Dr. S K Chahal was born on 6 September 1968 in Rohtak city of Haryana State, India. Having about 28 years' experience of teaching and research at different universities, Dr. Chahal is presently working as Professor& Chairman, Department of History, Kurukshetra University, Kurukshetra. In addition, he is holding charge of the prestigious Mahatma Jotiba Phule Chair in his university which is the only Chair after the name of Mahatma Jotirao Govindrao Phule in any university of north India. He also worked as Deputy Director of the Centre for Dr. B R Ambedkar Studies in his university. He has published two full-fledged research works entitled *Dalits Patronised: Indian National Congress and the Untouchables of India 1921-1947* and *Dr. B.R. Ambedkar: The Maker of Modern India*. Additionally, above two dozen papers of his are published in the reputed research journals and anthologies. He has also authored his autobiography under the title *Jakham Abhi Taaza Hain: Ek Dalit Aatamkatha*.

A self-made person coming from a very humble background and an Ambedkarite to the core, Dr. Chahal has been among the pioneers of Dalit Studies in India. His present study is the outcome of a research project for which Indian Institute of Advanced Study (IIAS), Shimla awarded him its residential Fellowship during 2019-2021.

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HINDU SOCIAL REFORM
THE FRAMEWORK OF JOTIRAO PHULE
Prof. S.K. Chahal
IIAS

HINDU SOCIAL REFORM

THE FRAMEWORK OF JOTIRAO PHULE

Prof. S.K. Chahal

IIAS

3.4.6

This study examines the approach of Mahatma Jotirao Govindrao Phule (1827-1890), the foremost social reformer and thinker as well as one of the nation-builders of modern India, with regard to the issue of Hindu social reform in India. A radical reformer of the nineteenth century Maharashtra, Phule visualized Hindu society free from all social inequalities based on caste, class and gender. He showed extreme concern for the depressed and marginalized sections of Hindu society and started a crusade against the *Brahmanical* orthodoxy and the 'slavery' it imposed upon the downtrodden sections of Hindu society. The study proposes that since Phule hailed from the lower strata of Hindu society, he naturally came out as, to apply Antonio Gramsci's phrase, an organic intellectual. In other words, his social location largely helped him develop his approach which was totally a ground laying and organic approach and based on a 'perspective from below' or that of the marginalized sections of Hindu society. He viewed the problem of Hindu social reform from this perspective. To use the Foucauldian paradigm, Phulesaw '*Brahmanism*' as the ideological and institutional system of monopolizing knowledge, power and privileges by a particular class which uses these to dominate, exclude, and exploit other groups in Hindu society. He, therefore, stressed that it was necessary to throw out this ideology from Hinduism in order to reform the Hindu society. To achieve this goal, he advanced a dynamic framework of Hindu social reform, in which heunderlined the need of complete 'reformation' in Hinduism as well as adoption of the ideas of morality, equality, fraternity and rationality as the core principles of the 'reformed' Hinduism. In sum, his idea of the reformed Hinduism was a popular form of Hinduism wherein he envisioned an egalitarian and moral society based on *Satyadharma* (religion of truth). A man of action, Phule pioneered a radical reform movement in colonial Maharashtra in order to materialize his framework of social reform for liberating the oppressed Hindus. The study finally comes out with the suggestion that Phule's insights and framework, if availed of, could have of great relevance to tackle the problem of social inequalities and to solve the complex issue of Hindu social reform, which is still laying unresolved and is a big hurdle in the way of nation-building in India.

ISBN 978-93-82396-78-9 Rs. 1155/-

3.4.6

Chairperson
Department of History
K.U. KURUKSHETRA

Women and Law

As per K.U. KURUKSHETRA & M.D.U. ROHTAK

Dr. Preeti Bhardwaj
Dr. Krishna Aggarwal

श्रीराम
SHREERAM

2023

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1.1 UNITED NATIONS AND HUMAN RIGHTS OF WOMEN

Introduction

Women and girls represent half of the world's population and, therefore, also half of its potential. Gender equality, besides being a fundamental human right, is essential to achieve peaceful societies, with full human potential and

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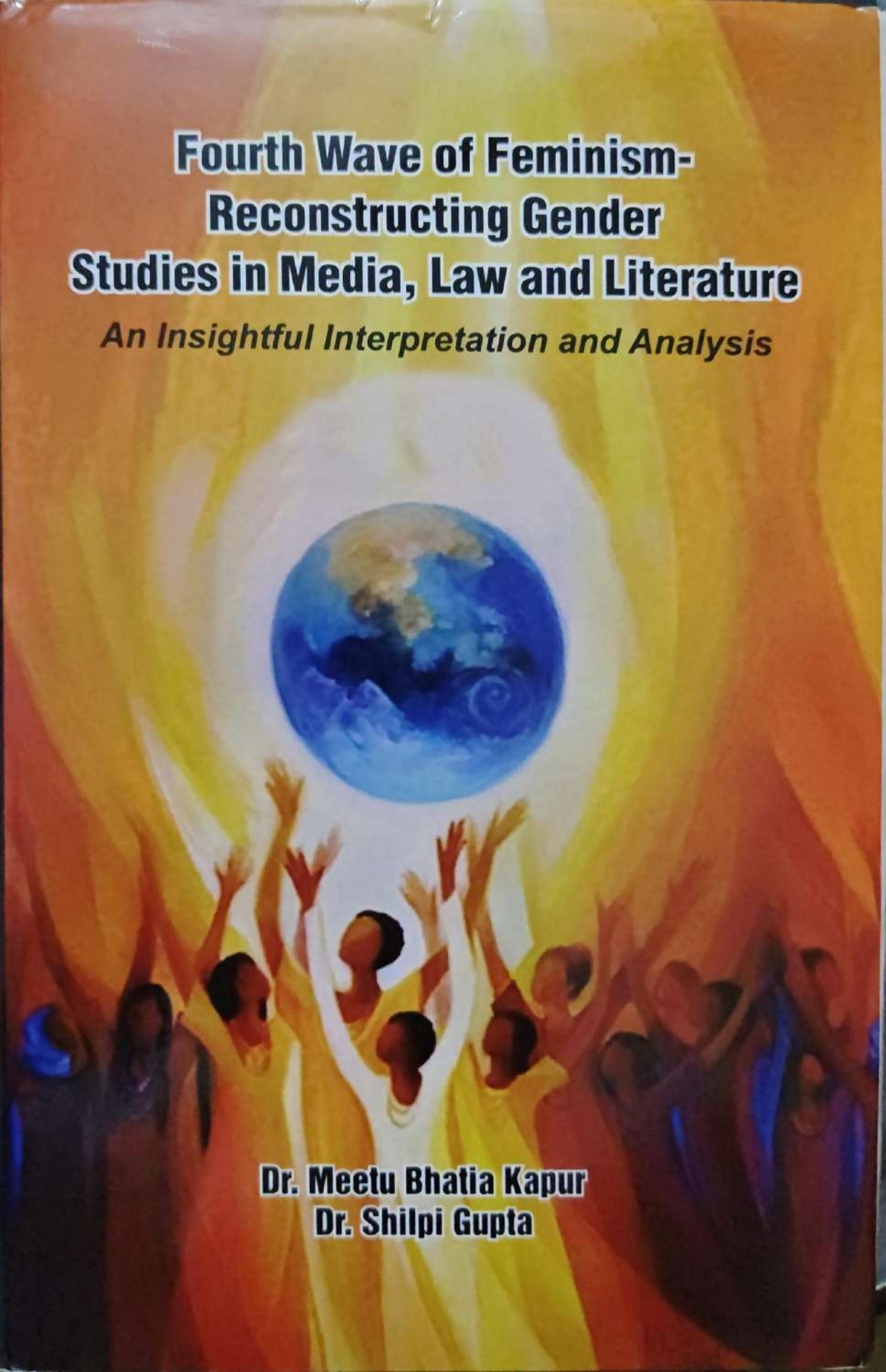
An Insightful Interpretation and Analysis



Dr. Meetu Bhatia Kapur
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Female Sexuality in the Select Poems of Indian Women Poets in English

Dr. Tripti Choudhary

Sexuality is to Feminism what work is to Marxism: that which is most one's own, yet most taken away.

(MacKinnon "Feminism, Marxism, Method, and the State: An Agenda for Theory" 515)

Feminism fundamentally identifies sexuality as the primary social sphere of male power. The centrality of sexuality emerges not from Freudian conceptions but from feminist practice on diverse issues, including abortion, birth control, sterilization abuse, domestic battery, rape, incest, lesbianism, sexual harassment, prostitution, female sexual slavery, and pornography. In all these areas, feminist efforts confront and change women's lives concretely and experientially. Taken together, they are producing a feminist political theory centring upon sexuality: its social determination, daily construction, birth to death expression, and ultimately male control.

Microbes for Humanity and its Applications

– Editors –

Deepak Kumar Malik

Meenu Rathi

Divya Bhatia

Shikha Jaggi

2022

Daya Publishing House®

A Division of

Astral International Pvt. Ltd.

New Delhi – 110 002

ISBN : 978-93-5461-397-5 (HB)

Published by : **Daya Publishing House®**
A Division of
Astral International Pvt. Ltd.
– ISO 9001:2015 Certified Company –
4736/23, Ansari Road, Darya Ganj,
New Delhi-110 002
Ph. 011-43549197, 8130496929
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Chapter 10

Microbial Endophytes as Biofertilisers: Sustainable and Promising Remedy for Ailing Soils

*Kajal Chauhan[1], Disha Chahal[2] and Sulekha Chahal[1]**

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ABSTRACT

In the last century, intensive and indiscriminate usages of chemical fertilizers to increase yield and productivity of agricultural crops have been a common practice. Though chemical fertilizers definetely boost up crop production, but their long term usage toxicated the soil, strengthened pesticides, polluted air and water, released greenhouse gases, and thereby generated negative impact on human health and environment. Biofertilizers are sustainable and promising alternative for chemical fertilizers, which have the potential for enhancing yield to meet the demands of the growing human population at the same time generate conditioning effect on ailing soil. Endophytes (microbes that reside inside the host plant) are the naturally occurring agriculturally important microorganisms, which have cost efficient biofertilizing potential and are also environment friendly. They provide host with the variety of beneficial attributes for example, secrete plant growth regulators and have nitrogen fixing and phosphate solubilising abilities and much more. This review also sees the sights of endophytic distribution

prototypes regarding their geographical locations, colonising behaviour and potentials for providing beneficial attributes to the host. Furthermore, explores the latest advancements of endophytic research including applications and limitations of using endophytes as biofertilisers.

***Keywords**: Biofertilisers, Endophytes, Agriculture, Chemical fertilizers, Microorganisms*

Abbreviations

PGPRs: Plant Growth Promoting Rhizobias; GFP: Green Flourescent Protein; BNF: Biological Nitrogen Fixation; GAs: Gibberellic Acids; JA: Jasmonic Acids; ABA: Abcissic Acid; ACCD: 1-Aminocyclopropane-1-Carboxylic Acid Deaminase

Introduction

Agriculture is the art as well as science of cultivating plants and domesticating animals and its establishment is considered, a major turning point in human evolution and civilization *i.e.* transition from a nomadic hunter-gatherer lifestyle dependent on foraging and hunting to settled life. Agricultural practices allow humans to have surplus food throughout the year and relocation and migration for searching food was no longer required. As a result, humans were able to establish communities, villages, towns and civilizations. This shift in survival mode provided a relatively safer existence and in general more leisure time for analytical and creative pursuits resulting in complex language development, and the accelerated evolution of art, religion, and science. However, developments of agriculture also amplify population. This expanding population places a heavy burden on agricultural system. To produce higher yields of crops, agricultural revolution were required. The green revolution thereby was intended to overcome food shortages in India by increasing the yields of agricultural produce with the help of better irrigation systems, pesticides, fertilizers, agricultural machinery, *etc.* And, although yields increased substantially due to green revolution but reciprocally, it also gifted many unpleasant after-effects. The increased use of chemical fertilisers paved way for their bio-accumulation and biomagnifications in soil and environment (Mishra *et al.,* 2015; Bisen *et al.,* 2015; Keswani *et al.,* 2014). Their continuous and long term usage containment groundwater, decrease soil fertility, increased soil salinity and sodicity and leads to the biodiversity loss. The chemical fertiliser's incorporation in to food chains reflected through fatal health and diseases state of flora and fauna of respective regions. Under such circumstances, the biofertilisers can be a desired alternative for chemical pesticides which can increase food production on one side and pose no harmful effect to the environment and human beings on the other side. The other advantages of biofertilisers are that they are low in cost, can be used in the form of spray therefore easy to apply, fix atmospheric nitrogen in the form usable for the host, can convert insoluble phosphate in the form suitable for the plant, produce phytohormones to stimulate plant growth hence provide nutrition to the soil and balance the fertility status of soil.

Microbial Endophytes

Endophytes are the microorganisms which lives inside the vascular plants (Fadiji and Babalola, 2020a; Brader *et al.,* 2017). Their intimate contact with the host is the attention seeker point which makes them suitable for acting as biofertilisers. Due to this intimacy, the endophytes are protected from the biotic and abiotic factors of the environment (Hallmann *et al.,* 1997; Rajkumar *et al.,* 2009). This leads to their unrestricted growth in host plant. This is a competitive advantage of endophytes over the PGPRs. The re-introduction of endophytes does not cause any change in the indigenous bacterial populations of the host whereas PGPRs causes change or shift in the microbial populations (Conn *et al.,* 2004). So, endophyte serves as a better option.

Endophytes are the microorganisms (bacteria and fungi) which colonise the host intracellularly and intercellularly asymptomatically (Wilson, 1995). Plant restricts the growth of endophytes but the endophytes acquire the capability to find a new way for their adaptation in the restricted conditions (Dudeja *et al.,* 2012).

Distinct endophytes may be located in varying host plant parts, for example, roots, stem and leaves (Fürnkranz *et al.,* 2012). In the course of association with the host plant, endophytes evolve novel ways to establish this association (Goyal *et al.,* 2016). The most favourable place of location of endophytes is roots followed by stem and least in the leaves.

Geographical locations and season also affect the pattern of distribution of endophytes. Some reports suggested that a seasonal fluctuation do affect the growth and presence of the endophytes in host plants (Gao *et al.,* 2005; Forchetti *et al.,* 2010) therefore, different types of endophytic species are likely to inhabit plant in different seasons. Soil type and rainfall distribution are major factors which determines the diversity of endophytes in plants (Hardoim *et al.,* 2012). The *Bacillus, Pseudomonas* and *Azospirillum* species which generally present in soil, usually found to be associated with plants as endophytes. In the study conducted by Duhan *et al.* (2020) on medicinal plant *Tinospora cordifolia*, the samples were collected during summer and winter seasons for one year of Kurukshetra region. The Kurukshetra district lies between 29°- 3401500 and 30°_1501500 North latitude and 76° to 1000 and 77°_17.500 East longitude. This region has a sub-tropical continental climate. Environmental conditions of this location also affect the distribution of endophytes. The rainfall distribution annually is comparatively satisfactory *i.e.* 290.5 mm. Saraswati, Markanda and Ghaggar are the central rivers of this region and the soil is commonly alluvial loam and clay. It is one of the affluent districts from an agricultural point of view. They have identified species from various genera such as *Bacillus, Aneurinibacillus* and *Pseudomonas*. Some different species were also reported from the similar plant of different geographical locations. The type of species screened can also be influenced by the culture medium used for isolation of bacterial endophytes from the plant tissue.

Endophytes can furthermore be classified on the basis of the method they use while living inside the host as follows-obligate endophytes, facultative endophytes and passive endophytes. Facultative endophytes are the one most preferable in plant growth promoting activities. This group resides in the soil freely and can approach the host roots in slight opportunity. Obligate endophytes are those which are transferred through seeds. They do not reproduce outside the host tissue. Passive endophytes are the one which colonise the host due to the effect of some events like wounds in root hairs instead of original colonisation (Hardoim *et al.,* 2015).

Endophytes colonise the host plant primarily through roots and can distribute systemically in the whole plant via vascular tissues. It is a site from where they launch into their proliferation. In an experiment, the distribution of endophytes was visualised by labelling the root and shoot tisuses with GFP – tagging methodology. As a result it was concluded that endophytes introduced in stem moved to the roots suggesting the uninterrupted distribution of endophytes in root microbiome (Johnston-Monje and Raizada, 2011).

Isolation and Identification of Endophytes

After a plant is selected, plant material can be collected and placed in sealed plastic bags to store at 4°C until isolation procedures begin. In the laboratory, plant materials are thoroughly surface sterilized to eliminate surface-contaminating microbes. Then, outer tissues are removed from the samples and the inner tissues are excised and placed on appropriate media. The endophytes are encouraged to sporulate on specific plant materials. After several days of incubation, hyphal tips of the fungi are removed and transferred to potato dextrose agar. Bacterial forms also emerge from the plant tissues and transferred on nutrient agar media. Eventually, when an endophyte is acquired in pure culture by subsequent subculturing, it can be identified via standard morphological and molecular biological techniques and methods. Further, isolated microbe can be tested for desired characteristics/ potential and on confirmation protocol for mass multiplication can be standardized. Consequently, further their formulation for using them as biofertizer can be finalized.

Applications of Endophytes as Biofertilisers

See Figure 10.1

Nitrogen Fixation

Artificial nitrogen fertilisers available in market are expensive in manufacturing and are also one of the main causes of soil and groundwater pollution with nitrate contamination (Spaink *et al.,* 2012). Nitrogen can be fixed by the endophytes without formation of nodule like structure within the host plant (Ladha and Reddy, 2003). There are some endophytic bacteria that naturally have BNF genes in their genome which convert nitrogen into plant usable forms such as nitrate and ammonia (Bhattacharjee *et al.,* 2008).

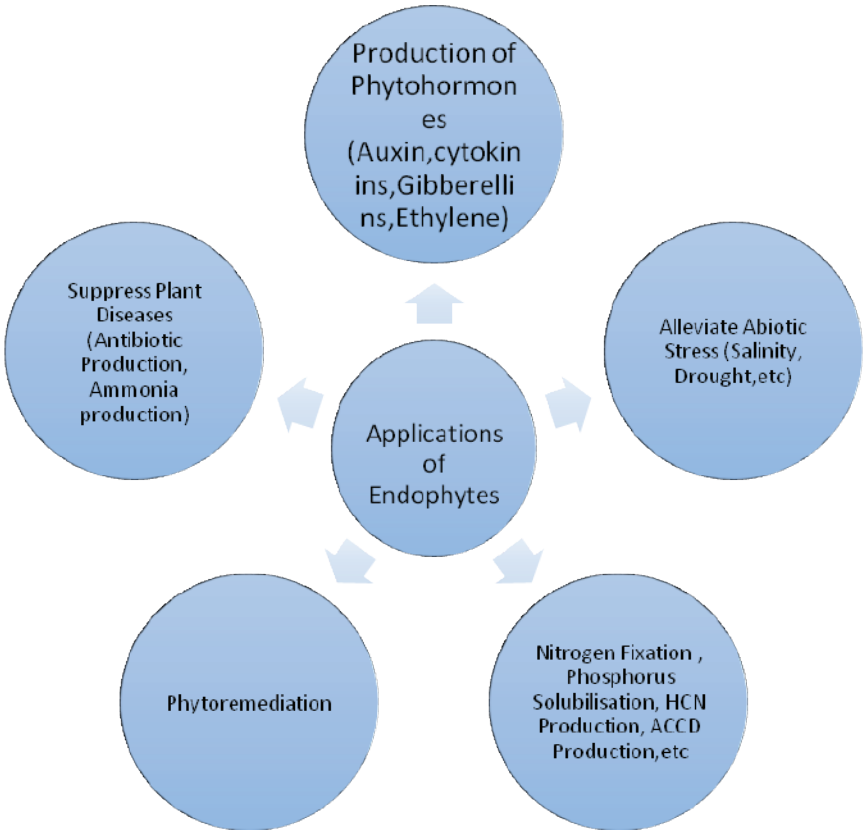

Figure 10.1: Showing Various Applications of Endophytes in Various Fields.

Triplett (1996) conducted an experiment on *Saccharum officinarum* L. The plants were cultivated without using artificial nitrogen fertilisers but were inoculated by diazotrophic endophytes like *Herbaspirillum seropedicae* and *Acetobacter diazotrophicus.* As a result, host plants were able to complete its nitrogenous needs by using solely atmospheric nitrogen. Andrade *et al.* (2014) suggested that out of 20 isolates from banana roots (Musa L) which had the prospective of growing on nitrogen free media, there were 4 strains belonging to *Bacillus spp* (Firmicutes) showed the capability of fixing atmospheric nitrogen. This ability was checked by kjeldahl and acetylene reduction assay methods. And also, the same strains exhibited other plant growth promoting abilities like phosphorus solubilisation and IAA production. The nitrogen fixing bacteria namely, *Herbaspirillum* spp., *Enterobacter cloacae*, *Burkholderia* spp., *Azospirillum* spp., *Klebsiella oxytoca*, *Pantoea* sp and *Klebsiella pneumonia* were isolated from the roots, leaves and stems of sugarcane plant by Govindarajan *et al.,* 2007,2008 and Mendes *et al.,* 2007. A nitrogen-fixing bacterium, *Klebsiella variicola* was isolated from the ROC22 sugarcane cultivar roots which has the ability of fixing atmospheric

nitrogen in correlation with sugarcane plants under aseptic conditions, promoting plant uptake of N, K, and P and GT21 cultivar growth under greenhouse conditions (Wei *et al.,* 2014).

Phosphorus Solubilisation

Plants use phosphate in monobasic and dibasic form from the soil, but most of the phosphate in the soil is in unusable form *i.e.*, immobilised and insoluble form (Gouda *et al.,* 2018). That is why, artificial or chemical phosphate fertilisers are used for compensation of phosphate deficiency in the host plant (Rodriguez and Fraga, 1999). Endophytes can act as an alternative to these chemical fertilisers as they have an ability to secrete phosphorus solubilising enzymes like phytase, phosphatase, *etc.* thus helping in solubilising the insoluble phosphate (Singh *et al.,* 2020).

For phosphate solubilisation, acetic, fumaric, malonic, tartaric, glycolic, citric, and gluconic acid (organic acids) are secreted by endophytes as a main mechanism (Heijden *et al.,* 2008). Phosphate uptake was promoted in the cassava plant roots (*Manihot esculenta* Crantz) due to the salicylic acid and benzene acetic acids secretion by endophyte *Pantoea dispersa* for more effective phosphorus solubilisation (Chen *et al.,* 2014).

Verma *et al.* (2015) recorded two species of Bacillus strain *i.e.*, B. *amyloliquefasciens* and B*. megaterium*, which were capable of solubilising insoluble zinc and potassium salts. Kurek *et al.* (2013) isolated *Pseudomonas letiola* capable of mobilizing insolublephosphorus and enhancing the length of shoot and growth of the apple tree variety Ligol. The three endophytic Pseudomonas strains L111, L228, and L321 showed high phosphorus solubilising activity isolated from the leaves of *Miscanthus giganteus* (Oteino *et al.,* 2015).

The faster growth and the better performance of the host plant named *Phyllanthus amarus* due to the better uptake of phosphorus, promotion of germination, and stimulation of the immune system was observed to be exhibited by the two phosphate-solubilizing and salt-tolerant bacteria (*Bacillus* sp. and *Acinetobacter* sp.) by enhancing the biosynthesis of antioxidative enzymes, phenolic compounds and the radical scavenging system (Joe *et al.,* 2016).

Phytohormones Production

Endophytes have the potential to generate plant hormones for example - auxins, cytokinins, gibberellins, ethylene, *etc.* An endophyte namely, *Burkholderia vietnamiensis* was isolated from wild cotton wood (*Populus trichocarpa*) which was capable of secreting IAA leading to plant growth promotion. As a result, the inoculated plants were having more nitrogen content and dry weight biomass than the control ones (Xin *et al.,* 2009).

Porostereum spadiceum AGH786 is an endophytic fungus which secreted phytohormones in host plant (soyabean seedling) when inoculated under NaCl stress. Gibberellic Acids, Jasmonic Acids, Abcissic acid and Isoflavones were secreted

by this fungal endophyte but GAs were more in secretion when compared with control (Hamayun *et al.,* 2017).

Endophytic bacteria such as *Micromonosporaspp*., *Rhizobium spp., Microbacterium trichothecenolyticum, Brevibacillus choshinensis and Endobacter medicaginis* have been studied for their presence in the root nodules of host plant (Igiehon and Babalola, 2018).

The endophytic fungi isolated from *Asclepias sinaica* and recognized as *Alternaria alternata* and *Penicillium chrysogenum* (Fouda *et al.,* 2015). The results showed that the isolates were secreting ammonia and IAA leading to improved root elongation and growth. According to the studies by Abdallah *et al.* (2016) an endophyte *Alcaligenes faecalis* isolated from *Withania somnifera* was capable of producing IAA and enhance phosphate solubilisation. The main function of IAA is cell elongation and differentiation (Asgher *et al.,* 2015). Common endophytic IAA producers belong to the bacterial genera *Azospirillum, Azotobacter, Alcaligenes, Herbaspirillum, Enterobacter, Pseudomonas, Klebsiella, Rhizobium, Burkholderia, Pantoea, Bacillus, Acetobacter* and *Rhodococcus* (Rashid *et al.,* 2012; Duca *et al.,* 2014; Apine and Jadhav, 2011; Costacurta and Vanderleyden, 1995).

Ethylene, a stress hormone is involved in various stress responses. Bacterial endophytes can possess 1-ACCD which formulates nitrogen sources α-ketobutyrate and ammonia from ACC which is an ethylene precursor (Sun *et al.,* 2009). For example, *Pseudomonas brassicacearum* SVB6R1 secrete ACCD in sorghum plants thereby enhancing salt stress tolerance (Gamalero *et al.,* 2020). Moreover, *Paenibacillus polymyxa* from the bulbs of *Lilium lancifolium* promotes the growth of two *Lilium* varieties through secretion of ACCD, among other effects (Khan *et al.,* 2020).

An endophyte, *Azospirillum lipoferum* was introduced in maize plant treated with gibberellins inhibitor synthesis and subjected to stress (drought) conditions. After inoculation, the host plant was performing well as compared to the control one under stress conditions because of the bacterial gibberellins (Cohen *et al.,* 2009).

Siderophore Production

The essential co-factor for number of enzymes accounting for the biochemical process of fixing nitrogen in nodules is iron but iron in the soil is accessible in the unusable form to the host plant. Soil iron is available in the insoluble ferric form of oxides, carbonates, phosphatase and hydroxides (Ma *et al.,* 2016). During iron deficiency, endophytes can produce siderophores which can bind divalent metal ions like Ferrous ion, ferric ion, *etc.* (Saha *et al.,* 2016). Sideropores help in prevention of uptake of undesirable metals like Zn, Cd, Cr, Pb, and Al, *etc.* through plant roots by scavenging these undesired metals present in rhizosphere thereby reducing toxicity for the host (Neubauer *et al.,* 2000). In the condition of iron limitation, an experiment showed the growth promotion of common bean by siderophores secreted by two endophytic *Bacillus* spp. strain (Sabate *et al.,* 2018).

The citrus endophyte *methylobacterium mesophilicum* released siderophores which when applied to *Xylella fastidiosa*, it promoted the chlorophyll content and growth of the plant (Lacava *et al.,* 2008).

Stress Tolerance

Both biotic and abiotic stresses are responsible for 30-50 per cent agriculture loss all over the world (Kumar and Verma, 2018). The major abiotic stresses include salinity, temperature, drought, trace metals, flooding, *etc.* So we need to have environment– friendly method to overcome these problems. Endophytes serve a very good option so that host plant could be stronger and healthier having a good immune system. Endophytic bacteria help plants to overcome drought stress via the production of volatile compounds, abscissic acid, ACC-deaminase, and IAA (Ullah *et al.,* 2019). Afridi *et al.* (2019) reported the improved growth and stress tolerance of two wheat varieties inoculated with ACC-producing bacterial endophytes.

Plants under stress produce exceeding amount of ethylene which is synthesised from ACC (Khan and Khan, 2014; Tiwari *et al.,* 2018). ACC-deaminase produced by the endophyte can alleviate the impact of elevated ethylene concentrations on stressful plants through the hydrolysis of ACC into α-ketobutyrate and ammonia. The ammonia and energy released from this process could be used by host for growth (Glick, 2014; Ali *et al.,* 2014).

Challenges and Limitations in the Use of Endophytes

Most endophytes can be isolated and screened by using customary microbiology techniques but some are hard to culture. So, un-culturable endophytes offer major challenge during structure and diversity measurement and identification process of endophytic community. Berg *et al.* (2014) suggested the use of fluorescence confocal microscopy and *in situ* hybridation techniques to explore endophytes. The other modern biotechnological tools such as a polymerase chain reaction, DNA fingerprinting and cloning techniques can be helpful to detect uncultivable species. The use of 16S and 18 S rRNA gene sequencing is a reliable and convenient way to survey bacterial and fungal diversity and to resolve the phylogenetic relationships among genera or species staring from lower levels (Nair and Padmavathy, 2014). The ITS sequences and large subunit analysis were exploited as tools to identify non-sporulating fungi and to confirm the identified fungi from Basidiomycetes. Furthermore, the bioinformatics tools such as genomic, proteomics and metagenomics can help in identification and to predict the functions of culturable and nonculturable microbial endophytes present in the parent samples (Brader *et al.,* 2017). So, the collective usage of conventional culture-dependent methodology along with modern culture-independent advances can help to discover abundant endophytic species which are difficult to notice using cultivable routine methodology.

