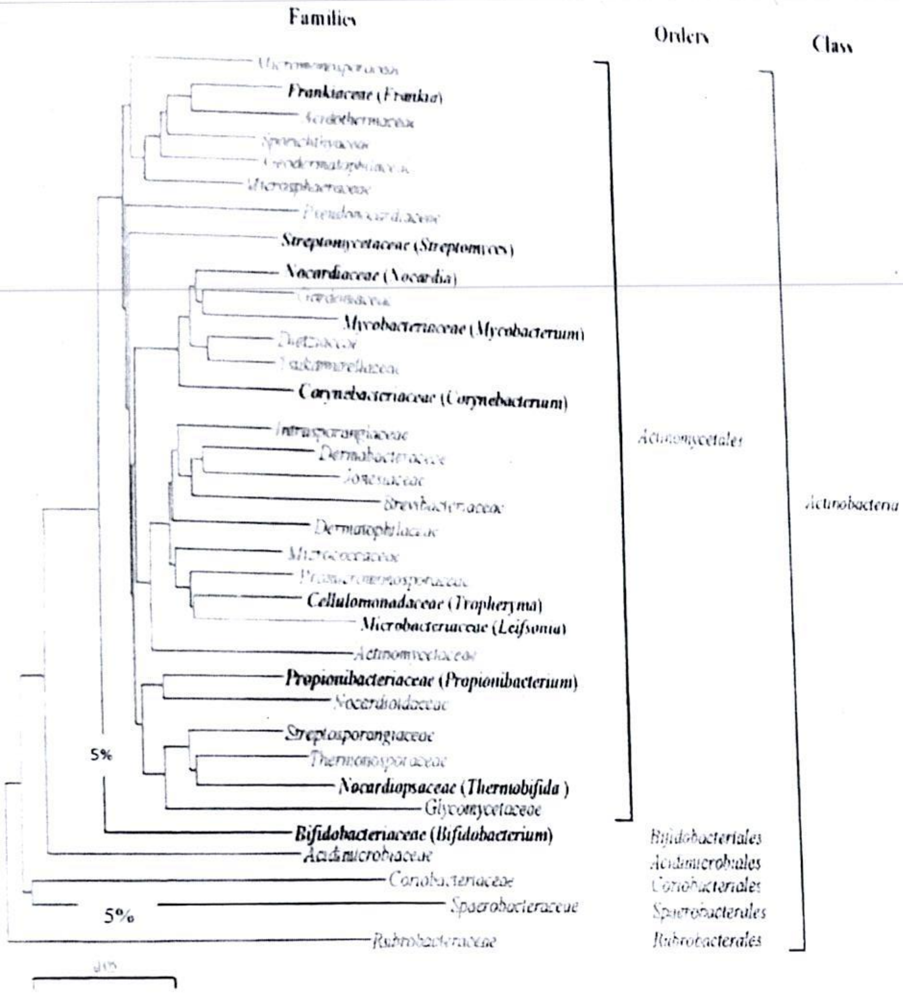

Fig.1 **Classification of the Phylum *Actinobacteria.*** The phylogenetic relationships between orders, suborders, and families based on 16S rRNA data are shown, having 5 nucleotide substitution per 100 nucleotides (Stackbrandt *et al*, 1997).

Review of literature

For the screening of potential Actinobacteria, less than one part of Earth's surface has been explored and approaches for exploration of random and exotic habitats would accelerate the production of bioactive substances from the Actinobacteria (Baltz, 2007). Large numbers of Actinomycetes are free living and found widely distributed in many natural environments and the niche habitats such as terrestrials caves, pristine forests, organic matter, aquatic environment like lakes, rivers, and wetlands, high salt environments, marine ecosystems, endophytic niches and gut of animals are promising targets for survey of bioactive Actinomycetes.

2.1 Distribution of Actinomycetes in natural habitats in India

In India various locations have been screened for studying diversity of Actinobacteria in which the Soil habitats (96%) have been largely surveyed as compared to other resources like endophytic plants (3%) and animal guts (1%) and for water, the marine resources (85%) is much higher than freshwater resources (15%) (Pereira and Kamat, 2013).

2.1.1 Actinomycetes in soil

The soil Actinomycetes gives earthy smell to the soil when water falls on it by producing a volatile compound called geosmin (Gust *et al*, 2003). Actinomycetes are found in various types of soils including rice paddy, agricultural fields, tropical forests, hills and natural caves (Jayasinghe and Parkinson, 2008). The isolation of Actinomycetes from soil is done by serial dilution method and plating them onto the media containing appropriate carbon and nitrogen source supplemented with specific antibiotics like Nystatin, Actidione, Polymyxin B sulphate, Penicillin, Novobiocin, Gentamicin, Rifampicin for preferential genus. Researches on the diversity of Actinomycetes from different ecological niches of terrestrial ecosystem from India, has led to the isolation of 26 genera, with most dominant being the *Streptomyces* followed by *Micromonospora*, *Actinomadura*, *Rhodococcus*, *Microbispora*, *Nocardia* and others (Pereira and Kamat, 2013)

Table.1. Actinomycetes genera isolated by different investigators from soidecade

S. No.	Actinomycetes taxa	Geographical location	Reference
2003			
1	*Rhodococcus* sp. nov., *Thermomonospora* sp. nov.	Novel extremophiles isolated from self heating compost soil	Ahmad *et al*, 2003a,b
2	*Streptomyces* CIMAP A1 sp. nov.	Novel strain from Geranium rhizosphere (US patent)	Alam *et al*, 2003
3	*Streptomyces* sp. *Streptomyces cyaneus*, *Streptomyces jendae*	Areas in Amritsar, Punjab	Gill *et al*, 2003
2004			
1	*Streptomyces* sp	Pune, Maharashtra	Augustine *et al*, 2004
2	*Streptomyces violaceusniger*	Soil from hospital surroundings, Lucknow, UP	Tripathi *et al*, 2004
2005			
1	*Streptomyces albidoflavus* PU 23, *Streptomyces rochei* AK 39	Pune, Maharashtra	Augustine *et al*, 2005a,b
2	*Planococcus stackbrandtii* sp. nov.	Novel species isolated from cold desert of Himalayas	Mayilraj *et al*, 2005
3.	*Actinoallotheicus spittiensis* sp. nov.	Novel species isolated from cold desert of Himalayas	Singla *et al*, 2005
2006			
1.	*Agrococcus lahaulensis* sp. nov. *Kocuria himachalensis* sp.nov. *Rhodococcus kroppenstedtii* sp. nov.	Novel species isolated from Lahaul–Spiti Valley in the Indian Himalayas	Mayilraj *et al*, 2006a, b, c
2.	*Kitasatospora sampliensis*	Novel species isolated from sugarcane field in Punjab	Mayilraj *et al*, 2006d
3.	*Streptomyces sannanensis* RJT-1	Alkaline soil from the Saurashtra University Campus, Rajkot, Gujarat	Vasavada *et al*, 2006
2007			
1.	*Streptomyces gulbargensis* sp. nov.	Novel alkalotolerant species, Gulbarga, Karnataka	Dastager *et al*, 2007

S. No.	Actinomycetes taxa	Geographical location	Reference
2.	*Streptomyces sampsonii*	Garden soil, Sagar, Madhya Pradesh	Jain and Jain, 2007
3.	*Streptomyces viridogen*, *Streptomyces rimosus*, *Streptomyces phaeoviridis* and *Streptomyces griseoloalbus*	Pirpanjal range, Himalaya Mountain	Radhakrishnan *et al*. 2007
4.	*Streptomyces* sp	Forest areas from Kaziranga national park, Assam and Tripura	Thakur *et al*, 2007
5.	*Streptomyces* sp	Rhizosphere soils of different medicinal plants in Kolli Hills-Tamilnadu	Thangapandian *et al*. 2007
2008			
1.	*Saccharomonospora saliphila* sp. nov.	Novel halophilic species from muddy soil in Karnataka	Dastager *et al*, 2008
2.	*Streptomyces fulvissimus*	Gangetic Belt soil, Kanpur	Malik *et al*, 2008
3.	*Kochuria* sp. RM1	Red mud soil, NALCO, Damanjodi, Orissa	Krishna *et al*. 2008
2009			
1.	*Streptomyces gulbargensis*	Gulbarga, Karnataka	Dastager *et al*. 2009
2.	*Streptomyces griseus*	Areas in Andhra Pradesh	Gurram *et al*, 2009
3.	*Streptomyces hygroscopicus* subsp. *ossamyceticus*	Thar desert, Rajasthan	Selvameenal *et al*. 2009
2010			
1.	*Yaniella fodinae* sp. nov.	Novel species from coal mine, West Bengal	Dhanjal *et al*. 2010
2.	*Nocardia and Streptomyces*	Laterite soil samples of Guntur region, Andhra Pradesh	Kavitha and Vijayalakshmi, 2010
3.	*Streptomyces* sp	Western ghat, Agumbe, Karnataka	Kekuda *et al*. 2010
4.	*Dactylsporangium* sp., *Intrasporangium* sp., *Micromonospora* sp., *Streptomyces* sp., *Streptoverticilium* sp.	Rohtang Hill, Himachal Pradesh	Raja *et al*., 2010
5.	*Saccharopolyspora* sp. *Saccharomonospora*, *Streptomyces* sp.	Amrithi Forest, Tamil nadu	Umarsankar *et al*. 2010
2011			
1.	*Agrococcus carbonis* sp. nov.	Novel species isolated from coal mine, Bonjemehari	Dhanjal *et al*. 2011

		colliery, West Bengal	
2	*Streptomyces* sp.	Coal mine soils, Andhra Pradesh	Gopinath *et al*, 2011
3	*Streptomyces* sp.	Ooty tea plantation region, Karnataka	Mythili and Das, 2011
4	*Streptomyces* sp.	Western Ghats	Mohana Priya *et al*, 2011
5	*Streptomyces rimosus*, *Streptomyces chromogenus*, *Streptomyces rouchi-3*, *Streptomyces antibioticus-3*, *Streptomyces filipinensis*, *Streptomyces atroolivaceus*, *Streptomyces exfoliatus-2*, *Streptomyces halstedii*, *Streptomyces cyaneus*, *Streptomyces violaceus*, *Streptomyces olivaceoviridis*, *Streptomyces lydicus*, *Streptomyces phaeochromogenes*, *Streptomyces chromofuscus*	Rhizosphere of plants, agricultural soil, preserved areas and forest soils of Durg District of Chhattisgarh.	Singh *et al*, 2011
6	*Micromonospora* sp., *Micropolyspora* sp.	Manali Ice point, Himachal Pradesh	Raja and Prabhakaran, 2011
7	*Streptomyces* sp, *Micromonospora* sp. *Nocadia* sp	Different areas of Coimbatore	Rakshanya *et al*, 2011
8	*Streptomyces hyderabadensis* sp. nov.	Novel species isolated from Hyderabad	Reddy *et al*, 2011
9	*Streptomyces* sp. VITTKGB	Agricultural soils of Vellore	Panigrahi *et al*, 2011
10	*Streptomyces aurantiacus*	Humus soil of Western Ghats, Karnataka	Vijayabharathi *et al*, 2011
11	*Streptomyces* MSL	laterite soil, Guntur region	Vijayalakshmi *et al*, 2011
2012			
1.	*Streptomyces* sp.	Rhizosphere region of plants of Nallamala forest	Balakrishna *et al*, 2012
2.	*Streptomyces* sp.	Kuruva Island, Kerala	Boroujeni *et al*, 2012
3.	*Streptomyces sp.*	Drainage and Forest areas of Gwalior, Madhya Pradesh	Chaudhary *et al*, 2012
4.	*Nocardiopsis alba* OK-5	Salt enriched soil of Okha, Gujarat	Gohel *et al*, 2012
5.	*Microbacterium immunditiarum* sp. nov.	Novel species from surface of landfill soil, Chandigarh	Krishnamurthy *et al*, 2012
6.	*Kitasatospora*, *Nocardia*, *Streptomyces*,	Fired plots, Shifting cultivation of Northeast	Malviya *et al*, 2012

		region	
7.	*Actinoplanes*, *Kitasatosporia*, *Micromonospora*, *Microbispora*, *Nocardia*, *Streptomyces*, *Streptoverticillium*,	Hypersaline soils of Kolhapur district	Nakade *et al*, 2012
8.	*Streptomyces manipurensis* sp. nov.	Novel species from lime stone quarry, Manipur	Nimaichand *et al*, 2012
9.	*Streptomyces* sp.	Rhizosphere of herbaceous plants	Salahuddin *et al*. 2012
10.	*Streptomyces* sp.	Western Ghats of Kanyakumari, Tamilnadu	Valan Arsha *et al*, 2012
2013			
1.	*Streptomyces* sp.	Coal mines of Godavari belt soil.	Gopinath *et al*, 2013
2.	*Actinomadura*, *Amycolatopis*, *Geodermatophilus*, *Intrasporangium*, *Micromonospora*, *Microbispora*, *Nocardia*, *Nocardiodes*, *Nocardiopsis* *Planobispora* *Saccharopolyspora*, *Streptomyces*, *Streptosporangium*, , *Thermoactinomycetes*	Hills of Uttarakhand	Kumar *et al*, 2013
3.	*Actinomadura* spp., *Micromonospora* spp *Nocardia* spp., *Nocardiopsis* spp., *Rhodococcus spp*., *Saccharomonospora* spp., *Streptomyces* spp.	Bamboo forest, Serghadama forest of Kodagu, Karnataka	Khandan and Janardhana. 2013
4.	*Streptomyces* sp.US 7	Different localities of Patna, Bihar	Kumari *et al*, 2013
5.	*Rhodococcus canchipurensis* sp. nov.	Novel species isolated from Limestone quarry, Manipur	Nimaichand *et al*, 2013
6.	*Actinomadura*, *Kib-delosporangium* *Kitasatosporia*, *Nocardiopsis*, *Pseudono-cardia*, *Streptomyces* *Streptoverticillium*	Paddy fields in Tiruchirappalli district, Tamilnadu	Priyadharshini and Dhanasekaran, 2013

In the past decade, seventeen novel taxa of actinomycetes had been isolated from different terrestrial niches in India (Table no. 1). Among these novel strains, four belongs of the genus *Streptomyces*; three belongs to each of the genus *Agrococcus* and *Rhodococcus*; and one from each of the genus *Actinoallotheicus*, *Kitasatospora* *Microbacterium*, *Planococcus*, *Saccharomonospora*, *Thermonomospora* and *Yaniella*.

2.1.2. Actinomycetes in aquatic environment

A variety of aquatic ecosystem such as World oceans, lakes, rivers, springs, ponds and ground water render the majority of living space on Earth. Actinomycetes are found to occur also in various aquatic environment including fresh water and marine habitats (Singh *et al*, 2008). Taxonomically diverse group of Actinomycetes, exhibit unique physiological and morphological characteristics in aquatic environment, which enables them to survive in extreme physical conditions such as pressure, salinity and temperature. The Oceans are the source of inexhaustible resources, covers more than 70% of Earth's surface and very little is known about the microbial diversity of marine sediments and yet unexploited. India has a long coast line of over 7,500 km and an area of 2.02 million square km as exclusive economic zone with very richest biodiversity and gives us an opportunity to investigate and ultimately for the economic uplift of India (Ramasamy *et al*, 2007).

Marine habitats like coastal sediment, deep sea floors and coral reefs and harbors contains unique micro flora which could be potential sources for bioactive compounds. Sivakumar *et al*, (2007) have reviewed Actinobacteria, antagonistic to varoius human, plant and fish pathogens from several marine habitats in India. The marine Actinobacterial research in India has been considerably in progressive. Significant efforts have been made in screening their metabolites against numerous plant and animal pathogens (Ramasamy *et al*, 2007). Both freshwater and marine habitats are dynamic in nature. Various genera of Actinomycetes are reported to be distributed in marine habitats of India such as, Marine sediments (Sujatha *et al*, 2005), Estuaries (Kathiresan *et al*, 2005; Vimal *et al*, 2009), Mangroves (Sivakumar *et al*, 2005; Anisha and Prema, 2006), Saltpans (Vijaykumar *et al*, 2012), Lagoons (Subramany and Narayanasamy, 2009), Coastal areas (Neladevi *et al*, 2005; Gorajana *et al*, 2010). Continental shelf (Augustine *et al*, 2013). Pereira and Kamat, (2013) reviewed that researches on marine habitat have yielded 30 Actinobacterial genera, with genus *Streptomyces* being the major component of total Actinobacterial population followed by genus *Micromonospora*, *Actinopolyspora*, *Seccharopolyspora*, *Actinomadura* and others.

Table.2. Actinomycetes genera isolated by different investigators from water in past decade

S. No.	Actinomycetes taxa	Geographical location	References
1.	*Streptomyces sp.* B6921	Sediment of India Ocean	Maskey *et al*, 2003
2004			
1.	*Actinopolyspora* species AH1	Alibag coast, Maharashtra	Kokare *et al*, 2004a
2.	*Actinopolyspora, Catellatospora, Nocardia, Streptomyces, Streptoverticillium*	Alibag, Jangira and Goa Coast line	Kokare *et al*, 2004b
2005			
1.	*Streptomyces chibaensis* AUBN1/7	Bay of Bengal, Vishakhapatnam, AndraPradesh	Gorajana *et al*, 2005
2.	*Actinomyces aurionmonopodiales, Streptomyces albidoflavus, Streptomyces fradiae, Streptomyces galtieri, Streptomyces helvaticus Streptomyces orientalis, Srteptomyces roseiscleroticus, Streptomyces roseolilacinus, Streptomyces sclerotialus*	Vellar estuary, Gulf of Kutch, Charo Island, Gulf of Mannar, Pichavaram, Kakinada Bay, Bhitarkanika , and Sundarbans	Kathiresan *et al*, 2005
3.	*Streptomyces psammoticus*	West coast of India	Niladevi and Prema, 2005
4.	*Streptomyces* sp.	Pichavaram mangrove, Tamilnadu	Sweetline *et al*, 2005
5.	*Streptomyces albidoflavus, Streptomyces aureocirculatus, Streptomyces clavifer, Streptomyces galtieri, Streptomyces gibsonii, Streptomyces kanamyceticus, Streptomyces xantholiticus, Streptomyces roseolilacinus*	Sediments of Pichavaram mangrove, Tamilnadu	Sivakumar *et al*, 2005a,b
6.	*Streptomyces, Micromonospora, Nocardia , Streptoverticilium Saccharopolyspora*	Andama coast of Bay of Bengal	Sujatha *et al*, 2005a
7.	*Streptomycete* BT-408	Sediments of Bay of Bengal	Sujatha *et al*, 2005b
2006			
1.	*Streptomyces corchorusii* AUBN(1)/7	Marine sediment of bay of bengal	Adinarayana *et al*, 2006

2.	*Streptomyces* sp	Mangrove region of West coast of India	Anisha and Prema, 2006
3.	*Streptomyces* sp.	Sediments from Parangipettai and Cochin coastal areas	Dhevagi and Poorani, 2006
4.	*Streptomyces aureofasciculus, Streptomyces vastus Streptomyces violaceus*	Vellure estuary, Tamilnadu	Sahu *et al*, 2006
2007			
1.	*Streptomyces galbus*	Seashore zone, Vellar estuary, Tamilnadu	Sahu *et al*, 2007a
2.	*Streptomyces xantholiticus, Streptomyces aureofasciclus, Streptomyces galtieri, Streptomyces vastus, Streptomyces galbus, Streptomyces. rimosus*	Naval area, Chandra nallah, Andaman Islands	Sahu *et al*, 2007b
3.	*Streptomyces, Actinopolyspora, Saccharopolyspora, Actinomadura, Nocardiopsis, Micromonospora, Actinomyces, Actinoplanes, Microbispora*	Sediments of Palk Strait region of Bay of Bengal, West Bengal	Vijayakumar *et al*, 2007
2008			
1.	*Streptomyces krainskii* SUK – 5	Krishna river, Maharashtra	Mane and Deshmukh, 2008
2.	*Actinopolyspora, Actinosynnema, Actinomadura Glycomyces, Kibdelosporangium, Kineosporia Nocardiopsis Nocardiodes Nocardi, Saccharopolyspora, Streptomyces, Thermoactinomycetes*	West Coast, Ernakulam to Kannur	Remya and Vijayakumar, 2008
3.	*Streptomyces roseiscleroticus*	Shrimp pond, Southeast coast of India	Vonothini *et al*, 2008
2009			
1.	*Streptomyces* sp.	Marine samples from Tamilnadu	Basha *et al*, 2009
2.	*Nocardiopsis prasina* HA-4	Biotope, Manipur	Nigthoujan *et al*, 2009a
3.	*Streptomyces* sp.	Loktak river, Manipur	Nigthoujan *et al*, 2009b

4.	*Streptomyces bikiniensis*	Vellure eastuary, Tamilnadu	Dhanasekaran *et al*. 2009
5.	*Streptomyces, Streptoverticillium*	Lonar lake, Gujarat	Kharat *et al*, 2009
6.	*Streptomyces* sp.	Ennore saltpan, coastal regions of Tamil Nadu	Lakshmipathy and Krishnan, 2009
7.	*Streptomyces canus, Streptomyces pseudogriseolus, Micromonospora brevicatiana*	Krishna River in Satara district	Mane and Deshmukh, 2009
8.	*Streptomyces tanashiensis* strain A2D	Loktak Lake, Manipur	Singh *et al*, 2009
9.	*Streptomyces* sp.	Pulicut lagoon, Kanyakumari, Tamilnadu	Subramani and Narayanasamy, 2009
10.	*Saccharopolyspora salina* VITSDK4	Marakkanam coast of Bay of Bengal	Suthindhiran Kannabiran, 2009
11.	*Nocardiopsis* sp. VITSVK5	Marine sediment, Puducherry coast	Vimal *et al*, 2009
2010			
1.	*Acitomycetes, Micromonospara, Nocardia, Streptomyces*	Karanjal region Sundarban West Bengal	Arifuzzaman *et al*, 2010
2.	*Streptomyces olivochromogenes*	Mangrove system of Parangipettai coastal area	Balagurunathan *et al*, 2010
3.	*Actinosynnema, Gordona, Intrasporangium, Kitasatospora, Micromonospora, Nocardia, Nocardiodes Pseudonocardia, Rhodococcus, Streptoalloteichus. Streptomyces*	Vembanadu - Kol Wetland, Kerala	George *et al*, 2010
5.	*Streptomyces albovinacius*	Machilipatnam coast of Bay of Bengal	Gorajana *et al*, 2010
6.	*Streptomyces gedanensis*	Nicobar Islands	Karthrik *et al*, 2010
7.	*Streptomyces orientalis*	Ennor saltpan, Tamil nadu	Lakshmipathy and Kannabiran *et al*, 2010
8.	*Actinopolyspara, Actinomadura Actinomyces, Nocardiopsis Micromonospara, Streptomyces*	Chennai harbor, Nagapattinum Mandap Tuticorn, Kanyakumari	Manivasagan *et al*, 2010

9.	*Streptomyces albogroseolus, Streptomyces aureocirculatus Streptomyces raceochromogenes Streptomyces achromogenes Streptomyces furlongus*	Chinnamuttan and Pallam coast in Arabian Sea	Ravikumar *et al*, 2010
10.	*Streptomyces* sp.	Pondicherry coast	Suthindhiran and Kannabiran, 2010
11.	*Streptomyces* sp.	Point Calimere, East coast of India	Vijayakumar *et al*, 2010
2011			
1.	*Streptomyces sundarbansensis* sp. nov.	Novel species from sundarban mangrove ecosystem	Arumugam *et al*, 2011
2.	*Streptomyces coelicolor*	Lonar Lake, Maharashtra	Avinash *et al*, 2011
3.	*Streptomyces* sp.	Andaman and Nicobar Islands	Baskaran *et al*, 2011
4.	*Sacchropolyspora* sp.	Marine sediment of west coast of India	Chakraborty *et al*, 2011
5.	*Amycolatopsis alba var* nov. DVRDG	Novel species from Bay of Bengal, Vishakhapatnam	Dasari and Donthireddy, 2011
6.	*Actinobispora yunnanensis Actinosynnema pretiosum, Actinoplanes brasiliensis Agromyces ramosu Actinomadura citrea, Catellatospora citrea Jonesia denitrificans Micromonospora echinospora Microtetrospora fastidiosa Nocardia amarae, Pseudonocardia thermophila, Saccharothrix australiensis, Saccharomonospora viridis, Saccharopolyspora hirsute, Streptoverticillium album, Streptomyces albus, Streptomyces rochei. Streptomyces anulatus, Streptomyces cyaneus, Streptomyces microflavus*	Saltpan, Nagapattinum, Tamilnadu	Gayathri *et al*, 2011
7.	*Intrasporangium, Micromonospora,*	Sundarban mangrove	Gluve and

		ecosystem	Deshmukh, 2011
8.	*Streptomyces carpaticus*	Sediment of Kakinada, Andhra Pradesh	Haritha *et al*, 2011
9.	*Streptomyces* sp.	Saltpan, Tuticorin	Jose *et al*, 2011
10.	*Kocuria assamensis* sp. nov.	Novel species from Bramhaputra River, Assam	Kaur *et al*, 2011
11.	*Streptomyces* sp.	Cape Comurin coast	Krishnakumar *et al*, 2011
12.	*Actinomadura, Micromonospora*	Mangrove sediment of Karwar	Naikpatil *et al*, 2011
13.	*Streptomyces* sp.	Thadhasamudram pond in Kanchipuram, Tamilnadu	Radhika *et al*, 2011
14.	*Nocardiopsis, Pseudonocardia, Streptomyces*	Biotope, Loktak Lake, Manipur	Sanasam *et al*, 2011
15.	*Streptomyces* sp.	Manakudi estuary in Arabian Sea	Satheeja *et al*, 2011
16.	*Actinomadura roseale, Streptomyces citricolor, Streptomyces kavamyceticus, Streptomyces platensis, Streptomyces spectabilis*	Parangipettai coastal area	Sathiyaseelan and Stella, 2011
17.	*Georgenia satyanarayani* sp. nov.	Novel species from Soda Lake in Lonar	Srinivas *et al*, 2011
18.	*Streptomyces* VITSTK7	Bay of Bengal, Pondicherry	Thenmozi and Kannabiran, 2011
19.	*Streptomyces caeruleus, Streptomyces maritimus*	Sea coast of Nizampattnam, Guntur	Vijayalakshmi *et al*, 2011
20.	*Streptomyces sclerotialus*	Hotspring, Rajgir	Yadav *et al*, 2011
2012			
1.	*Agromyces indicus* sp. nov.	Novel species from mangrove sediment of Chorao Island, Goa	Dastager *et al*, 2012
2.	*Streptomyces albus gangavarms*	Sediments of Vishakhapatnam coast	Kumari *et al*, 2012
3.	*Streptomyces rimosus, Streptomyces fradiae, Streptomyces griseoflavus*	Marine soil	Nimbekar *et al*, 2012

4.	*Actinomyces israeli*, *Actinomyces radingae*, *Actinomyces turiansis*, *Frankia alni*, *Nocardia asteriacea*	Coastal areas of Tamilnadu	Praseetha *et al*, 2012
5.	*Streptomyces*, *Streptomycetaceae*	Marine sediment from Kearala	Rajan *et al*, 2012
6.	*Actinomadura*, *Actinomyces*, *Actinopolyspora*, *Micromonospora*, *Nocardiopsis*, *Saccharopolyspora*, *Streptomyces*	Bhitherkanika Mangroves, Orissa	Rajkumar *et al*, 2012
7.	*Streptomyces* sp.	Mangrove region, Vishakhapatnam	Rao *et al*, 2012
8.	*Streptomyces* sp.	Pichavaram mangrove ecosystem	Sathiyaseelan and Stella, 2012; Sweetline *et al*, 2012
9.	*Streptomyces* sp, *Streptomyces rubralavandulae*, *Streptomyces cacaoi*, *Streptomyces cavourensis*, *Streptomyces avidinii*, *Streptomyces globisporus*, *Streptomyces variabilis*, *Streptomyces coelicolor*	Marine samples from Tamil nadu	Sudha *et al*, 2012
10.	*Streptomyces* sp.	Mahabalipuram Seashore and Adyan estuary	Valli *et al*, 2012
11.	*Streptomyces* sp. VPTSA18	Salt pan in Vedaranyam	Vijayakumar *et al*, 2012
2013			
1.	*Streptomyces*, *Nocardiopsis*	Continental self and slope of South west and east coast	Augustine *et al*, *2013*
2.	*Streptomyces* sp.	Elephanta, Radhanagar and Havelok beach of Andman and Nicobar Islands	Abirami *et al*, 2013
3.	*Actinokineospora*, *Actinopolyspora*, *Dactylosporangium*, *Microtetraspora*, *Nocardiopsis*, *Sacchromonospora*, *Streptoverticillium*, *Streptomyces griseus*, *Streptomyces salina*, *Streptomyces venezuelae*	Andman and Nicobar Islands	Balakrishnan *et al*, 2013
4.	*Actinomadura*, *Actinomyces* *Actinopolyspora*, *Micromonospora* *Nocardiopsis*, *Streptomyces*	Marine sediments, Vellappallam, Tamilnadu	Deepa *et al*, 2013a

5.	*Streptomyces griseoflavus*	Nagapattinam, Palk Strait region, Nagapattinum	Deepa *et al*, 2013b
6.	*Actinopolyspora* sp., *Streptomyces* sp.	Ramakrishna beach, Andhra Pradesh	Devi *et al*, 2013
7.	*Streptomyces* sp.	Nagapattinam, Bay of Bengal	Gunasekaran and Thangavel, 2013
8.	*Micromonospora*, *Streptomyces* sp.	Manakondur and Kothapally Pond of Karimnagar, Andhra Pradesh	Gunda and Charya, 2013
8.	*Actinokineospora*, *Actinopolyspora*, *Amycolata*, *Glycomyces*, *Microbispora*, *Microtetraspora*, *Micropolyspora*, *Nocardia*, *Nocardiopsis*, *Promicromonospora*, *Saccharothrix*, *Saccharopolyspora*, *Streptomyces microflavus*, *Streptoverticillium*, *Spirillospora* *Thermomonospora*.	Mangrove environment of Ennor, East coast, Tamilnadu	Karthikeyan *et al*, 2013
9.	*Streptomyces* sp.	Coringa mangrove and Nizampattnam mangrove system	Mangamuri *et al*, 2013
10.	*Steptomyces* sp.	Tiruchendur and Kulasekarapattinam	Mantada *et al*, 2013
11.	*Nocardiopsis*, *Streptomyces*	South east coast, Bay of Bengal	Mohan *et al*, 2013
12.	*Streptomyces* sp.	Marine sediments of Pongibalu area	Poosarla *et al*, 2013
13.	*Streptomyces* sp.	Marakkam coast, Bay of Bengal	Rajan and Kannabiran, 2013; Revathy *et al*, 2013
14.	*Streptomyces* sp.	Mangrove ecosystem, Vishakhapatnam	Rao and Rao, 2013
15.	*Streptomyces chilikensis* sp. nov	Novel species from brackish water lagoon of Chilka Lake, Orissa	Ray *et al*, 2013

16	*Micromonospora, Nocardia, Streptomycetes, Streptosporangium*	Bay of Bengal, Southeast coast	Sirisha *et al*, 2013
17.	*Streptomyces* sp.	East coast region, Tamilnadu	Thirumurugan and Vijayakumar, 2013

In the past decade, six novel taxa of actinomycetes had been isolated from different aquatic ecosystems in India (Table No. 2). Among these novel strains, two belongs to the genus *Streptomyces*; and one from each of the genus *Agromyces, Amycolatopis* ,*Georgenia* and *Kocuria*.

2.1.3 Actinomycetes of Endophytes

Endophytic Actinobacteria are known to be found as symbionts within the different parts of plants such as leaves, stem, roots, fruits, seeds etc. The tropical and temperate regions are having greatest diversity of endophytes (Strobel and Daisy, 2003). Endophytic Actinobacteria, especially from the genus *Streptomyces* are important prokaryotic organisms because they produce different secondary metabolites such as antibiotics, antitumor agents, enzyme inhibitors and immunomodifiers (Stach *et al*, 2003). They have been demonstrated to promote and improve growth of host plants as well as to reduce disease symptoms caused by plant pathogens or under various environmental stresses. Endophytic actinomycetes integrated with the medicinal plants of tropical region could be a source of functional metabolites (Strobel *et al.* 2004). They are mainly isolated from the roots than other parts of the plants indicating that endophytic actinomycetes are soil inhabiting actinomycetes which readily move from soil to contacting roots (Verma *et al*, 2009). They reported that among endophytes *Streptomyces* (49.09%) is dominating genera followed by *Streptosporangium* (14.5%), *Microbispora* (10.9%), *Streptoverticillium* (5.5%), *Sacchromonospora* (5.5%) and *Nocardia* (3.6%). The abundance and diversity of endophytic actinobacterial colonisation depends upon the plant species, type of soils and other associated environmental conditions (Govindswamy *et al*, 2014).

Table.3. Endophytic Actinomycetes genera isolated by different investigators in past decade in India.

S. No.	Actinomycetes Taxa	Plants	References
1.	*Microbispora, Nocardia, Streptomyces, Streptosporangium, Streptoverticillium*	*Azadirachta indica A. Juss* (Stem, leaves and roots)	Verma *et al.* 2009
2.	*Actinopolyspora, Sleromonospora, Saccharopolyspora Streptomyces*	*Aloe vera, Mentha arvensis and Ocimum sanctum* (Roots, stems and leaves)	Gangwar *et al*. 2011
3.	*Streptomyces cavourensis*	*Catharanthes roseus (L.)*(leaves, stem and roots)	Kafur and Khan, 2011
4.	*Streptomyces* sp.	*Emblica officinalis* (fruits, twigs and leaves)	Kumar *et al*, 2011
5.	*Streptomyces* sp.	*Coelogynae ovalis Lindl*	Gandotra *et al*, 2012
6.	*Streptomyces* sp.	*Citrus aurantifolia* (fruit)	Kandpal *et al*. 2012
7.	*Streptomyces* sp.	*Phyllanthus niruri, Withania somnifera, Catharanthus roseus and Hemidesmus indicus*	Mini Priya, 2012
8.	*Streptomyces* sp.	*Azadiracta indica, Ocimum sanctum* and *Phyllanthus amarus*	Shenpagam *et al*, 2012
9.	*Streptomyces coelicolor*	*Avicennia marina* and *Rhizopora apiculata* (Stems and roots)	Gayathri and Muralikrishnan, 2013
10.	*Streptomyces* sp.	*Vanda spathulata* (Roots)	Senthilmurugan *et al*, 2013

2.1.4 Other habitats of Actinomycetes

Despite of terrestrial, aquatic and endophytic origin, Actinomyctes are also found in some other habitats like animal, guts, fishes, marine sponges, waste materials, fermentation tanks etc. *Streptomyces rimosus* reported to be present in the gills and gut of fish *Chanos chanos (*Sivakumar *et al*, 2006). Murugan *et al*, (2007), have isolated actinomycetes from the gut of a finfish, *Mugil cephalus* Lin. and found few *Streptomyces* sp. which were identified as *Streptomyces canus, Streptomyces galbus and Streptomyces rimosus.* Aruna *et al*, (2009) has first reported the isolation of actinomycetes from earthworm gut having antagonistic activity against plant pathogenic bacteria and fungi. Two novel strains have also been isolated from the following habitats which belongs to the genus *Micrococcus and Streptomyces*.

Table.4. Actinomycetes genera isolated from other habitats in past decade in India

S. No.	Actinomycetes Taxa	Habitat	Reference
1.	*Streptomyces* sp.	Sponge *Dendrilla nigra*,	Selvin *et al*, 2004
2.	*Streptomyces rimosus*	Gills and gut of fish (*Chanos chanos)*	Sivakumar *et al*, 2006
3.	*Streptomyces tsusimaensis*, *Streptomyces caviscabis*	Herbal vermicompost, Andhra Pradesh	Gopalakrishnan *et al*, 2011
4.	*Streptomyces canus*, *Streptomyces galbus and Streptomyces rimosus*	Gut of finfish, *Mugil cephalus*	Murugan *et al*, 2007
5.	*Streptomyces tritolerans* sp. nov.	Novel species from earthworm gut (*Eisenia foetida*)	Aruna *et al*, 2009
6.	*Nocardiopsis alba* MSA 10	Marine sponge	Gandhimati *et al*, 2009
7.	*Nocardiopsis dassonvillei MAD08*.	Marine sponge	Selvin *et al*, 2009
8.	*Streptomyces akiyoshinensis*	Coral mucus	Nithyanad *et al*, 2010
9.	*Streptomyces* sp.	Mud crab, *Scylla serrata*.	Karthik *et al*, 2010
9.	*Micrococc lactis* sp. nov.	Novel species isolated from dairy industry waste	Chittpurna *et al*, 2011
10.	*Streptomyces nouresi* MTCC 10469	*Callyspongia diffusa*	Dharmaraj *et al*, 2011
11.	*Streptomyces* sp.	Gut of ornamental fishes,	Sheeja *et al*, 2011
12.	*Streptomyces* sp. PVRK1	Zebra fish embryo	Kanan *et al*, 2012
13.	*Streptomyces* sp.	Marine fish	Suguna *et al*, 2012

3. Conclusion

Being in tropics, India has many regions with great biodiversity which could be a source of various novel compounds for the welfare of mankind. Actinomycetes are the microorganisms which have been evolved as a group with greatest genomic and metabolic diversity and day by day they are increasingly recognized as the producers of large number of secondary metabolites as important novel compounds. The diverse physiological and climatic conditions in mainland area and Islands in India offer huge scope for sampling and isolation of many important and novel actinobacterial strains; despite of this many fertile habitats are waiting to be exhaustively explored. Among the various Actinomycetes isolated from different habitats including both terrestrial and aquatic, *Streptomyces* holds a dominant place followed by *Micromonospora, Actinomadura, Actinoplanes, Nocardia, Saccharomonospora* etc., It is therefore important that a new group of rare and uncommon actinomycetes from unusual ecosystems should be explored as a potential source of new therapeutic compounds. So, to find the diversity among species and new genus, diverse ecological niches must be explored. Along with diverse habitats, new isolation and identification techniques must also be employed to avoid the re isolation of same species of actinomycetes. Among the various explored regions, much research have been conducted in North, South and North East regions, but many areas in central region specially Chhattisgarh have not been much explored till now, therefore effort should be made to explore these areas to find the novel uncommon strains and also diversity among actinomycetes which could be a source of various important bioactive compounds.

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Right To
INFORMATION ACT
TOOL IN STRENGETHENING DEMOCRACY IN INDIA

DR.PUNYA SHAILAJA | DR.P.RENGARAJAN
DR. VINOD KUMAR CHERUKURI

CONTENTS

CHAPTER - 3

OBLIGATIONS OF PUBLIC AUTHORITIES UNDER RTI

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ABSTRACT : Democracy involves public participation in governance and transparent administration. Free access to information is a mechanism that makes government accountable to public regarding their actions. Right to Information Act (2005) is a tool that empowers the Indian citizens to seek information regarding matters of governance to know more about the plans and decisions of state bureaucracies. The success of RTI Act depends predominantly on its implementation by public authorities who act as repositories of information. This chapter examines the obligations of public authorities in facilitating access to information held under their control. Section-4 of the RTI Act not only lays down the rules and parameters for disclosing information but also defines the standards of transparency that the public authorities should seek to achieve. In that regard, the regulations related to maintenance of records, disposal of appeal by First Appellate Authority and various provisions of voluntary disclosures to be followed by public authorities have been discussed. The chapter also gives an account of the guidelines regarding decision making process, digital publication of disclosures made, norms established and budget allocation of public authorities.

Keywords: public authorities, voluntary disclosure, PIO

1.0 INTRODUCTION

Right to Information Act (2005) seeks to bring public grievances to light, promotes decentralization, thereby bringing equity and inclusiveness. It allows people to review, question and inspect decisions of the government, thereby making them partners in development rather than mere beneficiaries.

Right to Information Act has got a demand and a supply side. Its demand side gives public a right to seek information from public authorities. The supply side involves voluntary disclosure of information by the public authorities.