Moreover, there is need of elaborate studies to screen competent endophytes that have extensive application as biofertilizers and biopesticides for specific

agricultural crops. This is because numerous challenges are faced when isolated endophytes are applied to field crops. The most noticeable limitation is the poor plant –microbial endophytic interaction due to reduced rhizospheric competence in the presence of prevalent preexisting microbes (Schulz *et al.,* 2002). The endophytic flora also gets influenced by change in the season, climate, rainfall and soil physical, chemical and biological properties.

Apart from evaluating the potential of endophytes as biofertilizers other parameters such as marketing, optimum formulation, production methods and mode of application are some other restrictive factors for using these microbes for farming practices. One more fear is that endophytes may act as opportunistic pathogens and their subsequent application can cause mild to severe diseases in plants, animals or humans which may also create epidemic and pandemic scenario. So, judicious formulation, application- mode and methodology should first be completely workout before their commercial release for application as biofertilizers to agricultural crops.

Conclusion and Future Outlook

In the present scenario, there is an emergent need for new agrochemicals that are highly effective, less expensive, possess low toxicity, and have minor environmental impact. Endophytes pose all these attributes *i.e.* plant growth promoting prospective for maintaining vibrant plant physiology, restoring nutrition availability, eco-friendly nature and sustainable way to enhance yield of crop plants. Considering the significance of endophytes, more studies should be done to explore the way the endophytes react with the plant host in order to ascertain the best mode to make them effective for continuous crop production. Besides, most endophytes were screened through culture-dependent methods; there is still a need to investigate culture-independent techniques such as genomics and metagenomics, in order to explore more novel functions and species. Also, the mechanisms of action and interactions between endophytes and host plant and with other microbes in the tissue of plants are not fully understood. Factors influencing patterns of distribution are not fully understood as endophytic species differ from one plant to the other. Perhaps, elaborate research using metagenomics and bioinformatics tools could help us to have insight in to the mechanisms involved in plant–microbe interactions, evolutionary relationship and establish genomic determinants of endophyte lifestyle and diversity.

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Chapter 3

Fermented Plant Foods: Cereals and Vegetables

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ABSTRACT

The history of fermented food is with the origin of the microorganisms. The human race utilizes fermented plant products as an important source of food. Plants and plant products are subjected to microorganisms as soon as grown. If they are harvested and consumed immediately (e.g., fresh fruits and berries), there has been little, if any, or no fermentation. However, when stored for some period of time, the micro flora in the plant products starts the fermentation process. Fermentation of the plant products is acceptable as long as the products are attractive in flavour and aroma and do not contain any toxic products. Uncontrolled fermentation may result an unacceptable aroma and taste and lead to fermented food as spoiled. So, the fermentation of the plant's products should be controlled by their natural flora. Fermentation of the plant products not only protects them from getting spoiled but also adds nutritive value to the products prepared from them. In this regard the current chapter highlights the microbiology of various plant-based fermented foods that are consumed in various parts of the world along with highlighting a few fermented foods consumed in different parts of the world. A brief insight to the biochemistry behind the action of various microorganisms has also been discussed to learn more about the action of the fermenting microbes.

Introduction

Campbell Platt defined fermented foods as '*those foods that have been subjected to the action of microorganisms or enzymes so that desirable biochemical changes cause significant modification in the food*' (Campbell Platt, 1987). The process of fermentation is immemorial and was carried out unknowing. Mostly the fermentation is used as a cheap method of preserving the food and protecting them from spoilage before the advancement in the freezing, canning and refrigeration. The simple result of the fermentation was the lowering of the pH of the product by using the lactic acid bacteria and also the production of the alcohol by the yeasts (Bamforth and Ward, 2014). Biochemically that was the conversion of the carbohydrates into the alcohols, acids and carbon dioxide. In this way the population of the spoilage microorganisms was reduced without affecting the nutritional value of the product. The advancement of the technology created tools like refrigeration and also increased the knowledge about the microbiology behind such processes, which in turn has increased the consistency in the processing of food. More advancement removed the dependency of the process on the indigenous bacteria and replaced it with the spawned starter cultures which help in controlling the desired end products. Fermentation in the strictest sense of the word is anaerobic, but most people extend the use of the term to embrace aerobic processes and indeed related non microbial processes, such as those completed by isolated enzymes (Caballero *et al.,* 2003). The present chapter deals with an insight to the microbiology and biochemistry behind the fermentation of plant and plant-derived food products along with discussing few examples of fermented food that is prepared and consumed in different parts of the world.

Microbiology of Fermentation

Bacteria

A diverse range of bacteria are used in fermentation technology, but most of them are classified into one of the three phyla, the *Firmicutes*, the *Proteobacteria*, and the *Actinobacteria*. The most important of these are lactic acid bacteria that belong to the *Firmicutes* and are Gram positive bacteria that are the main organisms used in the manufacture of fermented foods. Other bacteria that are the part of same phylum are the genera, *Bacillus* and *Staphylococcus* used for manufacturing of some fermented foods. The *Proteobacteria* contains Gram negative bacteria that are involved in mainly fermentation to produce vinegar and other alcoholic products. Finally, the *Actinobacteria* contains several genera relevant to fermented foods, including *Propionibacterium*, *Kocuria*, *Micrococcus*, and *Bifidobacterium* (Gibbons and Rinker, 2015).

The Lactic Acid Bacteria

The term, lactic acid bacteria, used to describe a group of functionally and genetically related bacteria. This term carries significant meaning to the food

fermentation workers, therefore used freely in the text. Lactic acid bacteria contain lactic acid producing, low per cent G+C, non spore forming, Gram positive rods and cocci sharing many biochemical, physiological, and genetic properties. Most lactic acid bacteria are catalase negative, acid tolerant, aero tolerant, facultative anaerobes. They are classified as heterotrophic chemo-organotrophs, based on their carbon and energy needs as they require pre formed organic carbon both as a source of carbon and energy. The lactic acid bacteria are fastidious and grow only in nutrient rich, well fortified media (or food) under optimum conditions. These organisms can be isolated not only from plant material, milk, and meat, but also salt brines, low pH foods, and ethanolic environments (Holzapfel and Wood, 2014).

Different nutrient metabolism pathways have made the lactic acid bacteria to be used in fermented foods as they can metabolize sugars and make lactic acid and other metabolic end products. Two fermentative pathways exist in lactic acid bacteria that are, homofermentative pathway where more than 90 per cent of the sugar substrate is converted exclusively to lactic acid and the heterofermentative pathway with four end products–lactic acid, acetic acid, ethanol, and carbon dioxide. Lactic acid bacteria may possess either one or the other of these two pathways (*i.e.*, they are obligate homofermentative or obligate heterofermentative) or may show both pathways (referred to as being facultative heterofermentative).

The lactic acid bacteria group consists of 40 genera, of which 12 are used in fermented foods. Seven genera of lactic acid bacteria, *Lactobacillus*, *Lactococcus*, *Leuconostoc*, *Oenococcus*, *Pediococcus*, *Streptococcus*, and *Tetragenococcus*, are used directly in food fermentations. Whereas, genera like *Enterococcus, Carnobacterium, Aerococcus, Vagococcus,* and *Weissella,* are not widely found in foods due to their less significance.

Lactococcus

The genus *Lactococcus* consists of seven phylogenetically distinct species, *Lactococcus lactis*, *Lactococcus garviae*, *Lactococcus piscium*, *Lactococcus plantarum*, *Lactococcus fugiensis*, *Lactococcus chungangensis*, and *Lactococcus raffinolactis*. They all are non motile, ovoid cocci, obligately homofermentative, and facultative anaerobes, with an optimum growth temperature near 30°C. They have a distinctive microscopic morphology, usually appearing as ovoid cocci in pairs or short chains. One particular species, *L. lactis*, is among the most important of all lactic acid bacteria having foursubspecies: *L. lactis* subsp. *lactis*, *L. lactis* subsp. *cremoris*, *L. lactis* subsp. *hordinae*, and *L. lactis* subsp. *tructae*. However, only *L. lactis* subsp. *lactis* and *L. lactis* subsp. *cremoris* are used as starter cultures. *L. lactis* subsp. *lactis*, is an important commercially used variant due to its ability to metabolize citrate.

Plant material has long been considered to be the original habitat of *L. lactis* but now milk has become their new habitat. Due to this, the genomes of *L. lactis* reflect gene decay, implying that genes useful in their original habitat (*i.e.*, plant) are no longer essential in the new environment (*i.e.*, milk). Also, plasmid borne genes in lactococci encode for proteins involved in lactose transport and metabolism and

casein hydrolysis and utilization. Although, *L. lactis* subsp. *lactis* and *L. lactis* subsp. *cremoris* differ in just a few seemingly minor physiological respects, such as the highest temperature at which most strains of *L. lactis* subsp. *lactis* are able to grow is at 40°C, whereas most *L. lactis* subsp. *cremoris* strains do not grow above 38°C. Also, *L. lactis* subsp. *lactis* has greater tolerance to salt (up to 4 per cent) than does *L. lactis* subsp. *cremoris*. It has recently been noted that there are strains of *L. lactis* subsp. *lactis* that have a *lactis* genotype, but a *cremoris* like phenotype. Likewise, there are strains of *L. lactis* subsp. *cremoris* that have a *cremoris* genotype, but a *lactis* like phenotype.

Streptococcus

The genus, *Streptococcus*, consists of many species that are facultative anaerobe, non-motile and with homofermentative metabolism. Only one species of this genus is used in fermentation, which is *Streptococcus thermophilus*. The bacterium is very much similar to the *L. lactis* and is also found in milk converting lactose into lactic acid. But the pathway of the *S. thermophilus* is different from the lactococci and also it works on higher temperature than its counterpart. Nutritional requirements of *S. thermophilus* are also more than the lactococci and it requires amino acids in the medium for its optimum growth. It is also characterized by bile sensitivity, salt tolerance, and a limited metabolic diversity.

Leuconostoc (Lc)

Leuconostoc genus contains mesophilic, facultative aerobic bacteria that are heterofermentative and metabolize sugars using phosphoketolase pathway. Plasmids are commonly found in this genus and reported to code for citrate and lactose metabolism genes along with bacteriocin coding genes. The genus contains 12 species whereas many other species were moved to other genera like *Oenococcus* and *Weissella* after taxonomical revisions. Of the 12 species, those involved in plant-based fermentation are *Leuconostoc mesenteroides* subsp. *mesenteroides, Leuconostoc kimchii*, and *Leuconostoc fallax* which are capable of fermenting plant-based sugars. Due to the heterofermentative nature, the bacteria produce various end products like CO_2, ethanol, lactic acid, and acetic acid. The genus is particularly important for fermentation due to its ability to impart diverse flavour and aroma to the fermented foods.

Pediococcus

Pediococcus genus is similar to the cocci-shaped lactic acid bacteria and phylogenetically located in the *Lactobacillaceae* family. The difference is in their ability to tolerate high acid and salt conditions. Of the 12 species of *Pediococcus*, only 2 species (*P. acidilactici* and *P. pentosaceus*) are found naturally in plant products and play important role in fermentation. The genes for the key metabolic pathways of fermentation are located on the plasmids present in the bacteria. Also, plasmids encode the genes for bacteriocin production that additionally increases the shelf life of the fermented products.

Lactobacillus (Lb)

Lactobacillus is heterogeneous group of bacteria with similarity being rod-shaped bacteria. Many species of this genus are found commonly in plant and vegetable materials and also in juices and fermented foods. Although they are very important part of fermented foods, they are also responsible for the spoilage of fermented and non-fermented foods. Currently there are more than 250 species of *Lactobacillus* and they may be either obligate homofermentative, or facultative heterofermentative or obligate heterofermentative in their mode of fermenting sugars. Being natural inhabitant of plant products, they can ferment vegetables without the need of any starter cultures. However, now a days, starter cultures are preferred that contain *L. plantarum* and *L. brevis* for obtaining a controlled fermented pickle. The species are mostly acid and salt tolerance, hence can ferment the products to their end stage without the requirement of any other bacteria. The genes required for sugar metabolisms are encoded by the plasmids, which also codes for the bacteriocins and antibiotic resistance.

Other Bacteria Important in Food Fermentations

Apart from the lactic acid bacteria, some other bacteria are also involved in the fermentation process as culture adjuncts or as primary culture but they are used for single purpose for most cases. These non-lactic acid bacteria may be Gram negative or Gram positive and are involved mainly for a single function to perform.

Bacillus

Most of the species of the genus *Bacillus* are involved in food spoilage and only one species that is *B. subtilis* has been reported to be involved in fermentation process. The species is mainly involved in the formation of Asian fermented food natto that is made from the soybeans.

Bifidobacterium

The use of *Bifidobacterium* species in the fermentation is not clear as such and also these are not commonly found in the raw food materials. But some of the species have been found fermentative in nature that may produce acetic acid and lactic acid. Also, these bacterial species have probiotic property, so their addition to the fermentation adds to the food nutritive values. So, due to these properties, these bacteria are now commonly used as starter culture on many commercially important fermented products. There are about 50 species of the genus *Bifidobacterium*, which were earlier classified in the genus *Lactobacillus*, but later these were placed as a separate genus based on differences with the *Lactobacillus*. *Bifidobacterium* are anaerobic and growth optimum is near the neutral pH. These bacteria rarely contain any plasmid and sugar fermentation is by a unique pathway that results in the production of both lactic acid and acetic acid.

Yeasts and Moulds Used in the Manufacture of Fermented Foods

There are more than a million fungi known to exist, but only a few are used in the fermentation technology that is classified as Ascomycota and Zygomycota. The fungi commonly used are yeasts that are unicellular and non-filamentous and moulds that are multi-cellular and filamentous. Important genera of these two groups that are involved in fermentation are *Saccharomyces*, *Kluyveromyces*, and *Zygosaccharomyces* belong to yeast and *Aspergillus*, *Penicillium*, and *Rhizopus* belong to moulds group (Kirk *et al.,* 2008; Kurtzman *et al.,* 2011).

Saccharomyces

The most important microorganism that is used in fermentation is the yeast of genus *Saccharomyces*. These are used in fermentation even more than the bacteria and the fermented products are popular as well as impact the economy of a country. *Saccharomyces cerevisiae* is the most commonly used species of all and its whole genome has been already studied. The speciation has been made by studying the carbon assimilation and fermentation pattern. Some strains are halotolerant and osmophilic and used in fermentation where there is high amount of sugar and salts in the substrate or the end product. In some of the plant products, the natural presence of the yeast is enough to carry out the fermentation while in most cases; a starter culture of the yeast is required for initiating the fermentation process (Naumov *et al.,* 2000; Hittinger, 2013).

Fermentation Basics

Biochemically, fermentation is energy yielding reaction where electron accepter is an organic molecule. So, in this reaction either pyruvic acid formed in glycolytic pathway act as electron accepter to produce lactic acid or acetaldehyde formed by pyruvate decarboxylation act as electron acceptor to produce ethanol. So, the above definition of fermentation is true regarding these reactions (Bosma *et al.,* 2017). However, there are many fermented foods that are made by pathways that do not fit in the above definition. In these fermentations, instead of glycolytic products, proteins and polysaccharides are metabolized by the fungi. So, in this chapter, term fermentation is used for all the metabolic and enzymatic processes that are involved in the fermentation of food. The process of fermentation by the microbes is for the energy production in the form of ATP that is to be utilized by the microbe itself. However, the end products of the metabolic reactions impart flavour and aroma to the food but sometimes metabolic end-products may spoil the food and thus, requires controlled fermentation process. Therefore, there is a need of understanding the substrates and the pathways associated with them for consistency in the fermented foods with desired chemical, physical, biological and nutritional characteristics (Kowalczyk *et al.,* 2016).

Homofermentation

Homofermentation involves the metabolism of the sugar by using the glycolytic Embden-Meyerhof-Parnas (EMP) pathway. The pathway yields two moles of ATP along with two moles of pyruvate. Lactate dehydrogenase enzyme then hydrolyses the pyruvate to yield lactate which is then converted into lactic acid. The end product of the homofermentative pathway is always lactic acid and the pH of the product is very low due to high amount of acid production. Examples of homofermentative microbes are *L. lactis*, *S. thermophilus*, *Lb.helveticus*, *Lb. delbrueckii*, *P. acidilactici* and *Lb.* sakei (Gänzle, 2015).

Heterofermentation

Heteroferementation involves the metabolism of the sugar by phosphoketolase pathway which utilizes phosphoketolase enzyme instead of aldolase. The end products of the reaction are acetate and lactate in the equimolar concentration along with evolution of CO_2. These end products depend upon the type of the substrate used and the culture conditions provided. Most of the lactic acid bacteria that are used in fermentation are heterofermentative in nature and used predominantly as starter cultures. Under conditions like low sugar or aerobiosis, some homofermentative bacteria also divert some lactate towards the end-products such as acetaldehyde, formate or acetate. Such pathways are very important for the fermentation process as these end products imparts flavours and texture to the fermented foods. Examples of heterofermentative bacteria are *Lc. mesenteroides,Lc. lactis, Lc. mesenteroides, Lc. kimchii*, *Oenococcus oeni*, and *Lb. sanfranciscensis* (Zaunmüller *et al.,* 2006).

Sugar Metabolism by *Saccharomyces cerevisiae*

Saccharomyces cerevisiae utilizes the sugars in the similar fashion as the homofermentative lactic acid bacteria but they can utilize wide range of sugars. But the difference in the pathway is that the pyruvate is not reduced to lactate, instead the end product is ethanol and CO_2. Also, the yeast has functional electron chain and citric acid pathway, making them survive in aerobic conditions. The yeast has 18 different transport proteins that enable them to metabolize in high and low concentration of sugars. Due to this there is complete metabolism of the sugars ensuring high quality end products (Conrad *et al.,* 2014).

Other Metabolic Systems

The lactic acid and ethanol are the products of the sugar metabolism that forms the basis of most foods and beverages. But there are other metabolites like diacetyl which imparts flavour to the fermented foods. These metabolites are synthesised by using the components other than sugars. In this regard, fats and proteins are converted to the products that impart strong flavour and aroma to the foods.

Protein Metabolism by Lactic Acid Bacteria

Lactic acid bacteria are not able to utilize the inorganic nitrogen, so they require organic source of nitrogen like free amino acids. Hence, for the low concentration of the amino acids in the substrate, lactic acid bacteria have developed proteolytic systems for degradation of the peptides into free amino acids and transport system for up taking them. More than 20 different peptidases have been identified in lactococci and lactobacilli that generated a pool of amino acids from proteins. The protein metabolism systems in vegetables and bread are less important than the casein metabolism in milk. The casein is utilized in three steps that are casein hydrolyzation by extracellular proteinases to form peptides, transportation of the peptides into cells via peptide transport systems and hydrolyzation of peptides by intracellular peptidases to form free amino acids. This metabolism system is an important system for flavour and aroma enhancement (Liu *et al.,* 2010).

The Citrate Fermentation

Citrate is a common constituent of the plants that is fermented by the lactic acid bacteria to produce diacetyl, a flavouring and aromatic compound. The pathway of citrate to diacetyl is of no significance to the microbe as no energy is produced in this pathway. However, the protons formed during this pathway may initiate the proton motive force which when utilized properly may result in overall increase in the energy of the cell. Thus, citrate fermentation results in an increase in the metabolic energy available to the cell along with adding flavour and aroma to the fermented food (Pedersen *et al.,* 2012).

Fermented Plant Products

The process of fermentation of vegetables is almost same for different vegetables grown around the world; however, grains are fermented in different ways to produce different kind of final fermented foods. The diversity in the food product is contributed by the production process and microbiological variables. Vegetable's fermentation is an old process that was a means of food preservation involving salting and packing in jars for storage at ambient temperature. So, in this regard different plant-based products are fermented to prepare foods that are traditional to different parts of the world (Table 3.1). Some of them have been described below.

Boza

Boza is a traditional fermented beverage that is produced from millet, maize, wheat, rye, or rice and other cereals (Zorba *et al.,* 2003; Kohajdová, 2010; LeBlanc and Todorov, 2010; Nyanzi and Jooste, 2012; Kancabas and Karakaya, 2013). It is a viscous pale yellow colour liquid with a sweet or sour taste (Altay *et al.,* 2013) that is consumed in countries of the Balkan region including Bulgaria, Romania, Albania and Turkey (Cosansu, 2009; Kivanc *et al.,* 2011; Nyanzi and Jooste, 2012). The preparation of Boza involves milling of cereals and cooking in water in open

boiler. After that, bran and hull are removed and sugar is added to the cooled mixture. Fermentation is carried out at 30°C for 24 hr (Todorov, 2010; Altay *et al.,* 2013) by back-slopping or adding starter cultures as yoghurt or sourdough (Nyanzi and Jooste, 2012). After fermentation, the boza is cooled and stored in plastic bottles and has a shelf life of 15 days (Todorov, 2010; Nyanzi and Jooste, 2012). Fermentation is carried out predominantly by various *Lactobacillus* and *Leuconostoc* species along with some yeasts belonging to the genus *Saccharomyces* and *Candida* (Östürk *et al.,* 2013, Vashuda and Mishra, 2013). The bacteria used in fermentation also produce bacteriocins that increase the shelf life of the final product (Kivanc *et al.,* 2011).

Table 3.1: Fermented Plant Foods of different Regions of the World

Fermented Food	***Substrate***	***Microorganism***	***Country***	***Food Form***
Boza	Wheat, rye, millet, maize	*Lactobacullus* spp., *Leuconostoc, Sachcaromyces cerevisiae*	Bulgaria, Romania, Turkey, Albania	Beverage
Burong mustala	Mustard	*Lactobacillus brevis, Pediococcus cerevisiae*	Philippines	Salad, side dish
Bushera	Sorghum, millet	*Lactobacullus* spp., *Leuconostoc, Sachcaromyces cerevisiae*	Uganda	Beverage
Caper berries	Caper berries	*Lactobacillus plantarum*	Greece, Italy	Brine of capers
Cucumbers	Cucumbers	*Lactobacillus plantarum, Pediococcus pentosaceus*	Asia, USA	Pickle
Dakguadong	Mustard leaf	*Lactobacillus plantarum*	Thailand	
Dhamuoi	Cabbage, vegetables	*Leuconostoc mesenteroides, Lactobacillus plantarum*	Vietnam	Salad, side dish
Dhokla	Rice, Bengal gram	*Lactic acid bacteria, yeasts*	India, Sri Lanka	Soft spongy food
Dosa	Rice ad blackgram	*Lactobacillus fermentum, Leuconostoc* spp., *Sacharomyces* spp.	India	Crisp pancake
Gundruk	Cabbage, radish, leafy vegetables	*Lb. plantarum, Lb. casei*subsp. *casei, Lc. pseudoplantarum, Lb. fermentum, P. pentosaceus*	Nepal	Pickle
Hardaliye	Vegetables	*Lb. paracasei*subsp. *paracasei, Lb. casei Lb. pontis, Lb. brevis, Lb. acetotolerans, Lb. sanfranciscoensis*	Turkey	Beverage

Fermented Food	Substrate	Microorganism	Country	Food Form
Idli	Rice and black gram	*Leuconostoc mesenteroides, Lactobacillus delbruckei, Lactobacillus fermentum, Lactobacillus lactis, Sacharomyces cerevisiae*	India	Soft spongy food
Injera	Tef	Yeasts, *Lactobacillus* sp.	Ethiopia, Sudan	Bread
Jiang-gua	Cucumber	*Enterococcus casseliflavus, Leuconostoc lactis, Lc. mesenteroides, Lb. pentosus, Lb. plantarum, Lb. paraplantarum, Lactococcus lactis* subsp. *lactis, Weissella hellenica, Weissella cibaria*	China	Pickle
Kanji	Carrots	*Lactobacillus plantarum, Lactobacillus brevis*	India, Pakistan	Beverage
Kenkey	Maize, sorghum	*Lactobacillus* sp., yeasts	Ghana, Botswana	Gruel or dumpling
Khalpi	Cucumbers	*Lactobacillus plantarum, Lb. brevis, Leuconostoc fallax, Pediococcus pentosaceus*	Nepal	Pickle
Kimchi	Vegetables	*Leuconostoc mesenteroides, Leuconostoc kimchii, Leuconostoc citreum, Leuconostoc gasicomitatum, Lc. pseudomesenteroides, Lactobacillus plantarum, L. brevis, Lactobacillus curvatus, Lactobacillus sakei, Lactobacillus maltaromicus, Lactobacillus bavaricus, P. pentosaceus, Weissella confusa, Weissella kimchii, Weissella koreensis*	Korea	Salad, side dish
Kirsa	Sorghum	*Lactobacillus bulgaricus,* yeasts	Sudan, Ethiopia	Bread
Kishk	Wheat	*Lactobacillus plantarum, L. casei, L. brevis, Bacillus subtilis, Saccharomyces cerevisiae*	Egypt, Syria	Dry balls
Kocho	False banana	*Lactobacillus* sp.	Ethiopia	Bread
Koko	Maize, sorghum	*Sacharomyces* spp., *Lactobacillus* sp.	Ghana	Dumpling
Kvass	Rye, Barley	*Lactobacillus casei, Leuconostoc mesenteroides, Saccharomyces cerevisiae*	Europe	Non-alcoholic beverage

Fermented Food	***Substrate***	***Microorganism***	***Country***	***Food Form***
Mahewu	Maize	*Lactobacillus delbruckii, Lactobacillus bulgaricus, Streptococcus lactis*	East African countries	Beverage
Mawe	Maize, sorghum, millet	*Lactobacillus fermentum, Candida krusei, Saccharomyces cerevisiae*	South Africa, Benin	Dough
Ogi	Maize, sorghum, millet	*Lactobacillus*spp., *Aerobacter, Corynebacterium,* yeast, moulds	Nigeria, Benin	Gruel
Olives	Olives	*Lactobacillus plantarum, Lb. paracasei, Lb. pentosus, Lb. casei, Lb. vaccinostercus, Lb. suebicus, Lb. paracollinoides, Lactobacillus brevis, Pediococcus cerevisiae, Leuconostoc mesenteroides, Lc. Lactis*	Spain, Italy	Brine of olives
Onion and garlic	Onion and garlic	*Lactobacillus plantarum*		Sour onion Sour garlic
Pak-sian-dong	Leaves of Pak-sian	*Lactobacillus brevis, Pediococcus cerevisiae, Lactobacillus plantarum*	Thailand	
Poi	Taro	*Lactobacillus* sp., *Geotrichum* sp., *Saccharomyces cerevisiae*	Polynesia	Viscous liquid
Pozol	Maize	*Lactobacillus pantarum, Lactococcus lactis, Lactobacillus casei, Lactobacillus delbruckii, Lactobacillus fermentum*	Mexico	Beverage
Proviva	Oat	*Lactobacillus plantarum*	Sweden	Beverage
Puto	Rice	*Leuconostoc mesenteroides, Lc. Pseudomesenteroides, Lc. Citreus, Lc. fallax*	Philippines	Cake
Salgam	Black/Violet carrots, turnip, bulgur flour, sour dough, salt and water	*Lb. plantarum, Lb. paracasei subsp. paracasei, Lb. fermentum, Lb. brevis*	Turkey	Beverage
Sauerkraut	Cabbage	*Leuconostoc mesenteroides, Lactobacillus plantarum, Lactobacillus brevis*	China, Korea	Dried salted vegetable
Sinki	Radish	*Lactobacillus plantarum, Lb. brevis, Lb. fermentum, Leuconostoc fallax, Pediococcus pentosaceus*	India, Nepal, Bhutan	Pickle

Fermented Food	Substrate	Microorganism	Country	Food Form
Suan-tsai	Mustard leaves	*Pediococcus pentosaceus, Tetragenococcus halophilus*	Taiwan	Pickle
Sunki	Leaves of otaki-turnip	*Lactobacillus plantarum, Lactobacillus brevis, Pediococcus pentosaceus, Bacillus coagulans*	Japan	Salad, side dish
Sweet cherry	Sweet cherry	*Lactobacillus plantarum, Leuconostoc mesenteroides, Pediococcus acidilactici*	Asia	Brine of sweet cherry
Sweet potato	Sweet potato	*Lactobacillus plantarum*		Pickle
Tarhana	Wheat, milk	*Lactobacillus* sp. *Sachcaromyces cerevisiae*	Greece, Turkey	Dough
Tempeh	Soy beans	*Rhizopus oligisporus, Mucor* sp.	Indonesia, USA, Netherlands	Tempeh cake
Togwa	Maize	*Lactobacillus pantarum, Lactobacillus brevis, Lactobacillus fermentum, Lactobacillus cellobiosus, Sacharomyces cerevisiae, Candida tropicalis*	East Africa	Beverage
Tursu	Cucumbers, cabbage, green tomatoes, green peppers and other vegetables	*Lactobacillus plantarum, Lb. brevis, Leuconostoc mesenteroides, Pediococcus pentosaceus, Enterococcus fecalis*	Turkey	Pickle
Uji	Sorghum, maize, cassava	*Leuconostoc mesenteroides, Lactobacillus plantarum*	Kenya, Uganda, Tanzania	Non-alcoholic beverage
Yosa	Oat bran	*Lactobacillus acidophilus, Bifidobacterium*	Finland	Beverage

Bushera

Bushera is a traditional fermented beverage made from millet or sorghum flour and widely consumed in Uganda (Muyanja *et al.,* 2003). The production process involves mixing the germinated grains in boiled water and then cooling it. Then the grains are powdered and fermented up to 6 days to get the beverage with desired taste (Vashuda and Mishra, 2013). The bacteria that are involved in fermentation are *Lb. plantarum, Lb. paracasei*, *Lb. fermentum, Lb. brevis*, *Lb. delbruckii*, and *Streptococcus thermophillus* (Nyanzi and Jooste, 2012).