Department of Personnel and Training has been identified as the nodal department at the national level for the purpose of implementation of the said Act.

According to the RTI Act, a "public authority" means any authority or body or institution of self-government established or constituted by or under the Constitution; by any other law made by the Parliament or a State Legislature; or by notification issued or order made by the Central Government or a State Government and includes bodies owned, controlled or substantially financed and non-Government organizations substantially financed by funds provided by appropriate government.

2.0 APPOINTMENT OF PUBLIC INFORMATION OFFICERS,ASSISTANT PUBLIC INFORMATION OFFICERS ETC.

As per the directions of the government, all public authorities are required to appoint:

1) Public Information Officers (PIOs) in all administrative units or its subordinate offices

2) First Appellate Authorities

3) Assistant Public Information Officers (APIOs) at sub-divisional level

3.0 MAINTENANCE OF RECORDS AND INFORMATION DISSEMINATION BY PUBLIC AUTHORITIES

All public authorities are required to maintain their records with proper cataloguing and indexing. They should be computerized and connected through a network throughout the country to ensure easy accessibility. They should publish all information regarding crucial policies and decisions that will affect people. They should provide reasons for administrative and quasi-judicial decisions to the parties involved. Information dissemination can be done using the medium of notice boards, newspapers, public announcements, media broadcasts or internet keeping in mind the factors of cost effectiveness and use of local language.

4.0 VOLUNTARY DISCLOSURE BY PUBLIC AUTHORITIES

Section-4 of the RTI Act deals exclusively with the information processed by government departments and their subsidiaries.To strengthen the implementation of the Act, Central government has directed all the public authorities to include a separate chapter in their annual reports dealing with the implementation of RTI Act. That chapter should contain details of RTI applications received and disposed off by them along with the cases where information was refused.

To ensure that maximum information is proactively disclosed by public authorities, Department of Personnel and Training has ordered to conduct third party audit of obligatory disclosures on yearly basis.

Public authorities will also disclose information regarding their process, decisions and actions on their websites which will also be valuated and graded by CIC by grouping them into six categories, namely, organization and function, budget and programmes, publicity and public interface, e-governance, information disclosed as prescribed and information disclosed on own initiative. The areas for improvement in content and quality of disclosures will be identified and requisite measures will be taken to make them more effective.

5.0 SUPPLY OF INFORMATION BY PIOs

The PIOs have been directed to supply information according to the guidelines issued by the government so that second appeal is not filed later on. They should ensure that information is provided in such a form that applicant is able to understand it. If possible, it should be given in his local language and if needed, it should be properly stamped. Following points should be kept in mind while furnishing the information:

1) The PIO should check if the information that is asked for or a part of it is not permissible to be disclosed under Section 8 or Section 9 of the Act. Such a request can be rejected and rest of the information is to be supplied immediately or after submission of additional fees.
2) If the request for information is rejected, PIO must inform the applicant regarding the reason for rejecting the request and the duration within which and authorities to whom the appeal can be filed.
3) If the applicant needs to pay any additional fees as per the Fee and Cost Rules, it's the responsibility of the PIO to inform him after the receipt of RTI application.
4) If decision on information sought is not given within the given time limit, it will be deemed that it has been refused.
5) Information should be made available to the applicant within 30 days from receipt of his application. In case the information is related with issue of life or liberty of the information seeker, it should be provided within 48 hours. If the information is not provided within the prescribed time limit, it has to be provided without charging any fees.

6.0 GUIDELINES FOR PROVIDING INFORMATION

Although there is no standard format for providing information to the applicant or appellant, the replies should necessarily contain the following information:

(a) Application number with its date of filing and date of its receipt by the public authority

(b) Contact details of Central Public Information Officer- name, designation, official telephone number and e-mail id

(c) In case the application is rejected, reasons for refusing the request along with mention of relevant sections of the Act on the basis of which the request was denied.

(d) Information about the PIO to whom application has been transferred and who will be able to furnish the information

(e) Provision of appeal that can be filed with the First Appellate Authority within 30 days of receipt of reply

(f) Correspondence details of First Appellate Authority

If applicant has asked for certified copies of the documents or records, CPIO should endorse the document as "True copy of document/record supplied under RTI Act" and put his signature and seal underneath. If certified copies are required in large numbers, PIO can furnish the needed information and certification work can be done by a junior gazette officer.

7.0 SUO MOTU DISLOSURE

Public authorities should disclose information on proactive basis on regular intervals on public domain through different sources so that people need not use RTI application to obtain them. They need to publish information in 16 categories, namely, details of organization in terms of particulars, functions and duties; authority of the staff in terms of powers and duties of employees and officers; decision making procedure; norms established to perform functions; manuals and records maintained to discharge functions; statement regarding records of documents maintained; system for public consultation or representation for policy formulation and implementation; constitution of bodies for advisory purpose; staff directory; remuneration system; budget allocation; subsidy allocation and execution; details of people to whom concessions, permits or authorizations were granted; information held in electronic form; facilities provided to citizens for obtaining information and details of PIOs.

Publication of the above-mentioned information is not optional but obligatory. It is also statutory for public authorities to update this information on annual basis.

8.0 OTHER DISCLOSURES UNDER SUO MOTU DISCLOSURES

Other than the ones mentioned above, following information should also be provided by public authorities under Suo Motu disclosures:

- Procurement related information
- Public Private Partnerships used for providing public services
- Transfer Policies and orders of employees of various grades who are working in public authorities
- RTI applications and appeals received along with their responses
- Paras of Comptroller and Auditor General and Public Accounts Committee and Action Taken Reports after their presentment in houses of the Parliament
- Citizens Charter and half yearly performance report against its benchmarks
- Discretionary/non-discretionary grants given
- Details of foreign tours of Ministers and officials of government departments

9.0DISCLOSURE OF THIRD-PARTY RELATED INFORMATION BYPUBLIC AUTHORITIES

In case, PIO wants to disclose some information furnished by a third party, it needs to invite that party to make requisite submission in that regard. The third party can file an appeal against PIO's decision of disclosure to Departmental Appellate Authority. A second appeal can be filed with the Information Commission if its dissatisfied with the decision of the first appeal.

10.0 DISCLOSURE OF THE ANNUAL CONFIDENTIAL REPORTSAND PERSONAL INFORMATION OF INDIVIDUALS

According to the Ministry of Personnel and Training along with the Department of Legal Affairs, public authorities are under no obligation to disclose either personal information of their employees or details of a complaint filed against some government officer and action taken in that regard or information which is not related to public activity. Such a disclosure would mean invasion of privacy of an individual and its revelation is left on the discretion of the PIOs. If such information is disclosed for greater public interest, it should be done with the approval of a competent authority.

Similarly, while dealing with RTI applications, public authorities should neither ask for personal details of the applicants not publish them on their websites in case they have that information.

11.0 DISPOSAL OF APPEAL BY FIRST APPELLATE AUTHORITY

First Appellate Authority should act in a fair and judicious manner and give detailed justification of his decision in the order passed by him.If he is of the opinion that the PIO needs to provide extra information to the appellant, he can either direct the PIO to furnish such information or give it himself.

He should dispose off the appeal within 30 days of its receipt and if that is not possible, it should be disposed off in not more than 45 days. But reasons for such delay should be given by him in writing.

12.0 RETENTION OF RECORDS BY PUBLIC AUTHORITIES

Record retention is to be done by public authorities as per the related schedule applicable for them. In addition, weeding of records should not mean complete destruction of information present in that file. If such information is sought after 20 years, it should be made available to the public. Normally, the information whose disclosure was earlier exempted can be revealed after 20 years. However, in the following cases, public authorities are not obligated to disclose information even after 20 years:

1) The information, if revealed will affect the sovereignty, integrity, and security of the nation along with its relations with other countries.

2) It would lead to breach of privilege of the Parliament or State legislature.

3) It includes documents related to discussions of Council of Ministers, Secretaries and other government officers.

13.0 GUIDELINES FOR DIGITAL PUBLICATION OF INFORMATION DISCLOSED BY PUBLIC AUTHORITIES

Following principles should be followed along with adherence to standards of Department of Information Technology and Department of Administrative Reforms and Public Grievances:

- Electronic disclosure of entitlements to citizens and transactions between citizen and government
- Providing information from point of origin to point of delivery of services on their websites

- Uploading information about orders of public authorities after their issuance on their websites
- Furnishing information about relevant Acts, rules, forms and documents which are normally used by citizens on their websites
- Providing detailed directory of key officials on their websites
- Providing details of digital information which are not available on public domain on their websites
- Bringing greater transparency in delivery of e-services
- Automatic updating of digitalized information
- Presenting information from user's perspective i.e., in a simplified manner
- Ensuring ready availability of information as per 'National Data Sharing and Accessibility Policy'
- Presenting information in open data formats
- Including the mandatory field of 'Date last updated (DD/MM/YY)' on top right corner of every webpage of their websites

14.0 GUIDELINES REGARDING DECISION MAKING PROCESSES FOR PUBLIC AUTHORITIES

a. Identify the output/tangible results/services/goods to be provided to the pubic
b. Identify chain of decision making in form of a flowchart with clear explanation of the officials involved in decision making
c. Mention the powers of the officials next to the flowchart along with decentralization of decision-making process undertaken, if any
d. Application of above-mentioned presentation for all their operations
e. Explanation of alterations or changes made in decision making process

15.0 SETTING OF NORMS BY PUBLIC AUTHORITIES FORDISCHARGING THEIR FUNCTIONS

Public authorities are required to disclose the standards on the basis of which their performance is to be judged. They can be laid down with help of Citizen Charters. Such norms should be linked with decision making process. They should include information regarding goods/services provided by public authorities, process to access them, eligibility to receive those goods and services, applicability of quantitative parameters and timelines for their access, qualitative and quantitative outcomes sought by public authorities and determination of responsibility for delivery or implementation of goods or services.

16.0 GUIDELINES REGARDING THE BUDGET ALLOCATION OF PUBLIC AUTHORITIES

The public authorities should disclose their budget allocation on the public domain in a simplified form so that common man can understand it. Outcome budget should be presented in such a way that their actual performance can be easily compared with planned physical targets during that particular time period. Information about funds released to different organizations should be made available through their websites on quarterly basis along with links for accessing the budgets of those bodies. Sector specific allocations and achievements should be highlighted, especially if they deal with issues related to gender, children, Scheduled Castes and Scheduled Tribes and religious minorities.

17.0 PENALTY ON PUBLIC AUTHORITIES

Penalty on public authorities can be imposed by the central or state government in the following cases:

- It has refused to accept the request for information.
- It did not provide information within the prescribed time limit.
- It maliciously refused to give information.

- It destroyed the information which was requested.
- It created obstructions in supplying the information.

The penalty imposed by the Information Commission will be of Rs. 250 per day till the concerned public authority accepts the application or provides the information. The maximum penalty that can be imposed is Rs. 25,000. If rules are continually violated, then the Commission can recommend to take disciplinary action against the said authority after giving it an opportunity to be heard.

18.0 ORGANIZATION OF EDUCATIONAL PROGRAMMES BY PUBLIC AUTHORITIES

Public authorities should develop and organize educational programmes for the general public to increase their awareness about how to use their rights under RTI Act. In addition to that, they should also make arrangements for imparting training to PIOs, First Appellate Authorities and their other employees so that they can ensure effective implementation of the Act. The training programmes can be based on issues related to office procedures, civil society action, governance, legal literacy, information management etc.

19.0 CONCLUSION

Indian Constitution implicitly guarantees the right to information to all its citizens. Indian Parliament expanded this right in form of an Act to enhance its practical utility. Right to Information Act allows the citizens to seek information regarding government projects & plans at par with Members of Parliament and Members of State Legislatures. It ensures that the authority is not misused and funds allocated for public welfare are not diverted to private/personal purposes. Public can scrutinize records, tenders, agreements, payments etc. to find out misappropriations, if any.

The public authorities are required to send necessary information related to implementation of the Act on annual basis to their concerned Government department or ministry which will then forward it to Information Commissions. In case, Information Commission is of the opinion that any operation of a public authority is not in compliance with mandatory provisions of the Act, it may recommend steps to be followed to bring it in conformity with the Act.

However, according to an audit report submitted to Central Information Commission in 2018, it was found that public authorities have not fully shared and/or updated the crucial information on their websites. Such information included matters related to delegation of power, public consultation for policy making, minutes of meetings, postings & transfers of senior officials, applications for information & appeals received, grants given, grievance redressal mechanism, domestic & foreign visits of senior officers, allocation & utilization of funds, donations given to political parties and public private partnerships.

This calls for regular audits to be conducted by Central Information Commission to evaluate the disclosure standards of websites of public authorities. Till the state institutions embrace complete transparency in their functioning, Right to Information Act will be powerless to fortify accountability in the governance of public authorities.

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Research Column II

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Chapter-13

The Socio-Economic Conditions of Domestic Workers during COVID- 19: A Case Study of Bhilai Steel City, Chhattisgarh

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Abstract

The steel city Bhilai is one of the planned cities of Chhattisgarh, India and standard of living is better than other cities. The present study aims at understanding and examining the socio-economic conditions of domestic workers during COVID-19 in Bhilai City. To fulfill the objectives, 70 samples of domestic workers has been collected from different areas of Bhilai. The result shows that 96% of female domestic workers are engaged as a part-time basis in four to five houses per day with fixed and decided works and spending less than 2 hours per house for completing the job, and monthly salary receiving from each house is approx Rs. 1200/- to Rs. 2500/-, in this way their average monthly income converts approximately Rs. 5500/-. It has been found that 98% of people demands for female workers at their house instead of male workers. Due to high demand of domestic workers in Bhilai city their remuneration is also considered high as compared to other districts of Chhattisgarh. The maid who have been engaged for child care or adult care their monthly salary certainly between Rs. 5000/- to Rs. 9000/- per month depends on the nature of works. It has been found that maximum

number 55 out of 70 samples (78.57%) of female domestic workers are migrated from neighboring State Odisha. The socio-economic conditions of domestic workers are becoming underprivileged during COVID-19, many employers were started to cut their salaries, it has been found that they were highly dependent on their monthly salaries or daily wages, they don't have any savings to survive. The socio-economic crises during COVID-19 took birth of many social issues like domestic violence, divorce, unrest, suicide in study area.

Key Words: *Socio-economic conditions, domestic workers, demand & supply of domestic workers, economic development, exploitations, family background, COVID-19 Pandemic.*

Introduction

Chhattisgarh carved out of Madhya Pradesh and came into existence on 1 November 2000 as the 26th State of India. Bhilai is renowned for its multicultural and diverse population, it is also called as mini pan India, with an urban agglomeration had a population of 10,64,222. Bhilai has an average literacy rate of 86.63% and it is the second largest urban area after

Raipur. Bhilai Steel Plant was set up with the help of the USSR in 1955. The total of 68,742 permanent employees (data as of 1st June 2020, SAIL)[1] have been employed in Steel Authority of India Limited (SAIL) is a public sector undertaking. Mega Industry attracts many investments in this area. The socio-economic status of people is much better in Bhilai City. The demand for domestic workers is high as compared to its supply in this area. It is estimated that there are over four million domestic workers in India and according to the International Labor Organization (ILO), currently there are at least 67.1 million adult domestic workers worldwide. They are as a part of an informal and unregulated sector, obscured in private homes, not recognized as workers but rather as 'informal help'[2].

The COVID-19 induced lock down in entire country and maintains social distancing, has been an ultimate solution to stop spread of Corona virus, economic activity of various sectors was completely closed down in India and even the domestic workers were off from their work. Overall Gross Domestic Product (GDP) of our economy negatively affected in six months during COVID-19 pandemic. Incomes of individual domestic workers are also a part of National Income of our country. Country's economic health greatly threatened during this period and the GDP of India has been registered approximately 2.5% during pandemic time, whereas the overall GDP was estimated 5.3% in 2018-19.

Definition of Domestic Workers

The International Labour Organization (ILO)[3] defines "*domestic work*" as work performed in or for one or more households. "*Domestic workers*" are defined as all people engaged in domestic work within an employment relationship. Domestic worker may work full-time or part-time. They may do a number of different tasks, cleaning, cooking and washing to gardening or driving for the family. Domestic workers also engaged in caring people who needs care, such as children, persons who are elderly sick, or with a disability.

Methodology

The present study focuses on the socio-economic conditions of domestic workers with special reference to Bhilai Steel City of Durg district of Chhattisgarh. It helps to know the problems of domestic workers and their living condition during COVID-19 and how to overcome their problems. There are 68 wards in the Bhilai city; among which Bhilai Nagar Ward No. 63, is the most crowded ward which is selected for the present study with around 26 thousand people, consist of 52% male and 12% females are under the working population. The data has been collected through primary source, total 70 samples of male and female domestic workers has been collected through Stratified Radom Sample basis based on questionnaire and personal interview method.

Objectives of the Study

a) To study the demographic characteristics of domestic workers in study area.
b) To study the monthly income and expenditure pattern of domestic workers.
c) To find out the problems of domestic workers faces during COVID-19.
d) Suggestions for remedial measures.

Review of Literature

Many studies have been done in this topic, some of the consequences are taken here for compares this present study. *Javaid Ahmad Dhar (2014)*[4] examined on "Socio-Economic Conditions of Female Domestic Workers in Punjab: A Case Study of Sangrur District" found that monthly earnings of the lower caste female domestic workers and Sikh respondents are lower than that of other migrant workers, nearly half of these respondents are living below poverty line their families are negatively affected by anti-social habits of their husbands/fathers (like drug addiction). *Ramesh Maruti Adin and Mohan S Singhe (2016)*[5] studied on "Socio-economic conditions of women domestic workers in Mangalore city" found that domestic work is the major growing informal sector largely occupied by women and they are the most economically exploited group and there is no uniformity in the workers' wages structure. There is highly inequality and development discrimination among the urban livelihood and new life style patterns of living in the urban middle class.

Socio-Demographic Features of Domestic Workers

Social analysis starts from understanding the socio-economic and environmental context in which *people* live. That's why it is very important to know the socio-economic conditions of people of any region, because it helps to analysis an overview over the population living in that area such as their employment level, educational level, income source, standard of living etc. Table no.1 reflects on the socio-demographic features of respondents such as age, caste, religion, migration, education and their marital status. Out of total 70 samples 61.43% of domestic workers belongs to above 30 years of age, 25.71% are in between 20 to 30 years of age and only 12.86% in between 15 to 20 years of age group, many studies have proved that before the year 2016 people demanded for child labor because it was cheap. The Government of India expanded the coverage of the Child Labour Prohibition and Regulation Act and ban the employment of children as domestic workers and as workers in restaurants, dhabas, hotels, spas and resorts effective from 10 October 2016[6].

If we talk about the caste of the respondents 41.43% are belongs from scheduled tribe (ST) which percentage is maximum (41.43%) than general (21.43%) followed by Scheduled Caste (20%) and OBC (17.14%). It has been observed that maximum number of domestic workers belongs from Hindu family (92.86%), and a very negligible percentage 2.86% from Muslim family. Only 21.43% of domestic workers belonging from Chhattisgarh and largest number (55 out of 70 samples) i.e 78.57% are migrated from neighboring states like Odisha, Bihar, Maharashtra and they are living in their own hut (Kuccha and Khapda house)in the nearby basti, some of the respondents also staying in rental house (a very nominal rent has been paid between Rs. 800/- to Rs.1200/-). Respondents either local (Chhattisgarhi) or migrated, receiving all the welfare facilities provided by Chhattisgarh government such as items under Public Distribution System (PDS).

Table no. 1 also focused on educational level of domestic workers. Approximately 72.86% domestic workers are illiterate, 22.86% (16) female domestic workers were attained primary level of education and only 4.25% (3) respondents were reached for higher secondary school. It shows that domestic workers are educationally backward. But they are very positive for their children's schooling and size of family. But it has been observed that mentality of son preferences is still there among workers. Out of 70 samples, 65.71% of domestic workers are married and 12.86% are unmarried, so we can come to the conclusion that

illiterate/less educated women in labour class family are more interested to take up these jobs easily. Many women are in study area found suffering from domestic violence by their husband/father (due to consumption of alcohol/narcotics).