Cucumbers

Cucumbers are fermented to form dark green pickle that is consumed widely in Asia, Africa and Latin America. The production process involves washing of the cucumbers and then addition of the brine to it. Starter culture of *Lb. plantarum* or *P. pentosaceus* is added to the brine when the pH is around 4.7 (Steinkraus, 2002). The fermentation is carried out for two to four weeks until a final pH of 3.1-3.4 is reached and then the fermentation is stopped by adding salt to it (Tamang *et al.,* 2005).

Dhokla

Dhokla is a traditional fermented food made from rice and chickpea and is widely consumed in India and Sri Lanka (Das *et al.,* 2013). The production involves mixing the flours of the rice and chickpea and then keeping it for fermentation at room temperature for few hours to overnight for fermentation. The preparation is similar to the idli where fermented batter is poured into the greased pan and steamed to get soft and spongy dhokla (Kohajdová, 2010; Das *et al.,* 2013). The microorganisms involved in fermentation are lactic acid bacteria and yeast that bring about the changes making the food rich in flavour and texture.

Dosa

Dosa is a traditional fermented dish prepared from the rice and blackgram and consumed widely in Indian sub-continent (Das *et al.,* 2013). The production involves preparing the suspension of the ingredients separately with water and mixing them. Then the mixed suspension is fermented for 8-20 hours at room temperature for auto-fermentation. The dosa is prepared by spreading the thin layer of batter on flat heated plate with little oil that transforms the sol into a gel within a few minutes to form a crisp pancake like product (Kohajdová, 2010; Das *et al.,* 2013). The microbes involved in the fermentation are bacteria like *Lb. fermentum*, *Lc.Mesenteroides* and *Streptococcus faecalis* along with yeast like *Debareomyces hansenii*, *Trichosporon beigelii* and *Saccharomyces cerevisiae* (Kohajdová, 2010).

Gundruk

Gundruk is a traditional fermented vegetable such as radish and cabbage, consumed as pickle in Nepal (Tamang *et al.,* 2005). The dish is served as appetizer with the main food to add on minerals to the diet which lacks them. The production involves fermenting the shredded vegetables in earthen pots with warm water for 5-7 days at 18^{o}C. The microorganisms involved in fermentation are *Lactobacillus* and *Pediococcus* species that develop mild acidic taste (Steinkraus, 2002; Tamang *et al.,* 2005).

Idli

Idli is a traditional fermented soft and spongy snack food consumed widely in Indian sub-continent and is made from rice and black gram (Das *et al.,* 2013;

Manickavasagan *et al.,* 2013). Black gram can be substituted with other legumes like chickpea, green gram and soybean whereas small proportion of rice with millet (Maheswari and Shetty, 2013). The idli production involves grinding of the soaked ingredients separately and then mixing the batter together. Fermentation could be carried out naturally or sometimes sour buttermilk or yeasts can be added to it for enhancing fermentation (Sekar and Mariappan, 2007). The batter is fermented overnight at room temperature and then the batter is steamed in greased pans for few minutes to get soft, fluffy idlis with good taste and texture (Aachary *et al.,* 2011; Manickavasagan *et al.,* 2013). Fermentation process is a mixed auto-fermentation involving bacteria like *Lc. mesenteroides, Lb. delbrueckii, Lb. fermenti, Lb. lactis* and yeast like *Saccharomyces cerevisiae* (Nout, 2009; Kohajdová, 2010; Das *et al.,* 2013). Lactic acid bacteria reduce the pH of the batter from 6 to 4.2 which then favour the growth of the yeast for further fermentation of the batter for enhanced flavour and leavening of the batter, also increasing the vitamin and amino acid content of the food (Nout, 2009).

Injera

Injera is traditional fermented bread made from teff and sorghum and is widely consumed in Ethiopia (Anyango *et al.,* 2011). The production process involves mixing the flour with water and to prepare the dough by adding starter culture in the form of previously fermented dough (Abiyu *et al.,* 2013). The dough is fermented for 2-3 days after which made the bread from it. The fermented bread is further stored at room temperature for 3 days for enhancing the flavour of the product (Kohajdová, 2010). Fermentation is carried out by fungi like *Candida* sp., *Hormodendrum* sp., *Rhodotorula* sp.,*Penicillium* sp., and *Aspergillus* sp. along with some unidentified bacteria, which make the injera highly nutritional by increasing the amount of calcium and iron in it and also giving it slightly sour taste (Champagne, 2009; Kohajdová, 2010).

Kanji

Kanji is a traditional ready-to-serve beverage of India and Pakistan which is deep purple in colour. The production process involves mixing of finely grated carrot with water, salt, mustard seed and chilli powder followed by placing the mixture in sealed earthenware vessel. Fermentation is carried out for 7 to 10 days by *Lactobacillus plantarum* and *Lactobacillus brevis*. The kanji is thought to have high nutritional value with soothing effect but it is to be consumed within 3-4 days after which it goes bad (Ray and Panda, 2007).

Kenkey

Kenkey is a fermented food made from maize and is widely consumed in Ghana (Nout, 2009). The production involves mixing of raw fermented and partially cooked dough, and making balls of it which is wrapped in leaves and boiled for few hours. After that final product, dumpling is made which is eaten with stews and soups (Annan *et al.,* 2003). The fermentation involves mostly lactic acid bacteria like

Lb. reuteri and *Lb. fermentum* along with yeast *Candida krusei* (Kohajdová, 2010; Nyanzi and Jooste, 2012). Fermentation results in increase in the lysine content along with flavouring agents (Nyanzi and Jooste, 2012).

Kimchi

Kimchi is a traditional fermented dish prepared from the vegetables and served with almost every dish in Korea, its estimated production in Korea is around 1.5 million tonnes (Cho *et al.,* 2009). The production process involves cutting and brining (salting) of the vegetables followed by rinsing and draining of the water. After that some minor ingredients like spices are added to it and fermented in jars. Fermentation has been reported to increase the nutritional value of the food by increasing nutritional components along with phytochemicals, thus making it one of the healthiest food of the world (Lee *et al.,* 2011). Fermentation is done by lactic acid bacteria that vary with the pH during production process. Early fermentation is carried out by the *Lc. Mesenteroides* while the final product is formed by *Lb. sakei* (Cho *et al.,* 2009). Other bacterial species such as *Achromobacter*, *Flavobacterium* and *Pseudomonas* have also been reported from the kimchi fermentation (Kim and Chun, 2005).

Kirsa

Kirsa is traditional bread made from sorghum or millet and is widely consumed in Sudan (Asmahan and Muna, 2009). The production process involves mixing of the millet or sorghum flour with water in 1:2 and then addition of the starter culture in the form of fermented dough from the previous batch (Rahman *et al.,* 2010). The fermentation is carried out for 12-19 hours until pH-4.0 is obtained after which the dough is baked into breads (Asmahan and Muna, 2009). Fermentation is carried out mainly by *Lb. fermentum* and *Lb. amylovorus* with other bacteria and yeast like *Lb. brevis*, *P. pentosaceas, Acetobacters* sp. and *Saccharomyces cerevisiae* (Asmahan and Muna, 2009; Rahman *et al.,* 2010).

Kishk

Kishk is traditional food made from wheat and is consumed widely in countries like Jordan, Syria, Lebanon and Egypt (Kohajdová, 2010; Mahasneh and Abbas, 2010; El-Nawawy *et al.,* 2012). The production process involves boiling, drying, milling and sieving of the wheat to remove bran. Then started culture is added to the wheat paste in the form of yogurt to carry out fermentation. After fermentation, the product formed is dried, powdered and stored in the shape of balls (Kohajdová, 2010). Fermentation is carried out by *Lb. plantarum, Lb. casei Lb. brevis, Bacillus subtilis* and yeasts which not only enhances the mineral in the fermented food but also increases the bioavailability of the wheat nutrients (Blandino *et al.,* 2003).

Kocho

Kocho is a traditional food made from Ensete false banana and is widely consumed in Ethiopia (Steinkraus, 2002). The production process involves

fermenting the peeled banana (pulp) in the pits for three to six weeks. Fermentation results in increased CO_2 which creates an anaerobic atmosphere and an increase in temperature. The resulted fermented product has a low pH and a strong odour with paste like consistency (Ray and Panda, 2007).

Kvass

Kvass is traditional beverage made from barley and rye and is widely consumed in European countries (Nyanzi and Jooste, 2012). The beverage is similar to bosa in terms of usage and composition and is non-alcoholic in nature (Kohajdová, 2010). The production process involves the dilution of the flour batter in hot water and its clarification. After that sugar is added to it and fermentation is started by addition of the yeast to it. The fermentation is stopped by cooling the kvass to 4°C to obtain a nutritionally rich beverage (Nyanzi and Jooste, 2012). Fermentation is carried out predominantly by *Lb. casei*, *Lc. mesenteroides* and *Saccharomyces cerevisiae* which are not killed after fermentation thus providing a probiotic drink for the consumers (Nyanzi and Jooste, 2012).

Mahewu

Mahewu is a fermented beverage that is made from the maize and is widely consumed in Africa and Gulf countries (Chelule *et al.,* 2010; Kohajdová, 2010; Nyanzi and Jooste, 2012). The production involves mixing the maize porridge with water and then adding the flour of wheat, millet or sorghum to it, and allowed to ferment (Kohajdová, 2010; Vashuda and Mishra, 2013). The fermentation is carried out by natural flora consisting mainly of bacterium *Lactococcus lactis* (Champagne, 2009) whereas commercial production of mahewu employs *Lb. delbruckii* (Nyanzi and Jooste, 2012).

Mawe

Mawe is fermented dough made form maize and consumed widely in Togo and Benin (Greppi *et al.,* 2013). Production of mawe involves washing of maize, extracting endosperm and dough kneading. The dough is fermented at 30°C for about 3 days to reach the desired pH of 3.5-4.0 (Nout, 2009). Mawe so prepared is further used for preparation of other foods like albo, agidi, akassa and koko (Greppi *et al.,* 2013). Fermentation involves hetero-fermentative bacteria like *Lb. buchneri, Weissella confuse, Lb. curvatus, Lb. brevis, Lb. cellobiosus, Lb. fermentum* and yeast species like *Saccharomyces cerevisiae, Candida glabrata, C. kefyr, C. krusei* (Nyanzi and Jooste, 2012; Greppi *et al.,* 2013).

Ogi

Ogi is traditional fermented gruel made from maize and is widely consumed in Nigeria (Greppi *et al.,* 2013). The production process involves washing, steeping, milling and sieving of the maize. After that fermentation is carried out for 1-3 days at room temperature to obtain the final product (Evans *et al.,* 2013). Fermentation is spontaneous and is carried out by bacteria like *Lb. plantarum, Lb. brevis, Lb.*

fermentum and yeasts like *Saccharomyces cerevisiae, Candida krusei and C. tropicalis* which decreases the pH to 3.6 and also produce lactic acid and acetic acid during fermentation (Kohajdová, 2010).

Onion and Garlic

Onions are fermented to form the sour onions using yellow or white storage onions. The production process involves the slicing of onions followed by salt addition and anaerobic fermentation at 18°C. Fermentation is carried out by *Lb. plantarum* added as started culture in the form of brine of sauerkraut. The fermented onions have a pH of 3.25-3.35 with lactic acid content of 1.2-1.5 g/100ml. The sour onions produced have similar tartaric acid taste like that of sauerkraut with no pungency left of the raw onions (Roberts and Kidd, 2005). Garlic fermentation is carried out for a week by using garlic that are blanched in hot water (90°C) and addition of starter culture of *Lb. plantarum.* The fermented blanched garlic can be stored at 30°C in 3 per cent NaCl solution without addition of any preservative (De Castro *et al.,* 1998).

Pozol

Pozol is a traditional beverage made from maize and is widely consumed in Mexico (Diaz-Ruíz *et al.,* 2003). The production process involves cooking of maize grains in 1 per cent lime water for 90 minutes followed by grounding the dehusked grains to make dough (Nyanzi and Jooste, 2012). The dough is then made into balls and wrapped in banana leaf for fermentation. The fermentation is done for up to 4 days to attain a desired pH of 3.7-4.7 (Prado *et al.,* 2008; Vashuda and Mishra, 2013). Fermentation is carried out by a variety of lactic acid bacteria like *L. lactis, S. suis, Lb. plantarum, Lb. casei, Lb. alimentarium* and *Lb. delbruekii* however amylolytic enterococci and streptococci importance has been reported in recent studies (Díaz-Ruíz *et al.,* 2003; Champagne, 2009; Kohajdová, 2010).

Proviva

Proviva is a probiotic beverage made from oats and is widely consumes in Sweden (Prado *et al.,* 2008). The production involves addition of malted barley to the oats and fermenting it with the bacterium *Lb. plantarum* 299v (Nyanzi and Jooste, 2012). The final product has a bacterial count of 5×10^{10} cfu and is a mixture of 5 per cent oat meal and rest is fruit juice (Nyanzi and Jooste, 2012).

Puto

Puto is a fermented food made from rice and is widely consumed in Philippines as snack or in breakfast. The production involves washing, soaking of rice, grounding and then addition of coconut milk and sugar. The batter so formed is then fermented for few hours till it is acidified. Then the batter is steamed and served (Kohajdová, 2010). Fermentation involves lactic acid bacteria like *Lc. fallax, Lc. citreus, Lc. pseudomesenteroides,* and *Lc. mesenteroides* (Kelly *et al.,* 1995).

Sauerkraut

Sauerkraut is a form of fermented cabbage that is consumed in China and Korea (Liu *et al.,* 2011). The fermentation of the cabbage results not only increase digestibility of the cabbage but also used for long time as a preservation technique to protect cabbage from spoilage (Steinkraus, 2002; Viander *et al.,* 2003). Currently the sauerkraut production is a big part of food industry in Vietnam and Korea. The fermentation process involves the addition of the salt (2.25-2.5 per cent) to the shredded cabbage followed by anaerobic fermentation in a tank which is carried out at 18°C for three weeks (Viander *et al.,* 2003). The fermentation is carried out by *Lc. mesenteroides*, which produces lactic acid, acetic acids, and CO_2 which maintains anaerobic conditions and well as decrease the pH quickly. At lower pH, *Lactobacillus* and *Pediococcus* species continue to decrease the pH until it reaches 3.5-3.8 (Yoon *et al.,* 2006; Xiong *et al.,* 2012).

Sinki

Sinki is a traditional pickle prepared from radish and consumed mainly in India, Bhutan and Nepal (Dahal *et al.,* 2005). The fermentation procedure involves shredding of sundried radish and fermenting it for 12 days at 3°C in sealed containers. Fermentation is done by *Lb. fermentum* and *Lb*. *brevis*, followed by *Lb*. *plantarum* until the pH reaches 3.3.

Sunki

Sunki is traditional fermented vegetable prepared for the otaki-turnip leaves and is consumed with rice in Japan. The fermentation procedure involves mixing of boiled otaki turnip with zumi and addition of previous year sunki as starter culture to ferment it for two months. Fermentation is carried out at low temperatures during winter and involves *Lb. plantarum*, *Lb. brevis*, *Bacillus coagulans* and *P. pentosaceus* (Battcock and Azam-Ali, 2001).

Sweet Potato

Sweet potatoes are fermented to form pickles. The production procedure involves the blanching of the sweet potato followed by brining with NaCl solution (2-10 per cent) and inoculation with *Lb. plantarum* at 28± 2°C for 28 days. The fermentation results depend upon the choice of sweet potatoes used. The anthocyanin rich sweet potatoes fermentation results in lower pH (2.5-2.8), lactic acid (1.0–1.3 g/kg), starch (56–58 g/kg), and titratable acidity (1.5–1.7 g/kg) as compared with the β-carotene-rich sweet potatoes fermentation leads pH (2.9–3.0), lactic acid (2.6-3.2 g/kg), starch (58–68 g/kg), and titratable acidity (2.9–3.7 g/kg) (Panda *et al.,* 2007). β-carotene rich fully boiled potatoes when fermented under same conditions for 2 days results in formation of lacto-juice that is biochemically similar to the sweet potato pickle formed by fermentation (Panda and Ray, 2007).

Uji

Uji is a popular non-alcoholic fermented beverage that is made from sorghum, maize and millet. It is widely consumed in breakfast in East Africa in fermented as well as unfermented form. The production process of fermented uji involves grinding of soaked grains followed by filtration to remove the coarse particles and bran. The fermentation is carried out for few days in submerged culture state (Kohajdová, 2010). Starter culture of *Lactobacillus* species is added to it in the form of small amount of previously fermented uji. The dominant *Lactobacillus* species is *Lb.plantarum* while *Lb. cellobiosus* and *Lb. buchneri* are also the part of fermentation process (Kohajdová, 2010; Nyanzi and Jooste, 2012). Some part of the supernatant is boiled and mixed with the remaining part to obtain thin cooked beverage which is then consumed by adding some salt or sugar to it for taste (Nout, 2009).

Yosa

Yosa is a fermented drink made from oat bran using probiotic bacteria (Rivera-Espinosa and Gallardo-Navarro, 2010; Zubaidah *et al.,* 2012). The flavour of the drink is similar to yoghurt and is consumed widely in Finland and other Scandinavian countries (Rivera-Espinoza and GallardoNavarro, 2010). The production process involves the cooking of the rice bran in water and then fermenting it with bacteria *Lb. acidophilus* and *B. lactis* (Nyanzi and Jooste, 2012; Zubaidah *et al.,* 2012). Nutritionally yosa is a rich source of fibre and β-glucan along with potential probiotic beverage (Zubaidah *et al.,* 2012).

Conclusion

It is concluded that the fermentation of the plant products is very significant as this not only helps in preservation of the food, but also adds to the nutritive value of the product formed. Fermentation of vegetables and grains increases their shelf life along with increased digestibility and mineral content. Different metabolic pathways involved in fermentation process decreases the harmful microbe content from the food and also increases the probiotic potential by incorporating the good bacteria to the final product. Thus, fermentation is a cheap means of preservation and increasing the quality of the plant-based food products along with increasing the palpability of the food.

Authors' Contributions

NM- Initial writeup of the manuscript; NM, PR and RS- collected the literature; RS- conceptualize, editing and final writing of the manuscript.

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Handbook of Research on Advanced Phytochemicals and Plant-Based Drug Discovery

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A volume in the Advances in Medical Diagnosis, Treatment, and Care (AMDTC) Book Series

Published in the United States of America by
IGI Global
Medical Information Science Reference (an imprint of IGI Global)
701 E. Chocolate Avenue
Hershey PA, USA 17033
Tel: 717-533-8845
Fax: 717-533-8661
E-mail: cust@igi-global.com
Web site: http://www.igi-global.com

Library of Congress Cataloging-in-Publication Data

Names: Singh, Ajeet, 1991- editor.
Title: Handbook of research on advanced phytochemicals and plant-based drug discovery / Ajeet Singh, editor.
Description: Hershey, PA : Medical Information Science Reference, [2022] | Includes bibliographical references and index. | Summary: “This book offers contributions that examine the applications of bioactive molecules from a health perspective, looking at the pharmacological aspects of medicinal plants, the phytochemical and biological activities of different natural products, and ethnobotany/and medicinal properties, and also present a novel dietary approach for human disease management”-- Provided by publisher.
Identifiers: LCCN 2022014802 (print) | LCCN 2022014803 (ebook) | ISBN 9781668451298 (hardcover) | ISBN 9781668451304 (ebook)
Subjects: MESH: Phytochemicals | Plants, Medicinal | Drug Discovery | Plant Preparations
Classification: LCC RS164 (print) | LCC RS164 (ebook) | NLM QV 766 | DDC 615.3/21--dc23/eng/20220412
LC record available at https://lccn.loc.gov/2022014802
LC ebook record available at https://lccn.loc.gov/2022014803

This book is published in the IGI Global book series Advances in Medical Diagnosis, Treatment, and Care (AMDTC) (ISSN: 2475-6628; eISSN: 2475-6636)

British Cataloguing in Publication Data
A Cataloguing in Publication record for this book is available from the British Library.

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ISSN:2475-6628
EISSN:2475-6636

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Medical Information Science Reference • © 2022 • 352pp • H/C (ISBN: 9781799882251) • US $470.00

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Chapter 8
Current Status of Commercial Anticancer Phytochemicals and Their Derivatives:
Natural Anticancer Bioactive Compounds

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ABSTRACT

Cancer is one of the most deadly diseases caused due to abnormal division of the cells. Researchers are facing major challenge for finding the effective treatment of the cancer. Various methods of cancer treatment are chemotherapy, surgery, stem cell/bone marrow transplant, radiotherapy, hormone therapy, and anticancer drugs. The anticancer drugs may be natural, semi-synthetic, or synthetic in nature. The most widely used anticancer drugs are the phytochemicals isolated from the plants of their semi-synthetic analogues. So the research focuses on the isolation and identification of the bioactive compounds from natural sources as a potent anticancer agent. However, now the trend has been moved from the natural plant-based products to the natural products mimics of molecule that is the part of human response system. So, the present chapter briefly highlights the current status of commercialized phytochemicals used as anticancer drugs along with mechanism of action of some important drugs.

INTRODUCTION

The pharmaceutical industry is always in search of new lead compounds. The main sources of these

DOI: 10.4018/978-1-6684-5129-8.ch008

compounds have been the natural products from different sources that possess different pharmacological important properties. These compounds are very much beneficial for the maintenance of human health. The natural compounds such as aspirin, morphine, digitoxin, quinine and many more are the natural products that have been used for long time for the treatment of various diseases (Cragg *et al.,* 2005). Cancer is one of the diseases which were initially thought as an incurable disease. It is a deadly disease that is characterised by the uncontrolled growth and division of the cells of a part of the body that have started invading the surrounding tissue and then ultimately to the whole body (Cancer Research UK, 2019). Theoretically, there are more than 200 types of cancer but the prominent ones are breast, colon, lungs and prostate cancer. Based on their activity and infection type, cancer has been classified into five classes of brain tumour, carcinoma, leukaemia, lymphoma and sarcoma (Gezici & Sekeroglu, 2019). It is estimated that the global cancer cases will be around 20 million in the next few years (Seca & Pinto, 2018). So the major challenge is the looking for the cancer treatment by investigating new effective anticancer drugs. The currently used treatments for the cancer are radiotherapy, chemotherapy, surgery, bone marrow transplant and using some anticancer drug. The most effective and successful chemotherapeutic and anticancer drugs used for the cancer treatment have been surprisingly natural in origin. The commercialised anticancer drugs can be classified into the synthetic (Chemically synthesised in laboratory), natural (obtained from the natural sources like plants, microbes, marine sources, etc.,), Natural product derivative (include all the semi synthetic analogues of natural products), and natural product mimic (compounds that are similar to natural compounds that are found in humans as the part of their process) (Newman & Cragg, 2020). In actual the most widely used anticancer drugs are either natural products or their analogues that are semi-synthetic in nature (Nahar & Sarkar, 2019). Natural compound shave been used as the basic molecule for the synthesis of analogues for the effective cancer treatment. In fact the natural products are also used to learn about the mechanism of action for the cancer treatment and he same is used for the synthesis of anticancer drugs by doing modifications at specific sites in the basic compounds. These days there is development of the synthetic analogues that are the compounds which mimics the natural compound that is very important for the cancer progression (Kinghorn *et al.,* 2016). The natural products potential for the treatment of cancer was first obliged in 1950 by United States National Cancer Institute which then provided funds to carry out the research related to the identification of the anticancer compounds from the natural sources. After that numerous studies have been carried out to identify the potential anticancer drugs from different natural sources that could be used for the treatment of different cancers. Although initially only natural products were sued for the cancer treatment but with time there has been increase in the use of new approaches for the anticancer drug development that have now overshadowed the potential diversity among the natural products. Among different natural sources, the most widely used are the plants and marine organisms due to their sedentary lifestyle which means they will produce more secondary metabolites to protect themselves from the predators or parasites. This leads to the development of vast diversity among the compounds produced by these organisms as the part of their complex defence system (Williams *et al.,* 1989). Thus these have been the source of many potential therapeutic drugs which have very high specific binding with the potent target (Paul, 1992).

The use of the natural sources for obtaining the compound of interest has been supported well by the following facts. Firstly, the products obtained naturally are synthesised in a combinational manner due to the shuffling of the genes in between different taxa resulting in new combinations that may be beneficial to the mankind (Kingston &Newman, 2002). Secondly, there have been reports of natural products possessing anticancer potential (Shu, 1998; Newman *et al.,* 2000; 2003). Thirdly, the natural products

are very unique and none of these compounds can be artificially synthesised and are not accessible by any other source. Compounds such as halichondrin or paclitaxel can never be synthesised artificially even with the modern combinational chemistry. It is also stated that no artificial compound can ever be same as the natural counterpart structurally or in specificity and there is always diversity among them. Fourth, despite being a non-effective drug, the compounds may act as template for designing of more effective drugs. The compounds have a three-dimensional structure with various ligands on the surface (Henkel *et al.,* 1999). These provide an insight to the protein-protein interactions, which may help the combinational or medicinal chemists to design safe and effective drugs for specific target sites. So this chapter will provide a convenient summary of the commercialised anticancer drugs available which may serve as an inspiration for the scientist of next generation to carry out further research in this area.

PLANT BASED NATURAL ANTICANCER PRODUCTS

Plants are known for synthesising various compounds which may be simple molecules or very complex compounds, for their protection against various biotic and abiotic stresses (Howes, 2018). These plants based chemicals or alternatively known as phytochemicals, have been used since ancient times for the treatment of various ailments including tumours and cancer. Historically the use of plants for the cancer treatment have been reported in 1500 BC but the actual search for the compound which is responsible for the anticancer activity started in 20th century. The modern science has developed tools for the easy accessibility of the plants and their compounds that helped a lot for the identification of the compounds with potential anticancer activity. Plants are not only the source of anticancer drugs, but also provide template for chemical modifications to develop compounds known as analogues that are more effective agents than their natural counterparts (Grothaus *et al.,* 2010). The first and the most successful story of the plant based anticancer drug is the drug paclitaxal, obtained from the bark of *Taxus brevifolia*. The higher plant based anticancer drugs have been classified under four major classes. These classes are Vinca bisindole alkaloids (vincristine, vinflunine, vinorelbine and vinblastine), semi synthetic epi-podophyllotoxins (teniposide, etoposide phosphate and etoposide), taxanes (cabazitaxel, docetaxel and paclitaxel), camptothecin derivative (topotecan and irinotecan). In last two decades, a number of reports have been published related to the plant derived compounds potential as anticancer drugs (Iqbal *et al.,* 2017; Rayan *et al.,* 2017; Lichota & Gwozdzinski, 2018; Khalifa *et al.,* 2019). Mostly the compounds' anticancer potential has been tested in vitro studies against the human cancer cell lines (Mehta *et al.,* 2019; 2021) but a limited have been under clinical trials. A large number of anticancer drugs which are of natural origin or naturally derived have been commercialised (Table 21.1). Some of them have been discussed below.

Camptothecin and its Analogs

The camptothecin is an antineoplastic agent, which has very low solubility in water and has been isolated from the plant *Camptotheca acuminata* extracts (Wall *et al.,* 1966). The compound showed very good activity against the L1210 leukemia but its study was very limited due to its low solubility in water. However it solubility was increased by using its sodium salt, but that resulted in poor activity and increased side effects. Thus its sodium salt was discarded and further study was carried out on the compound (Moertel *et al.,* 1972). Later it was found that the action site for the camptothecin was topoisomerase

Table 1. Commercial Available Natural or Naturally Derived Anticancer Drugs.