Table No.-1

Social Factors of Respondents

Social Factors	*Respondents*	*Frequencies*	*Percentage*
Age	*15-20*	*9*	*12.86%*
	20-30	*18*	*25.71%*
	30 & above	*43*	*61.43%*
	Total	*70*	*100%*
Caste	*ST*	*29*	*41.43%*
	SC	*14*	*20%*
	OBC	*12*	*17.14%*
	Others	*15*	*21.43%*
	Total	*70*	*100%*
Religion	*Hindu*	*65*	*92.86%*
	Muslim	*2*	*2.86%*
	Christian	*3*	*4.28%*
	Others	*0*	*0*
	Total	*70*	*100%*
Migration	*Yes*	*55*	*78.57%*
	No	*15*	*21.43%*
	Total	*70*	*100%*
Education	*Illiterate*	*51*	*72.86%*
	Primary	*16*	*22.86%*
	Higher school	*03*	*4.25%*
	Total	*70*	*100%*

Marital status	Married	46	65.71%
	Unmarried	9	12.86%
	Married but separate	11	15.72%
	Widow	4	5.71%
	Total	70	100%
Family size	2-3	6	8.57%
	3-4	26	37.14%
	4-5	31	44.29%
	5 & above	7	10%
	Total	70	100%

Source: Primary data;

Economic Conditions of Domestic Workers

As we all know that economic condition expresses the standard of living of people, as income increases consumption expenditures and savings also increase. It means overall demand by people increases. Symbolically we can write as -

Y= f (C+S)

Where Y= Income

C= Consumption

S= Savings

F denotes functional relationship

It means Consumption (C) and Savings (S) depends on Income (Y) of people. Table no.2 specifies about the economic status of domestic workers. Out of 70 samples 61.43% respondent's monthly income range between Rs.5000 to Rs.7000, and only 2.86% respondents earning minimum between Rs.1000 to Rs.3000. It has been found that monthly salary of domestic workers is high in the area of Private personal houses instead of BSP Quarter (Bhilai Steel Plant Quarter). The 54.29% respondents said that their monthly family expenditure up to Rs.5000/- and 44.28% replied Rs.5000 to Rs.7000/- and a very less percentage i.e 1.43% replied Rs.7000/- and above their monthly expenditure. Seventy five percent (75%) of domestic workers of all age group agreed that their owners are well behaved with them and timely paid, where as 25% were not happy with their owners. It has been noticed that female domestic workers have their own local level group, where they share and discusses their views related to income, owners' behavior etc.

Poor people don't have enough money for permanently saving, even though 27.14% respondents are aware about saving and have their future plan for child's education, marriage etc, and 61.43% taken loans from the banks or owners to fulfill their family requirements.

Table No.-2

The Economic Conditions of Domestic Workers

Economic Factors	*Respondents*	*Frequencies*	*Percentage*
Monthly income (Rs.)	*1000-3000*	2	*(2.86%)*
	3000-5000	22	*(31.43%)*
	5000-7000	43	*(61.43%)*
	7000& above	3	*(4.28%)*
	Total	70	*100%*
Monthly expenditure (Rs.)	*3000-5000*	38	*(54.29%)*
	5000-7000	31	*(44.28%)*
	7000 & above	1	*(1.43%)*
	Total	70	*100%*
Timely paid by their owner	*Yes*	53	*(75.71%)*
	No	17	*(24.29%)*
	Total	70	*100%*

Nature of saving	Yes	19	(27.14%)
	No	51	(72.86%)
	Total	70	100%
Debt / loan taken	Yes	43	(61.43%)
	No	27	(38.57%)
	Total	70	100%

Source: Primary data

Domestic workers and Payment Cut during COVID-19

Domestic workers are may be male or female, but female's demand is high for the household work and it is largely considered as a feminine work in our society. Table no. 3 deals with the types of job of domestic workers, where 85.71% respondents are engaged for part time and only 10% engaged for full time job from morning 9.00 am to 5.00 pm for caring child or elders. Only 3 male domestic workers out of 70 samples are residing with their family in the premises of owner's house, in such a case their whole family has been engaged for the owner's service like cooking, washing utensils, mopping cleaning, dusting, gardening, car washing etc.

Table no. 4 depicts about payments of domestic workers during COVID-19, 48.57% of respondents fully paid by their owner during tough time of COVID-19 lock down, 31.43% half paid and 20% not received any payment from their owner.

Table No.- 3

Types of Job of Domestic Workers

Types of Job	Gender		Total
	Male	Female	
Part time	1(25%)	59 (89.39%)	60 (85.71%)
Full time	0	7 (10.61%)	7 (10%)
Live with family in the employers' premises	3 (75%)	0	3 (4.29%)
Total	4 (5.71%)	66 (100%)	70 (100%)

Source: Primary data;

Table No.-4

Respondents Views' to Payment during COVID-19

Types	Male	Female	Total
Fully paid	1	33	34 (48.57%)
Half paid	2	20	22 (31.43%)
Not Paid	1	13	14 (20%)
Total	4 (5.71%)	66 (94.29%)	70 (100%)

Source: Primary data:

The Nature of Job of Domestic Workers

The nature of job of domestic workers like washing utensils, brooming and mopping, dusting, caring children and dependent old people. Table no.5 reveals that 65.71% of respondents are engaged for housekeeping where cent percent are females, 15.72% engaged for cooking (2 male and 9 females),11.43% engaged of baby or elders care (cent percent females). Female work participation rate in unorganized sectors are growing rapidly because of many reasons such as to increase their family income, mentality of self-depend and to raise the standard of living.

Table No.- 5

Nature of Job of Domestic Workers

Nature of Job	Gender		Total
	Male	Female	
Housekeeping	0	46	46 (65.71%)
Cooking	2	9	11 (15.72%)

Baby /Elders care	0	8	8 (11.43%)
Other works	2	3	5 (7.14%)
Total	4	66	70 (100%)

Source: Primary data:

Problems of Domestic Workers during COVID-19

Earlier studies are evident that women are largely engaged in household works in our Society and facing many problems in their workplace as well as in their family. In Bhilai steel city the percentage of workplace harassment or exploitation of domestic workers are found very negligible. In study area 95% of middle-class family demands for female maid and only 4% of upper middle-class family or from a higher entity of respondents' demand for male domestic workers.

The advantages of male domestic workers are along with domestic works, they helps in buying vegetables, buying grocery items from market, gardening, dusting, picking baby from the school and many more. Table no.6 deals with the problems of domestic workers, out of 70 samples only 10 (14.29%) respondents exploited by their owner like engaged in extra works and not behaving well. Female domestic workers have their local level small group where they share and exchange their views. They aren't tolerates any kind of exploitation or harassment at their workplace, if it is so immediately they quit the job. Every female household worker has been engaged in more than three to four houses and compares their owner's behaviour, burden of works and salary. Only 48% of respondents not getting their monthly salary in time, 100% agreed that they have no security of jobs and no particular holidays has been there, even no leave provided during Diwali or Dushera holidays, which is the most popular festival of our country. In Bhilai city 15% of owner cut their wages/salaries during first lockdown from March 2020.

Table No.- 6
Problems of Domestic Workers

Problems	Respondents (%)
Exploited – Yes	10 (14.29%)
No	60 (85.71%)
Total	70 (100%)
Not timely paid	34 (48.57%)
More works with less payment	55 (78.57%)
No Holiday	70 (100%)

Source: Primary data;

Conclusions

The economic conditions of domestic workers are found better in Bhilai Steel City but on the other hand social conditions of female domestic workers are found vulnerable due to family distractions with consumption of alcohol by their husband/father (male head of their family).

The demand for female domestic workers are found basically for broom and mopping, dusting, cleaning, washing utensils and caring children/ or elders, and the demand for male domestic workers are found for cooking, gardening, car wash and other outside works. Female domestic workers in unorganized sectors are growing day by day to become an economically self-depend, to increase their family income and to uplift their standard of living, 78.57% of female domestic workers are found migrated from Odisha, internal migration also attracts people to Bhilai city because of job scopes are available and well known City for best educational institutions and coaching center.

Almost all domestic workers are belonging from BPL (Below Poverty Line) family and getting benefits of Public

Distribution System (PDS) provided by the Chhattisgarh Government. Even widows are also getting monthly financial support from the Chhattisgarh government. The socio-economic conditions of domestic workers are becoming underprivileged during COVID-19, many employers were started to cut their salaries. they are highly dependent on their monthly salary or wage. they don't have any savings to survive. The socio-economic crises took birth of many social issues like domestic violence, divorce, unrest, suicide etc.

If we talk about the caste of the respondents 41.43% are belongs from scheduled tribe (ST) which percentage is maximum (41.43%) than general (21.43%) followed by Scheduled Caste (20%) and OBC (17.14%). It has been observed that maximum number of domestic workers belongs from Hindu family (92.86%), and a very negligible percentage 2.86% belongs from Muslim family.

Suggestions

Some of the suggestions for policy marker or the Government to improve the conditions of domestic workers are as follows-

1. Festival leave should be introduced for the domestic workers.
2. Strict restrictions should be implemented for the entry of child labour in domestic works.
3. Awareness campaign publicity is necessary for BPL families regarding government schemes.
4. Alcohol consumption should be banned in state, because alcohol is one of the reasons for family distractions in such families.
5. Adult educational facilities should be extended by the Government so that the quality of domestic workers or workers in unorganized sectors will improve.

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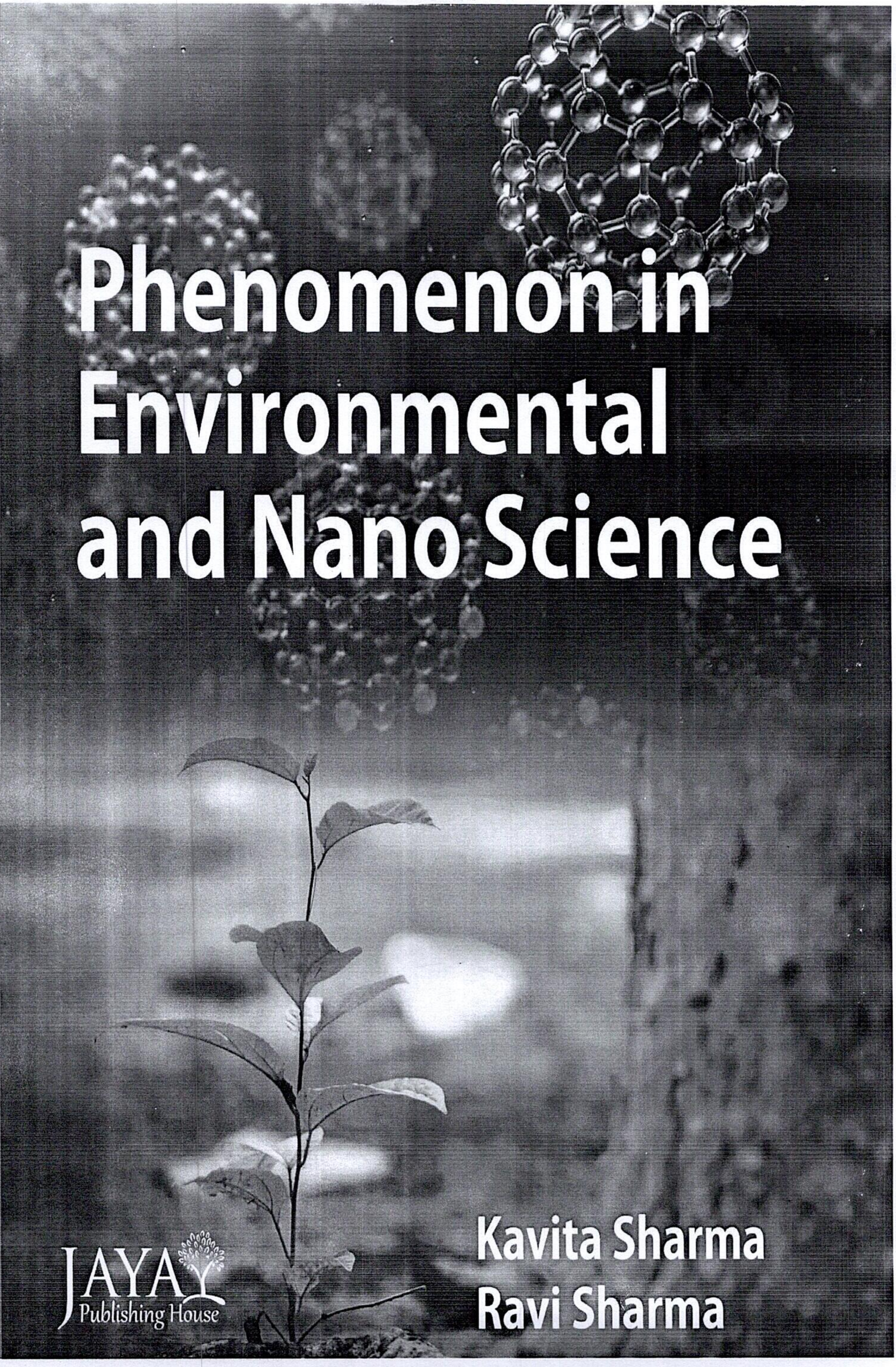

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LIGNIN DEGRADING ENZYMES AND THEIR INDUSTRIAL APPLICATIONS

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Abstract

Lignin is one of the most primitive organic polymers for modern applications. This chapter portrays the concepts of lignin degrading enzymes and their insights. The chapter also portrays the industrial applications of these enzymes ranging from food industries to biotechnological applications with detailed sub-application areas. Additionally, the chapter opens the gate for researching the application of enzymes in more enhanced applications like WFRC (Weather and Forecasting Research Model).

Keywords: Enzymes, Lignin, Organic Polymers, Biotechnology.

Introduction

Lignin is a complex constituent of the wood. After cellulose, lignin is one of the most bountiful organic polymers in plants. In wood it is present in 20-40% and in gramineae present in 15-20%. It is the sole chemical composition of angiosperm and gymnosperm (Jiang, 2001). Lignin is a complex chemical compound linked with mainly three monomers coniferyl alcohol, sinapyl alcohol and coumaryl alcohol. On the bases of their monomers it will be divided in to three types; guaiacyl lignin polymerized by guaiacyl propane, syringyl lignin polymerized by syringyl propane and hydroxy-phenyl lignin polymerized by hydroxy-phenyl propane. Usually, gymnosperm contains guaiacyl (G) lignin; monocotyledon contains guaiacyl-syringyl-hydroxy-phenyl (GSH) lignin and dicotyledon contains guaiacyl-syringyl (GS) lignin (Wei and Song, 2001).

Structure of lignin

It consists of aromatic rings with the units of guaiacyl propane, para-hydroxy-phenyl-propane and phenyl-propane units. Lignin is part of secondary cell wall of plants. It is different from cellulose and hemicellulose (Ralph *et al.*, 2004). It has highly resistance to biological degradation and chemicals (Martinez *et al.*, 2005). Lignin is composed of three basic units of *p*-coumaryl alcohol, coniferyl alcohol and sinapyl alcohol (Liu *et al.*, 2008; Cai *et al.*, 2010).

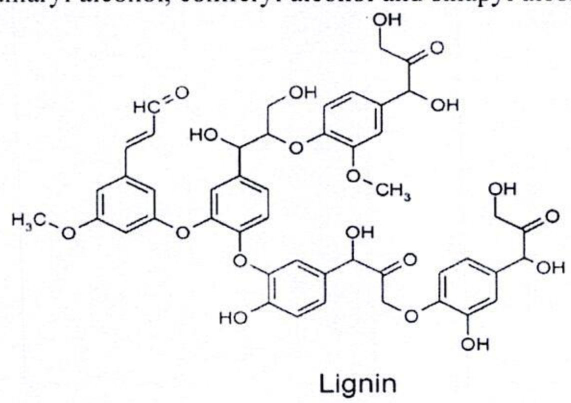

Fig. 1. Structure of a lignin molecule (Chhabra, 2013).

Lignin Degrading Enzymes

Lignin is highly resistance for biodegradation. White-rot fungi are known to best lignin degrader. Lignin is mainly degraded by three types of lignolytic enzymes such as lignin peroxidase, manganese peroxidase and laccase (Eriksson *et al.*, 1990).

Lignin Peroxidase

Lignin peroxidase is an enzyme, which degrade lignin in the plant cells. It produced from fungi like *Phanerochaete chrysosporium*. It interacts with veratryl alcohol (lignin polymer),

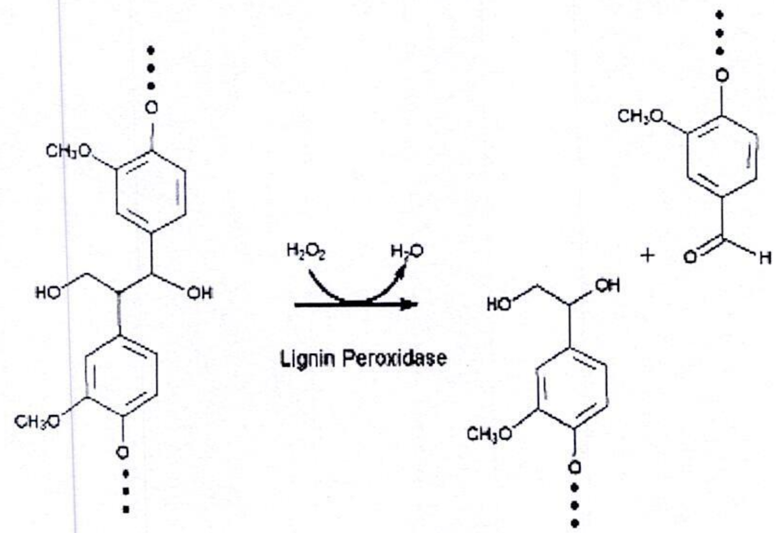

Fig. 2. Lignin-peroxidase mediated conversion of veratryl alcohol (VA) to veratraldehyde (Albayrak and Yang, 2002).

which is secondary metabolites and acts as cofactor. Lignin peroxidase enzyme catalyzes the chemical reaction. Use 1,2-bis (3,4-dimethoxyphenyl) propane-1,3-diol and H_2O_2 use as substrate (Renganathan *et al.*, 1986).

1. Manganese Peroxidase

Manganese peroxidase enzyme belongs to oxidoreductase family. It discovered in 1985 from *Phanerochaete chrysosporium* (Glenn and Gold, 1985; Paszcynski *et al.*, 1985). Manganese peroxidase enzyme catalyzes the chemical reaction. Use Mn (II) H^+ and H_2O_2 as a substrate. It oxidizes the substrate by one-electron oxidation process with intermediate cation radical formation (Malherbe and Cloete, 2002).

$$2Mn\ (II) + 2H^+ + H_2O_2 \leftrightarrow 2Mn\ (III) + 2H_2O_2$$

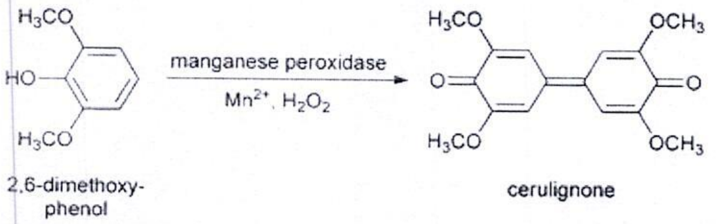

Fig. 3. Manganese peroxidase mediated conversion of 2,6-dimethoxyphenol to cerulignone (Lopez *et al.*, 2004).

Laccase

Laccase is a copper- containing polyphenol oxidase (blue multi copper oxidase) enzyme. It was discovered in the effluence of Japanese lacquer tree *Rbus vernicifera* (Yoshida, 1883). It is broadly distributed in fungi, higher plants bacteria and insects. Deuteromycetes, Ascomycetes, Basidiomycetes and many white-rot fungi are contains laccase (Kunamneni, 2008).