Year of Approval	Trade Name	Generic Name
1981	Aclacin	aclarubicin
1981	Pepleo	peplomycin
1983	Celiptium	elliptinium acetate
1984	Farmorubicin	epirubicin HCl
1986	Decapeptyl	triptorelin
1988	Pinorubicin	pirarubicin
1989	Curaderm	solamargines
1989	Navelbine	vinorelbine
1990	Zavedos	idarubicin HCl
1992	Actinex	masoprocol
1992	Nipent	pentostatin
1993	Lentaron	formestane
1993	Leustatin	cladribine
1993	Miltex	miltefosine
1993	Starsaid	cytarabine ocfosfate
1993	Taxol	paclitaxel
1994	Campto	irinotecan HCl
1994	Delivert	angiotensin II
1994	Smancs	zinostatin stimalamer
1995	Taxotere	docetaxel
1996	Etopophos	etoposide phosphate
1996	Hycamptin	topotecan HCl
1999	Agenerase	arglabin
1999	Aromasin	exemestane
1999	Panretin	alitretinoin
1999	Valstar	valrubicin
2000	Levulan	aminolevulinic acid
2000	Mylotarg	gemtuzumab ozogamicin
2001	Metvix	aminolevulinic Me ester
2002	Calsed	amrubicin HCl
2002	Faslodex	fulvestrant
2003	Lipusu	paclitaxel liposomal
2004	Camtobell	belotecan HCL
2004	Docrised	vapreotide acetate
2004	Hexvix	hexyl aminolevulinate
2004	Laserphyrin	talaporfin sodium
2005	Abraxane	paclitaxel nanoparticles
2007	Genexol-PM	paclitaxel nanoparticles
2007	Ixempra	ixabepilone
2007	Nanoxel	paclitaxel nanoparticles
2007	Toricel	temsirolimus
2007	Yondelis	trabectedin
2009	Folotyn	pralatrexate
2010	Halaven	eribulin
2010	Istodax	romidepsin
2010	Javlor	vinflunine
2010	Jevtana	cabazitaxel
2010	Junovan	mifamurtide
2011	Adcetris	brentuximab vedotin
2011	Zytiga	abiraterone acetate
2012	Ameluz	bf-200 ala
2012	Ceflatonin	homoharringtonine
2012	Kyprolis	carfilzomib
2012	Picato	ingenol mebutate
2013	Kadcyla	trastuzumab emtansine
2015	Stakel	padeliporfin potassium
2017	Besponsa	inotuzumab ozogamicin
2017	Mundesine	forodesine HCl
2017	Rydapt	midostaurin
2018	Aplidin	aplidine
2019	Polivy	polatuzumab vedotin

I, which leads to detailed investigation behind its mechanism of action. Now a day's its water soluble semi synthetic analogues topotecan (Hycamtin) and irinotecan (Camptosar) are used for the treatment of solid tumours. Further, various new analogues developed by using the combinational techniques are under clinical trials (Rahier *et al.,* 2005).

Topotecan

Topotecan (Hycamtin, GlaxoSmithKline) approved in 1996 by U.S. FDA, is a semi synthetic analogue of camptothecin. The compound was made water soluble by the addition of basic *N*, *N*-dimethyl-amino-methyl functional group at C9. The compound was marked as miracle for the treatment of advanced ovarian cancer where chemotherapy with paclitaxel and platinum based chemotherapy were failed. Apart from the use for the ovarian cancer, the drug has also been approved for the treatment of recurrent small cell lung cancer. The administration of the drug in human is intravenously and it lack accumulation in the body due to its short half-life. Moreover its affinity towards the blood proteins is also very low compared to other compounds of this class. The side-effects associated with the use of this drug are neutropenia as main toxicity and thrombocytopenia to less extent. Apart from its use in the treatment of ovarian and lung cancer, the drug has also shown promising results against haematological malignancies. The use of topotecan for developing combinational regimes with other drugs such as cyclophosphamide, cytarabine, cisplatin, etoposide, and paclitaxelis is under development (Ulukan & Swaan, 2002).

Irinotecan

Irinotecan (Camptosar, Pfizer) approved in 2000 by U.S. FDA, is a semi synthetic analogue of camptothecin. The compound was made water soluble by the addition of the potent 7-ethyl-10-hydroxycamptothecin analog SN 38. The drug also has a basic bispiperidine on the 10-hydroxy position, which is cleaved in the liver by the enzyme carboxyl-esterase that produces SN-38. This enzymatic activity product is an active compound that is a very potent drug having about 1000-fold more topoisomerase I inhibition activity *in vitro* than the drug, irinotecan itself. Irinotecan has been used for the treatment of advanced colorectal cancer. The drug can be used alone as first line therapy or may be employed in combination with 5-fluorouracil for the treatment. The mode of administration for the dug is intravenously and stays in the body for a longer duration in its lactone form thus increasing its pharmacological importance. The specificity of the irinotecan (lactone form) and SN-38, with the serum albumin results in increased stay of the drug in body. The side-effects associated with the use of drug are limited to diarrhoea and in some cases neutropenia. Besides the activity of the drug against the colorectal cancer, the drug also showed promising results against the cervical, ovarian and lung cancer along with malignant gliomas as evident in the recent clinical trials. Further studies are being carried out to know the effect of combinational therapies along with other drugs like vinca alkaloids, anthracyclines and taxanes (Garcin-Carbonero & Supico, 2002).

Homoharringtonine and Related Compounds

The genus *Cephalotaxus* has been used by the Chinese in their traditional medicinal system for treatment of various ailments. The bark of these Asiatic origins, evergreen trees and shrubs contain various phytochemicals with pharmacological important properties (Huang *et al.,* 1983). More than 20 differ-

ent alkaloids have been isolated from the genus which has been grouped into three categories based on their functional side chain (Takano *et al.,* 1996a; 1996b; 1996c; 1996d; 1996e; 1997). One group has a carboxyl group at the end of the chain and the compounds in this group are3¢*S*-hydroxy-5¢-des-*O*-methylharringtonine, 5¢-des-*O*-methylisoharringtonine, 5¢-des-*O*-methylhomoharringtonine, and5¢-des-*O*-methylharringtonine. The other group has varied number of methyl groups and the members of this group are bishomodeoxyharringtonine, homodeoxyharringtonine, and nordeoxyharringtonine. And the third group contains aromatic rings at the terminal positions of the side chain and the members of the group are 3*S*-hydroxyneoharringtonine, homoneoharringtonine and neoharringtonine. Studies suggested that the bark of *Cephalotaxus fortunei Hook. F* possesses many alkaloids that have antitumor properties. Another species of the same genus, *C. harringtonia* K. Koch, contains an active alkaloid Homoharringtonine (cephalotaxine-4-methyl-2-hydroxy-4-methylpentyl-butanedioate) in its alcoholic fraction which is one of the members of *Cephalotaxus* alkaloids (Grem *et al.,* 1988). Different species contain different alkaloids of the same class with cephalotaxime being their parent compound. Initially the cephalotaxime was isolated from two different species of the genus *Cephalotaxus*, whose structure was revealed later using the x-ray crystallography by using the compound cephalotaxime methiodide (Abraham *et al.,* 1969). Cephalotaxime and its derivatives have a common and unique ring system. Thought the compound cephalotaxime does not exhibit any anticancer potential, but its derived esters are of significant interest due to potent anticancer potential. The most potent anticancer agents that are the analogues of the compound cephalotaxime are homoharringtonine and harringtonine along with other ester derivative, deoxyharringtonine and isoharringtonine (Powell *et al.,* 1970). The clinical trials of the homoharringtonine for its anticancer activity were conducted at the National cancer institute in Bethesda, Maryland. The main issues associated with the use of this drug for cancer treatment is side-effects related with its use. Further study is going on the analogues that are associated with the main drug homoharringtonine (Itokawa *et al.,* 2005).

Podophyllotoxins and Analogs

Podophyllotoxins are the non-alkaloid lignans that have been isolated from different parts of the *Podophyllum* plants. The analysis of podophyllotoxin biologically was followed by inventing its mode of action and opened gates for synthesizing etoposide and teniposide (anticancer drugs). This research demonstrated the interesting development of useful anticancer drugs using natural compounds by chemical alteration. The structural variation in podophyllotoxin resulted in modification of action mechanism is specifically different approach. At present, many new analogs of podophyllotoxin had been reported as potential anticancer drugs. Many recent literatures had various comprehensive updates regarding this compound class (Lee & Xiao, 2005).

The study on *Podophyllum* plants to podophyllotoxin and then to etoposide and teniposide was in continuation for more than a century which resulted in flourishing development of useful drugs using natural sources. The researchers had described this complex path retrospectively (Stähelin & von Wartburg, 1991). In the early 1950s, scientists in Sandoz, Ltd. supposed that, in comparison to cardiac glycosides, podophyllotoxin glycosides might deliver pharmacological profiles that were superior to the aglycone. This assumption encouraged broad efforts to attain both natural and synthesized *Podophyllum* glycosides and in 1963, led to the expansion and commercialization of SP-G (condensation product of the crude *Podophyllum* glycoside fraction with benzaldehyde). SP-G was used to isolate a highly active "antileukemia factor" in minor quantity (<0.25%). Cell proliferation was significantly inhibited by this

component at a low dose *in vitro* and prolonged the survival time of leukemic mice considerably. It had the unique structural features of a free phenolic hydroxyl group at C 4¢ and an epi configuration at C4 and was identified as 4¢-*O*-demethyl-epipodophyllotoxin benzylidene β-Dglucoside (DEPBG). Successive synthetic work to condense 4¢-*O*-demethylepipodophyllotoxin glucoside (DEPG) with various aldehydes and ketones resulted to the discovery of etoposide and teniposide in the latze 1960s (Stähelin & von Wartburg, 1991). In 1983, the FDA approved etoposide for the treatment of testicular cancer, and in 1992, teniposide was brought into the U.S. market. Variety of cancers including small cell lung cancer, testicular cancer, lymphoma, leukemia, and Kaposi's sarcoma are currently treated using these drugs (O'Dwyer *et al*., 1985).

Taxol and Its Analogs

No naturally known anticancer compound had a stronger effect in cure of cancer than Taxol® also known as paclitaxel. Beside its well-known use as anticancer drug in treatment of breast cancer and ovarian cancers and having a several analogs at clinical trials, Taxol never became a drug at all till now. Discovery and development of taxol along with description of its synthesis, medicinal chemistry, interaction with tubulin and its relationship with compounds having same action mechanism such as the epothilones and discodermolide were briefly covered in this review.

On August 21, 1962, Dr. Arthur Barclay from U.S. Department of Agriculture, led a team of botanists working on contract from National Cancer Institute (NCI) began the story of taxol by collecting *Taxus brevifolia* Nutt. Samples in the Gifford Pinchot National Forest in Washington state. At that Time, extraction from samples was done by the Wisconsin Alumni Research Foundation contract laboratory, and cytotoxicity test to KB cells (human epidermoid carcinoma of the nasopharynx) was performed by Microbial Associates in Bethesda, Maryland. Bark and stem extract samples gave positive results and were assigned under a contract from NCI to Dr. Monroe Wall working at newly established Research Triangle Institute in North Carolina and work progressed slowly. This work was organised in parts because of structural complexity and secondly that another compound, camptothecin was under investigation which had consumed much of his resources in Wall's Lab. Dr. Wall in 1971, with his collaborators Dr. Mansukh Wani and Dr. Andrew McPhail, demonstrated the structure of the major active constituent of *T. brevifolia* as taxol, which had been trademarked by a French company for an unrelated laxative product which was later attained by Bristol-Myers Squibb (BMS) who later applied for drug formulation (Wani *et al*., 1971). The chemical compound of was assigned with generic name 'paclitaxel'. The name taxol was retained for compound with no infringement of BMS trademark. Selecting *T. brevifolia* as a source of taxol was very fortunate because it contained only low amount of toxic alkaloids taxine A and B (Itokawa, 2003). very few species had been investigated for probable fractionation leading to isolation of cytotoxic constituents (taxines) and presence of taxol in smaller amount in other species might had remained undetected.

For several decades, a major role in cancer chemotherapy had been played by Paclitaxel (taxol). Monroe E. Wall and Mansukh C. Wani used the bark of Taxus brevifolia (Northwest Pacific Yew Tree) earlier to isolate taxol in 1967. A complex diterpene having a ring of taxane attached with a four-membered ring of oxetane and at C-13 position, an ester side chain is also attached.

Taxotere

Another taxoid drug currently used for clinical purpose and historical section would not be completed without accounting its discovery was docetaxel (Taxotere). In the early 1980s, the Potier group in Paris working at the Centre National de la Recherche Scientifique showed interest in taxol and a series of experiments were carried out for its isolation and semisynthetic studies. As studied earlier, significant initial research was that good yield of the taxol precursor 10-deacetylbaccatin III could be obtained from the needles of *T. baccata* (Denis *et al*., 1988). For semisynthetic studies of taxol from 10- deacetylbaccatin III, the group developed various approaches on the basis of availability of this compound. The first approach involved hydroxyamination of a cinnamoyl substituted baccatin III derivative that resulted in a mixture of stereo- and regioisomeric hydroxyamines (Guèritte-Voegelein *et al*., 1986). It showed excellent activity slightly more than taxol in some tests and thus developed as an equivalent drug to taxol. Taxotere, had gone under phase-I trials in 1993 and in 1996, it was approved for healing of advanced breast cancer and in 1999, it was approved for non-small cell lung cancer and was generically named as docetaxel.

Pro-drugs of Taxol

A major drawback of taxol was its low water-solubility in its earlier development, so developing water soluble pro-drugs was important work on the drug. In a recent survey of taxanes, the only pro-drug in development is T-3782 (Yamaguchi *et al*., 1999). Initial studies focused on 2-position simple ester derivatives because these were rapidly hydrolyzed to taxol. Various succinate and glutarate derivatives (Magri & Kingston, 1988; Deutsch *et al*., 1989), as well as sulfonic acid salt (Zhao *et al*., 1991) and amino acid derivatives were prepared (Magri & Kingston, 1988; Mathew *et al*., 1992). These general types of prodrugs have been noted above but they were having a modified side chain substituent as well as the amino acid attached with a glycolate spacer. As phosphatases were already present in cells, Phosphate prodrugs attracted more interest and this fact was ingeniously used in synthesizing new prodrugs with stability in water but taxol was released by dephosphorylation by phosphatases followed by internal lactonization (Ueda *et al*., 1993). Unfortunately, its binding with plasma proteins and deemed unsuitable to be used as prodrug, beside this it showed better activity against the murine M109 tumor *in vitro* (Ueda *et al*., 1993). Another ingenious approach for the solution to water solubility drawback was developed by showing that migration of 2¢-benzoyl-3 ¢N-debenzoyltaxol from O-benzoyl to N-benzoyl was slow at pH 4.0. it was found that solubility of this compound was more than taxol at this particular pH and under physiological conditions, it can be used as prodrug by converting it into taxol occurring relatively quickly (tò = 15 min) (Hayashi *et al*., 2003). Similar process was applied to develop a prodrug of canadensol. Presently, taxol and docetaxel are the taxane drugs that are used to treat breast, lung, and ovarian carcinomas and also for AIDS-related Kaposi's sarcoma. Taxanes were proved to be most effective agents for treatment of advanced metastatic breast cancer (Rowinsky, 1997) but their benefits for treating breast cancer at early stage had been evaluated recently. Two major reviews elaborated their value recently. One stated, "Evidence of improved outcomes for patients with breast cancer had cleared the addition of taxanes to standard adjuvant regimens," (Hudis, 2003) and other systematic review for treating early breast cancer accounting taxane versus nontaxane concluded, "The results supported that taxanes can be used as adjuvant chemotherapy for women suffering from early stage breast cancer involving lymph nodes." It was refractory to primary chemotherapy that docetaxel was the choice of drug for treating advanced non–small cell lung cancer (Kris & Manegold, 2001). No significant difference was

seen in the response rates and survival on comparing the efficacy of three different regimens (cisplatin and docetaxel, cisplatin and gemcitabine, or carboplatin and taxol) (Levin, 2001). The significance of taxol was firstly discovered as an anticancer drug for ovarian cancer and still it is a main target. In the early findings of a European–Canadian study, the regimen of cyclophosphamide–cisplatin used previously was found inferior to the combination of taxol–cisplatin (Piccart *et al*., 2000) and also confirmed as the standard of care in women with advanced ovarian cancer. Taxanes were not to be considered as wonder drugs, they had nevertheless brought significant benefits to most of the cancer patients. The recent studies of successful phase III trial done using albumin nanoparticle based formulations of taxol ABI-007 showed that enhanced formulations could have significant effect (Garber, 2004). In metastatic breast cancer patients, the overall response rate for ABI-007 was 33% that was much better than taxol i.e. 19%. Thus, it is clear that in Twenty-first century, taxols and its analogs would be going to play significant role in cancer chemotherapy.

MECHANISM OF ACTION

Numerous phytochemicals have been used for the treatment of different cancers and a lot are under the clinical trials. However, the mechanism of action of these phytochemicals varies greatly. The mode of their action may be inside the cell or outside and they are very specific in their action (Figure 21.1). A brief about the some mechanism of action like enzyme inhibition, cell cycle arrest, macromolecule binding etc., have been discussed below.

Enzymes Inhibition

Topoisomerases I or II

Gossypol, known for its potency as male contraceptive, was isolated from the cotton plant. The action of the compound against the cancer cell lines (mammary adenocarcinoma, Ehrlich's ascites carcinoma and ulcerated melanoma) leads to curiosity to know the mechanism of action behind its anticancer potential (Adlakha *et al.,* 1989). The results showed that the compound exhibits the anticancer potential by a unique mechanism by interacting with the topoisomerase II resulting in its decreased DNA cleavage activity (Adlakha *et al.,* 1989). Further investigation lead to the discovery of two different ligand-topoisomerase complexes. One class of the complex helps in the stabilisation of the DNA-topoisomerase complex thus inducing the DNA breaks while the other class ligands do not induce ant DNA breaks but interfere with the catalytic activity of the topoisomerase. The study reported that the gossypol compounds acts as the second class ligand where the DNA-topoisomerase interaction is blocked without DNA breaking (Senarisoy *et al.,* 2013). The anticancer compound camptothecin also works with the same mechanism as topoisomerase inhibition along with some effects on the DNA. It had shown its anticancer activity against the cultured human keratinocytes as well as in mouse model (Lin *et al.,* 1999). Another compound (-)-epicatechin-3-O-gallate (EGCG), an important catechin found in the tea, showed the inhibition potential against the topoisomerase I but with varied response depending upon its source. It does not show the inhibitory potential against the cancerous cell (COLO 201, HeLa and A549 cells) topoisomerases but very strong activity against the vero cells, calf thymus gland cells and wheat germ cells' topoisomerases. The inhibitory potential of the compound can be altered by substitution of the functional groups with

other groups. One of the example is gallic acid substitution at the 3 position significantly amplified the activity against the human placenta topoisomerase II. Similarly, the hydroxyl group substitution at the 39 position enhanced the activity in similar way but against the topoisomerase I (Suzuki *et al.,* 2001). Another compound GAX46 isolated from *Ganoderma amboinense* sensitized the cell towards their apoptosis by its topoisomerase I &II inhibitory potential in HuH-7 cells (Li *et al.,* 2005).

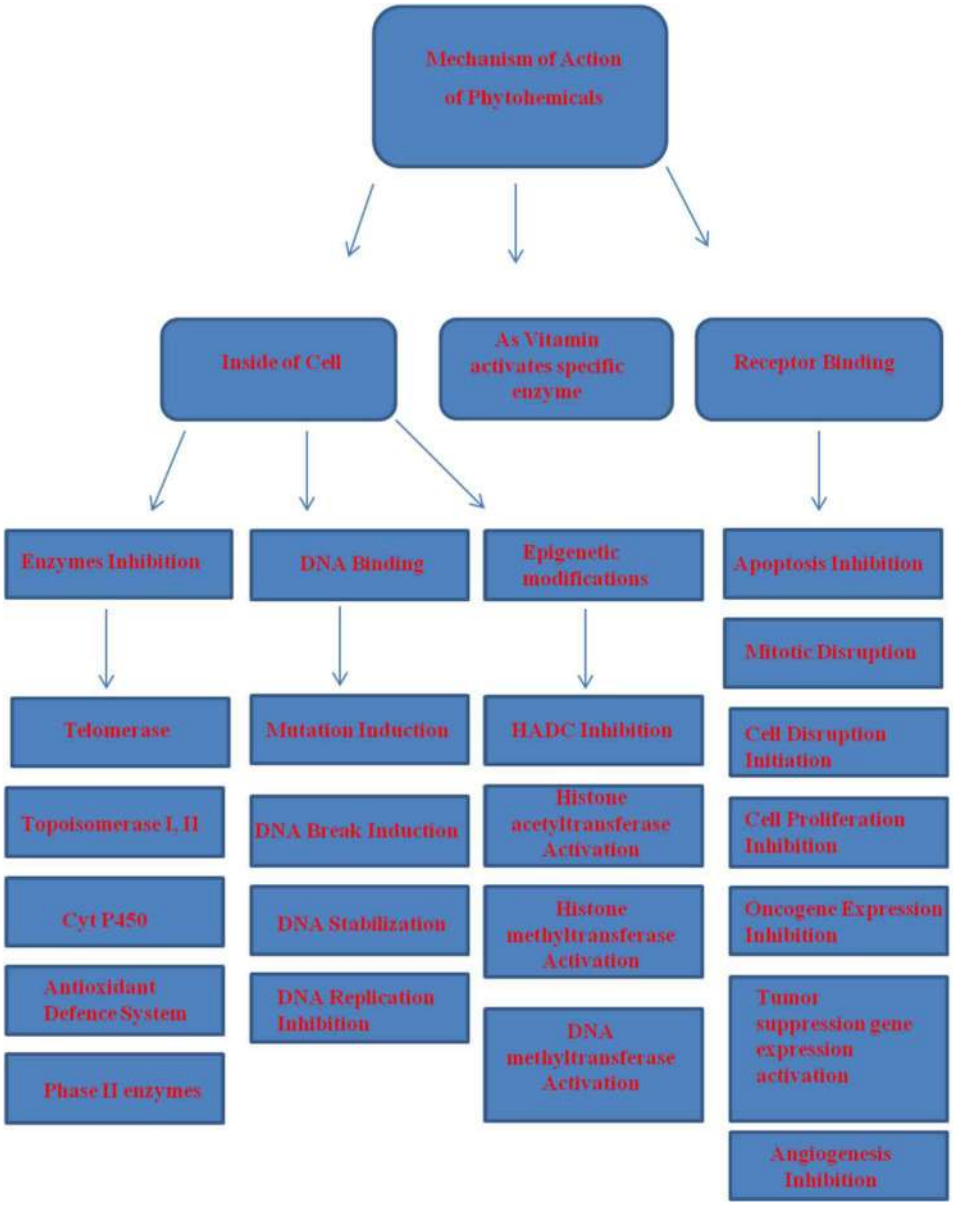
Telomerase

Telomerase are the eukaryotic enzymes that have the reverse transcriptase activity and are formed of different components such as RNA, proteins (p95 & p80) and reverse transcriptase motif (p133). The enzyme is very much essential for the cell division activity (Collins & Gandhi, 1998). The activity of the telomerase has been compromised by the EGCG thus inhibiting the proliferation of the colon adenocarcinoma (HT290) and monoblastoid leukemia (U937) cells. The inhibitory potential against the telomerase has been checked both in vivo and in cell free system. Additionally the ECGC at non-toxic concentration resulted in chromosomal abnormalities and short telomeres which resulted in limiting the cell life span (Naasani *et al.,* 1998). Another study reported that ECGC results in the prevention and apoptosis of telomerase activity thus helps in the prevention of the cervical cancer carcinogenesis. These effects of the ECGC are supposed to be happening in the early stages of cervical lesions (Yokoyama *et al.,* 2004). The EGCG exposure to the cells can result in decreased proliferation along with induction of the apoptosis in the breast cancer cells (MCF-7). The action of the compound was supposed to be due to the decreased expression of the hTERT or human telomerase reverse transcriptase (Berletch *et al.,* 2006). Camptothecin also showed the apoptotic effect in the HL-60 cells. It was reported that the effect of the compound was due to decreased telomere activity in a time dependent manner. The expression of other components associated with the telomerase was also studied and no significant different in the expression pattern was reported for the telomerase associated protein I (TLP1), hTERT and human telomerase RNA, after the exposure to the camptothesis. However a significant decrease in the expression of the Bcl-2 was reported which was supposed to be responsible for the compounds activity. The camptotehcin induce the apoptosis of the cell without disturbing the RNP complex associated genes expression (Jiang *et al.,* 2000). The telomerase inhibitory effect of the camptothecin has also reported in human keratinocytes HaCa T-cells which resulted in the inhibition of proliferation resulting in cell apoptosis. This action was found associated with the telomerase activity down regulation (Liu *et al.,* 2006). An analogue of the camptothecis that is isocamptothecin also exhibited the same effect on the HaCa T-cells (Lin *et al.,* 2008). A high dose of crocin also resulted in the growth inhibition of the cancer cell lines which ultimately lead to the apoptosis. The therapeutic study on the saffron compounds including crocin showed that these compounds interact with the telomerase-DNA structures along with the i-motif and G-quadruplex (Hoshyar *et al.,* 2012; Khosrojerdi *et al.,* 2012; Noureini & Wink, 2012).

Other Enzymes

Apart from the telomerase and topoisomerases, the compounds inhibit the cancer cell proliferation by affecting other enzymes such as VEGF49, MMP48-2 and -9. By affecting the expression of these enzymes, the invasion and migration of the human lung cancer cell line (A549) has been inhibited by the curcumin (Lin *et al.,* 2009).

Figure 1. Different mechanism of action of the phytochemicals for the cancer management.



Direct Binding to Bio-macromolecules

The cellular process can be altered by binding of the phytochemicals with biomolecules like proteins, DNA and microtubules. Paclitaxal, a derivative of taxol that has been in use as an effective chemotherapeutic compound is very unique in its functioning. The compound acts by stabilizing the microtubule assembly against the depolymerisation process by binding with it even in the absence of proteins and GTP50. The in vitro study revealed that the compound binds with the microtubule β-subunit and produce parallel rays after polymerisation. The mechanism of action is in contrast with the cochicine which inhibit the

formation of microtubules. Paclitaxel at high dose hold back the detachment from the centrosomes thus blocks the cell cycle in the G2/M phase (Horwitz, 1994; Priyadarshini & Keerthi, 2012).

Numerous phytochemicals such as delphinidin, kaempferol, quercetin, crocetin, crocin, genistein and resveratrol, act by direct binding with the DNA (Usha *et al.,* 2005; Kanakis *et al.,* 2005; 2009; Bathaie *et al.,* 2007; Gatz & Wiesmuller 2008). However the exact mechanism of their action is not clear but these are known to protect the nucleic acids from the damage caused due to oxidative stress. However the role of resveratrol is quite antagonistic and it has been reported to break the DNA in presence of copper ions along with inhibiting the action of DNA polymerases α and δ. Despite the presence of antioxidant potential, the low concentration of the resveratrol has been reported to possess carcinogenic effect as studied in mice (Sgambato *et al.,* 2001).

RNA Modulation

MicroRNAs (miRNAs) are 19-25 nucleotides long non-coding RNAs which have been found to actively involved in regulation of gene expression. The cancer initiation and progression has been reported to be associated with the miRNA deregulation. Later it was reported that the mRNA function is post-transcriptionally regulated by miRNAs. The miRNAs could act as both effectors and targets in gene silencing and hypermethylation as evident for a study on human cancer (Liao *et al*., 2013). The effect of curcumin in the modulation of the miRNAs has been reported by several workers in different cancer cell lines (Yu *et al*., 2010; Fang *et al*., 2011; Liang et *al*., 2012; Liao & Leung, 2013). The down regulation of the miR-186* miRNA by the curcumin is thought to be the mechanism behind the anticancer property of the compound against A549/DDP59 cell lines. Addition of the miR-186* inhibitor in the A549/DDP cells have been reported to induce apoptosis while miR-186* over expression inhibited the apoptosis induced by curcumin significantly confirming the miR-186* requirement for the cancer progression along with the effectiveness of curcumin for the lung cancer management (Yang *et al*., 2013). The miRNAs expression in the gemcitabine resistance and sensitive PC62 cells were compared along with the effect if isoflavone and DIM63 on miRNAs expression. It was reported that the resistant cells have lower expression levels of the miRNAs. The treatment of resistant cells with either isoflavone or DIM resulted in the morphological changes consistent with the epithelial cells, which indicated the mesenchymal-to-epithelial transition showing the role of the compounds in the regulation of miRNA involved in phenotypic expression (Lin *et al*., 2012). Curcumin has also been reported to alter the miRNA expression leading to the sensitization of the chemo-resistance cancer cells which might be associated with the epithelial-mesenchymal transition (EMT) in some cancer cells (Sondhi *et al*., 2010; Pergola *et al*., 2012). Other chemicals that could affect the EMT by regulating the miRNA are EGCG and I3C67 (Pathania *et al*., 2014).

Autophagy and Unfolded Protein Response (UPR)

The two cellular responses autophagy and UPR shows alteration against environmental factors that affect a cell's survival or death. These factors are accompanying with the proteasomal degradation and cellular pathways that degrade and recycle excess or damaged proteins to maintain cellular homeostasis and life. In response to nutrient depletion, autophagy was discovered as a survival signal for the degradation of cellular components. The UPR, on the other hand, starts when the ER detects an overabundance of unfolded proteins. Autophagy can be initiated to alleviate damage and stress when proteasome function

and/or UPR induction (due to ER stress) are insufficient. If this network of processes is unable to repair the damage or overcome the stress, the cell is killed by apoptosis (Lee *et al.,* 2009; Benbrook, 2012). In recent clinical trials, the combination of autophagy suppressors with apoptosis inducers has been examined (Benbrook, 2012). However, further research is needed to determine how utilising phytochemicals in cancer therapy affects autophagy, proteasomal degradation, UPR, and apoptosis. Autophagy has been classified as type II programmed cell death, and its induction has been studied in the presence of certain phytochemicals. For example curcumin has been found in both in vitro and in vivo investigations to block the Akt/mTOR/p70S6K pathway and activate the ERK1/2 pathway, resulting in the induction of autophagy in malignant glioma. Curcumin causes differentiation in glioma-initiating cells in vivo and in vitro through triggering autophagy, which was discovered several years later (Zhuang *et al.,* 2012). Curcumin stimulates autophagy in A54969 cells by activating the AMPK70 signalling pathway, according to later research (Xiao *et al.,* 2013). The effects of taxol have been examined in MDA-MB-231 and T47D breast cancer cells. Taxol promoted UPR and ATF4 activation (the latter in connection with hypoxia-induced genes) and was implicated in taxol-induced autophagy completion, according to the findings (Notte *et al.,* 2015).

Apoptosis Induction

Apoptosis is a type of programmed cell death that occurs naturally (genetically) in some cells (other forms include autophagy and necroptosis). Caspases (cysteine-rich aspartic acid-containing proteases) catalyse this self-destruction process to destroy cells with a short life span (such as erythrocytes), cells that are unneeded (such as the separation of fingers and toes in a growing human embryo), and cells that are damaged. The presence of a stimulus or the removal of a suppressing signal activates it. Excessive apoptosis leads to atrophy and neurological diseases, whereas insufficient apoptosis leads to excessive cell growth, which can lead to cancer. Apoptosis is promoted by activation of extracellular or intracellular death signals via Fas and Bax, respectively, although Bcl-2 opposes it. Death receptors are members of the TNFR71 family and have an intracellular death domain. P53 is a key activator of the intrinsic pathway and a sensor of cellular stress. Antiapoptotic signal NF-B72 can be triggered by growth factor receptors. In cancer and other disorders, targeting apoptotic pathways with phytochemicals, medicines, and other methods is a therapeutic goal. Using an in vivo strategy in which 4T1 cells were transplanted subcutaneously in Balb/c mice, the effects of dietary GSPs73 were investigated. In the tumour microenvironment, dietary GSPs (0.2 percent and 0.5 percent, w/w) significantly reduced the development of implanted 4T1 tumour cells and increased the Bax/Bcl-2 ratio, released cytochrome c, stimulated Apaf-1, and activated caspase-3 (Livraghi *et al.,* 2003). Saffron extract has been shown to induce apoptosis in MCF-7 breast cancer cells. The mechanism involved the production of the Bax protein and the release of caspases (Mousavi *et al.,* 2009). Crocin, a carotenoid derived from saffron, was found to be responsible for apoptosis induction in animal models of gastric cancer and AGS cells. The Bax/Bcl-2 ratio and caspases both increased significantly, according to the findings (Martel et al., 2008). Crocetin inhibited gastric cancer growth in AGS (Bathaie *et al.,* 2013) and BGC-823 (He *et al.,* 2014) gastric cancer cells by inducing apoptosis, cytochrome c, and caspase release, and raising the Bax/Bcl-2 ratio.

Inhibiting Angiogenesis

The progression of the tumor is very much dependent on the angiogenesis due to the demand of high amount of oxygen during the growth of the tumor. The process of uptake of nutrients and elimination of the wastes is done simply by the diffusion process but during speedy growth there is deficiency of the nutrients in the micro-environment of the tumor. This leads to the expression of the vascular epithelial growth factor (VEGF) by the tumor cell which is required for the process of angiogenesis. Thus one can control the growth of the tumor by controlling the angiogenesis. Various plant extracts have been reported to exhibit the anti-angiogenic effect which could be used for controlling the tumour growth by inhibiting the angiogenesis (Sagar *et al.,* 2006). Different compounds such as querticin, curcumin, resveratol, EGCG, aloe vera, ginger, etc., have been studied which works by different pathways like direct method by inhibition of VEGF or indirectly by affecting angiogenesis related genes such as c-jun, Src, EGFR, K-ras, Tp53 and so on. The mechanism of action of an alkaloid piperine, isolated from the black pepper is by inhibition of the G(1)/S transition and thus the proliferation of the HUVECs without actual killing of the cells. The inhibitory potential was due to the inhibition of the phosphorylation of Akt. It has been reported that piperine affects various aspects of angiogenic process under both in vivo and in vitro conditions as tested by the MDA-MB-231 induced angiogenesis in chick embryo (Doucette *et al.,* 2013).

CONCLUSION

The plant derived natural products have been used as potential anticancer drugs and is expected to be the potential source of new and more effective drugs. The vast diversity of the plants added by the combinational approach for the product development has led to the infinite number of phytochemical obtained. The synthetic approach for the production of natural compound analogues have also benefitted in the way of increasing the specificity and anticancer activity of the natural compounds. Numerous plant based phytochemicals as well as their analogues are under the clinical trials and are expected to be commercialised soon. The demand of time is not to restrict the anticancer agent discovery approach to in vitro studies on the cancer cell lines but to use the collaborative and multidisciplinary approach for the final drug development.

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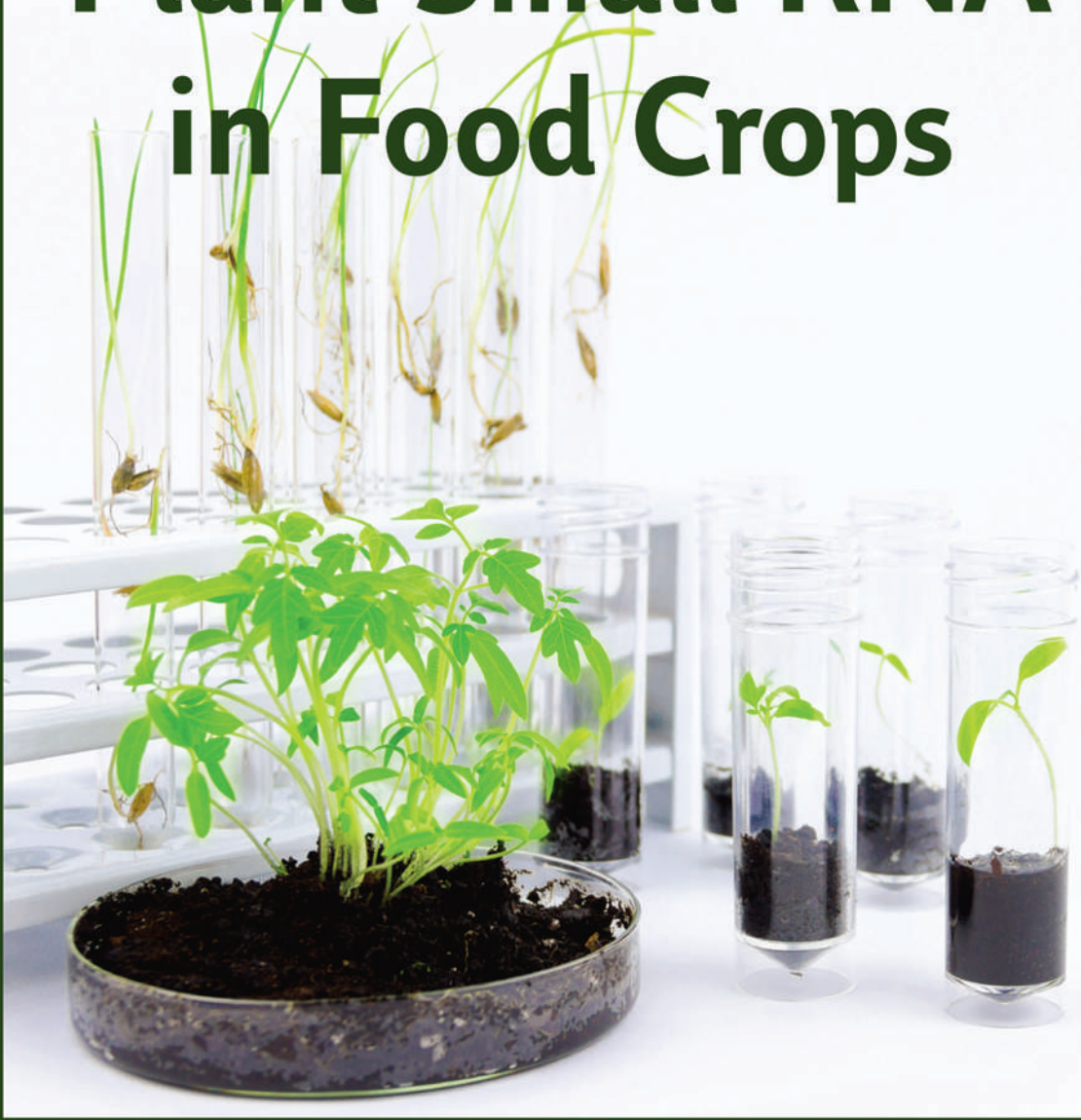
Plant Small RNA in Food Crops



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PLANT SMALL RNA IN FOOD CROPS

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ISBN: 978-0-323-91722-3

Publisher: Nikki Levy
Acquisitions Editor: Nancy Maragioglio
Editorial Project Manager: Kathrine Esten
Production Project Manager: Sruthi Satheesh
Cover Designer: Victoria Pearson Esser

Typeset by TNQ Technologies

Contents

CHAPTER 7

RNAi based approaches for abiotic and biotic stresses tolerance of crops

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1. Introduction

Plants provide all of humanity's essential necessities, including food, fodder, and shelter, as well as additional products derived from plants such as timber, gum, resin, fiber, oil, colors, pharmaceutically related secondary metabolites, medications, and fossil fuels, directly or indirectly. Abiotic, biotic stressors and climatic factors affect the growth, development, yield, and plant products in the face of the worldwide shortage of arable land, water resources, and climate change (Mohr et al., 2020). Currently, the world population size is approx. 7.9 billion by January 2021 and it is expected to rise by 9.7 billion by 2050 according to UN Reports. As the world's population grows, so does the need for plants, resulting in future food security, malnutrition, and famine (Godfray et al., 2010). A combination of new contemporary breeding, molecular genetics, recombinant DNA, and biotechnology approaches based on genomics and proteomics will be required to improve crop production (Rabuma et al., 2022; Gupta et al., 2022a). By using these novel techniques new crop varieties showing resistance to various diseases and stress-tolerant lines are produced for higher yield (Tester & Langridge, 2010). The development and growth of the plant, pathogen defense, and environmental challenges are all regulated by RNAi (Gupta et al., 2014a,b). This is a sequence-specific mechanism that interferes with or suppresses the function of a gene. The small RNA is produced inside the nucleus, and maturation takes place in the cytoplasm of the plant cell by activating the RNAi machinery. It reduces the expression of target genes by blocking the process of protein synthesis. Fire and Mello discovered RNAi in nematodes in 1998 and Nobel Prize was awarded in

Plant Small RNA in Food Crops
ISBN 978-0-323-91722-3
https://doi.org/10.1016/B978-0-323-91722-3.00013-0

2006. The first miRNA was discovered in *Caenorhabditis elegans* in 1993 (Lee et al., 1993). Subsequently, other miRNAs have been discovered in plants, human beings, fruit flies, and other species, etc. RNAi is a technique that is more particular and precise in its activity, and it is being evaluated as a potential tool for functional genomics research. It helps in the development of food varieties without compromising other agronomic qualities in the last 15 years. This is more accurate, stable, and efficient as compared to previously used antisense RNA technology. It has also been used as an innovative way of gaining a better knowledge of the fundamentals of plant defense and metabolism (Khalid et al., 2017). Protection of crop against biotic and abiotic factors, increase in the shelf life of fruits and vegetables, improvement of nutritional content, change in plant architecture for better adaptation to environmental conditions, overexpression or removal of secondary metabolites, generation of male sterile lines, and production of seedless fruits are just a several of the desirable traits that have been improved in crops by using RNAi. RNAi has been used successfully in the last two decades to delineate the functional roles of numerous key genes in various plant species. These genes play a role in fiber development, somatic embryogenesis, allergen/toxin elimination, and tolerance to various types of stresses among food crop varieties (Jagtap et al., 2011). Increased agricultural productivity has long been a major goal in the quest to feed the world's ever-increasing population. Crop diseases provide a significant obstacle to accomplishing these objectives. Among various plant diseases, viral pathogens cause a serious hazard to crops, resulting in a large loss of agricultural productivity (Sharma et al., 2021). The use of small (sRNA) based silencing technology helps in the generation of disease-resistant agricultural varieties by targeting pathogenic genetic controls using the host-induced pathogenic gene silencing mechanism. However, there are public issues and uncertainties about this technology's usage in modern agriculture, biosafety requirements, and the environmental impact of genetically altered crops, specifically when genes originated from creatures other than plants are employed (Herdt, 2006). The production of transgenic plants and food crops has prompted concerns about potential risks to humans and the environment. The main concern involves transgene migration to other types and wild relatives, which could result in monster crops, a loss of genetic diversity, and ecological disruption. As a result, before releasing transgenic crops for general use, they must undergo extensive testing to identify the hazards and ensure their safety. Transgenic crop development consequently necessitates additional time, money, and

skill. As a result, new crop improvement strategies and safe methods must be developed, which may be more acceptable to the general public. sRNA-based silencing mechanism has been caught the interest of scientists who were working in various fields of molecular biology working all over the world. The various researches on RNAi help in the understanding of gene regulation of genes their function and analysis, as well as opening up new avenues for the development of fascinating technology with enormous potential for use in genetic analysis, plant protection, and a variety of other areas related to crop improvement. In the following section, we look at the advances made in the field of RNAi using small RNA (sRNA) for crop development in various types of varieties. In 2002, the miRNA Registry which was later renamed miRBase was established. It contains a comprehensive and detailed database of identified miRNAs, their nomenclature, precursor and mature sequences, and corresponding literature (Griffiths-Jones et al., 2006). Approximately 48,885 mature miRNAs from 271 species (Kozomara et al., 2019) has been submitted in the current release (v22.1), *Arabidopsis thaliana* (428 mature miRNAs), *Medicago truncatula* (756 mature miRNAs), *Brachypodium distachyon* (525), *Oryza sativa* (738), *Triticum aestivum* (125), *Zea mays* (325) and *Solanum lycopersicum* (147) (Šečić & Kogel, 2021) (Fig. 7.1).

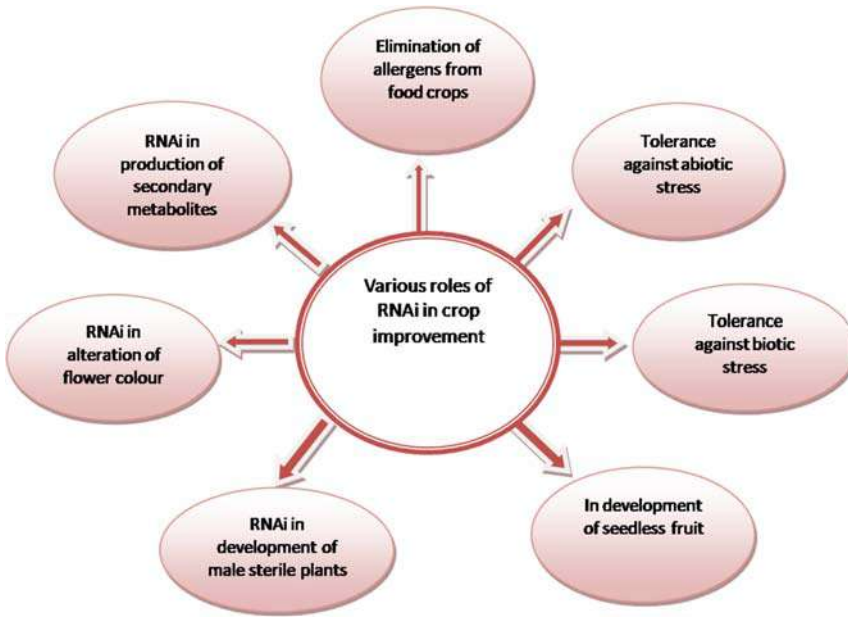

Figure 7.1 Schematic representation of the possible role of RNAi in crop development.

2. Mechanism and biogenesis of sRNA

Different forms of sRNAs are produced via RNAi-related pathways in plants i. e, siRNAs, miRNAs, ta-siRNA, and pha (phased)-siRNAs (Treiber et al., 2019). In this chapter, we studied the general mechanism of small RNA (sRNA) pathways. The different forms of dsRNAs derived from plant endogenous RNA-dependent DNA polymerase, dsRNAs of natural sense and antisense transcripts, and single-stranded RNAs that form hairpin-loop secondary structures are all used to create siRNAs and miRNAs. Dicer-like (DCL) proteins identify and cleave these dsRNA molecules, resulting in siRNAs. The plants have a core set of four types of DCL proteins (DCL1−4) that produce various forms of siRNAs. DCL4 produces 21-nt siRNA that play an important role in trans-acting siRNAs (ta-siRNAs), which are used to modulate gene expression. DCL2 produces 22-nt siRNAs and has been shown to work in tandem with DCL4 in antiviral defense; in the absence of DCL4, DCL2 can produce a large number of viral secondary siRNAs (Martínez et al., 2015). DCL3 produces 24-nt siRNAs that are linked to the silencing of transposons and repetitive elements and have been linked to DNA virus defense (Allen et al., 2005). After the conversion of dsRNA into siRNA duplex by DCLs each duplex is loaded with RISC complex and AGO protein. Furthermore, one of the duplex molecule's strands is chosen to serve as a guide strand. By Watson-Crick base pairing, the guide strand targets and identifies certain cognate RNAs, resulting in RISC cleavage/slicing of the RNA target (Joga et al., 2016). Plants, like DCLs, have numerous AGOs encoded. AGO2 is one of the AGOs that has been linked to antiviral, antibacterial, and anti-stress defenses via siRNA. AGO proteins generally have three types of conserved domains PAZ, MID and PIWI domains (Swarts et al., 2014). The PAZ domain is present near the ND and binds the 3′ end of short RNA (the guide RNA). The MID and PIWI domains are found in the C-terminal domain. A binding pocket exists at the intersection of these two domains, which anchors the guide RNA's 5 ends. The PIWI domain of the siRNA-target duplex-loaded AGO protein has an RNase-H-like activity and a conserved catalytic site, that cleaves the target RNA. Intronic and independently transcribed pri-miRNAs both are co-transcriptionally processed by Drosha in human cells (Kim & Kim, 2007). Plant *MIR* genes are similar to protein-coding genes in that their promoters contain the TATA-box motif and other transcription factor binding motifs. The transcription of *MIR* genes requires general and specific transcription regulators (Megraw et al., 2006). Primary miRNAs (pri-miRNAs) in plants have distinct

secondary structures and are first converted into precursor miRNAs (pre-miRNAs). The pre-miRNA are processed by various protein complexes called Transcription Coupled Export 2 (TREX2), DICER-LIKE 1 (DCL), SERRATE (SE) and double-stranded RNA binding protein called HYPONASTIC-LEAVES1 (HYL1). TREX-2 complex plays an important role in the biogenesis of miRNA including transcription, processing of pre-miRNA, and export of miRNA RISC complex to the cytoplasm by nuclear pore complex. TREX-2 had two core subunits THP1 and SAC3A which interacts and colocalize with RNA polymerase II to promote the transcription of *MIR* genes in the nucleoplasm (Zhang et al., 2020). After processing of pri-miRNA HEAT SHOCK PROTEIN 90 (HSP90) helps in loading of miRNA into AGO1 (Iki et al., 2010). ENHANCED MIRNA ACTIVITY1 (EMA1) and TRANSPORTIN1 (TRN1) proteins interacts with AGO1 and inhibited or promoted the loading of miRNAs into AGO1. A nuclear export signal in AGO1 allows AGO1−miRNA complexes exported them to the cytoplasm. Certain molecular processes are restricted to either the nucleus or the cytoplasm by the nuclear envelope. Nuclear pore complexes (NPCs) carry mRNAs and small RNAs from the nucleus to the cytoplasm, where they function (Beck & Hurt, 2017). The miRNA is further transported to the cytoplasm by EXORTIN5 (Bologna et al., 2018; Zhang et al., 2020). miRNA duplexes are then loaded into AGO in the RISC complex, and one of the strands in 5′ to 3′ direction is chosen as the guide strand. The guide strand binds with targeted 3′ to 5′ RNAs and translationally repressed or degraded the targeted gene (Cui et al., 2017; Stepien et al., 2017; Yu et al., 2017) (Fig. 7.2).

3. Role of small RNA in abiotic stress tolerance

3.1 Heavy metal tolerance

Accumulation of non-essential metals such as cadmium, mercury, arsenic at excessive levels can be dangerous for plant growth and development and these metals affect the health of human beings through the food chain (Gielen et al., 2012; Gupta et al., 2014b; Dhiman et al., 2021). Overexpression of miR395 in *B. napus* results in a reduction of the level of oxidative stress caused by heavy metals and provides tolerance to Cd stress (Zhang et al., 2013a,b). It was studied that miRNAs have a role in $Al3^{+}$ toxicity and tolerance. They discovered that 18 miRNAs responded after 4 h of $Al3^{+}$ treatment and that 4 miRNAs from 4 families responded after 4 h and 24 min of $Al3^{+}$ therapy (Chen et al., 2012). The treatment of $Al3^{+}$

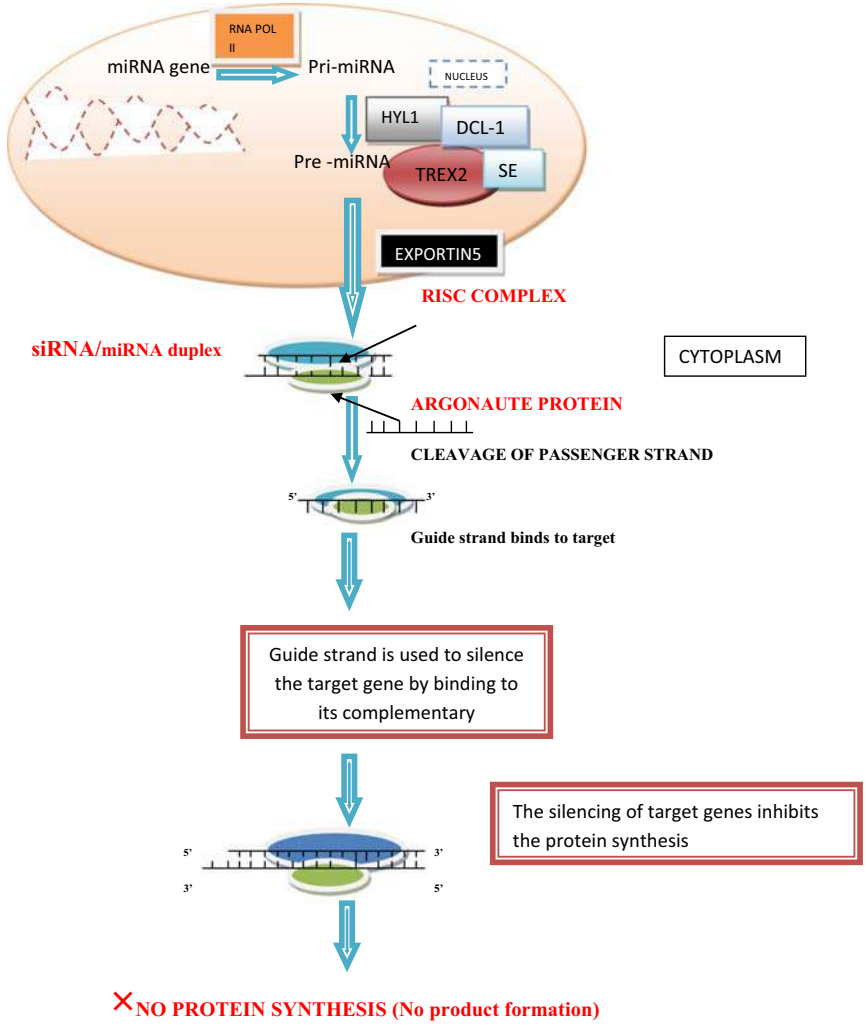

Figure 7.2 ***Mechanism and biogenesis of small RNA:*** miRNA are derived from endogenously ln-RNA and act as a regulator of gene expression. The primary microRNA or (pri-miRNA) are first processed into precursor microRNA or (pre-miRNA) or mature miRNA. TRANSCRIPTION COUPLED EXPORT 2 (TREX2) protein associated with DICER-LIKE1 (DCL-1), SERRATE (SE), and (HYPONASTIC LEAVES1 HYL-1) helps in the processing of pri-miRNA. TREX2 also helps in the export of the miRISC complex to the cytoplasm with the help of EXPORTIN5 (EXPO5). The miRNA duplex is loaded into the RISC complex having argonaute (Arg) protein in the cytoplasm and the guide strand in a 5′ to 3′ direction is selected to silence the target gene in a 3′ to 5′ direction and the other strand acts as a passenger strand.

Table 7.1 List of micro RNA associated with crop development.

Plant	miRNA/siRNA	Target gene	Function	References
Apple ***(Malus domestica)***	miR169a, miR160e, miR167b,g, miR168a,b	ARF transcription factors	Fire blight resistance	Kaja et al. (2015)
Barley (*Hordeum vulgare)*	miR164	ARF transcription factor	Lateral root and leaf development	Deng et al. (2015)
Cassava ***(Manihot esculenta)***	miR156, miR157, miR159, miR160	Transcription factors	Development, stress response	Patanun et al. (2013)
Cassava ***(Manihot esculenta)***	miR395, miR172, miR319, miR396	Transcription factors, growth factors	Starch biosynthesis, metabolism	Chen et al. (2015)
Coffee (*Coffea arabica)*	miR171	GRAS family transcription factors	Development metabolism	Chaves et al. (2015)
Coffee ***(Coffea arabica)***	miR390	TAS3	Development, cellular signaling pathways	Chaves et al. (2015)
Potato ***(Solanum tuberosum)***	miR160	Auxin response factor	Growth and development	Din et al. (2014)
Potato ***(Solanum tuberosum)***	miR172	Auxin response factor	Starch accumulation	Din et al. (2014)
Potato ***(Solanum tuberosum)***	miR473	Serine/threonine kinase	Metabolism	Din et al. (2014)
Potato ***(Solanum tuberosum)***	miR475	Thioredoxin	Metabolism	Din et al. (2014)
Rice (*Oryza sativa)*	miR397	OsLAC	Grain size shape and quality	Zhang et al. (2013a,b)

Continued

Table 7.1 List of micro RNA associated with crop development.—cont'd

Plant	miRNA/siRNA	Target gene	Function	References
Sugarcane ***(Saccharum)***	miR159	MYB protein	Development	Zanca et al. (2010)
Soybean ***(Glycine max)***	miR156, miR160	Squamosa binding protein	Seed development	Song et al. (2011)
Soybean ***(Glycine max)***	miR164, miR166	ARF transcription factors	Seed development	Song et al. (2011)
Soybean ***(Glycine max)***	miR172, miR396	Growth factors	Seed development	Song et al. (2011)
Wheat ***(Triticum aestivum)***	miR397/437	L-ascorbate oxidase	In development process	Han et al. (2013)

for 24 h is responsible for the downregulation of late responsive miRNAs, miR390. Only miR390 has been identified as a regulator of the auxin response factor, which is involved in lateral root growth (Marin et al., 2010).

3.2 Drought stress

Drought-responsive miRNAs were studied in the legume *M. truncatula*. In response to drought stress, upregulation of 22 members of four miRNA families (miR399, miR 2089, miR2111, and miR2118) was observed, and downregulation of 10 members of six miRNA families (miR164, miR169, miR171, miR396, miR398 and miR1510) were observed. Drought-responsive miRNAs' known and projected targets were discovered to be engaged in a variety of cellular activities in plants, they play important role in development, transcription, protein degradation, detoxification, nutritional status, and cross adaptability (Wang et al., 2011; Gupta et al., 2014c). In potato plants (*Solanum tuberosum*), miR171 family members (miR171a, miR171b, and miR171c) have been discovered which show a response to drought stress (Hwang et al., 2011). Trindade et al. (2010) have reported that in water-stressed *M. truncatula* plants, numerous conserved miRNAs have differential expression levels with miR169 being down-regulated in roots and miR398a/b and miR408 being highly up-regulated in both shoots and roots. By using RNAi farnesyl transferase genes FTA or FTB has been suppressed which is responsible for lower stomatal conductance and thus transpiration, and results in greater crop yield (Wang et al., 2009).

3.3 Heat and cold stress

The unique plant thermotolerance mechanism has been discovered, which is important for reproductive organ protection. It was discovered that miR398 leads to downregulation of target genes, the *CSD* (*copper/zinc superoxide dismutase*) genes *CSD1* and *CSD2*, and *CCS* (encodes copper chaperone for both *CSD1* and *CSD2*. The *CSD1, CSD2*, and *CCS* mutants are responsible for a higher accumulation of heat stress transcription factors and heat shock protein which causes less flower damage in plants and they show more resistance in comparison to control plants (Guan et al., 2013). Cold stress declines the growth and development of plants. Cold stress promotes the evolutionarily conserved miR319 in sugarcane and rice. Overexpression of miR319 decreases the expression of TEOSINTE BRANCHED1, CYCLOIDEA, (PCNABF) Proliferating cell nuclear antigen-binding factor genes, and improves cold tolerance in both species, implying that miR319 provides tolerance against cold stress. By targeting

the auxin receptor gene TIR1/AFB, cold-inducible miR393 also favorably controls cold tolerance in switchgrass. Cold tolerance is improved by overexpression of miR393 or mutation of TIR1/AFB, which is enhanced expression of cold-responsive genes (Liu et al., 2017). In wheat (*T. aestivum L.*), 12 miRNAs were identified that were responsive to heat stress (Xin et al., 2010). In the Rice plant, the two miRNAs, miR393 and miR169, have been discovered which were up-regulated in response to dehydration stress (Zhao et al., 2007). It was studied that in Arabidopsis miR159 was involved in the hormonal signaling and dehydration process (Achard et al., 2004). As a result, miR156 and miR172 expression patterns are revealed to be inversely associated. In rice plants, it was observed that *Histone deacetylase* genes have different expression patterns and developmental activities as compared to closely related Arabidopsis homologs and that the majority of them are drought and salt tolerant (Hu et al., 2009).