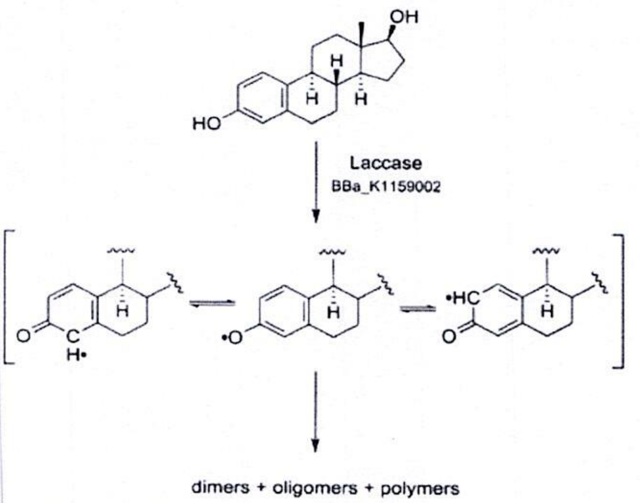

Fig. 4. Catalytic breakdown of 2,6-dimethoxyphenol by laccase (Arora and Sharma, 2010).

Fungal laccase is involved in the lignin degradation and during degradation it removes potentially toxic phenol from the lignin. It requires oxygen for enzymatic action as a second substrate. It is capable to catalyze the ring cleavage of aromatic compounds. It used ABTS, 2,6-dimethoxyphenol, dimethyl-p-phenylenediamine and syringaldazine as a substrate. It moniterate with an oxygen sensor, through the oxidation process reduces oxygen to water (Claus, 2004).

Versatile Peroxidase

Versatile peroxidase is a novel class enzyme of ligninolytic peroxidases. It shows combine properties of lignin peroxidase and manganese peroxidase (Ruiz-Duenas *et al.*, 1999; Camarero *et al.*, 2000; Martinez, 2002). Little data shows versatile peroxidase oxidizes lignin or lignin-derivatives. *Bjerkandera* sp. Strain BOS55 is first reported versatile peroxidase secretes in vitro testing (Moreira *et al.*, 2001).

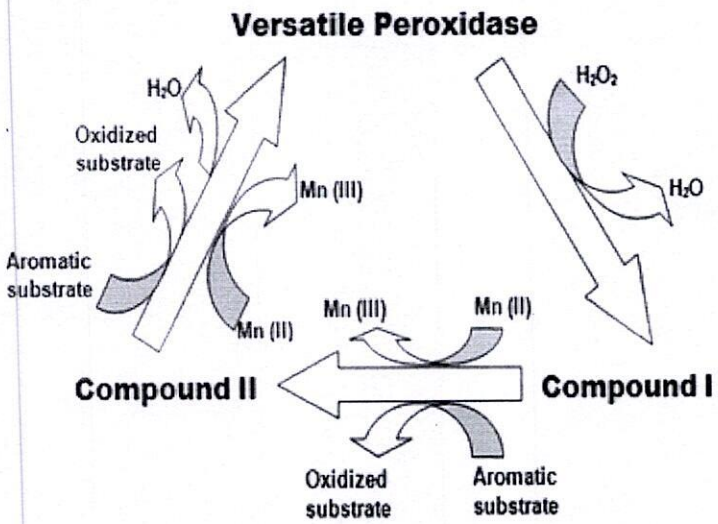

Fig. 5. Oxidation of manganese and aromatic substrates by versatile peroxidase (Ravichandran and Sridhar, 2016).

Lignin Degrading Microbes

Basidiomycetes group fungi are mainly degrades lignin and its derivatives. In environment it will be ability to grow in accommodate detrimental conditions and act as environmental natural lignocelluloses destroyers. Leaf litter, white rot and brown rot fungi are present in these groups (Cho *et al.*, 2009). Lignin is natural aromatic polymer and recalcitrant aromatic polymer on the earth. They are mostly degrading by white rot fungi by enzymatic combustion. Basidiomycete's families as well as Ascomycetes family fungi also degrade lignin in nature (Kirk and Farrell, 1987).

Table 1: Lignin degrading enzyme producing fungi

S. No.	Organisms	References
I.	**Fungi**	
	1. *Trametes versicolor*	Dion, 1951
	2. *Glomerella sp.*	Mayer and Harel, 1979
	3. *Podospora anserina*	Durrens, 1981
	4. *Aspergillus nidulans*	Kurtz and Champe, 1982
	5. *Fomes annosus*	Haars and Huttermann, 1983
	6. *Daedalea flavida*	Arora and Sandhu, 1985
	7. *Schizophyllum commune*	De Vries *et al.*, 1986
	8. *Pleurotus ostreatus*	Arora and Sandhu, 1987
	9. *Pleurotus sajor-caju*	Bourbonnais & Paice, 1988
	10. *Polyporus pinsitus*	Huttermann *et al.*, 1989
	11. *Rigidoporus lignosus*	Galliano *et al.*, 1991
	12. *Armillaria ostoyae*	Robene-Saustrade *et al.*, 1992
	13. *Ceriporiopsis subvermispora*	Ruttimann-Johnson *et al.*, 1993
	14. *Agaricus bisporus*	Bonnen *et al.*, 1994
	15. *Ganoderma trabeum*	Palaez *et al.*, 1995
	16. *Pycnoporus cinnabarinus*	Eggert *et al.*, 1996
	17. *Ganoderma lucidum*	Perumal, 1997
	18. *Trametes trogii*	Garzillo *et al.*, 1998
	19. *Lentinula edodes*	D'Annible *et al.*, 1999
	20. *Marasmius quercophilus*	Farnet *et al.*, 2000
	21. *Phellinus ribis*	Min *et al.*, 2001
	22. *Trametes modesta*	Nyanhongo *et al.*, 2002
	23. *Piloderma byssinum*	Chen *et al.*, 2003
	24. *Volvariella volvacea*	Chen *et al.*, 2004
	25. *Irpex lacteus*	Svobodova, 2005
	26. *Volvariella speciosa*	Fasola *et al.*, 2007
	27. *Ganoderma austral*	Mendonca *et al.*, 2008
	28. *Lentinus polychrous*	Suwannawong *et al.*, 2010
	29. *Pycnoporus sanguineus*	Kalarani *et al.*, 2011
	30. *Lentinus squarrosulus*	Tripathi *et al.*, 2012
II.	**Bacteria**	
	1. *Azospirillum lipoferum*	Givaudan *et al.*, 1993;
	2. *Aquifex aeolicus*	Deckert *et al.*, 1998
	3. *Escherichia coli*	Sanchez-Amat *et al.*, 2001
	4. *Pyrobaculum aerophilum*	Fitz-Gibbon *et al.*, 2002

[Table Contd.

Contd. Table]

S. No.	Organisms	References
	5. *g-proteobacterium*	Bains *et al.*, 2003
	6. *Thermus thermophiles*	Miyazaki, 2005
	7. *Streptomyces galbus*	Sharma *et al.*, 2007
III.	**Insect**	
	1. *Bombyx mori*	Yamazaki, 1972
	2. *Lucilia cuprina*	Barrett, 1987
	3. *Anapheles gambiae*	Dittmer *et al.*, 2004
	4. *Nephotettix cincticeps*	Hattori *et al.*, 2005

Industrial Applications of Lignin Degrading Enzymes

D'Souza *et al.* (2006) studied that ligninolytic enzyme such as lignin-peroxidase (lip), Manganase-peroxidase (MnP) and laccase had three major classes of lignin degrading enzymes, which have great potential for industrial applications.

Food Industries

In the food industries laccase is the known a best wine stabilizer. They easily control to the haze formation. Haze formation occure in the presence of phenolic compound such as proanthocyanidins (Osma *et al.*, 2010). Brijwani *et al.* (2010) reported to presence of enzyme in dough they improve the dough consistency and also inhance the gulten structure. After the addition of laccase in the dough, they showed softness, volume increasing and crumb changes into the structure.

Paper and Pulp Industries

While using wood for paper making, lignin is the main compound and harsh chemicals (sulphite, chlorine and oxygen based oxidants) or strong acid used for processing. These compounds generate water pollution and soil pottution (heavy soil) (Scott *et al.*, 1998). Laccase is capable to depolymerize and de-lignifing the wood pulp fiber, use in chlorine-free in bio-palpation process (Camarero *et al.*, 2004; Vikineswary *et al.*, 2006).

Textile Industries

In the textile industry various dyes are secrested with wast water. Generally effluents of waste water are highly coloured with COD (chemical oxygen demand) and BOD (biological oxygen demand) (Nagraj and Kumar, 2006). *Trametes versicolor* (white rot fungi) help in the decolourazation of dyes (Roseline *et al.*, 2013).

Laccase enzyme are applicable for denim finishing, it is a new trend. For stone-washed look of denim fabrics pre-bleach, rinsing and neutralize by sodium hypochloride. All steps of denim processing are cause substantial environmental pollution. For bleaching of denim fabrics *Trametes versicolor* secretes laccase at normal environmental conditions (Sharma *et al.*, 2005). Some textile dyes degradation showed in the table no. 2.

Bioremediation

Lignolytic enzymes producing microorganisms are capable to degrade lignin. They also degrade several xenobiotic compounds and recalcitrant pollutants like PHA (polyhydroxyalkanoates). White rot fungi totally mineralized the lignin compounds. It generates the research interest in the industries and environmental microbiology fields (Van and Villaverde, 2005; Ruiz-Duenas and Martinez, 2009; Dashtban *et al.*, 2010). Bioremediation by ligninolytic enzymes showed in the table no. 2.

Table 2: Ligninolytic enzymes used in the processing of textile dyes and bioremediations

S. No.	Compounds	Organisms	Ligninolytic enzymes	References
1.	Textile dyes	*Phanerochaete chrysosporium*	Manganese peroxidase	Koyani *et al.*, 2013
2.	Azo dyes	*Pleurotus ostreatus*	Manganese peroxidase	Arunkumar and Sheik Abdulla, 2014
3.	PHAs	*Pleurotus ostreatus*	Laccase and versatile peroxidase	Pozdnyakova *et al.*, 2010
4.	Bentazon	*Ganoderma lucidum*	Manganese peroxidase and laccase	De Silva *et al.*, 2009
5.	Textile effluents	*Phanerochaete chrysosporium*, *Curvularia lunata*	Laccase	Miranda *et al.*, 2013
6.	Poly R-478 (polymeric model dye)	*Irpex lacteus*	Manganese peroxidase	Wang *et al.*, 2013
7.	Olive oil waste-water	*Hapalopilus croceus*, *Phanerochaete chrysosporium*, *Irpex lacteus*	Manganese peroxidase, manganese independent peroxidase and laccase	Koutrotsios and Zervakis, 2014
8.	Endocrine disrupters	*Cerrena unicolor*	Laccase	Songulashvili *et al.*, 2012
9.	Nonyphenol	*Pleurotus ostretus*	Laccase	Macellaro *et al.*, 2014

[Table Contd.

Contd. Table]

S. No.	Compounds	Organisms	Ligninolytic enzymes	References
10.	Naphthalene, Benzo[a] anthracene and anthracene	*Lentinula edodes*	Laccase	Wong *et al.*, 2013
11.	Diclofenac and bisphenol A	*Aspergillus oryzae*	laccase	Nguyen *et al.*, 2014
12.	Salicylic acid, triclosan, naproxen, diclofenac, ibuprofen and gemfibrozil	*Trametes versicolor*	Laccase	Nguyen *et al.*, 2014

Bio-Ethanol Production

Production of fuel ethanol by wood hydrolysates fermentation is very difficult. White-rot fungi are capable to degrade lignin. White-rot fungi (*Trametes versicolor*) secrete peroxidases (lignin peroxidase and manganese peroxidase) and phenol oxidase laccase, which is transform the aromatic compounds of wood (Lipin *et al.*, 2013). *Saccharomyces cerevisiae* is used for ethanolic fermentation. Peroxidases and laccase a phenol oxidase increase the productivity of ethanol (Olsson, 1996).

Conclusion

Ligninolytic enzymes are involved in recalcitrant polymer lignin and complex lignin polymers degradation. They are highly versatile group in nature and very wide applicable in various industries. Ligninolytic enzymes applications in industries and also found in WRFC (Weather Research and Forecasting Model) have (a) paper whitening, (b) textile industries in degradation of industrial dye, (c) biotechnological application and (d) xenobiotics compounds degradation, including herbicides, polycyclic aromatic hydrocarbons, phenolics and other pesticides. Laccase as an oxidase used in many industrial, agricultural and medicinal applications (Arora and Sharma, 2010). Fungal enzyme laccase had been used for decades in enzyme-technology industries (Shukla, 2014).

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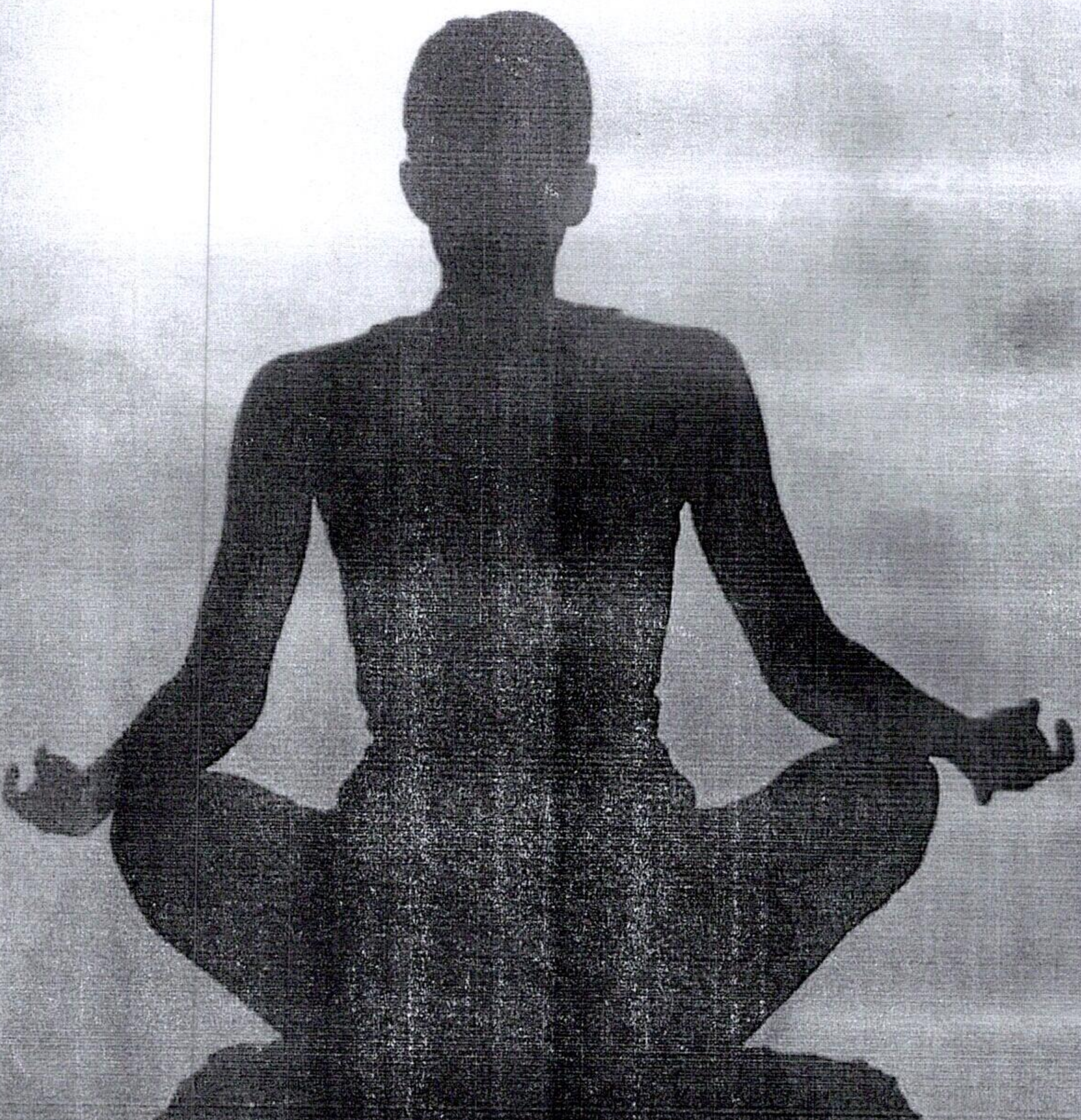
TEACHING-LEARNING EXCELLENCE THROUGH YOGA

A Psychosomatic Intervention

Dr. Pradip Debnath



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CONTENTS

Chapter 26

Yoga Education at Academic Institutions

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Introduction

In such a busy life full of responsibilities, long working and busy schedule, we mostly forget to be happy. Sometimes it becomes very difficult to balance between work life and personal life which affects our mental and physical health. It is very important to take out some time for physical exercise, yoga, etc. So, it is very important to include yoga in our daily life because it helps in balancing our body, mind and soul, which in turn brings the physical and mental discipline which is necessary for good mental and physical health. Yoga leaves a positive effect on our life and also has many physical and mental benefits.

Life is very busy today. We all Human beings have become machines – mentally, physically as well as emotionally. We chase for money more than we chase for our relationships. We put our mind and body through regular hours, days and months of work, and take it as a complement when termed as "workaholics". We make a resolution every year that we will leave all unhealthy habits and live a healthy life, we will eat fresh instead of junks, and we will not take stress we will care about our near and dear one more than worrying about money-oriented things; but believe it or not, life now has become materialistic, goal-oriented, competitive. After only a few days of New Year we forget all the promises we made with ourselves and our New Year resolution goes in vain. Yoga helps us to maintain a balance between our work and personal life by making our body and mind healthy.

Anyone can start doing yoga at any age. It is suitable for all age group people and can be done without much physical strain. We can easily include it in our daily life. It also opens the path of self-knowledge and self-realization. It also helps in developing positive thinking, persistence, discipline, right orientation, prayer as well as humbleness and kindness.

Health is the most important thing in our life, if we have a healthy body, then only we will be able to develop a healthy mind in it and will be able to achieve goals of our life which in turn will help us to live a happy and successful life.

It is rightly said that "Health is Wealth" if we have a good health we will be able to accumulate wealth too.

Importance of Yoga in Our Daily Life

Practicing yoga in regular basis develops mental and physical health. It helps in developing good social health; if we will have a good mental health, our social health will automatically be healthy. Yoga also helps in developing spiritual health and so as self realization.

Yoga is comprised of several postures or asanas to keep our body healthy. Yoga also includes some breathing exercises like pranayama and meditation to develop a healthy mind.

Benefits of Yoga

Yoga is helpful in many diseases like heart disease, blood pressure, Diabetes, Sciatica and many others. It is also helpul in weight management. It also improves our digestive system and improves our metabolism. It is helpful for treatment of insomnia. It helps in flushing out toxins from our body as well as mind and thus helps in leading a peaceful life.

Yoga helps in self-control, reducing stress, boosts immunity, increases flexibility, increases lungs and liver functioning and makes bones stronger.

Over the last few years, there is an instant increase in application of yoga. Medical professionals and celebrities are also practicing and emphasizing the daily practice of yoga due to its various benefits.

From the very beginning to college level, children during studies also live a life full of pressure. They sit for hours for studying on their study table as well as laptop and computer. They also suffer from social, peer and family pressures. They also face anxiety, abuse and bullying, etc. -----all these lead to high level of pressure and tension which lead to mental and physical fatigue, which adversely affects their life. It is the reason why parents and educators are taking interest in yoga education at school and college level. In fact, some of the surveys conducted also show highly significant effect of yoga on mental as well as physical heath.

Yoga Education

Yoga education can enhance the quality of school and university education. It can help in strengthening the students physically and mentally and make them stress-free so as to make them better citizens of a country. It also helps in improving concentration power which helps in improving their academic outputs and makes them self-disciplined.

Benefits of Yoga education are:

1. It helps the students to gain good health.
2. It improves mental health and awareness.
3. It improves emotional health and thus brings emotional stability.
4. It helps in inculcating moral values.
5. It helps in higher level of consciousness.

Yoga education can help a person in adjusting well in all life situations.

Yoga education is also helpful in improving all the activities of the students, be it academic or sport or social. Yoga helps in improving attention in studies, better stamina and good co-ordination for sports and balanced attitude for social activity.

Yoga not only helps in sharpening the mind and making the heart healthy but it also lays emphasis on moral human values. It holds the power of changing the world by changing their lifestyle. It must be an important and compulsory part of everyone's life, especially it must be included in students' life as it not only contributes to their all round mental and physical development but also helps in development of positive attitude towards every aspect of life.