3.4 Phosphate deficiency

Abiotic stressors like phosphate deficiency have also been shown to up-regulate miR399 and miR2111 (Bari et al., 2006; Pant et al., 2009). In all living species, inorganic phosphorus (Pi) is required for macromolecule production, energy transfer, enzyme activity, and signal transduction. Furthermore, agricultural outputs are frequently hampered by Pi levels. MiR399 was the first miRNA discovered to be upregulated in Pi starvation response in Arabidopsis (Fujii et al., 2005). Under Pi-depleted conditions, the putative ubiquitin-conjugating enzyme PHO2 attaches polyubiquitin to the Pi transporter PHOSPHATE TRANSPORTER 1 (PHT1) and directs PHT1 for destruction (Huang et al., 2013), allowing for optimal Pi absorption. In Arabidopsis and rice, low-Pi stress causes miR399 to downregulate PHO2. PHO2 is downregulated by miR399, which raises PHT1 levels and hence promotes Pi acquisition and translocation (Bari et al., 2006; Fujii et al., 2005; Hu et al., 2011). PvPHR1 positively regulated the genes involved in phosphorus transport, mobilization, and homeostasis. miRNA399 (PvmiR399) from *Phaseolus vulgaris* is a key component of the PvPHR1 signaling pathway in common bean (Valdés-López et al., 2008). MiR395 and miR399 are up-regulated in Arabidopsis plants when they are deprived of sulfur and phosphate (Jones-Rhoades & Bartel, 2004).

3.5 Salinity stress

The RNAi approach has been effectively used to promote salt tolerance in plants, similarly to other drought and temperature stress (Dutta et al., 2020).

Similarly, RNA interfering lines of the gene OsVTC-1 revealed that it is involved in salt tolerance (Qin et al., 2017). OsVTC-1 is a GMPase gene that catalyzes the conversion of D-mannose-1-P to GDP-D-mannose and is involved in cellular and developmental events such as cell division, senescence, root expansion, and blooming (Zhang et al., 2013a,b). OsVTC-1 in the production of ascorbic acid works as a scavenger and eliminates reactive oxygen species (ROSs). Under salt stress, OsVTC-1-RNAi lines demonstrated decreased tolerance and a higher amount of reactive oxygen species (ROSs). Furthermore, decreased grain output in OsVTC-1-RNAi lines revealed that OsVTC-1 genes are involved in supplying resistance in both the vegetative and reproductive phases (Qin et al., 2017). In Arabidopsis AtbZIP24 gene which belongs to the bZIP TFs family, was discovered to be a negative regulator of salt stress tolerance, with the AtbZIP24-RNAi line showing increased resistance to salt stress (Yang et al., 2009). One more main gene peroxisomal biogenesis factor 11 (OsPEX11), was discovered in rice using RNAi technology, and it was observed that OsPEX11 is involved in Na+/K+ homeostasis and salt tolerance. OsPEX11-RNAi lines were more sensitive to salt stress, with lower levels of lipid peroxidation, a lower Na^+/K^+ ratio, and poorer antioxidant enzyme activity such as SODs, PODs, and CATs (Table 7.2).

4. Role of small RNA during biotic stress

miRNAs, 21−23 nucleotides long, and siRNAs, 21−24 nucleotides long are two important families of small RNA produced from double-stranded RNA (dsRNA) or single-stranded RNA precursor. sRNA was gained widespread recognition as a key signaling molecule for its important role in the development and growth of plants and abiotic and biotic stress responses via post-translational gene silencing (PTGS) since the discovery that dsRNA can cause gene silencing in *C. elegans* (Pattanayak et al., 2013). Plants must struggle with a variety of diseases, including bacteria, fungus, viruses, and parasites, to survive and reproduce in a harsh environment (Ali et al., 2020). Pattern-triggered immunity refers to the pathogen-associated molecular pattern-induced basal resistance response in plants (PTIs). The resistance protein (R protein) and intracellular nucleotide-binding/leucine-rich-repeat (NLR) receptors in plants can detect pathogen effectors and generate a robust resistance response known as effector-triggered immunity. Pathogens release tiny cysteine-rich proteins containing signal peptides during host colonization to modify host defense responses, thereby establishing host colonization (Muhammad et al., 2019).

Table 7.2 List of miRNA associated with abiotic stress tolerance in plants.

Plant	miRNA/siRNA	Target gene	Function	References
Arabidopsis	miR169	NFYA5	Drought tolerance	Li et al. (2008)
Arabidopsis	miR398	*CSD1, CSD2, CCS*	Heat stress tolerance	Guan et al. (2013)
Barley ***(Hordeum vulgare)***	miR156d	Squamosa binding protein	Development, drought stress	Curaba et al. (2012)
Cassava ***(Manihot esculenta)***	miR164	NAC transcription factors	Drought tolerance	Patanun et al. (2013)
Coffee (*Coffea arabica*)	miR393	Transport inhibitor like protein, DNA binding protein, GPR 1 like protein	Chitin cold, salt stress, and water deprivation	Akter et al. (2014)
Rice ***(Oryza sativa)***	miR5517	Target genes that are involved specifically in flower or embryonic development	Crucial role in the regulatory network of drought response	Cheah et al. (2017)
Rice*(Oryza sativa)*	miR319	PCF5/PCF8	Cold tolerance	Yang et al. (2013)
Soybean and Arabidopsis	miR169	GmNFYA3	Drought tolerance	Ni et al. (2013)
Sugarcane ***(Saccharum)***	miR164	NAC transcription factors	Drought stress response	Ferreira et al. (2012)
Sugarcane ***(Saccharum)***	miR169	HAP12-CCAAT-box transcription factors	Salt stress tolerance	Carnavale Bottino et al. (2013)
Sugarcane ***(Saccharum)***	miR398	*Serine/threonine kinase-like*	Salt stress tolerance/ metabolism	Carnavale Bottino et al. (2013)
Wheat ***(Triticum aestivum)***	miR395	ATP-sulfurylase genes	Abiotic stress	Akdogan et al. (2016)
Wheat ***(Triticum aestivum)***	miR393	TRANSPORT INHIBITOR RESPONSE 1 (TIR1)	Regulate auxin signaling and would thus reduce plant growth under drought stress	Giusti et al. (2017)

4.1 Parasitic weeds

The parasitic weeds the crop fields in many areas around the world, resulting in significant agricultural yield losses. There are various traditional techniques for controlling parasitic weeds, but they all have drawbacks, hence a biotechnological instrument to manage parasitic weeds is needed. RNAi technology has recently been used to generate weed-resistant plant kinds, according to some researchers. Transgenic tomato plants with the M6PR dsRNA-expression cassette were developed by (Aly et al. 2009). In transgenic tomato plants decrease in the concentration of mannitol and endogenous M6PR mRNA in the tubercles and underground shoots of *Orobanche egyoetiace* and an increase in the amount of dead *Orobanche aegyptiaca* tubercles were observed. hpRNA-mediated RNAi resistance to *Striga asiatica* L. was used to generate a parasitic weed-resistant maize cultivar (Aly et al., 2009).

4.2 Insect and nematode resistance

Crop losses and insecticides cost billions of dollars due to insect pests. Insecticide resistance remains a constant danger to farmers, fueling a never-ending hunt for alternate pest-control measures (Ferry et al., 2006; Banerjee et al., 2017). These worms act as a vector for transmitting virus diseases thereby responsible for the decline in yield concentration (Ali et al., 2015). Uncontrollable phytoparasitic nematodes cause annual crop losses of roughly US$125 billion. Plants' resistance against nematodes has been produced by the expression of dsRNA in a host plant against housekeeping or parasitism genes in the root-knot nematode (Gheysen & Vanholme, 2007). Plant-parasitic cyst nematodes cause syncytium (plant root organ) differentiation as a source of nourishment. The syncytium is generated by the re-differentiation and fusing of a large number of root cells. miR396 is involved in phase transition in Arabidopsis (Hewezi et al. 2012). The beginning of the syncytial formation phase is marked by strong down-regulation of miR396 in cells that give rise to the syncytium, and the beginning of the maintenance phase is marked by upregulation of miR396 in the mature syncytium when no new cells are absorbed into the syncytium. MiR396 and its growth-regulating factor (GRF) target genes induced a reduction in syncytium size and a halt in worm development. This identified miR396 as a major regulator in root cell reprogramming, indicating that it could be a useful molecular target for parasitic animals looking to manipulate plant cells into a new developmental route. Targeting of parasitism-related genes in place of nematode housekeeping genes showed

tolerance against multiple nematode species (Huang et al., 2006). Opperman et al., 2008 sequenced the genome of *Meloidogyne hapla* and discovers the new HD-RNAi targets. Host-induced RNAi has been used to target nematode parasitism genes 3B05, 4G06, 8H07, AND 10A06 of the sugar beet cyst worm (*Heterodera schachtii),* in the *A. thaliana* host. No resistance was seen, and the number of mature nematode females was reduced by 23−64% in different RNAi lines (Sindhu et al., 2009). RNAi constructs were used to target four distinct genes against *Heterodera glycines* (essential soybean cyst nematode) and *C. elegans* to see if they were effective in reducing *Meloidogyne incognita* galls in roots of the soybean plant. It was observed that by targeting genes codes for Tyrosine phosphatase (TP) and Mitochondrial stress 70 protein precursor (MSP), two of them constructs capable of minimizing gall formation by 92 and 94.7% (Ibrahim et al., 2011). Plant-nematode interactions are also thought to be mediated by miRNAs. In Arabidopsis, miR161, miR164, miR167a, miR172c, miR396c, miR396a,b, and miR398a were down-regulated in response to infection by the nematode *H. schachtii* (Khraiwesh et al., 2012). According to a comparative investigation of soybean miRNA profiling, 101 miRNAs from 40 families were sensitive to infection by the soybean cyst nematode (SCN; *H. glycines*), the most damaging disease in soybean. It was also shown that 20 miRNAs were expressed differently in SCN-resistant and susceptible soybean cultivars (Li et al., 2012). Different miRNAs and sRNAs are produced by nematode which is involved in the development of feeding sites and parasitism (Hewezi et al., 2008). Overexpression of these nematode-induced candidate miRNAs, as well as degradation of their targets, reveals new insights into plant-nematode parasitism, as well as nematode resistance in agricultural plants. Resistance against nematodes has also been accomplished by producing a miRNA, which combines with known miRNA genes of the seed region of a plant-parasitic nematode's essential gene (parasitism or housekeeping).

4.3 Virus resistance

Resistance derived from pathogens is the most effective strategy for combating virus infections in plants among the several options. The PDR idea has aided in the development of virus-resistant plants (Simón-Mateo & García, 2011). Another technique targets numerous areas of a viral gene in tomato plants, resulting in broad-spectrum resistance to topoviruses. This technique is based on using a miRNA construct that is capable of expressing

numerous artificial miRNAs (amiRNAs) that target different sections of a viral gene (Bucher et al., 2006). The influence of RNAi which targets the coat protein (CP) gene of the virus, is particularly successful in the development of virus resistance in plants. Some viral coat proteins target RNAi-modified virus-resistant plants, such as BNYVV-resistant tobacco (Andika et al., 2005), and PVY-resistant potato (Missiou et al., 2004), PRSV-W-resistant *Cucumis melo* L. var. cantalupensis cv. Sun Lady (Krubphachaya et al., 2007). According to (Pradeep et al., 2012), introducing inverted repetitions of the Tobacco Streak Virus (TSVs) CP gene may be an effective and dependable technique for establishing TSV resistance in commercially significant crops. Rice Stripe Virus CP gene and disease-specific protein gene sequences were used to produce an RNAi construct (Zhou et al., 2012). *Suyunuo* and *Guangling xiangjing*, two sensitive japonica cultivars, were altered using an RNAi construct to develop resistance to Rice Stripe Disease. After self-fertilization, the homozygous progeny of rice plants expressing RNAi constructs in the T5 and T7 generations were shown to be highly resistant to viral infection, with no morphological or developmental abnormalities. The African cassava mosaic virus (ACMVs) was silenced by RNAi, which results in a 99% decline in Rep transcripts and a 66% reduction in viral DNA (Vanitharani et al. 2003). The siRNA method can only silence ACMV strains that are closely related. RNAi-mediated resistance was first observed in cassava (*M.esculenta*) against Cassava Brown Streak Disease (CBSD) (Patil et al., 2011). CBSD was regarded as the most serious threat to cassava farming in East Africa (Pooggin et al., 2003). demonstrated that the DNA of a reproducing virus can also be a target of RNAi using the black gram (*Vigna mungo*) as a study system. They were able to recover *V. mungo* from MYMIVs (Mungbean Yellow Mosaic India Virus) infection by using an RNAi technique to silence the gene associated with the bidirectional promoter. RNAi technique has been used to create geminivirus-resistant BGMV-resistant common bean (Bonfim et al., 2007). Many other transgenic plants such as Tomato Yellow Leaf Curl Virus (TYLC)-resistant tomato (Fuentes et al., 2016), Rice Tungro Bacilliform Virus (RTBV)-resistant rice (Tyagi et al., 2008), and Citrus Tristeza Virus (CTV)-resistant Mexican lime (López-García et al., 2010), have improved defense through RNAi-mediated gene silencing. According to (Schwind et al., 2009), employing the hpRNA construct in *S. lycopersicum* (tomato) against Potato Spindle Tuber Viroid (PSTVd) results in PSTVd-resistant tomato plant varieties.

4.4 Bacterial pathogens

Bacterial pathogens are among the most serious problems in tomato, soybean, and banana and various type of crop production. Bacterial diseases spread quickly and are difficult to manage; therefore, the only method to avoid bacterial infections is to prevent them. The use of RNAi to improve bacterial resistance in the experimental plant *A. thaliana* has yielded promising results. In Arabidopsis (Dunoyer et al., 2006), studied the silencing of bacterial genes (iaaM and ipt) reduced the crown gall tumors (*Agrobacterium tumefaciens*) to nearly zero, implying that crown gall disease resistance engineered in various trees and ornamental plants. Four apple miRNAs (miR169a, miR160e, miR167b−g, and miR168a,b) have recently been discovered to be implicated in the resistance to fire blight, a contagious bacterial disease caused by *Erwinia amylovora*, by targeting stress response proteins (Kaja et al., 2015) (Table 7.1).

4.5 Fungal resistance

RNAi has been proved to be an effective technique for generating disease resistance in a variety of agricultural plants. RNAi-mediated silencing of the aricegene OsSSI2 resulted in increased resistance to the blast fungus *Magnaporthe grisea* and the bacterium *Xanthomonas oryzae* that causes leaf blight (Jiang et al., 2009). Furthermore, the inhibition of two genes, OsFAD7 and OsFAD8, which are -3 fatty acid desaturase genes, resulted in increased disease resistance against *M. grisea* in rice (Yara et al., 2007). Due to the decline in the concentration of lignin, RNAi-mediated targeting of genes involved in lignin formation improved soybean resistance to the phytopathogen *Sclerotinia sclerotiorum* (Peltier et al., 2009). 24 miRNAs were recently discovered to be involved in the response to the fungus *Blumeria graminis* f. sp. tritici (Bgt) attacking wheat, which causes the fatal illness powdery mildew (Xin et al., 2010). Similarly, several miRNAs have been identified in wheat in response to stem rust infection (Gupta et al., 2012). Furthermore, it was discovered that overexpression of OsmiR397 and downregulation of the corresponding OsLAC target gene increased grain size and promoted panicle branching, increasing yield (Zhang et al., 2013a,b) In reaction to the blast fungus *Magnaporthe oryzae*, the rice miRNA osa-miR7695 negatively regulates a natural resistance-associated macrophage protein6 (OsNramp6). Overexpression of Osa-miR7696 resulted in improved resistance to rice blast infection (Campo et al., 2013). (Jiao & Peng, 2018) studied that in wheat plant miR1023 targeted the alpha/beta hydrolase gene in *F. graminearum* and suppressed the invasion of the fungal pathogen (Table 7.3).

Table 7.3 Role of small RNA in fungal resistance.

Plant	Target gene	Trait improved	References
Potato	SYR1	*Phytophthora infestans*	Eschen-Lippold et al. (2012)
Rice	OsFAD7 And OsFAD8	*Magnaporthe grisea*	Yara et al. (2007)
Rice	OsSSI2	*Magnaporthe grisea* *Xanthomonas oryzae*	Jiang et al. (2009)

5. Applications of RNAi technology in crop development

A new combination of biotechnology techniques like genetic engineering, genomics, proteomics, and plant physiology, will be required to solve all malnutrition and food-related requirement of a large population (Mittler & Blumwald, 2010). The promise of the RNAi technique in crop development has been demonstrated by its contribution to achieving desirable traits by modifying genetic expression.

5.1 Seedless fruit development

Phytohormones have been widely known for their role in regulating the transition between blooming, fertilization, and fruiting. Parthenocarpy has the potential to produce vegetables and fruits when pollination fails to occur. Seedlessness has been found in recent research to improve the texture and shelf life of fruits, such as watermelon and eggplant (Pandolfini, 2009). Seeds were found to be the source of fruit deterioration in watermelon. Thus, substituting edible fruit tissue for seeds and seed cavities is useful (Varoquaux et al., 2000) and can be beneficial to consumers, the processing business, and breeding companies. It has been studied that ARF8 of *A. thaliana* and ARF7 of tomato both have high levels of expression in non-pollinated flowers before being down-regulated after pollination (De Jong et al., 2009). SlARF7 works as a modulator of both auxin and gibberellin responses during tomato fruit set and development. After pollination and fertilization, SlARF7 transcript levels are normally lowered (Vriezen et al., 2008). SlARF7 repression may be released by an RNAi

method, resulting in partial activation of auxin and GA signaling pathways enforced by SlARF7 independent of pollination and fertilization, and thus in parthenocarpic fruit growth in tomato (*S. lycopersicum*). As a result, the auxin signaling transduction pathway's fertilization-dependent stage may be avoided, which may be required to commence cell division activity and boost GA production.

5.2 Enhancement of the shelf life of crop plants

Fruits and vegetables are higher vulnerable to spoilage as compared to grains, and this spoilage results in inedible waste. Despite being one of the world's top producers of fruits and vegetables, India loses roughly 30% of its overall production because of spoiling. As a result, an increase in the shelf life of vegetables and fruits is required as another important agronomic attribute that can reduce the degradation and rotting of vegetables and fruits, hence reducing horticulture loss. The silencing of genes involved in ethylene generation or ripening has enhanced the shelf life of tomatoes. RNAi technology was utilized by Xiong et al. (2005) to extend the shelf life of tomatoes. They used a unit of dsRNA to stop the ACC oxidase gene from expressing in tomato. The rate of ethylene generation in transgenic plants' ripened fruits and leaves was shown to be greatly reduced, ensuring a longer shelf life for tomatoes. (Meli et al., 2010), on the other hand, identified two ripening-specific N-glycoprotein modifying enzymes, mannosidase (Man) and -D-N-acetylhexosaminidase, in tomato and repressed them.

5.3 Male sterility and fertility

The essential quality to assure purity in hybrid plants for hybrid seed production are the establishment of male sterility. Plant scientists utilize a variety of approaches based on conventional and genetic engineering to abort pollens from various crop species. RNAi has been employed in genetic engineering to create male-sterile plant species such as tobacco and tomato (Nizampatnam & Kumar, 2011). Small RNA (osa-smR5864) has been regulated the photoperiod and temperature-regulated male sterility in rice (Zhu & Deng, 2012). In plants mitochondria and plastids MutS HOMOLOG 1 (Msh1) is a nuclear gene product that keeps the genome stable. When Msh1 is suppressed in response to abiotic stressors, it activates a plastidial response that involves non-genetic inheritance and changes a variety of plant metabolic pathways (Xu et al. 2012). RNAi technology has

been used to alter Msh1 expression in tobacco and tomato, resulting in mitochondrial DNA rearrangements consistent with naturally occurring cytoplasmic male sterility (Sandhu et al., 2007). The use of these RNAi lines for breeding may have a few downsides, such as the hybrid carrying the construct in the F1 generation, resulting in severe impacts. In terms of fertility, studies shows that mir151 affects the development of rice anthers. Overexpression of miR159 in rice will result in malformed flower development and no pollen in the stamens. In addition overexpression of wheat miR159 in rice or tae-miR159 can also cause male sterility in rice (Wang et al., 2012). Recent studies found that miR1227 and miR2275 may be related to male sterility in wheat and targated the CAF1 (CCR4 AF1) and SMARCA3L3 genes (Sun et al., 2018).

5.4 Biofortification

Over two-thirds of the population around the world consumes food that is deficient in various key mineral elements (White & Broadley, 2009; Gupta et al., 2022b; Ibba et al., 2022). The tomato plant has been biofortified with dietary antioxidants and important elements such as Zn, Mg, Cu, Se, Ca, Fe, I, S, P, and others by using RNAi technology (Niggeweg et al., 2004). Molecular pharming or bio-pharming is the process of creating perspective pharmacological substances by applying novel genetic engineering and transgenic techniques such as agroinfiltration, virus infection, and magnification. Various proteins and secondary metabolites have been produced by using molecular pharming. Molecular pharming is used to create a variety of medicines and nutraceuticals (Obembe et al., 2011). The use of RNAi has reduced the sinapate esters to 76% in T3 generation transgenic canola seeds. It suppresed the UDP-Glc:sinapateglucosyltransferase gene activity. The flavor of canola seeds has been enhanced by the elimination of sinapate esters (Hüsken et al., 2005). RNAi technology was used for the development of GluB hairpin RNA which resulted in the LGC-1 (low glutenin content 1) rice variety with reduced glutenin levels, thus providing comfort to kidney patients who are not able to digest gluten (Kusaba et al., 2003). The ingestion of alpha-linolenic acid (18:3) is harmful to both humans and animals. The lowering of alpha-linolenic acid (18:3) improves the flavor and stability of soybean oil while reducing the requirement for hydrogenation (Flores et al., 2008). used the glycinin promoter to create Hairpin RNA for seed-specific silencing of omega-3 fatty acid desaturase (GmFAD3A, GmFAD3B, and GmFAD3C). Sucrose biosynthesis is divided

into two phases, each of which is catalyzed by an enzyme: sucrose-phosphate synthase (SPS), which is then hydrolyzed by another enzyme sucrose phosphatase (SPP) to produce sucrose and Pi inorganic phosphate). In a process known as "cold sweetening," storing potato tubers at a lower temperature (4°C) results in the accumulation of glucose and fructose. To suppress SPP expression in transgenic potato tubers a CaMV 35S promoter-driven hairpin RNAi construct has been synthesized having part of the coding region of the tobacco NtSPP2 gene (Chen et al., 2008). Suc6P accumulates in RNAi-silenced sucrose phosphatase (SPP) potato tubers after cold storage at 4°C, according to the researchers. They discovered that in SPP-silenced tubers, cold-induced expression of vacuolar invertase (VI) was prevented, resulting in a lower sucrose-to-hexose conversion. VI expression was found to be adversely linked with Suc6P levels. RNAi technology was used for silencing the expression of specific -gliadins, reporting a 55—80% reduction in -gliadins in the bread wheat cultivar "Bobwhite" lines (BW208) and a 33—43% reduction in the "Bobwhite" lines (BW 2003) (Gil-Humanes et al., 2008). Furthermore (Gil-Humanes et al., 2012), found that RNAi-mediated downregulation of gamma-gliadins in wheat lines resulted in a compensatory impact in the remaining gluten proteins, with no statistically significant changes in overall gliadin content but an increase in glutenin content. As a result, the total protein content of most transgenic lines was modestly raised.

5.5 Allergen and toxin elimination

Food allergy is an overactive immune reaction in our bodies caused by allergens found in foods like peanuts, apples, mangoes, etc. As a result, allergen levels in our meals must be reduced or eliminated. Not only that but there is a need to design plants that are devoid of hazardous chemicals, as natural toxins can be found in a wide range of plants that are regularly eaten as food. These hazardous compounds can be dangerous to human health if consumed in large amounts or if they are not handled properly, resulting in food poisoning. The removal of allergens and toxic compounds can be accomplished through RNA interference, which can alter allergen production by altering its metabolic pathway, thereby improving food quality and reducing the risk of food allergy and toxicity. Mal d1, a prominent apple allergen that belongs to the PR10 group of pathogenesis-related proteins, was inhibited using RNAi (Gilissen et al. 2005) used RNAi-based gene silencing to successfully decrease Mal d1 expression. In

crude peanut extract, a 25% drop in Arah2 content was observed by employing RNAi which leads to down-regulation of its expression using its hpRNA construct. (Dodo et al., 2008). Ara h2 is an allergenic protein found in peanuts, out of a total of seven allergenic proteins (Jørgensen et al., 2005). used RNAi to inhibit the biosynthesis of linamarin and lotaustralin by suppressing the cytochrome P450 enzyme, resulting in transgenic cassava *(Manihot esculenta*) plants with less than 1% cyanogenic glucosides in leaves and 92% reduction in cyanogenic glucosides in tubers. Grass peas are consumed by people in India, Bangladesh, and Ethiopia (*Lathyrus sativus*). The neurotoxic beta-N-oxalyl-ami-noalanine-L-alanine (BOAA) found in grass peas and chickling peas can cause lathyrism, a paralytic condition (Spencer et al., 1986). BOAA provides immunity to plants in stress conditions and by using RNAi technology level of BOAA is reduced to a suitable concentration can make the crop safe to eat (Angaji et al., 2010). Cotton seeds contain a higher amount of dietary protein, but their poisonous terpenoid component, gossypol, makes them unfit for human ingestion. Cotton stocks with decreased levels of delta-cadinene synthase, a major enzyme in the gossypol biosynthesis pathway, have been created using RNAi without influencing the enzyme's production in other sections of the plant, where gossypol is vital in avoiding pest damage. Transgenic cotton seeds had a 99% lower gossypol level than wild cotton seeds. It has been studied that silencing of delta-cadinene synthase gene by using RNAi knockdown technology cotton plants has been developed that generated cottonseed with ultra-low gossypol levels (ULGCS) (Sunilkumar et al., 2006). They also discovered that the ULGCS phenotype induced by RNAi exhibited multi-generational stability (Rathore et al., 2012).

5.6 Phenotype change and altered architecture

Flowers and ornamental plants have been enhanced since antiquity by adjusting numerous qualities of size, shape, color, appearance, as well as plant architecture. Changes in the architecture of crop plants, such as Dwarf Rice, may also result in increased crop output. As a result, there is a need to improve plant and flower phenotype. Plant architecture is responsible for different patterns of plant growth such as plant height and canopy, leaf size and number, branches, number of flowers, fruit size and shape, root size, and structure. The plant architecture can be modified by using RNAi techniques. It helps in the enhancement of the yield of ornamental, fruit, and crop plants (Dai et al., 2018). The Arabidopsis flowering locus T (FT) and terminal flower I (TFL1) genes, as

well as orthologs from other species, are well known for balancing and distributing indeterminate and determinate growth. These genes can be altered to improve plant/flower morphology or increase agricultural output (McGarry & Ayre, 2012). The use of RNAi in plants to change their morphology as needed has shown its potential (such as height, inflorescence, branching, and size). The cauliflower mosaic virus 35S promoter has been used for over-expression of the unique maize miRNA gene dubbed Corngrass1 (Cg1), which belongs to the miR156 family. When compared to wild-type stem lignin, transgenics had significantly larger axillary meristem expansion, shorter internode length, and up to a 30% drop in stem lignin concentration (Rubinelli et al., 2013). McGarry and Ayre (2012) recently revealed that the HSPp:FT1/FT2-RNAi lines produced inflorescences as well, implying that FT1 signaling is adequate for reproductive onset. Various miRNAs have been discovered that are involved in the development and ripening of tomato fruits (Molesini et al., 2012). miR156 is a small RNA that silenced the gene involved in fruit ripening called colorless never ripe. The color of transgenic tomato plants over-expressing sly-miR156 was slightly lighter than wild-type controls, but they could eventually ripen (Zhang et al., 2011). Further, it has been observed that the miR156 overexpression in tomato leads to smaller fruit size, increased leaf numbers, and reduced height and size of leaf implying that reduction in miR156 expression helps in increased yield of the crop (Zhang et al., 2011). Transgenic studies are needed to confirm this. Recent researches show that miR172 regulates fruit ripening and negatively regulates ethylene generation. AP2a is also favorably regulated by CNR, and play important role in fruit development and ripening (Karlova et al., 2013).

6. Conclusion and future prospective

With continued population growth and consumption, global food demand is expected to rise. The challenge for agriculture will be rising as agricultural output is sustainably in the future time. By using genetic engineering and metabolic engineering novel techniques high yielding crops will be designed, so that the world can produce more food and assure that it is used more efficiently. According to a WHO report, 2020 malnutrition is a major problem all over the world especially in developing countries and acc to WHO reports India is among countries that miss world nutrition targets set for the year 2025 (WHO, 2020). Chronic food deficits have an effect on approximately 811 million population worldwide as well as 20 % of the population in developing countries. It is necessary to develop high-quality

biofortified food crop varieties, fruits, and vegetables by enriching them with nutritionally vital components such as essential minerals, antioxidants, vitamins, fatty acids, and amino acids to assure a healthy diet for a healthy world. Biotic and abiotic stress tolerance is one of the most significant agronomical qualities that agricultural plants should have. The improved or engineered varieties are helpful against food insecurities that arise around the world. RNAi technology plays a major role in crop development to address food security, hunger, and famine issues. Small non-coding RNA research, on the other hand, is opening the way for agricultural advancement and, as a result, enhancing the overall people's lives. Many unique crops have been produced by using sRNA and microRNA technology including highly biofortified nutrient-rich crops. The genetically modified Arctic apples are on the verge of becoming approved in the United States. The apples were created by gene silencing inhibition of the PPO (polyphenol oxidase) gene, which resulted in apple cultivars that do not brown when sliced. By silencing PPO receptors using RNAi mechanism chlorogenic acid will not be able to convert into a quinone product. Using different advanced molecular biotechnological approaches the function of miRNA can be manipulated for better crop improvement and yield resistance. The ability of biomolecules like glucose, lignin, and fat to create bioactive compounds. Metabolic engineering can also be used to make it easier to synthesize and mass-produce commercially valuable plant products like medicines, pigments, perfumes, volatile oils, and flavors. sRNA can be used in a novel way to reduce enzyme activity, which will alter biochemical reactions and lead to the synthesis of desired chemicals rather than unwanted/toxic molecules. RNAi can reduce photorespiration and thereby increase C3 plant output. Reduction of the flowering period, delayed ripening and senescence, breaking dormancy, production of stress resistance plants, overcoming self-sterility, and other traits could be induced with this knockdown approach. Artificial restriction enzymes have recently been developed that may successfully able to alterations in genes. These are viable alternatives to gene silencing and have a promising future. Zinc finger nucleases (ZFNs), transcription activator-like effector nucleases (TALENs), and LAGLIDADG homing endonucleases (LHEs), sometimes known as "meganucleases," are three types of nucleases that help in crop development along with desired characters or traits. ZFNs and TALENs allow programmed subtle genetic changes by causing breaks in the double strands of DNA (Curtin et al., 2018). TALEs (programmable DNA binding domain) and FokI (cleavage domain) have been fused to create TALENs

and further by using this stress resistance novel varieties with improved characters and traits can be developed by applying gene editing in the double-stranded DNA (Yasumoto et al., 2020).

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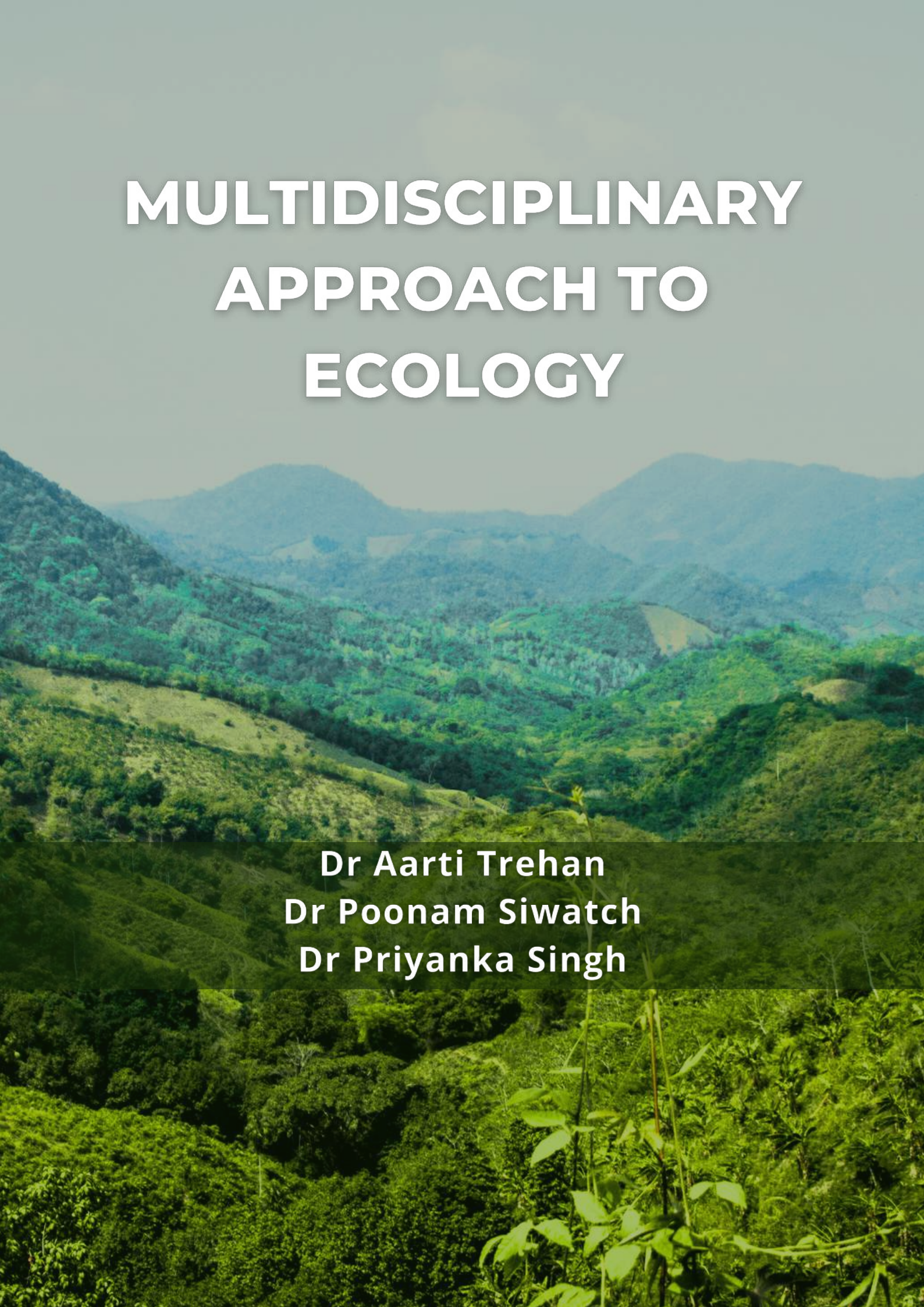

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Multidisciplinary Approach to Ecology

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First Impression: August 2023

Multidisciplinary Approach to Ecology

ISBN: 978-93-93810-84-7
Rs. 1000/- ($80)

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ENDOPHYTIC-BACTERIA OF HALOPHYTIC GRASSES: A MUTUALISTIC ECOLOGICAL ASSOCIATION OF PLANT AND MICROBES

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ABSTRACT

Soil salinity is a significant abiotic factor that limits the growth of glycophyte agricultural plants. Therefore, a low-cost, reliable, environmentally friendly and sustainable approach for dealing with salt affected soils is required. It is well known that halotolerant endophytes related to halophytes have a substantial impact on plant growth and salinity stress resistance. Therefore, the current study was carried out with the objective of isolating halotolerant endophytic bacteria from halophytic grasses. These isolates may then help in enhancing the yield of important cereal crops of the grass family, such as rice, wheat, barley, and oats in saline soil based agricultural practises. A total of 56 pure bacterial isolates were obtained for the current investigation from various explants of three halophytic grasses namely Sporobolus marginatus, Urochondra setulosa and Leptochloa fusca. Comparing the number of isolates, Sporobolus marginatus appears to be richer than Leptochloa fusca and Urochondra setulosa. It appears that root and node explants are more preferred explants. Analysis of morphological characteristics including form, colour, motility test, gram staining and endospore staining were used to characterise the isolates. The biochemical tests were carried out to determine the various exoenzyme activities of the isolated bacterial endophytes as per the Bergey's manual of systematic bacteriology. These tests included catalase, gelatinase, amylase, methyl red (MP), voges-proskauer (VP), citrate utilisation, and H_2S production.

Keywords: Halophytes, Endophytic bacteria, Salinity, Sustainable agriculture

INTRODUCTION

Different parts of the world's agricultural production are severely constrained by salinity. Saline soils develop in parched and semi-arid regions where precipitation is insufficient to satisfy the plants' water needs and remove mineral salts from the soil. Although soluble salts can frequently be found in small amounts in almost all arable lands, certain geogenic and anthropogenic factors have a significant impact on the salinity issue, which can lead to a partial or complete loss of soil productivity (Sharma and Singh, 2015).

Around the world, 900 million hectares (M ha) of land are affected by salt to varying degrees, which accounts for about 20% of all agricultural land (Sharma and Singh, 2015). The Amu-Darya River Basins of Central Asia's, the Indo-Gangetic Basin of India, the Indus Basin of Pakistan, the Yellow River Basin of China, the Euphrates Basin of Syria and Iraq, the Murray-Darling Basin of Australia, and the San Joaquin Valley of the United States are some well-known places where salinization has received extensive press (Qadir et al., 2014).

According to Sharma and Singh (2015) and the FAO (2007), 6.73 M hectares of land in India are already damaged by salinity or sodicity, and this number is expected to rise (Verma et al., 2023; Sheoran et al., 2023). Rajasthan, coastal Gujarat, the southern-western districts of Haryana, and the Indo-Gangetic plains make up the majority of the impacted regions. In Haryana, farmers of Rohtak, Jhajjar, Sirsa, Jind, Bhiwani, Sonepat, Fatehabad, Karnal, and Mewat districts refer themselves as the "poor cousins" of those in other districts where the quality of the soil and water is better because salinity is directly related to their economic vulnerability.

The twin threats of water logging and salinity have grown to frightening proportions in recent decades, especially in irrigated places, in addition to the negative effects that increased salt

levels have had on settled agriculture. Water intake is hindered by high salinity, which lowers the growth medium's osmotic and water potential. This can interfere with natural soil physic-chemistry and uptake pathways, which in turn can influence how well nutrients are absorbed (Morton et al., 2019; Kumar et al., 2021, 2022).

The presence of too much salt in the soil and water results in a number of morphological and physiological problems in plants, which ultimately inhibit plant growth. Such negative impacts include osmotic stress, which reduces water intake, and ionic imbalances, which degrade cell function, depending on parameters including agro-climatic conditions, plant species, crop growth stage, and salinity magnitude (Sharma and Singh, 2015; Singh et al., 2010).

These restrictions render saline-sodic lands either unsuitable or just partially appropriate for the majority of cultivable crops, suggesting the need to increase crop salt tolerance or devise bioremediation approaches for utilising salt-affected soils. The salt-affected soils remain barren in the absence of suitable salt-tolerant cultivars or the availability of sustainable bio-remedial treatment, with serious ramifications for the generation of biomass energy and national food security.

Halophytes are plants that can thrive and reproduce naturally in settings with salt concentrations higher than 200 mM of NaCl (20 dS/m). About 1% of the world's flora is made up of these species. Under conditions of similar salt concentrations, halophytes produce more biomass and yields economically than non-halophytes. Halophytes can therefore be used as model systems to research various mechanisms.

Furthermore, a staggering variety of microorganisms inhabit all plants, including halophytes. These microbial species that are found in plants make up the plant microbiome, which can have cell densities much higher than the number of plant cells. These accompanying bacteria have a significant impact on plant growth and adaptation, especially under stressful circumstances. Numerous studies have shown that the plant microbiome can have a significant impact on many different aspects of plant growth and development, including seed germination, seedling vigour, nutrition, disease, and productivity. When regarded in this light, plants can be thought of as super-organisms that partially rely on their microbiome for some traits and functions. The halophyte microbiome must be adapted to the salinity of the soil in order to support plant growth when there are high levels of salt and dramatic pH fluctuations.

A plant's endophytes are endosymbiont microorganisms that dwell inside the plant for at least a portion of the plant's life cycle without obviously causing disease. Endophytes are widespread and have been seen in nearly all plant species that have been researched to date. There have been reports of significant differences in the numbers of both native and foreign endophytes. These variances are explained by the kind of tissue, age, and habitat of the plant.

Endophytes often have more advantageous impacts than many rhizobacteria and are less likely to experience a drastic change in the soil environment due to the insulation provided by plants. Endophytes establish a mutualistic relationship with the host plant and promote plant health and productivity by acting as biocontrol and biofertilizers (Reinhold-Hurek & Hurek, 2011). Endophytic microorganisms have the potential to serve as biofertilizers since they have the ability to provide plant growth regulators such auxins, cytokinins, and gibberellins. In addition, endophytes help with nitrogen fixation, phosphate solubilisation and the suppression of stress-related ethylene synthesis in vegetation by producing 1-aminocyclopropane-1-carboxylate deaminase (Rodrguez-Llorente et al., 2019; Rosenblueth and Romero, 2006; Hardoim et al., 2008). Furthermore, endophytes engage in biocontrol activities by generating pathogen-antagonizing substances (such as hydrogen cyanide (HCN), siderophores, antibiotics, and insecticidal compounds) or competing with pathogenic organisms for colonisation and nutrients

(Rosenblueth and Romero, 2006). These activities protect flora against pathogens by inducing plant defence mechanisms.

Halophytes can adapt to harsh environments with the aid of endophytic bacteria. In order to increase their growth and tolerance to saltwater environments, halophytes develop symbiotic interactions with a variety of endophytic bacteria. According to Molina-Montenegro et al. (2018), plants of lettuce and tomato that had been endophyte-inoculated fared better in terms of survival and yield under salt stress conditions. This is likely because they were more efficient at using water and maximising photosynthesis. In other words, endophytic bacteria of halophytes have the ability to restore salt-polluted soils, enhance plant growth, and hence increase production in a sustainable way.

The negative effects of chemical-based agriculture are already being felt around the world in the form of air, water, and land pollution, which in turn leads to cancer, allergies, and a host of other ailments. Punjab and Haryana in India are two of the best instances of the destruction that is occurring under the guise of the "green revolution." Crops have lost over 75% of their genetic variety as a result of ongoing usage of high yielding, genetically uniform cultivars (Buchanan-Wollaston et al., 2017). Thus, a farming system that aims to raise crops in a way that keeps the soil alive and in good health, strives for sustainability and biological diversity while banning synthetic pesticides, antibiotics, synthetic fertilisers, and growth hormones is necessary today. Therefore, screening of endophytes from halophytes for salt tolerance and growth-promoting potential is an environmentally friendly and pollution-free way to use salinized lands and increase production in a sustainable way.

These facts led to the proposal of the current study, which aimed to isolate, screen, and characterise endophytes from three halophytic grasses, namely *Sporobolus marginatus*, *Urochondra setulosa*, and *Leptochloa fusca*, in order to assess their potential salt tolerance and bio-fertilizing activity on alkaline/saline soil.

MATERIAL AND METHODS

Collection of Plant Material

The study was conducted on the three grass halophytes, namely *Sporobolus marginatus*, *Urochondra setulosa* and *Leptochloa fusca.Sporobolus marginatus* and *Urochondra setulosa* grass halophytes seeds and root slips were obtained from the very saline and sodic Kachchh plains of Bhuj, Gujarat, India, while *Leptochloa fusca* (Karnal grass) was obtained from the severely sodic region of Uttar Pradesh, India. Since seed germination was very poor, these grasses were grown from root cuttings in the screen house during the month of April in pots filled with sandy loam soil. After establishing themselves in pots, grasses were moved to micro-plots in June and given three replications of three distinct salinity treatments, ECe: 30, 40, and 50 dS m1. The treatments with the highest salinity (Fig. 1), ECe: 50 dS m1, were chosen further for sample explants extraction. The screen house was covered with high-quality sheeting to prevent precipitation from entering the microplots, allowing us to maintain the optimum salinity level. In order to isolate and characterise bacterial endophytes, the leaves, roots, and nodes of the three grasses were collected in the months of August and September 2021 and maintained in saline (ECe: 50 dS m1) conditions. The samples were then transported in a sealed plastic bag to the laboratory at the department of biotechnology at Kurukshetra University in Kurukshetra.

Fig. 1: Halophytic grasses maintainedundersalineconditions(ECe~50dSm^{-1}) in microplots

Isolation of Endophytic Bacteria

The explants (root, node, and leaf) of all three grass species, *Sporobolus marginatus*, *Urochondra setulosa*, and *Leptochloa fusca*, established in saline conditions (ECe: 50 dS m-1), were thoroughly rinsed under running water for at least 20 minutes to remove adhering soil and dirt particles, followed by washing with a mild detergent (Tween-20), and finally by double distilled water before processing. The explants were then surface-sterilized to remove surface microbes in a laminar air flow cabinet by soaking in 70% ethanol for 60 seconds, followed by sodium hypochlorite (1% of 4% available chlorine) solution for 90 seconds. This procedure was done in order to isolate endophytic bacteria. By culturing aliquots of water from the final rinse onto nutrient media and incubating them at 37° C for 24-48 hours, the validity of the surface sterilisation technique was verified. On the control plate, there was no growth seen (Fig. 2-a). Small pieces (0.5-1.0 cm) of node, stem, and leaf were placed on nutrient agar medium (Hi-Media laboratories Pvt. Ltd) supplemented with an antifungal agent after the surface sterilised plant material had been properly dried. Since nutrient agar is a simple medium and does not contain any ingredients that are known to inhibit the growth of endophytic bacteria, it was chosen for the isolation. Amphotericin B, an antifungal drug, was added to the media at a dosage of 10 mg/ml to inhibit fungal growth. Parafilm tape was used to seal the plates, which were then incubated for 24-48 hours at 37°C. To obtain pure isolates, physically distinct colonies were chosen and streaked repeatedly once the incubation time was complete. Later, for future use, all of the pure cultures were sub-cultured in nutrient agar slants and kept at 4°C. The Hi-medium laboratories Pvt. Ltd. was used to purchase all of the chemicals, reagents, and medium. During the protocol, water that had been autoclaved and twice distilled was used.

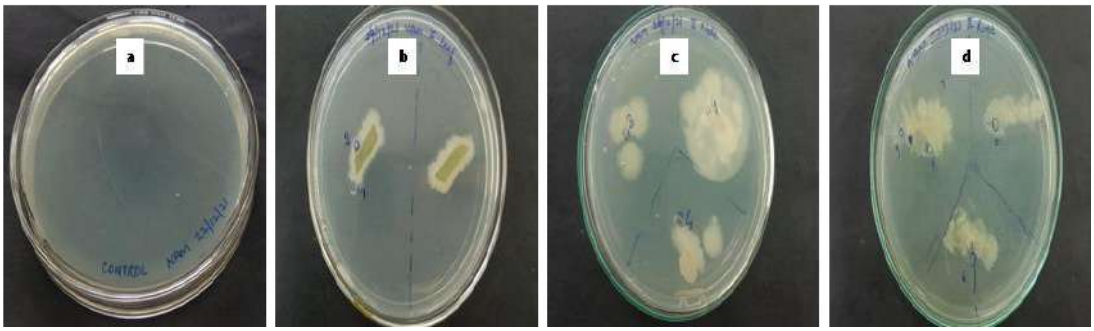

Fig. 2: (a) Control plate (b) Bacterial growth from margins of leaf tissue (c) Bacterial growth from margins of node tissue (d) Bacterial growth from margins of root tissue.

Identification and characterization of endophytic bacteria via morphological and biochemical analysis

By analysing morphological characteristics such shape, colour, motility test, gram staining, endospore staining, and biochemical testing, identification was accomplished. According to Bergey's manual of Systematic Bacteriology (Sneath et al., 1986), biochemical tests such as the catalase, gelatinase, amylase, methyl red (MP), voges-proskauer (VP), citrate utilisation, and H2S production tests were carried out to characterise the various exoenzyme activities of the isolated bacterial endophytes (Table 2).

RESULTS

In the current study, surface sterilised explants (root, node, and leaf) of three halophytic grasses, *Sporobolus marginatus*, *Urochondra setulosa*, and *Leptochloa fusca*, were used to obtain a total of 56 pure bacterial isolates. These grasses were maintained under saline conditions (ECe: 50 dS m1) in microplot facilities. The total eradication of epiphytic microorganisms from sample explants was made possible by the efficacy of the surface sterilisation process, which was a critical step in disinfecting explants. Our analysis found that this step was satisfactory because there was no development on the control plate. The control plate in Fig. 2 (a) illustrates the validation of the surface-sterilization process as the plate exhibits no growth following the culture of aliquots of water from the final rinse from the surface-sterilization process and subsequent incubation at 37 °C for 24-48 hours. Following a 24- to 48-hour incubation period at 37°C, the (b), (c), and (d) images show the growth of various endophytic bacteria from the margins of leaves, nodes, and roots, respectively.

A total of 56 isolates were screened, and 24 were found to be *S.marginatus*, 15 to be *U.setulosa*, and 17 to be *L. fusca*. Three halophytic grass explants from various sources were used to create the number of isolates shown in Table 1. Root explants of *S. marginatus* (KC1) were used to obtain the greatest number of isolates.

Table 1: Distribution of endophytes isolated from different explants of three halophytic grasses

S.NO.	Halophytic grasses	Population of bacterial isolates acquired from different explants			Total
		Leaf	Node	Root	
1	*S. marginatus* (KC1)	3	4	17	24
2	*U. setulosa* (KC2)	4	6	5	15
3	*L. fusca* (KC3)	4	9	4	17
Total number of isolates = 56					

Identification was carried out using various methods, including gram staining, endspore staining, and culture appearance. A total of 56 isolates were examined, and only 17 were gram positive, whereas 39 were gram negative. According to Bergey's manual of systematic bacteriology, the biochemical tests carried out to characterise the different exoenzyme activities of the isolated bacterial endophytes were the following: gelatinase, amylase, catalase, motility, methyl red (MP), voges-proskauer(VP), citrate utilisation, and H2S production tests. The findings of the morphological, biochemical, and exoenzyme assays conducted on isolated endophytes from all three halophytic grasses are shown in Table 2. *Sporobolus marginatus*, *Urochondra setulosa*, and *Leptochloa fusca* are the species designated by KC1, KC2, and KC3, respectively.

Table2: Biochemical characteristics of isolated endophytes from *S. marginatus* (KC1), *U. setulosa* (KC2) and *L.fusca* (KC3).

Cultures KC I	Gram's staining	Cultural appearance after staining	Endo-spore staini-ng	Amylase Test	Catalase Test	Gelatinase Test	Motility Test	Methyl Red Test	Voges – Proskauer Test	Citrate Utilisation Test	H_2S Producti-on
KC1-a	-	Rod shape	-	-	+	+	+	-	-	+	-
KC1-b	-	Rod shape	-	+	+	-	+	-	-	+	-
KC1-c	-	Rod shape	-	+	+	+	+	-	-	+	-
KC1-d	+	Rod shape	+	+	+	+	+	+	-	+	-
KC1-e	-	Rod shape	-	-	+	+	+	-	-	+	+
KC1-f	-	Rod shape	-	+	+	+	+	-	-	+	-
KC1-g	-	Rod shape	-	-	+	+	+	-	-	-	-
KC1-i	-	Rod shape	-	-	+	-	+	-	+	+	-
KC1-j	-	Rod shape	-	-	+	+	+	-	-	+	+
KC1-k	-	Rod shape	-	+	+	+	+	-	-	+	-
KC1-1-1L	+	Rod shape	+	+	+	+	+	+	-	+	-
KC1-1-3N	-	Rod shape	-	+	+	+	-	+	-	-	-
KC1-1-5N	+	Rod shape	+	+	+	+	-	+	-	+	-
KC1-1-6N	-	Rod shape	-	+	+	-	+	-	+	+	-
KC1-1-7R	-	Rod shape	-	-	+	+	+	-	-	+	-
KC1-1-8R	+	Rod shape	+	+	+	+	+	+	-	-	-
KC1-1-10R	-	Rod shape	-	-	+	-	+	-	-	+	-
KC1-1-12R	-	Rod shape	-	+	+	+	+	-	+	+	-
KC1-1-13R	-	Rod shape	-	+	+	-	-	-	+	+	-
KC1-1-14R	-	Rod shape	-	-	+	-	+	-	-	+	-
KC1-1-16R	+	Rod shape	+	-	+	-	+	+	-	+	-
KC1-1-17R	-	Rod shape	-	-	+	+	+	-	-	+	-
KC1-1-19R	-	Rod shape	-	-	+	-	+	-	+	+	-
KC1-1-20R	-	Rod shape	-	+	+	-	+	-	-	+	-
KC2-a	-	Rod shape	-	-	+	+	+	+	-	+	-
KC2-b	-	Rod shape	-	+	+	-	+	+	-	+	-
KC2-d	-	Rod shape	-	-	+	-	+	-	+	+	-
KC2-f	-	Rod shape	-	-	+	-	+	+	-	-	-
KC2-g	-	Rod shape	-	-	+	+	+	-	-	+	+
KC2-h	-	Rod shape	-	+	+	+	+	-	-	+	-
KC2-i	-	Rod shape	-	-	+	-	+	-	+	+	-
KC2-2-1L	+	Rod shape	+	-	+	+	+	+	-	+	-
KC2-2-2L	+	Rod shape	+	+	+	+	+	+	+	+	-
KC2-2-3N	-	Rod shape	-	+	+	+	+	-	-	+	-
KC2-2-4N	+	Rod shape	+	+	+	+	+	+	-	+	-

KC2-2-6R	-	Rod shape	-	+	+	+	+	-	-	+	-
KC2-2-N6R	-	Rod shape	-	-	+	+	+	-	-	+	+
KC2-2-8R	+	Rod shape	+	-	+	+	+	+	+	+	-
KC2-2-10R	-	Rod shape	-	-	+	+	+	-	-	+	-
KC3-a	-	Rod shape	-	-	+	-	+	+	-	-	-
KC3-b	-	Rod shape	-	+	+	-	+	-	-	+	-
KC3-c	+	Rod shape	-	+	+	-	-	+	-	+	-
KC3-d	-	Rod shape	-	-	+	-	+	+	+	-	-
KC3-e	-	Rod shape	-	-	+	+	+	-	+	+	-
KC3-f	+	Rod shape	+	+	+	+	+	+	-	+	-
KC3-g	+	Rod shape	+	+	+	+	+	-	-	+	-
KC3-h	-	Rod shape	-	+	+	+	+	-	-	+	-
KC3-i	+	Rod shape	+	+	+	+	+	-	-	-	-
KC3-j	+	Rod shape	+	+	+	+	-	+	-	+	-
KC3-k	+	Rod shape	+	+	+	+	+	-	-	+	-
KC3-l	-	Rod shape	-	-	+	-	+	-	+	+	-
KC3-3-1N	+	Rod shape	+	+	+	+	+	+	-	+	+
KC3-3-2N	-	Rod shape	-	-	+	+	+	-	+	+	-
KC3-3-4N	-	Rod shape	+	+	+	+	+	-	-	+	-
KC3-3-5R	-	Rod shape	+	+	+	+	+	+	+	+	+
KC3-3-6L	+	Rod shape	+	+	+	+	+	+	-	+	-

DISCUSSION

One of the major factors reducing crop yields globally is soil salinity. Saline soils make it more difficult for plants to acquire the amount of water they require. This is because varying ions (salt) concentrations in the plant roots promote a natural flow of water into the roots of the plants from the soil. If the soil is sufficiently salinized, no matter how much water is provided, the plant will wilt and die. The soil becomes dense and impermeable as a result, allowing little room for air, water from irrigation or rainfall, and oxygen for plant growth. As a result, just a small amount of irrigation or rainfall may reach the soil. The high pH of high-salt soils also has a substantial impact on how readily available nutrients are to plants. When their ionic forms are altered by these high pH levels, many plant nutrients become unavailable to plants. Plants known as halophytes are able to complete their life cycles in conditions that are extremely salty (NaCl). Many halophytic grasses and non-grasses have the innate genetic ability to survive and continue growing at salt concentrations even greater than sea water. This ability is based on their genetic make-up, physiological traits, and molecular properties (Lata et al., 2019a, b & 2022). For those who live in salt-affected areas, using halophytes to reduce salinity can be a good source of food.

Plants and microbes collaborate in a way that benefits both groups. According to several studies (Khan et al., 2013, Karthik et al., 2016, Puri et al., 2016), plant-microbe symbiosis also affects plant health and growth, which effectively change agricultural attributes and enhance soil quality and nutrient cycling. Most frequently, it is discovered that a variety of microorganisms interact with plants to obtain nutrients for their continuing life. These interactions may be neutral, detrimental (parasitism), or advantageous (mutualism or symbiosis) to the host (Shen et al., 2006; Thrall et al., 2007).

Endophytes are microbes that reside within the tissues of plants without causing significant harm or obtaining compensation other than securing their residency. The diverse population of endophytic microorganisms that live on plants, including helpful bacteria, fungus and actinomycetes is a gift from nature. They live inside the plant for the majority or all of their life cycle, causing no outward signs of illness (Hallmann et al., 1997). Due to their capacity to improve plant quality and growth, the organisation of such beneficial plant-coupled microorganisms is continuously attracting interest in the scientific community and from the perspective of industries (Carroll, 1992; Schulz et al., 1999). ACC-deaminase activity, phosphate solubilisation, nitrogen fixation, indole-3-acetic acid (IAA), abscisic acid (ABA), siderophores, and volatiles production are a few examples of how endophytic bacteria isolated from halophytes growing in salty soils may help plants. They may also alter plant hormone status and nutrient uptake and/or modulate the production of reactive oxygen species (ROS).