Yoga Education has numerous advantages which can be proved as a blessing for a student in every aspect of life.

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भारत में महिला सशक्तिकरण के विविध आयाम

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भारती पब्लिकेशन्स
नई दिल्ली

सर्वाधिकार सुरक्षितः संपादक

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9

आदिवासी समाज के उत्थान में महाश्वेता देवी का साहित्यिक योगदान

डा. सुरेखा जवादे[१] एवं शुभांगी सिंह[२]

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लेखिका ने तीन दश्क आदिवासियों के मध्य व्यतीत किया। बिना संसाधनों के जीवन यापन करने वाले इन आदिवासियों के हर पहलू को आत्मसात् किया और यही पीड़ा उनके लेखन कीसामग्री बनी। दलितों और साधन-हीनों के हृदयहीन शोषण का चित्रण उनका विशिष्ट क्षेत्र रहा हैं और इसी संदेश को वे बार-बार सहीं जगह पँहुचाना चाहती थी ताकि अनन्त काल से गरीबी-रेखा के नीचे साँस लेने वाली विराट मानवता के बारे में लोगों को सचेत कर सके। उन्होंने समाज में व्याप्त आदिवासियों, दलितों, मजदूरों शोषित-पीड़ित वर्ग, महिलाओं की समस्याओं को समाज के समक्ष लाकर रख दिया है। जिससे की इन्हें न्याय मिल सकें।

महाश्वेता देवी का रचना संसार साहित्य क्षेत्र का वह चमकता सितारा है जिसका प्रकाश सदैव ही दमकता रहेगा। उनके द्वारा चयनित विषयों पर लिखित

साहित्य विगत छः दशकों से मानवीय समाज के लिए प्रेरणा दायक है। उनके साहित्य का अध्ययन करने वाला व्यक्ति उसमें निहित शाशवत सत्य से इतना अधिक प्रभावित होता है कि पाठक होने के बावजूद वह पात्र बन जाता है। उनके द्वारा रचित कहानी, उपन्यास या लेख पाठक वर्ग को स्वयं के साथ घटित घटना सा प्रतीत होता है। चाहे वह पश्चिम बंगाल के बुद्धन शवर का प्रकरण ही क्यों न हो? जिसे पुलिस द्वारा आत्महत्या मान कर फाईल को बंद कर दिया गया था, परन्तु महाश्वेता देवी का सफल प्रयास था कि उस पूरे प्रकरण को वह न्यायालय ले गई और न्यायालय में जीत प्राप्त कर मारणोपरांत बुद्धन शवर को न्याय दिला सकी।

महाश्वेता देवी के विचारों, आन्दोलन और समाज के प्रति समपर्ण को ध्यान मे रखते हुए पश्चिम बंगाल सरकार द्वारा बंगला साहित्य अकादमी के अध्यक्ष पद पर उन्हें पदासीन किया गया। जबकि मीडिया जगत पिछले साठ वर्षो से समय-समय पर प्राथमिकता के आधार पर उनके लेखो को प्रकाशित करता रहा है। ताकि समाज में व्याप्त अव्यवस्थाओं से अनभिज्ञ आमजन परिचित हो सके और इन लेखो से शिक्षा प्राप्त कर चेतना वश इन सामाजिक बुराईयों पर विजय प्राप्त कर सके।

वह स्वयं भी कहती है कि मानवीय पीढ़ा ही उनके लिखने का विषय है। उनकी रचनाओं से यह महसूस भी किया जा सकता है कि उनके सम्पूर्ण विषय सामाजिक अव्यवस्थाओं पर पूर्ण रूप से आधारित होते है। उनके सभी साहित्य के विषय सत्यता के आस-पास ही होते है। महाश्वेता देवी द्वारा रचित कथा साहित्य की कहानियों में बाढ़, बांयेन, बीज, प्रेतछाया, रांग नंबर, शनिचरी, ईट के ऊपर ईट, छुक छुक आ गेल गाडी, मूर्ति एवं भारत वर्ष आदि सभी ८० एवं ६० के दशक में लिखी गई हैं। गागर में सागर कहावत को चरितार्थ करने वाली महाश्वेता देवी की यह रचनाएं ३० से ४० वर्ष पूर्व लिखा होने के बावजूद उनके लिखे विषयों की प्रासंगिकता आज भी कायम है। मानवीय पीढ़ा के पश्चात् सामने आये विषयों में महिला उत्पीड़न, मजदूरों के अधिकारों का हनन, युवा के मध्य भटकाव, विधवा विवाह, वैश्यावृत्ति, भूखमरी,आदिवासी समुदाय को समाज की मुख्य धारा से जोडना आदि विषयों पर आज भी कार्य करने की आवश्यकता है।

महाश्वेता देवी द्वारा रचित 'अरण्येर अधिकार' उपन्यास के माध्यम से मुण्डा आदिवासी वर्ग समाज की मुख्य धारा से जुड़ सका। उन्हें यह महसूस होने लगने लगा की आदिवासियों के प्रति उनका दायित्व और अधिक बढ़ गया है।उन्होंने आदिवासियों के बारे में ओर भी जानने की कोशिश जारी रखी।वेहमेशा आदिवासी इलाकों में जाती और उनके उनके साथ समय व्यतीत करती। आदिवासियों वर्ग की पीढ़ा कोमहसूस करती थी। जिसके कारण उनका लेखन शोषित आदिवासी समाज और उत्पीड़ित दलितों में केन्द्रित हो गया। न्यूनतम मजदूरी, मानवीय गरिमा, सड़क, पेयजल, अस्पताल, स्कूल की सुविधा से वंचित, भूमिहीन होने से अभिशप्त इन आदिवासियों और दलितों को आजादी के इतने साल बाद भी न्याय नहीं मिला हैं और यही महाश्वेता देवी के चिंता का कारण बनते गये। उनकी यही वास्तविक चिंताएं उनकी कहानियों और उपन्यासों में नजर आती हैं।

दलितों और साधन-हीनों के हृदयहीन शोषण का चित्रण उनका विशिष्ट क्षेत्र रहा हैं और इसी संदेश को वे बार-बार सहीं जगह पँहुचाना चाहती हैं ताकि अनन्त काल से गरीबी-रेखा के नीचे साँस लेने वाली विराट मानवता के बारे में लोगों को सचेत कर सके। उन्होंनें समाज में व्याप्त आदिवासियों, दलितों, मजदूरों शोषित-पीड़ित वर्ग, महिलाओं की समस्याओं आदि को समाज के प्रतिबिम्ब में लाकर रख दिया है। महाश्वेता देवी की रचनाएं देश के ग़रीब आदिवासी लोगों के खिलाफ सामाजिक भेदभाव, छुआछुत, शोषण पर केन्द्रीत हैं। इन्होंने अपने सशक्त कलम से समाज में हो रहे इस अन्याय के खिलाफ आवाज उठाई, ताकि समाज की इस अनीतिगत व्यवस्था में सुधार लाया जा सके। उनकी सभी रचनाएं सामाजिक असमानता के आस-पास ही थी। इन्होंनें सौ से भी ज्यादा रचनाएं, जनजातियों एवं २५ लाख आदिवासियों को समर्पित कर दी और उनके जीवन की कुरुपता एवं दुख को अपनी रचनाओं में उल्लेखित किया है।

महाश्वेता देवी ने जीवन में जनजातिय समुदाय का कल्याण करने एवं उनके उत्थान के लिए अनेक कार्य किये। पश्चिम बंगाल के पुरूलिया जिले में आदिवासी समुदाय उत्थान के लिए बड़े पैमाने पर भी कार्य किये। आदिमजाति कल्याण के क्षेत्र के लम्बे समय तक कार्य करते हुए पश्चिम बंगाल की 'उराव वेलफेयर

सोसायटी' और 'भारतीय बांधव लिबरेशन मोर्चा' के साथ जुड़ी और आदिवासी संयुक्त एसोसिएशन की संस्थापक सदस्य बनी। सन् १९८० में आदिवासी पत्रिका 'बर्तीका' का संपादन कार्य भी शुरु किया। महाश्वेता देवी के शब्दों में -

"मैं आराम करना चाहती हूँ पर वंचितों, दलितों एवं आदिवासियों के लिए संघर्ष के लिए और न्याय दिलाने के लिए अपना सारा जीवन लगा दूंगी और मेरी प्रत्येक रचना इस वर्ग के लिए समर्पित रहेगी ।"

उन्होने लेखन कार्य के अलावा सशक्त सामाजिक कार्यकर्त्ता की भूमिका अदा करते हुए आदिवासीयों के उत्पीड़न, अन्याय एवं भारतीय समाज के सबसे निचले दलित वर्गो की मुक्ति के लिए विरोध प्रदर्शन करते हुए, उन्हें न्याय दिलाने के लिए अभियान चलाया। उनकी प्रमुख **रचनाओं** में टेरोडैक्टिल, जंगल के दावेदार, १०८४ वे की माँ, भटकाव, दौलती, शालगिरह की पुकार पर, श्री श्री गणेश महिमा, अक्लान्त कौरव, अग्निगर्भ, चोट्टिमुंडा और उसका तीर, नील छवि, ग्राम बांग्ला, घहराती घटाएं, मूर्ति, ईंट के ऊपर ईंट, भारत में बंधुआ मजदूर, अमृत संचय, जली थी अग्निशिखा, बनिया बहू , झाँसी की रानी, कृष्ण द्वादशी, भारतवर्ष की अन्य कहानियां, महाश्वेता देवी की श्रेष्ठ कहानियां आदि शामिल है।

महाश्वेता देवी द्वारा रचित रचनाओं से स्पष्ट होता है कि आजादी के ७२ वर्ष बाद भी आदिवासी वर्ग मूलभूत सुविधाएं पाने में आज भी वंचित है। यही पीड़ा महाश्वेता देवी की चिंता का कारण बनी रही। महाश्वेता देवी जी ने अपना अधिकतम समय आदिवासियों के बीच रहकर व्यतीत किया। उनकी समस्याओं को बड़े ही नजदीकियों से समझा व जाना है अर्थात् यह कहा जा सकता है कि उन्होंने जीवन के तीन दशकों का समय उनके द्वारा जल, जंगल और जमीन की लड़ाई के संघर्ष में खर्च कर दिया हो। उन्होंने पश्चिम बंगाल की दो जनजातियों लोधान और शबर पर विशेष कार्य किये है। इन संघर्षो के दौरान पीड़ा के स्वर को महाश्वेता देवी ने बहुत करीब से सुना और महसूस किया है। इन्होंने अपना सारा जीवन साहित्य, आदिवासी और भारतीय जनजातीय समाज को समर्पित कर दिया हैं। उनके नौ कहानियों के संग्रह में से आठ कहानियों के केन्द्र में आदिवासी जाति केन्द्रित है ये आदिवासी वर्ग आज भी समाज की मुख्यधारा से कटकर जी रहा है। आदिवासी वर्ग की पीड़ा के वे स्वर उनकी रचनाओं में

साफ-साफ सुनाई पड़ते है। महाश्वेता देवी की रचनायें केवल साहित्य नहीं है अपितु सामाजिक अव्यवस्था का स्रोत है। उपन्यास एवं कहानियों ने शोषित और पीड़ित वर्ग के साथ होने वाली पीढ़ा को एक तरीके से दूर किया है। साहित्य अकादमी से पुरस्कृत 'अरण्येर अधिकार' में बिरसा मुण्डा आदिवासी समुदाय को समाज से मुख्यधारा में जुड़ने की शासकीय स्वीकृति मिली। महाश्वेता देवी के शब्दों में-

"एक लम्बे अरसे से मेरे भीतर जनजाति समाज के लिए दर्द की जो ज्वाला धधक रही है। वह मेरी चिता के साथ ही शांत होगी।"

लेखिका द्वारा तीस वर्षो तक आदिवासियों के मध्य रहकर उनकी दिनचर्या को समझा एवं जाना। आदिवासियों को होने वाली हर पीड़ा को लेखिका ने आत्मसात् किया और यही पीड़ा उनकी लेखन का विषय बना। महाश्वेता देवी की कहानियाँ बताती है कि संस्कार व असामर्थ्य आदिवासियों के मन और चरित्र पर भी असर करता है जिससे आदिवासियों के जीवन शैली पर भी प्रभाव पड़ता है। महाश्वेता देवी के कहानियों में सामंती ताकतो के शोषण उत्पीड़न, छल प्रपंच के विरूद्ध सताये हुए लोगों के संघर्ष अनवरत जारी दिखाई पड़ते है।महाश्वेता देवी ने उपन्यास की तरह ही अपनी कहानियों में आदिवासी वर्ग की अस्मिता के सवाल को सशक्तता के साथ उठाया हैं उनकी कई कहानियाँ आदिवासियों की सच्ची संघर्ष गाथाएं है।

महाश्वेता देवी रचित साहित्य भाषा को लेखनी नहीं अपितु हथियार के रूप में इस्तेमाल किया करती थी। उनका जीवनकाल ब्रिटिशकाल, स्वतन्त्रता और उत्तर उपनिवेषवादी के पचास वर्षो तक फैला है उनकी लेखनी ने भारतीय साहित्य को नया जीवन दिया है और लेखकों, पत्रकारों और फिल्म निर्माताओं की दो पीढ़ियों को प्ररित किया है। सामाजिक कार्यकर्त्ता रहते हुए सामाजिक भेदभाव को समाप्त करने का प्रयास आन्दोलन एवं लेखन दोनों ही माध्यम से किया। भारत की जनजाति लोगों के अधिकार को दिलाने के लिए उनके द्वारा किये गये अथक कार्य उनके जीवन का एक हिस्सा है। महाश्वेता देवी के द्वारा गंभीर विषयों में लिखी गई कहानियाँ आज भी प्रासंगिक है।

संदर्भ ग्रंथ

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Actinomycetes: Implications and Prospects in Sustainable Agriculture

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Abstract

Biofertilizers are being considered as a great gift of nature to mankind. The latent microorganisms being active ingredients of biofertilizers have served the purpose of solving environmental and health issues related to indiscriminate usage of harsh chemical fertilizers. Biofertlizers serve as important components of integrated nutrition management system for sustainable agriculture. Among the diverse types of microorganisms in nature, the role of actiomycetes cannot be underrated. Their large population in diverse soil types and their dynamic nature to maintain soil fertility and ecology is of prime importance in agriculture field. Biological management of soil ecosystem by actinomycetes through their diverse features like plant growth-promoting ability, managing plant health and vigor, and production of agro active compounds greatly contributes to the agricultural sector. The capacity of actinomycetes to mitigate unsafe and adverse effects of chemical fertilizers and also to promote positive effects in plants highlights their role in ecosystem resilience. These filamentous bacteria have immense beneficial effects in soil and hence open a great avenue for improved crop production in future.

Keywords: Actinomycetes, sustainable agriculture, agro active compounds, biofertilizer

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11.1 Introduction

Nutrient management is a practice which deals with conservation of soil by managing essential soil nutrients at their best and optimum levels, and biofertilizers are considered as an important part of this management system. It is believed that biofertilizers have an edge over the chemical fertilizers. They are unique in the sense that they are safe, eco-friendly, and, at the same time, quite efficient [1]. In simple terms, biofertilizers can be described as substances containing living, efficient microorganisms that help upgrade and assist plant yield by enhanced extension of required nutrients to the host plant [2]. Their role in sustainable crop production and effective, eco-friendly nature is of paramount importance in agricultural field. These features of biofertilizers are inspired by the very nature of their constituent components—the microbes. The microbes tend to provide all the beneficial properties a biofertilizer should possess. Biofertilizers, as tools for food safety and sustainable agricultural practices, incorporate within them impressive features like nutrient mineralization and mobilization, serving as effective biocontrol agents against several plant diseases [3], sustaining plants under both biotic and abiotic stress and maintaining soil ecology and fertility by incorporating certain plant growth-promoting factors, etc. [4].

Microorganisms in biofertilizers are the ones which are creditable for all these features. Many different microorganisms are considered suitable for preparation of biofertilizers. But actinomycetes among them are unique. Characteristic distinctive features from bacteria and fungi: actinomycetes are unique by playing pivotal role in soil ecosystem, and their benefits being reaped not only in industries but in agriculture as well [5]. As prospective contenders for production of biofertilizers, actinomycetes possess the characteristic feature to secrete wide range of secondary metabolic derivatives and factors with antibacterial, antifungal, and antagonistic effects [6].

Actinomycetes rule the roost among the large diverse microbial population in terms of production of bioactive compounds. Reports confirm that of the 23,000 varieties of bioactive compounds produced by microbes; nearly 50% of them are produced by actinomycetes [7, 8]. Antibacterials, antivirals, and agrobiologicals like weedicides, insecticides, and growth regulatory compounds are some of them [9, 10]. Their ability to exist and survive in diverse soil conditions help themselves to indulge in various soil processes: nitrogen fixation, phosphate solubilization, and formation of humus to name a few [11]. Also, production of agro active substances and hence their role in sustainable agriculture arguably makes actinomycetes the most impressive and potent contenders for biofertilizer formulations.

Among the vast assortment of microbes that exists on earth and in nature, actinomycetes are one of the most widely distributed organisms. Almost more than 100 genera of actinomycetes are natural inhabitants of soil [12]. Actinomycetes belong to the order Actinomycetetales and can be distinguished from other microbes with elevated levels of G+C content (74 mol %) [13, 14]. These gram-positive bacteria exist as saprophytes in the soil [15]. Being saprophytic soil inhabitants, they possess the ability to decompose organic matter like lignocelluloses and various types of complex carbohydrates like starch and chitin [16]. Morphologically, they show mycelia growth which culminates in sporulation. Actinomycetes usually exist in significantly high numbers in semi-arid soil environments although very little numbers of actinomycetes have also been known to exist in other climatic conditions too [17]. Actinomycetes usually prefer low level of moisture for growth and survival and are very well acclimatized to semi-dry conditions [18] probably due to their ability to sporulate even under dry conditions [19]. Actinomycetes are mesophilic in nature, though some species may be found in thermophilic habitats too [20]. They can also grow as epiphytes and have a wide host range [21, 22].

Recently, actinomycetes have garnered a lot of interest in microbiologists because of their diverse properties which makes them a good source for development of bioinoculants [23, 24]. Actinomycetes are very important microbes which can promote the overall vigor and yield of crop plants. They can be introduced directly into soil or can be applied to crop seeds [25, 26]. Actinomycetes are known to directly influence growth of plants by mechanisms like nitrogen fixation, phosphate solubilization, production of growth hormones, or indirectly by scavenging of iron by siderophore production and hence protection of plants from pathogens [27]. Also, they influence their growth by magnifying their sufferance to various stress conditions [28, 29].

A well-known genus of actinomycetes is *Streptomyces* [30]. *Streptomyces* and other actinomycetes genera contribute to over 75% of the many known active biological compounds [31]. Actinomycetes have long been inviting a lot of attention due to their capability and capacity to inhibit a broad range of fungal pathogens by producing antifungal agents, thereby protecting the plants from a variety of fungal diseases [32]. Actinomycetes are very good repositories of antibiotics and extracellular enzymes [33, 34]. Also, their prospective ability to serve as a source of biocontrol elements, biologically active agricultural agents and plant growth-enhancing ingredients cannot be ignored.

11.2 Role in Maintaining Soil Fertility

11.2.1 Nitrogen Fixation

One of the critical element which limits plant growth is nitrogen. Availability and uptake of sufficient nitrogen by plants is crucial and indispensable for their growth and maturation [35]. The importance of nitrogen for plants lies in the fact that it is utilized for biosynthesis of important nitrogenous compounds like nucleic acids, amino acids, and proteins [36, 37]. It is a vital component of photosynthetic pigment; chlorophyll and also it is used for biosynthesis of ATP and nucleic acids [38]. However, the element nitrogen in spite of its abundance in earth's atmosphere is not available to plants due to its inert nature unless it is converted to a more available form [39]. Elemental nitrogen is to be converted to either ammonium ion $\left(NH_4^+\right)$ or nitrate $\left(NO_3^-\right)$ for it to be used conveniently by plants. There are a variety of microorganisms including actinomycetes with a potential to fix atmospheric nitrogen in both leguminous and non-leguminous plants, but when compared to other microbes, actinomycetes have a unique property of entering into a more collaborating relationship with a diverse group of plants [40] which other nitrogen fixing microbes lack. This feature of actinomycetes ensures its place as a top contender for production of biofertilizer in terms of nitrogen fixation ability.

Actinomycetes can form nodule clusters and possess nitrogen fixing ability. Some actinomycetes enable their potential of nitrogen fixation by interacting with the plant while some help the plant by existing independently in the soil. In either case, the beneficial effect in plants is very much obvious. A considerable number of studies have evolved associated to the group of actinomycetes which interact with plants in some or the other way and increase soil fertility and hence affect the nature of plant growth. Some species of actinomycetes exhibit a very strong plant-microbe interaction which is of great importance for the health of the plant. A unique and substantially strong interaction exists between *Streptomyces lydicus* WYEC108 which is a root-colonizing actinobacteria and *Pisum sativum*, a leguminous plant as reported by Tokala *et al.* [41]. This interaction between the pea and actinomycetes seems to be of utmost importance because the root-colonizing soil actinomycetes, *Streptomyces* *lydicus* WYEC108 not only promotes growth of healthy nodules in the legumes but also influences the pea root by greatly enhancing the frequency of root nodulation. Pea being a leguminous plant also is known to enter into symbiotic relation with bacteria (*Rhizobium*). Studies reveal that probably *Streptomyces lydicus* colonizes the pea root at a time when the common symbiotic nitrogen fixing *Rhizobium* species infects the pea plant to form root nodules. These active bacteria after colonization start to sporulate within the nodules and precisely within their cell layers [42]. So, such settlement by both *Rhizobium* and *Streptomyces* possibly causes an increase in nodule size which finally helps to improve the vigor of organisms inside the root nodules. This helps to enhance the assimilation of various essential soil nutrients by the nodules [43]. So, perhaps, it is quite clear that several important actinomycetes like *Streoptomyces* act as natural soil fertility enhancers for improved growth of not only pea but also for many other leguminous plants. Such study reports provide substantial evidence that many actinomycetes have nitrogen fixing ability and may work independently to promote plant growth and health but the fact that they are also quite compatible with other root nodulating organisms cannot be ignored.

It is also believed that some actinomycetes have poor to average N_2 fixing ability as independent organisms but, when combined with other nitrogen fixing microorganisms or bacteroides, show extraordinary improvement in nitrogen fixation. This has also been experimentally proved by Soe *et al.* [44]. The evaluation of the compatibility of *Streptomyces griseoflavus* P4 strain isolated from pea root nodules with *Bradyrhizobium japonicum* strain USDA 110 was successful. It was reported that the combination had noteworthy effects on the dry weight of nodules, shoot nitrogen accumulation, seed weight, etc. Individually, neither *Bradyrhizobium japonicum* nor *Streptomyces griseoflavus* P4 strains improved nodulation and seed weight but the two, when combined, had significant beneficial effects in soybean. Improved nodulation and hence enhanced nitrogen fixation were some of them.

Actinomycetes not only interact symbiotically with leguminous plants but also fix atmospheric nitrogen by interacting with non-leguminous plants. In fact reports confirm that actinomycetes can fix comparably higher rates of atmospheric nitrogen with non-leguminous plants than leguminous plants [45]. Gautheir *et al.* [46] were the first to report the isolation of free-living actinobacteria from a nitrogen fixing non-leguminous tree (*Casuarina equisetifolia*) with the ability to form nodules. Two different actinomycetes were isolated from the nodules which were shown to possess nitrogenase activity based on acetylene reduction test [47]. The actinomycetes strains *Streptomyces* sp. D11 and *Streptomyces* sp. G2 although did not initiate nodulation in the host plant indicating the non-infective nature of these strains, these strains produced significant amount of nitrogenase which was found to be more sensitive to the presence of combined nitrogen. The influencing nature of *Streptomyces* sp. to nodulate pea root to a very high degree was reported by Tokala *et al.* [41]. *Streptomyces* sp. was also responsible for enhanced assimilation of iron by the root nodules and other soil nutrients.

Non-legumes like *Casuarina*, *Alnus*, and *Hippophae* can symbiotically interact with the actinomycete called *Frankia*. These organisms have been reported to revive the soil fertility by fixing huge amounts of atmospheric nitrogen. Such interactions are believed to be very important for ecology also because such woody trees and shrubs are known to actively grow under stressful soil conditions [48, 49].

Frankia ceanothi has been reported to contain nitrogen fixing properties [50]. This actinomycete exists as an endophyte within the cortex of a shrub, *Ceanothus greggii* [51]. Nitrogen fixing ability was long assumed to be limited to the genus *Frankia* but there are non-*Frankia* actinomycetes which have shown to possess *nif* genes and catalyze atmospheric nitrogen to a more assimilable form. Gtari *et al.* [52] have reported presence of *nif* genes in non-*Frankia* actinomycetes like *Slackia exigua*, *Rothia mucilaginosa*, and *Gordonobacter pamelaecae*. It was verified by their capability to grow and multiply on a medium lacking nitrogen and also by their potential to reduce acetylene [53]. It has been reported that these *nif* gene sequences are transferred either vertically or horizontally [54, 55]. Several non-*Frankia* actinomycetes have been isolated till date with nitrogen fixing ability. All actinomycetes including *Frankia* show typical filamentous cellular morphology in their initial stage of their life cycle. Later on, these filaments show fragmentation. Apart from nitrogen fixation ability, actinomycetes species, *viz.*, *Streptomyces*, *Actinoplanes* sp., and *Micromonospora* sp. reportedly have shown promotional effect on shoot growth and also enhanced actinorhizal symbiosis with *Frankia*. Also, these atinomycetes have been reported to produce bioactive metabolites [56].

11.2.2 Phosphate Solubilization

Plant growth depends on availability of all essential nutrients of which phosphorus is one of them. Its essentiality to plants lies in the fact that it is basis for synthesis of several macromolecules, respiratory chain components, energy transduction processes, etc. [57]. Plants take up phosphorus only when available in soluble form, but unfortunately its insoluble nature in soil makes it unavailable to plants [58]. The conversion from soluble to insoluble form is aided by presence of large quantities of cations (Zn^{2+}, Ca^{2+}, etc.) [59, 60]. The problem of phosphorus precipitation has not only caused depletion in soil fertility but also great economic loss to farmers in terms of low crop productivity. These issues have instigated an urge in researchers to look out for probable solutions which culminated into the implementation of phosphate solubilizing microbes in crop farming. The category of phosphate solubilizing microbes includes a range of soil inhabiting microbes like bacteria, actinomycetes, fungi, etc. These organisms are believed to solubilize phosphorus by producing specific enzymes and making it available to plants [61, 62].

Among the different phosphorus solubilizing microbes, actinomycetes probably have an edge over other microbes firstly because of their large population numbers in rhizosphere soil than other microbes [63] and secondly because the slow, yet steady degradative activities of actinomycetes compared to bacteria or fungi [64] allow them to constantly release soluble phosphorus throughout the plant life. Actinomycetes are one such group of organisms which help improve plant development and hence crop productivity. The growth of plants and the agricultural yield from such plants finally depends on the soils' nutritional quality and capacity of plants to uptake and assimilate those plant supplements. An important and commendable aspect of these organisms is that they have the ability to survive on the plant root exudates, which is their only source of nutrient supply [65]. In return, these actinomycetes help release soluble phosphate. The most important group of actinomycetes with phosphate solubilizing ability is *Streptomyces* but non-Streptomyces actinomycetes include *Micromonospora endolithica* [66], *Gordonia*, *Rhodococcus*, and *Arthrobacter* [65, 67, 68].

Actinomycetes have evolved to transform insoluble phosphates into soluble form by adapting different means. Some actinobacteria solubilize insoluble phosphates by secreting enzyme phytases. These extracellular enzymes enable degradation of phytate in a stepwise manner and belong to phosphomonoesterase group [69, 70]. Another method by which actinomycetes enable phosphate solubilization is by creating an acidic environment by producing a combination of acids like oxalic, malic, propionic acid, and gluconic acids. The acidic pH near the rhizosphere soil plays critical role in transformation of insoluble phosphates and making this essential nutrient available to plants [68, 71].

The phosphate solubilizing actinomycetes like *Streptomyces griseus* BH do not just act as soluble phosphate suppliers for the plants but also exhibit multitasking activities like inhibition of potential phyto pathogens including fungi, yeasts, and bacteria. Some strains of *Streptomyces* have shown to stimulate exorbitant increase in wheat aerial growth and biomass of nearly 70% in *in vitro* studies and to more than 30% in farm conditions when compared to controls. So, such reports are quite convincing for the development of biofertilizers and biocontrol agents from actinomycetes.

11.2.3 Potassium Solubilization

Another essential element required for growth of plants is potassium. The ionic state of potassium usually absorbed by plants is required for opening and closing of stomata pores. Apart from decreasing stress effect in plants, potassium is also associated with plant detoxification process by disabling the toxic effect of reactive and unstable species of oxygen. Also, its role in various respiratory chain and metabolic processes is well known [72]. Deficiency of potassium is known to make the plant vulnerable to various plant pathogens including infestation by pests [73]. Depletion in potassium levels along with other essential plant macro nutrients is a common problem in the present situation citing reasons of intensive crop production system and use of high-yielding varieties [74]. An eco-friendly approach of integrated nutrient management system is to use potassium solubilizing microbes to alleviate the depleted potassium levels and revive the fertility of soil. These microbes enable this by using several mechanisms like exchange and complexation reaction, organic acid production followed by acidolysis, and chelation [75]. Various *Streptomyces* species have been reported to possess good potassium solubilizing ability, for example, *Streptomyces* sp. KNC-2 and *Streptomyces* sp. TNC-1 [76–78].

11.3 Role in Maintaining Soil Ecology

Actinomycetes are known to be abundantly present in the root-soil interface of plants. These microorganisms are known to exercise favorable effects on plants. On the same note, the abundance can still be increased by application of biofertilizers prepared from actinomycetes. The approach of adding actinomycetes in form of biofertilizers would be beneficial to crop plants and enhance crop yields as demanded by the current status of agriculture which make indiscriminate application of chemicals as fertilizers leading to decline in fertility of soil and its nutritive value. Actinomycetes are known to possess certain compounds which upgrade plant growth ability and aid in maintaining ecology of the soil. These organisms have a unique potential of producing a variety of extracellular enzymes in soil like cellulase, amylase, protease, phytase, chitinase, and phosphatases [79].

These exoenzymes help maintain the ecological health of soil by recycling the nutrients [80]. These enzymes help organisms to utilize the nutrients secreted by the plants in the plant rhizosphere soil. This activity helps to construct a nutritive pool of sugars, amino acids, peptides, organic phosphorus, and many other important supplements in the rhizosphere, hence enhancing both soil ecology and fertility. Such plant growth-promoting ability of actinomycetes can ensure extensive growth of plants and their development with respect to root length, plant height, vigor, and overall improved biomass [81].

Various species of actinomycetes are known to play critical role in rhizosphere by suppressing pathogenic species and, at the same time are also known to encourage both growth and multiplication of useful groups of soil microbes like nitrogen fixing microorganisms. For example, *Streptomyces fumanus* when applied or treated to wheat seeds in the form of biofertilizer, encouraged enhanced colonization of *Azotobacter* sp. contributing to additional inputs of nitrogen to the soil [82]. Also, actinomycetes have shown to create a balance between the rhizosphere inhabitants and stimulate secretion of growth stimulating compounds from these inhabitants which ultimately are reported to promote and improve soil ecology and hence improved plant growth. A good soil ecosystem ensures delivering all the essential services for overall plant growth and development with respect to enhanced division of root hair cells by producing growth stimulating compounds like auxins and cytokinins, thus leading to increment in numbers of lateral root hairs. This helps in developing a good and appropriate surface root system [83].

Actinomycetes are filamentous, thread-like organisms. Their intense hyphal networks allow them to penetrate through lignocellulosic organic materials like lignin and xylan and cause their degradation, thereby converting complex polymers to more simple assimilable form [84, 85]. Such degradative ability of actinomycetes plays crucial roles in production of compost from plant materials which are beneficial to plants [86]. Representatives of actinomycetes mainly *Streptomyces* like *S. griseus*, *S. termoviolaceus*, *S. globisporus*, *S. albovinaceus*, *S. caviscabies S. setonni*, *S. virginiae*, *S. ruber*, and *S. viridosporus* are known to secrete a combination of hydrolytic extracellular enzymes like chitinases [87], cellulases, glucanases [88], and peroxidases which aid in decomposition and degradation of polymers during composting [89, 90]. Such breakdown of polymers into small molecules helps turnover of essential nutrients like carbon and nitrogen [91]. Actinomycetes secreting extracellular enzymes like N-actyl glucosaminidase and urease help them to act on substrates like chitin and urea, enabling them to recycle soil nitrogen [92]. Their role in carbon cycling is with regard to their potential in solubilization of insect cuticles, exoskeleton of crustaceans, and cell walls of plants and fungi by secreting extracellular enzymes. Also, enzymes produced by these microbes cause breakdown of complex recalcitrant biomolecules like lignin and chitosan [93].

Actinomycetes are known to exert a positive effect on plants by intensifying their growth and overall performance. Biological nitrogen fixation, secretion of growth influencing elements, and production of micronutrients like vitamins are some mechanisms which actinomycetes are known to exert on plants as a part of their positive effect. Some variants of actinomycetes also appear to enhance both the quality and quantity of growth-promoting nutrients in the rhizosphere of plants which ultimately promotes growth and development [94]. There are reports which suggest that addition of actinomycetes into the plant root surroundings indeed enhances their growth and yield [95]. Inoculation of actinomycetes to plant rhizosphere is known to generate Indole Acetic Acid (IAA)—a phytohormone which acts on plant root system and stimulates nutrient consumption by the plants [31]. Also, Vurukonda *et al.* [96] have reported increased dry mass and higher protein content in peas when inoculated with *Streptomyces.* Berg *et al.* [97] reported that presence of actinomycetes especially certain species of *Streptomyces* in the strawberry plant rhizosphere reflected antagonistic effect in opposition to diverse number of fungal pathogens which usually infect and cause decline in strawberry yield.

Several species of actinomycetes encourage plant growth promotion. They are believed to exhibit a positive and beneficial impact on the plant height and weight. Many species like *Streptomyces sp* 9K have shown to influence plant growth and dry mass of plants. Rhizosphere soil is rich in microflora. These microflora engage themselves in producing several plant growth influencing components resulting in enhanced productivity. The microbiological processes of these rhizosphere microorganisms can be additionally energized by applying biofertilizers. The application of biofertilizers stimulates microbial reproduction in soil and henceforth their magnified extracellular enzyme levels aids in maintaining influential levels of essential organic components in soil [98]. However, the impact of introducing bacterial inoculants and thereafter the consequential rise in microbiological activity in soil ultimately depends on several factors like condition and soil type, plant variety, adaptability, and survival rate of microorganisms introduced [99, 100].

There are different soil types where crops can be grown. Each soil type varies from other in its organic matter content. A good biofertilizer based on actinomycetes requires that it works under broad and wide varieties of soils and organic matter content. Several important representatives of actinomycetes have tremendous ability to promote growth of plants and are termed as plant growth-promoting rhizobacteria (PGPR). PGPR are believed to enhance growth of plants like sugar beet, both under green house conditions as well as under different soil types. These rhizobacteria are known to affect these promotional activities at early stages of plant growth where they have been proved to serve as suitable resources for organic and sustainable agriculture and farming [101]. Sugar beet seeds applied with nitrogen fixing and phosphate solubilizing rhizobacteria have shown to undergo drastic changes in their growth pattern and yield as compared to controls. Moreover, there was a tremendous increase in beet root weight to as high as 46.7% and also the beet sugar content by nearly 15% by such seed treatment.

11.4 Role as Biocontrol Agents

The conventional pest management systems are presently facing a huge crisis [102]. The use of chemical insecticides and pesticides has not only caused serious environmental harm but also evolution of resistant pathovars and resurgence and ability to bioaccumulate are causing hazardous health issues. The recalcitrant property of these chemicals is also causing extensive damage to biodiversity. These and several other issues have prompted researchers to think of alternatives to pest control measures and thus the emergence of integrated pest management system. This system is conceptualized around biological control, which works on the principle of using living organisms to either completely inhibit or reduce the density of population of other living organisms [103]. Protection to crops throughout the crop period, environmentally safe, non-toxic to plants, and, above all, encouraging beneficial soil inhabitants are some of the commendable and impressive features of biocontrol agents [104]. Actinomycetes produce diverse chemical substances like β-lactums, peptides, and polyketides apart from a wide range of secondary metabolic compounds [24, 105]. Studies reveal that about 70% of biologically active agents are derived from actinomycetes [106, 107]. Diverse biological functions of actinomycetes to manage the plants in good health compel us to consider these organisms as good biological control agents [108, 109].

Another impressive feature of actinomycetes is that they exhibit their potential as biocontrol agent not only by existing independently in the plant rhizosphere but also as plant symbionts. So, obviously considering their bio controlling properties, various species of actinomycetes grow as symbionts in various plant organs as in case of rhododendron. This plant is commonly subjected to various fungal diseases just like any other plant, but experimental studies have proved rightly that rhododendron harbors various species of actinomycetes (*Streptomyces* sp.) as endosymbionts during its growth, helping the plant against major fungal pathogens especially *Phytophthora cinnamomi* and *Pestalotiopsis syndowiana*, suggesting the production of antifungal compounds by actinomycetes relieving the plant from attack by such fungal pathogens [110]. A simple yet impressive mechanism acquired by actinomycetes to enable their biocontrol potential for the plants is to colonize their internal structures. Most of the actinomycetes especially those belonging to *Streptomyces* genus enact their disease suppressing activity by occupying the intracellular plant structures as endophytes and prevent attack by phytopathogens [111].

11.4.1 Production of Antibiotics

The secretion of variety of bioactive compounds by actinomycetes in rhizosphere soil of plants is believed to show pronounced positive outcome on productivity of crops. Enhanced defense mechanism and crop productivity by actinomycetes is made possible due to their mechanism of antibiosis which is enabled by production of several groups of antibiotics ranging from erythromycin, oleandromycin of macrolides group; streptomycin and kanamycin of aminoglycosides group; and nystatin and levorin belonging to polyene group [112, 113]. Some of these antibiotic producing actinomycetes genera include *Streptomyces*, *Microtetraspora*, and *Actinoplanes* [114, 115].

Biofertilizers based on certain actinomycetes like *Streptomyces fumanus* have divulged reports to successfully foster plant growth in extensive soil types and also in different host cultivars. Seeds pre-treated with actinomycetes have shown to stimulate growth and enhance yield even in low fertile soil and in low irrigated soil [116]. Many species of actinomycetes are very good antibiotic producers. The toxicological properties of these antibiotics against plant pathogens are abundant [117]. Such ability of these microorganisms probably can be exploited to inhibit specific plant diseases. The variants of actinomycetes used for such biological control depends on the plant disease. At this point, the ability of certain actinomycetes for use as both biocontrol agent and as a root-nodulating agent in leguminous plants should be well acknowledged. The actinomycetes have been known to exhibit these properties when the seeds are coated before planting or treating the seeds at the time of planting [118]. For example, antibiotic producing *Streptomyces* species when introduced around the alfalfa (*Medicago* *sativa* L.) seeds at the time of planting showed that those alfalfa seedlings which received *Streptomyces* amendments had produced hyphal filaments and spore chains as compared to control with no *Streptomyces* amendments. These strains of *Streptomyces* also enhanced root nodulation in the plant causing exemplary increase in nitrogen fixing ability. Moreover, the same *Streptomyces* species because of its antibiotic producing nature could inhibit the growth of *Phoma medicaginis*, causal organism of spring black stem and leaf spot disease in alfalfa.

Many actinomycetes especially *Streptomyces* are known for their intimate relationship with plants by colonizing their internal tissues. For example, *Streptomyces* strains as endophytes in tomato roots have been acknowledged to produce antibacterial and antifungal elements and are responsible for impeding the growth of *Rhizoctonia solani*, a fungal pathogen of tomato affecting the crop and yield [50, 119]. Also, other actinobacterial strains like *Microbispora* sp. and *Streptosporangium* sp. are known to have strong relationship with maize roots and show antagonistic effect against many fungal and gram-positive bacterial pathogens [120, 121].

Alnus glutinosa is another plant which harbors *Streptomyces* sp. in its root nodules and this endophyte reportedly produces a novel antibiotic called naphthoquinone, which protects the host plant against attack from many bacterial and fungal pathogens suggesting the broad spectrum attribute of the antibiotic [122]. The intimate relationship of *Streptomyces* strains with plants like tomato and wheat suggest that harboring these organisms as endophytes within their tissues is only to derive some benefits of them, in form of secondary metabolites produced by endophytes. Also, these endophytes have an ecological edge over the competitive fungal pathogens [123]. These reports make it quite clear that many strains of actinomycetes play prominent role in plant development and also confer enhanced resistance to diseases hinting that these organisms indeed have an outstanding potential to serve as prspective biocontrol agents for many cash crops like wheat and maize [120, 124, 125].

As part of their ability to protect plants from various pathogens, reports of *Streptoverticillium albireticuli* possessing nematicidal activity are quite interesting. Innumerable *Streptomyces* representatives have been isolated and reported with ability to produce potent antihelminthic agents, thereby providing protection to plants from attack by various nematodes. For instance, *Streptomyces avermitis* has been disclosed to synthesize avermectins which showcase their potency against nematodic pathogens like *Meloidogyne incognita* [126] and *Caenorhabditis elegans* [127]. Avermectins have been classified as a new class of macrocyclic lactones.

11.4.2 Production of Siderophores

Actinomycetes also possess another feature making it a unique contender as an active ingredient of biofertilizers. They synthesize small molecular weight and iron chelating molecules described as siderophores [128, 129]. Important representatives of actinomycetes producing siderophores belong to *Streptomyces* genus. For example, *Steptomyces coelicolor* is known to produce a peptide siderophore called coelichelin [130]. Another siderophore called enterobactin is reported to be produced by *Streptomyces tendae* [131]. There are many other representatives of actinomycetes which exhibit biocontrol activity through siderophore production. Some of which are *Rhodococcus* and *Nocardia*, which produce heterobactin type of siderophores [128]. These siderophores help scavenge ferric iron forming ferric-siderophore complexes [132]. The siderophores produced by actinomycetes are of hydroxymate type [133] possessing the capability to inhibit growth of a variety of phytopathogens. The pathogens succumb due to non-availability of iron in the rhizosphere soil environment [134] due to scavenging activity of actinomycetes like *Streptomyces rochei* IDWR19 and *Pseudonocardia halophobica*.

Many different types of plants like *Cicer arietinum* L. (chick pea), *Lens sativum* (pea), and *Vicia faba* (faba bean) harbor different types of actinobacterial strains in their rhizoshere soil. Most of these actinomycetes are known to produce various kinds of antimicrobial components suggesting their role as biocontrol agents. Also, most of the actinomycetes obtained from these plants possess the ability to produce siderophores and phosphate solubilizing enzymes, thereby helping the concerned plants in improving their nutrient uptake from soil and thus enhanced yields. Many different pathogens like *Phytophthora*, *Pythium irregulare*, and *Botrytis cinerea* were suppressed when a combination of *Streptomyces* species strains was applied to seeds before sowing [135]. Such reports probably suggest that co-inoculation of seeds with selected combination of actinomycetes possessing biocontrol activity can indeed prove to be beneficial to combat diverse plant diseases.

The biocontrol action and other different attributes like growth-promoting activity and siderophore production by actinomycetes are not only restricted to cash crops like maize and wheat but also are very much prominent in fruit crops like guava [136]. Species of *Streptomyces* like *S. canus*, *S. fradiae*, *S. avermitilis*, *S. Cinnamonensis*, and *Leifsonia poae* are prominent in guava rhizoshere soil. Guava seedlings inoculated with a combination of these *Streptomyces* cultures reportedly caused considerable increment in both plant dry matter and height. Studies revealed that the culture combination of *Streptomyces* produced phosphate mobilizing enzymes, siderophores, and chitinases along with phytohormones like auxins and Gibberllic acid (GA3) [19, 22].

Crop plants are not only infected by primary pathogens like bacteria and fungi but are also prone to secondary infectious agents like nematodes which are commonly found in soil [137]. Several *Streptomyces* species are known to have brilliant antagonistic effect on nematodes as well. *Streptomyces* sp. CMU.MH021 is known to possess excellent potential to lessen the egg hatching rate of nematode pathogen like *Meloidogyne incognita*, and at the same, this nematophagous strain effectively promotes plant growth by producing IAA and hydroxamate siderophores.

11.4.3 Production of Hydrogen Cyanide

Another mechanism of actinomycetes enabling it to act as a potential biocontrol agent is production of hydrogen cyanide (HCN). Several *Streptomyces* species have been recognized to produce HCN which inhibits the terminal electron acceptor in electron transport chain system of respiratory phyto pathogens and thereby inhibiting their growth and survival [138, 139]. Moreover, reports of actinomycetes producing HCN enhance phosphate and other mineral solubilization, thus enriching the fertility of soil is quite encouraging [140].

11.4.4 Production of Lytic Enzymes

Actinomycetes have been acknowledged to secrete innumerable number of lytic enzymes [141] as one of their mechanisms to exhibit their roles as biocontrol agents. These lytic enzymes bring about the disintegration of cell wall material and hence the pathogens [142, 143]. For example, *Pythium aphanidermatum*, causal agent of damping-off disease in seedlings of cucumber (*Cucumis sativus* L.) can be inhibited by the exceptional and competent biocontrol activity of several strains of actinomycetes like *Actinoplanes phillippinensis*, *Microbispora rosea*, *Micromonospora chalcea*, and *Streptomyces griseoloalbus*. All these actinobacterial strains were shown to produce significant quantities of β-glucanases with the ability to lyse the fungal pathogen hyphae. Some strains produce diffusible inhibitory metabolites while a few have the ability to parasitize the oospores of pathogens [144]. Similarly, *Streptomyces* sp. 9P is another potent strain having broad spectrum antifungal properties. This strain secretes many important hydrolytic enzymes like chitinases, glucanases, and cellulases along with lipases and proteases, enabling it to inhibit a range of fungal phytopathogens like *Alternaria brassiceae*, which infects plant belonging to Brassica species; *Collectotrichum gleosporioides*, a common pathogen of perennial plants; *Rhizoctonia solani*, a pathogen with wide host range; and *Phytophthora capsici*, pathogen affecting peppers and other commercial crops [145].

There are many crop plants other than cash crops which add to the economy for the farmers and agriculturists. These include fruits and vegetables. Fruits and vegetables are probably more vulnerable to bacterial, fungal, and viral diseases, causing great economic loss probably due to their texture, nutritional content, etc. Considering the environmental issues and emergence of pathogen resistance to chemicals, natural and eco-friendly biocontrol agents are the need of the hour. In this very context, microbes like actinomycetes have garnered ample interest owing to their ability to produce volatile organic compounds. Although many soil inhabitants are known to produce these compounds which possess antifungal and antibacterial properties, but actinomycetes are considered good biocontrol agents with regard to this aspect as they show broad range antifungal activity and can control and sometimes prevent a variety of plant diseases [146]. The ability of actinomycetes originated volatile organic compounds to diffuse easily through the soil particles and cause severe morphological damage to the attacking pathogens [147] make these organisms to be used as a potent biocontrol agent over other conventional agents.

There are several reports which corroborate with this remark. For example, volatile organic compounds produced by *Streptomyces globisporus* JK-1 have been reported to exert excellent antifungal activity against *Botrytis cinerea*, a pathogen attacking many plants like tobacco and tomato [148]. Similarly, *Streptomyces coelicolor* is known to inhibit spore germination of *Penicillium chrysogenum* and *Botrytis cinerea* [149]. The pathogenecity of *Fusarium moniliformei* can easily be damaged by volatile organic compounds from *Streptomyces philanthi* [73]. Another fungus *Peronophythora litchii* which causes litchi downy blight in litchi (*Litchi chinensis* Sonn) can be easily countered by volatile organic compounds produced by *Streptomyces fimicarius* BWL-H1 [150]. Studies reveal that *Streptomyces fimicarius* produces around 32 different volatile organic compounds of which important ones include phenyl ethylalcohol, caryophyllene, α-copaene, and methyl salicylate, each exerting its own systemic resistance to plants [151]. Studies confirm that volatile organic compounds like methyl 2,4,6-trichlorophenyl ether and methyl 2-methylpentanoate from *Streptomyces* have the ability to completely inhibit hyphal growth [152]. Also, the characteristic earthy smell of moist soil is due to volatile organic compounds-2-methylisoborneol and trans-1-10-dimethyl-trans-9-decalol produced by *Streptomyces* species [153].

11.5 Role as Plant Stress Busters

Agricultural productivity depends on a number of factors including both biological and non-biological factors. The most important and significant factors which influence the crop productivity is the genetic makeup of the crop plant. The genetic makeup of a particular plant decides the productivity and hence yields of the plant, ability of the plant to resist attack of various pathogens and thus diseases, and also the genes enable the plants to resist various abiotic stresses like water scarcity, salinity, and drought conditions. Therefore, it is clear that genetic makeup of a plant is an asset as well as greatest limitation in the field of agriculture. But fortunately, the knowledge and techniques in genetic engineering have advanced leaps and bounds in containing these limitations.

Development of new and better crop varieties has certainly solved these issues, of course, only when even the non-biological factors like average rainfall, humidity, and soil nutrition are present within the favorable limits considering the genetic makeup of the plant. The non-biological factors at times may limit the crop productivity and may prove to be stressful to the plants in spite of the intrinsic ability of plants to cope up with external environmental pressures. But not ignoring the power of nature, we have been provided with a diverse group of microorganisms with enormous ability. These natural inhabitants have evolved such that they can cope with a variety of adverse conditions and hence can be considered as natural mitigating agents for plants against abiotic stress. Animals including humans created a rather unique relationship with microorganisms. Plants also have shown great interaction with microbes. In fact, plant-microbe interactions are considered as important and integral in an ecosystem. Such integrated interaction between plants and microbes are believed to benefit both the partners. Plant rhizosphere creates a unique environment for microbial population while the microbes benefit the plant in various ways. They are also believed to offer defense against many abiotic stress conditions apart from overall development of [154, 155].

Plants are constantly confronted with innumerable stress factors including biotic and abiotic stress. Some of these stress elements include exposure of plants to high salinity conditions, infections from various pathogens including nematodes, attack from pests, water scarcity, and stress due to heavy metal contamination. Fortunately, plants have evolved such that they have an inbuilt mechanism to respond to all these stress conditions, the mechanism opted ultimately depends on type of stress. Plants produce an assortment of secondary metabolites [156] which help maintain their metabolism, and at the same time, their roots exude an important mixture of compounds into the root-soil interface which include amino acids, sugars, and organic acids. This is where the rhizosphere microbiome and plant interaction begins. The microbial population load in the plant rhizosphere interacts with roots and responds to stress by producing ethylene—a plant hormone for overall growth and development, in large quantities. Ethylene production in plants occurs at two successive phases [157, 158]. In the first phase, lower levels of ethylene production enable the plant to sense the stress and respond in a milder way. The second successive phase of ethylene peak helps the plant to overcome the stress, but such high levels also prove toxic to plants which can be seen in the form of low productivity, yellowing and falling of leaves, etc. [159]. It is at this point that the plant growth-promoting bacteria like actinomycetes help to bail out the plants from ethylene toxicity by producing 1-aminocyclopropane-1carboxylate deaminase (ACC deaminase) which acts by degradation of ethylene to non-toxic low molecular weight compound, leaving just enough ethylene to burst the stress and at the same time promote growth [160].

11.5.1 Resistance From Heavy Metal Toxicity

Industrialization and persistent use of harmful chemicals have made man realize the seriousness of environment related issues. The indiscriminate use of chemicals containing heavy metals in industries and the release of hazardous industrial effluents without proper treatment into water bodies has caused serious implications on the ground water resources and to the environment as well. Heavy metal contaminated soil and water resources have taken a heavy toll on mankind. Of course, certain heavy metals like zinc, cobalt, iron, and chromium are considered as essential micronutrients necessary for growth of plants, microorganisms, and animals. But their presence exceeding even in millimolar concentrations than their required limits proves to be highly toxic to life forms. They cause various devastating effects on life forms like chromosomal aberrations and reduced growth rate. Plants usually are exposed to such heavy metal contamination stress in soils. Plants although have inbuilt mechanisms to wade off such stressful conditions, but only to a certain limit.

There are some soil-borne microorganisms like actinomycetes which are naturally resistant to many heavy metals and have an excellent ability to either accumulate or remove such metals from soil, thereby serving as a unique heavy metal stress buster for plants [161]. The major and important representative genera of actinomycetes, i.e., *Streptomyces* have been reported to have an efficient bioaccumulation and biosorption mechanism for heavy metals, some of which are summarized in Table 11.1. This important characteristic feature of actinomycetes plays vital role in biological disposal of heavy metals from polluted or contaminated soils. Their ability to amass and remove particular heavy metals from soil is probably due to their

Table 11.1 Actinomycetes with soil bioremediation properties.

S. No.	Name	References
1.	Chromium	
	Streptomyces sp. MC1	[163, 164]
	Streptomyces rimosus	[165]
	Amycolatopsis sp.	[166]
2.	Zinc	
	Streptomyces viridochromogenes	[167]
	Streptomyces chromofuscus	[168]
	Streptomyces ciscaucasicus	[169]
	Streptomyces rimosus	[170]
	Streptomyces zinciresistens	[171]
	Streptomyces sp. K11	[172]
3.	Copper	
	Streptomyces coelicolor	[173]
	Streptomyces fradiae	[174]
	Streptomyces zinciresistens	[171]
4.	Lead	
	Streptomyces fradiae	[175]
	Streptomyces rimosus	[176]
	Streptomyces sp. VITSVK9	[177]
	Streptomyces Sp. WW1	[178]

extensive surface structures and enormous intracellular space [162] which other heavy metal resistant microbes lack. So, there is no reason to argue as to why actinomycetes cannot be exploited for agricultural purposes in the form of biofertilizer formulations owing to their soil bioremediation efficiency.

11.5.2 Resistance Against Drought/Water Deficit

Lack of proper irrigation system and dependency on natural precipitation is a grave problem in many countries. Development of drought resistant crop varieties is of course a good solution to the problem. But developing new varieties do come with a cost. Sustainable agricultural practices using valuable microbes that may augment drought resistance of plants and enhancing crop yield even under acute water deficits may solve the issue [179]. Actinomycetes are known to grow and survive in dry and semi-dry conditions in contrast to other rhizosphere microorganisms. These organisms are adapted so well to the adverse climatic conditions that they may very well be used to compensate the crop loss due to such detrimental environmental conditions [180, 181]. Actinomycetes can colonize the roots or survive as endophytes and help the plants in increasing their survival rate and also enhance their resistance to various abiotic stresses simultaneously supporting the plants to acquire essential supplements efficiently from soil [182, 183].

Colonization of actinomycetes and other rhizosphere microbes in soil proves to be a cordial yet intense relationship which certainly enable the plants to establish properly even in water deficit soil conditions and improved fertility of soil help boost productivity [184]. So, role of such drought-tolerant actinomycetes, be it free-living, symbiotic, or endophytic [156], has caught the attention of agricultural research in recent years. Actinomycetes especially strains belonging to *Streptomyces* genus like *S. coelicolor* DE07, *S. olivaceus* DE10, and *S.* DE 27 obtained from rhizosphere soil are believed to be quite tolerant to drought and their plant growth-enhancing attributes and acute water stress tolerance attributes are quite commendable. Records of significant enhancement in wheat yields when seeds were grown in water stressed soil after treatment with these inoculants [185] provide enough evidence to prove the different attributes of actinomycetes.

Many crop plants have to deal with erratic precipitation patterns. Global warming leading to lack of rains and drought-like conditions are common problems which many agriculture-based countries have to face. Lack of proper irrigation system further adds to the woes of farmers in most developing countries resulting in low productivity and yield. Many crop plants like onion (*Allium sepa* L.) have to deal with conditions like drought and osmotic stress. So, novel agricultural strategies need to be pulled up and the fact that microbes like osmotolerant actinomycetes can surely alleviate the crops from such problems [186] is quite encouraging. Osmotolerant actinobacterial strain, *Citricoccus zhacaiensis* B-4, has a plethora of traits ranging from plant growth promotion, secretion of zinc and phosphate solubilizing enzymes, and plant growth hormones like IAA, GA3, and ACC deaminase activity to tackle the osmotic stress conditions. The strain when applied to seeds caused a drastic increase in germination rate under stress conditions [187].

11.5.3 Resistance Toward Salinity

Salinity, of the many environmental problems, is another stress factor which crop plants usually encounter. Loss in productivity due to reduced plant cell division is the common issue that plants face under salinity stress condition. Many plant crops like *Oryza sativa* L. have shown significant resistance by withstanding salinity stress conditions. Investigations have revealed that ability of these crop plants to encounter such stress was by the virtue of existence of endophytic actinomycetes with the characteristic feature to secrete several bioactive metabolites rendering the plants to sustain under such stressful conditions and at the same time enabling enhanced productivity. Studies reveal that actinomycetes like endophytic *Streptomyces* sp. GMKU 336 in plants with ability to produce ACC deaminase caused significant increase in potassium and calcium levels but decreased ethylene levels enabling *Oryza sativa* plants to encounter the salinity stress [188]. Additional traits like plant growth-promoting ability and siderophore production facilitated even more stability to the plants to survive under conditions like heavy metal toxicity.

11.6 Conclusion

Actinomycetes by virtue of their capacity to influence plant growth and promote plant development have engrossed enormous consideration in recent years. Their interdependency with variety of plants and association with major soil inhabitants are the key factors which enables them to survive diverse and adverse environmental conditions. The remarkable characteristics of actinomycetes to create a healthy and conducive environment can be exploited and employed fruitfully for agricultural practices in future. Their role in nutrient recycling, providing defense to plants against pathogens and abiotic stress conditions, promoting plant growth is commendable, all of which ultimately targeted toward healthy crop plants and hence enhanced productivity. Furthermore, actinomycetes play significant role in maintaining soil equilibrium by possessing properties to remove harmful and destructive heavy metals in soil. Actinomycetes, with their competent caliber to produce several secondary metabolites like broad spectrum antibiotics, lytic enzymes, and volatile substances help in using them as potential biocontrol agents in agriculture. A dominant and principal feature of producing extracellular degradative enzymes and agroactive compounds by these organisms is effective in formation of humus and compost. The ability to confer innumerable advantages over plants and the multi-tasking actinomycetes can be efficiently used as a tool in alternate farming technique, thereby replacing harmful chemicals. It is obvious that all these qualities of actinomycetes are compelling enough to force our focus on these microbes and consider them as efficient and inevitable alternative for sustainable agricultural farming.

11.7 Future Perspectives

Actinomycetes no doubt can be considered as rejuvenating agents for development of sustainable agriculture. Many important representatives of actinomycetes play critical role in healthy soil management process. The diverse characteristics of actinomycetes to benefit plant growth even under adverse environmental conditions are remarkable. Identification of effective and competitive strains of actinomycetes is the need of the hour. Also, multitasking actinobacterial strains need to be identified to cut down the economical burden in isolating and culturing single function varieties. Such actinobacterial consortium with most of the desirable characteristics will ensure improved assimilation of growth supporting nutrients by plants and hence productivity. Also, there is a need to evaluate the efficacy of these actinobacteria-based biofertilizers over a wide range of crop varieties. Needless to say, certain advanced methodological approaches are to be developed for further improving the dynamics of these organisms. Various advanced biotechnological tools can be employed to improve the standards of actinomycete-based biofertilizers. The shelf life, screening of potential carriers to support the credentials of actinomycetes, and hence the economic implications thereafter have to be evaluated and explore approaches for their mass production. The problem of creating awareness concerned to the concept of biofertilization and its beneficial effect over chemical fertilizers is to be properly addressed and above all taking the end-users into confidence and mobilizing them to switch over from using conventional chemical fertilizers to safe eco-friendly biofertilizers is an enormous task.

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