In comparison to the non-inoculated treatment, the plants' morphological traits and antioxidant capacities increased after being injected with PGPEs (plant growth promoting endophytes), while their Na+ contents decreased in all treatments (Afridi et al., 2019). The gladiolus (flowering plant) treated with strains CSR-G-1, CSR-B-2, and CSR-B-3 considerably produced marketable spikes and increased the amount of florets per spike in addition to displaying stronger superoxide dismutase, phenylalanine lyase, catalase, peroxidase, phenols, and proline activity than control.

Since the benefits provided by endophytes acquire a competitive advantage over (PGPR) plant growth promoting rhizobia, endophytes have attracted the attention of sustainable agriculture as an alternative to rhizospheric bacteria (Etesami et al., 2014). In contrast to endophytes, the survival and colonizing ability of PGPR are highly dependent upon their intrinsic physiological characteristics as well as the biotic and abiotic components of soil. The endophytes are substantially protected from the abiotic and biotic stress conditions in the soil because they are in close contact with their hosts (Rajkumar et al., 2009).

The variety of endophytes identified in poplar trees growing at a toluene-contaminated phytoremediation field site are described by Moore et al. (2006). Germaine et al. (2004) showed that various endophytic strains with the potential to improve phyto-remediation of volatile organics and herbicides were present in the diverse bacterial communities observed in poplar trees. For this reason, a number of bacterial species have developed a range of strategies to lessen the stress caused by heavy metals (Van Houdt et al., 2009). These mechanisms include genes responsible for resistance to salt. Geographical locations, soil types, and seasons significantly affect the distribution patterns of endophytic bacterial communities (Singh et al., 2022; Duhan et al., 2020; Priti et al., 2020). According to several studies (Gao et al., 2005; Forchetti et al., 2010; Priti and Rani, 2021) seasonal variations do affect the kind and growth of endophytes isolated from medicinal plants.

Thus, after reviewing the literature, it was determined that endophytes are essential for plants' health and sustainability. Microbial endophytes may exhibit similar, distinct, or different features to those of their host plant. Therefore, under saline/alkaline soil conditions, microbial endophytes of halophytes must have the ability to promote growth and salt tolerance capability of salt sensitive crops. Additionally, they can be used to produce enzymes like amylase, proteases, cellulose, and lipases that are stable at high salt concentrations and can thus be used in a variety of industrial applications. These enzymes can also be used to bioremediate polluted land and water that has been contaminated with heavy metals/ions. Only a few reports, though, have been published on the isolation and testing of bacterial endophytes from the halophytes *Sporobolus marginatus, Urochondra setulosa,* and *Leptochloa fusca* for salt tolerance and biofertilizing properties in alkaline/saline soils.

Therefore, in the current study, the sample grass halophytes *Sporobolus marginatus* and *Urochondra setulosa* were acquired from extremely saline regions in Uttar Pradesh, India, and *Leptochloa fusca* (Karnal grass) was established in microplots under saline conditions (ECe: 50 dS m1) in the microplots at Department of Biotechnology, Kurukshetra University, Kurukshetra. Explants from the three grasses, including leaves, roots, and nodes, were gathered in the months of August and September 2021 and kept in saline conditions in order to isolate and screen halotolerant bacterial endophytes from these halophytic grasses. All three grass halophytes were used to screen a total of 56 pure bacterial isolates.

Further investigation reveals that, in terms of the quantity of isolates, root and node explants appear to be preferred over leaf. According to earlier research, the endophytes' localisation can either be at the point of entry or it can be across the entire plant. They might be found inside of cells, the xylem and phloem vascular system, and intercellular spaces (Rosenblueth and Martnez-Romero, 2006; Ryan et al., 2008). According to Furnkranz et al. (2012), distinct endophytes may be found in plant sections such as the root, stem, and leaf. Endophytes discover new strategies to forge this relationship while interacting with the host plant (Goyal et al., 2017). The root, stem, and leaf are the most and least favoured explants for endophytic localisation, respectively (Priti and Rani, 2020; Priti et al., 2020). By enhancing the plant's water connection and mineral intake, root-associated bacteria may aid glycophytic plants in growing in saline soil and increasing productivity (Hallmann et al., 1997).

CONCLUSION

Endophytes establish a mutualistic relationship with the host plant and crucial for wellbeing of plants and also for their sustainability. Microbial endophytes may display same/ alter or unique characteristics as exhibited by their host plant. Hence, microbial endophytes of halophytes must have the potential to promote growth and salt tolerance capability of salt sensitive crops under saline/alkaline soil conditions. They may be used further for bioremediation of polluted land and water contaminated with heavy metals/ions and also for production of enzymes such as amylase, proteases, cellulose and lipases which remain stable at high salt concentrations and as result can be exploited for wide industrial applications.

FUNDING

The funding for the present research is provided under ‘Seed money grant’ (DPA-1/32/22/MRP/2358-2500**)** of Kurukshetra University, Kurukshetra-136119, Haryana, India for promoting research and development activities.

ACKNOWLEDGEMENTS

The authors are deeply thankful to the Department of Biotechnology,KurukshetraUniversity,Kurukshetra-136119,Haryana,India, for providingresearch facilitiestowork out the presented study and ICAR-CSSRI, Karnal, Haryana, India for providing the plant material.

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3.4.6 Number of books and chapters in edited volumes published per teacher during the years 2022-23

3.4.6.1: Total number of books and chapters in edited volumes / books published, and papers in national/international conference-proceedings during the year 2022-23

Sl. No.	Name of the teacher	Title of the book/chapters published	Title of the paper	Title of the proceedings of the conference	Name of the conference	National / International	Year of publication	ISBN/ISSN number of the proceeding	Affiliating Institute at the time of publication	Name of the publisher
1	Dr. Sushil Sharma	Contemporary Issues in Innovation, Entrepreneurship and Business Management	Exploring the Evoluation of Social Media Marketing: A Bibliometric Analysis	_	_	National	2023	978-9391798-34-5	Kurukshetra University	Academic Publication
2	Dr. Saloni Pawan Diwan	Banking, Insurance, and Financial Services: Digitalization and Covid led Trends	Changing landscape of Insurance distribution in the era of digitalization and covid-19 Panemic: An empirical study of India	_	_	National	2023	978-81-19079-07-0	Kurukshetra University	Bharti Publication

3	Dr. Ajay Solkhe	Floregium-Management theory, Research and Practices	Managing Diversity and Inclusion (D&I) in Different Nations: Issues and Challenges	_	_	National	2023	9.78936E+12	Kurukshetra University	Arihant Books Pvt. Ltd.
4	Dr. Ajay Solkhe	Skill Development in India: Challenges and Way Forward	A Periscopic view of skill stock in India: Challenges and Way Forward	_	_	National	2022	9.78939E+12	Kurukshetra University	Synergy Books India Pvt. Ltd.
5	Dr. Ajay Solkhe	Contemporary Issues in Banking, Insurance, and Financial Services	An Assesment of Emerging Landscape of Skill Development in India Contemporary Issues in Banking, Insurance, and Financial Services	_	_	National	2022	9.7882E+12	Kurukshetra University	ABC Printers

6	Dr. Ramesh Chander Dalal	Floregium-Management theory, Research and Practices	Herd Bias and Investment Decision Making: A Bibliometric Analysis	_	_	National	2023	9.78936E+12	Kurukshetra University	Arihant Books Pvt. Ltd.
7	Dr. Ramesh Chander Dalal	Advance Research in Technology, Management, Social Science, Sustainable Development & Humanities	Investor Sentiments and Stock Market Anomalies: A study	_	_	National	2023	978-93-93646-03-3	Kurukshetra University	Alankar Publishing House

Part VI: Digital Marketing and Recent Issues in Human Resource Management

CHAPTER 2

Herd Bias and Investment Decision Making: A Bibliometric Analysis

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The main aim of this study is to conduct a bibliometric analysis of the impact of herd bias on investment decision-making. The search for publications was done through the Web of Science database, which led to 1454 articles published between 1989 and 2023. But after applying various filters final count of research papers was 737. Analysis of these 727 papers was done through two types of software VOSviewer and bibliophily. Where results have confirmed that throughout the given timespan the number of publications and citations have increased, depicting the increasing interest of researchers in this area. Behavioral finance and risk are the major terms used a maximum number of times in these publications. The Journal of behavioral finance is the most relevant source of publications. Authors Hirshleifer, David, and Fama, ef provide the maximum document count and most cited publication respectively. These results can be useful for financial advisors, investors, and financial agents to invest efficiently in the stock market. They can apply the suggestions given in these highlighted papers and by these recommended researchers regarding investment decision-making and herd bias.

Keywords: *behavioral finance, investment decision-making, herd bias, bibliometric analysis.*

INTRODUCTION

Behavioral finance emerged as a modern concept in the 1980s in the financial decision-making area. Before that, traditional finance also known as standard finance was in use, where markets were systematic and efficient. According to the efficient market hypothesis, while deciding the price of security all the available information is being used completely and expected utility theory states that investors are rational and make a balanced investment decision by weighing all the alternatives along with their utility and attached risk (Kumar & Goyal, 2015). Modern portfolio theory provides a way for portfolio selection by evaluating the ng risk and return of risky assets and forecasting the returns of assets. But there is a gap between expected and actual returns termed market anomalies (Nair & Antony, 2013). The volatile behavior of the stock market creates complexities and invests in a complicated procedure. A major reason for this complexity is the large number of investors' emotions and trading behavior patterns. Stock market efficiency is questionable because of its anomalies (Zahera & Bansal, 2018). The stock market is volatile in nature because of the demand and supply situation, it goes up and down and all the queries of the stock market regarding price overreactions reactions, etc. are being answered by behavioral finance (Jetti & Bhaskar, 2022). Finance professionals can take recommendations from behavioral finance areas for behavior change and better communication tactics with their clients (Muradoglu & Harvey, 2012).

Investors are unique because of their heterogeneous nature, different investors from various countries may possess different emotional biases which affect their risk perception and ultimately their investment decision-making (Raut et al., 2018). Individual investors found this thing as an opportunity to invest in an efficient Indian financial market. But the behavioral tendencies of investors make it a questionable thing for market regulators (Baker et al., 2019).

Objective and Relevance of Study

The aim of this study is to perform a bibliometric analysis of the impact of herd bias on investment decision-making. So that we can identify the most relevant papers on herd bias, investment decision making and behavioral finance.

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Investor Sentiments and Stock Market Anomalies: A Study

Ms. Preeti Gupta, Ms. Shivani**, Dr. Ramesh Chander Dalal*** & Dr. Bhag Singh Bodla*****

ABSTRACT

The study aims to observe and analyse the literature which examine the impact of investor sentiment or behaviour on stock market returns and its association with market anomalies. The existence of anomalies reflects the violation of efficient market hypothesis. The paper also highlights the literature, which concerns various anomalies like January effect, Halloween effect, day of the week effect, and Monday effect etc. These anomalies have strong association with stock market efficiency as well as market's trading strategies. The results of the study reveal that anomalies affect the investor's reaction to the market information, which led to inefficient markets. Therefore, investor behaviour affects the stock prices. However, investors must keep in mind the fact that these market anomalies disappear or persist ultimately.

Keywords: *Efficient Market Hypothesis, Investor Sentiment, Stock Market Anomalies, Irrational Behaviour, Stock Returns.*

Introduction

According to efficient market hypothesis, all the available information is reflected by asset prices and presents the fact that stocks all the time trade at their fair value. Because of this, there was no scope to sell overpriced securities and

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buy under-priced securities and hence to earn profits in the stock market was a matter of chance only. The different forms of the EMH depicts that all the available information of market is represented through public surveys, company's report, and political announcements etc. All this available information is reflected by the stock prices, which makes it difficult for investors to earn any excess return out of that information (Khanna, 2016). One of the factors that results in divergence of the efficient market theory is that investors act and operate differently in response to the available information(Nurdina et al., 2021). Sometimes investor's behaviour and emotions tend to be hyped, such as hope, fear and doubt, which makes stock market inefficient. These reactions produce movements in the market and finally transformation in the asset prices, which is below or above their fair value(Bondt & Thaler, 1985).

However, Financial markets investigate the systematic patterns in terms of volume and returns. These patterns are against the efficient market theory(Nishat & Mustafa, 2002). If the stock market is efficient informationally then prices adjust themselves accurately and rapidly to the current information(Kuria & Riro, 2013).In this context,anomaly refer to situation when securities perform opposite to the idea of EMH. With continuous dissemination of the new information, all most times it is not easy to achieve efficient market and its

Chapter 1

The Second Shift: The Rise of Moonlighting in the Digital Era

Shubham Kumar* & Dr. Pradeepika**

Abstract

This comprehensive research investigates the multifaceted phenomenon of moonlighting in the context of the contemporary digital workplace, with a primary focus on understanding its prevalence, motivations, and sector-specific nuances, particularly within the Information Technology (IT) sector. Drawing upon data from reputable sources such as PwC's Global Workforce Hopes and Fears Survey 2023, Indeed Hiring Tracker Report 2023, and Cutshort's Moonlighting Ground Report 2023, the study conducts a thorough exploration of the intricate reasons compelling individuals to engage in secondary employment. The analysis of motivations for moonlighting reveals a diverse landscape, with financial considerations emerging as a primary driver for a significant portion of respondents. The desire to learn new skills, build professional networks, and explore entrepreneurial opportunities also plays a substantial role, showcasing the multifaceted nature of moonlighting motivations. Sector-wise perceptions elucidate varying attitudes toward moonlighting, with the IT sector standing out as notably favorable, reflecting its dynamic and adaptable nature. Examining the experiences and attitudes of IT professionals across different experience levels uncovers intriguing patterns. While early-career professionals demonstrate a higher inclination towards moonlighting, mid-level professionals show a decline, possibly influenced by factors such as higher earning potential and a focus on work-life balance. In contrast, a notable surge in moonlighting is observed

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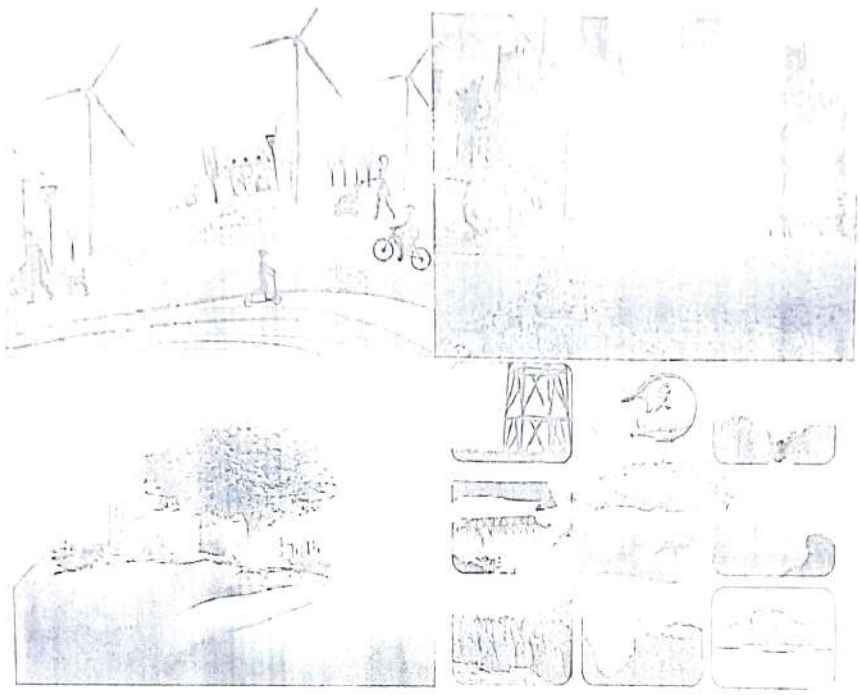

Edited by
K. Surjit Singh

Institute for Spatial Planning and Environment Research India (ISPER)

Registered office : C-1, Amravati Enclave, Panchkula, Haryana 134105

First Impression 2021

Price:

ISBN 978-81-927014-4-8

Printed and bound:
Chandika Press Pvt. Ltd.
240, HSIIDC Industrial Estate, Vill. Alipur, Barwala, Distt. Panchkula (Hry.)
Tel.: 95019 33889, 93161 33389
chandikapress.k@gmail.com

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SUSTAINABLE RURAL AND URBAN DEVELOPMENT

EVOLUTION, GROWTH AND DISTRIBUTION OF SLUMS IN HISAR CITY

Kiran Bala
Assistant professor, Department of Geography, Govt. College Bhuna (Fatehabad), Haryana
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Abstract

Over the last century there has been tremendous growth in the urban population. The increased urbanization has also lead to more and more people residing in informal settlements generally known as slums. The emergence of slums in the urban areas is the direct output of better economic opportunities accessible in the cities and towns and consequent rural to urban migration. In the present paper an attempt has been made to analyses the evolution, growth and distribution of slums in the study area. The Index based on primary data collected from 21 slum clusters of Hisar city in 2013-14. A total number of 600 sample households have been selected through proportionate random sampling technique. Hisar city is an important industrial town of Haryana. The study result reveals that the evolution and growth of slums in Hisar city in three temporal phases viz 1960-1980, 1981- 1995 and 1996-2011. Rapid urbanization and industrilization attracted the rural migrants in search of better employment opportunities. It has been noticed that near about one third of the slum population has been living in core area however, occupying only 3.36 percent of the city area. It is because core area or Central Business District (CBD) is the hub of commercial and retail activities and where jobs are available to the slum dwellers. The Nearest Neighbour analysis of the slums in the study area reveals their random distribution.

Key words: Urbanization, Settlement, Industrilization, Opportunities, Slum.

Introduction

Over the last century there has been tremendous growth in the urban population. This growth however, has not been uniform. Growth in urban areas in less developed regions of the world has been especially rapid due to mechanization and industrialization (United Nations, 2015a). Today, over half of the world's population lives in urban areas and by the middle of this century 7 out of 10 people will live in a city. This enlarged urbanization has also lead to more and more people residing in informal settlements generally known as slums. In India, for instance, around 13.7 million households, or 17.4 per cent of urban Indian households, are considered to be living in slums. In India alone this equates to over 200 million people. Over a third of India's slum population lives in 46 million-plus cities (Census of India, 2011). Moreover, urban growth is largely the result of 'urbanization of poverty' (Mathur, 2011). Facts, such as [illegible] poverty' leads to the growth of slums in [illegible] countries.

The emergence of slums, and growing number of people living in slums, is now a very significant and intricate global challenge for our society (UN-HABITAT, 2011a). While there are many different definitions and categorization criteria of what constitutes slums (Ooi et al., 2011), for residents the reality is often [illegible] shelter, poor access to basic services such as water and sanitation, inadequate access to healthcare and in general a low quality of life. Slums are the by-product of social and economic impact due to rapid urbanization.

Furthermore, slums are increasing [illegible] 2 per cent annually in developing [illegible]

Environment and Development: Issues, Challenges and Measures

Edited by

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H. S. R. A PUBLICATIONS

Published by

HSRA Publications 2022

#02, Sri Annapoorneshwari Nilaya, 1st Main,

Byraveshwara Nagar, Laggere,

Bangalore – 560058

Sales Headquarters – Bangalore

ISBN: 978-93-5506-413-4

First Edition 2022

No. of Pages – 120

₹200.00

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3. Impact Assessment of Urban and Industrial Development on Solid Waste Management in Faridabad City

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Impact Assessment of Urban and Industrial Development on Solid Waste Management in Faridabad City

Abstract:

Present paper has tried to find out the change which has taken place in landscape of Faridabad City in Haryana from 1991-2008.The urban expansion mapping of Faridabad city and its surrounding was done with the help of Landsat TM acquired in 1991, of Landsat ETM acquired in 1999 and IRS geo-coded LISS-IV MSS satellite imagery for the year 2008, industrial data is obtained from DIC, Faridabad and solid waste generation from MCF. The rapid urban expansion in Faridabad city has taken place at the cost of wasteland and agricultural land. Cultivated land has experiences decline on account of encroachment of it by industrial, residential, commercial, institutional activities and urban infrastructure. Rapid industrialization and urbanization are the main driving forces behind this increasing population of Faridabad. Urban core, which represents the heart of the city, is high-density area is used for the residential, commercial, institutional, recreational, public and semi-public purpose. Presently, total quantity of solid waste generation is 617.60 T/ per day with per capita generation of about 400 grams per day. Rapid urbanization, population growth, growing economy and emerging opportunities in the region have placed an enormous demand for quality civic infrastructure. There is a positive relation between temporal change in population and quantity of generation of waste. Similarly, there is a positive relation in number of industries and solid waste generation. Solid waste of Faridabad city is increasing rapidly due to industrial growth and location in NCR. The population, urbanization, higher per capita income, standard of living, and changing lifestyle is also contributing to increased solid waste. Very large quantities are produced by household sector and industrial activities. Improper management of waste leads to environmental pollution, public health hazard, and adverse effects on an urban economy. Collection and dumping of domestic and municipal wastes is a serious problem in Faridabad city since a large part of it remains unattended due to in house constraints of the MCF which has serious impact on environment and public health.

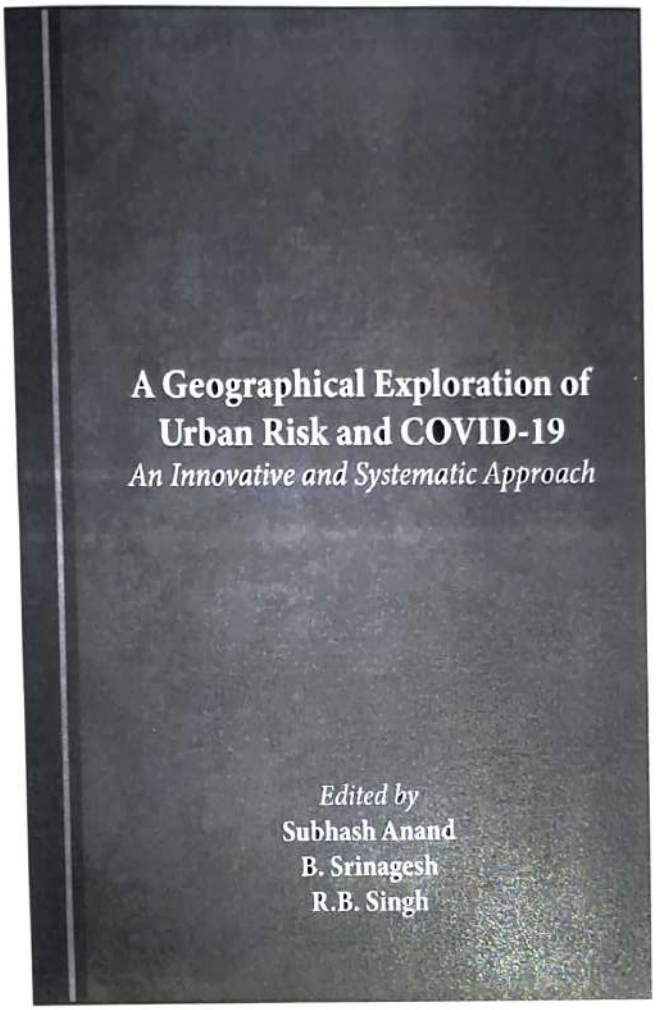
Key Word: Solid Waste Management (SWM), Municipal Solid Waste (MSW), New Industrial Township (NIT), National Capital Region (NCR), Tone per Day (TPD), Municipal solid waste management (MSWM), Urban Expansion and Population Growth.

Introduction:

There is an unequal urban growth, which is taking place all over the world, but the rate of urbanization is very fast in the developing countries, especially in Asia. In 1800 A.D., only 3% of the world's population lived in urban centers, but this figure reached to 14% in 1900 and in 2000, about 47% (2.8 billion) people were living in urban areas (United Nations Population Division, 2001). In 1991, there were 23 metropolitan cities in India, which increased to 35 in 2001and 53 in 2011 (Census of India, 1991, 2001and 2011). Rapid urban development ensuing dramatic changes in the landscape have been recently witnessed in many developing countries as a result of fast economic advancements (Yeh and Li, 2001). Since urbanization is an unavoidable process, efforts can be made to direct it in the most proper way by urban land use planning so as to protect the natural resources and the needs and rights of the people (Soffianian et al., 2010). Hence, accurate mapping of urban environments and monitoring urban growth is becoming increasingly important at the global level (Guindon and Zhang, 2009).

In India alone currently, 25.73% of the population (Census of India, 2001) lives in the urban centers, while it is projected that in the next fifteen years about 33% would be living in the urban centers. As urban population increases, the demand of land for various urban activities also increases. This indicates the alarming rate of urbanization and the extent of sprawl that could take place. The trends towards sub urbanization and urban sprawl (low density, spatially dispersed, and segregated land use) emerging in urban spaces have a direct and indirect

Geographical Exploration of Urban Risk and COVID-19: An Innovative and Systematic Approach



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ISBN13: 978-1-5275-2940-3
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An Innovative and Systematic Approach

Edited by Subhash Anand, B. Srinagesh and R.B. Singh

This book first published 2023

Cambridge Scholars Publishing

Lady Stephenson Library, Newcastle upon Tyne, NE6 2PA, UK

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

ISBN (10): 1-5275-2940-1
ISBN (13): 978-1-5275-2940-3

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Gouri Sankar Bhunia
Adimalla Narsimha *Editors*

Chapter 2
Variability and Trends in Temperature, Rainfall, and Discharge in a Western Himalayan Catchment

Omvir Singh and Milap Chand Sharma

Abstract Temperature, radiation, precipitation, and stream flow are all critical climatic variables that affect the ecosystem. Understanding the complex mechanisms involved in climate change is a concern for scientists because it is likely to exacerbate current food shortages and issues with irrigated agricultural systems across the world. Therefore, the current research aims to quantify the long-term variability and patterns in temperature, rainfall, and discharge in a catchment of the western Himalayan region in the state of Himachal Pradesh over a four-decade period. Temperature, rainfall, and discharge trends were studied using Mann–Kendall and simple linear regression models. The investigation revealed that the rainfall amount in the catchment has not changed significantly during different seasons as well as annually. However, temperature trends in the basin demonstrated a slight increase during all the seasons but only the winter season temperature has demonstrated a significant positive change. Conversely, these warming reflections on the water discharge have not been observed accordingly and a significant decline was detected in the annual, seasonal as well as monthly streamflow pattern of the catchment. The shifting nature of rainfall, less snow cover in the lower and middle reaches, and thinning of small glaciers and ice patches over the study period can all be blamed for the decreasing discharge. This reduction in streamflow will influence the hydropower production in the upstream parts and agricultural activities in the downstream areas and thus affecting local as well as the national economy.

Keyword Temperature · Rainfall · Streamflow · Trend analysis · Mann–Kendall test · Parbati catchment

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S. Rani and R. Kumar (eds.), *Climate Change*, Springer Climate,
https://doi.org/10.1007/978-3-030-92782-0_2

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Chapter 12
Understanding the Development and Progress of Extremely Severe Cyclonic Storm "Fani" Over the Bay of Bengal

Pankaj Bhardwaj and Omvir Singh

Abstract The Bay of Bengal (BoB) experiences the occurrence of tropical cyclones (TCs) almost throughout the year. However, the extremely severe cyclonic storm (ESCS) Fani has formed in April 2019 has shown uniqueness in terms of its location of origin, direction of track, and landfall location. Therefore, in this study, an attempt has been made to examine the development and progress of ESCS Fani over the BoB. The analyses have shown that a low pressure area has formed near equator (approximately 2.7°N latitude) over the southern BoB on 25 April 2019 and strengthened into depression on 26 April at the same location. This depression has further strengthened into cyclonic, severe cyclonic, very severe cyclonic, and extremely severe cyclonic storm and moved northwestward. Then, it has recurved and moved northeastward and make landfall over Orissa coast. It has been reported among the long-lasting cyclones of BoB as it travelled the distance of about 3030 km. The total accumulated cyclone energy and power dissipation index generated by the ESCS Fani have been found higher than their long-term mean (1972–2017). The analyses of large-scale dynamic and thermodynamic conditions have shown favorable environment for the development of cyclone over the southern BoB. The consistent strong convective activity, high SST (approximately 30 °C), more relative humidity, strong vertical motion, low level cyclonic vorticity, and less vertical wind shear have supported for further intensification of cyclonic system. The cyclone Fani has followed the recurving track which has been chiefly steered by an upper tropospheric level anticyclonic circulation.

Keywords Tropical cyclone · Fani · Development · Environmental conditions · Bay of Bengal

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P. K. Shit et al. (eds.), *Geospatial Technology for Environmental Hazards*, Advances in Geographic Information Science, https://doi.org/10.1007/978-3-030-75197-5_12

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An Innovative and Systematic Approach

Edited by Subhash Anand, B. Srinagesh and R.B. Singh

This book first published 2023

Cambridge Scholars Publishing

Lady Stephenson Library, Newcastle upon Tyne, NE6 2PA, UK

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library

ISBN (10): 1-5275-2940-1
ISBN (13): 978-1-5275-2940-3

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CHAPTER 14

AN ANALYTICAL STUDY OF AGRICULTURAL LABOURERS' AND FARMERS' SUICIDE IN PUNJAB

KIRAN MANN*[1] AND SUMAN CHAUHAN[2]

Abstract: Over the past two decades, declining agricultural production and rising cultivation costs have decreased farmers' income across India. Moreover, the large-scale adoption of commercial farming has increased farmers' credit needs, leading to widespread credit defaults. Since 1995, acute agrarian distress, caused by indebtedness and other socio-economic factors, has led to a frightening series of farmers' suicides in several states, i.e., Maharashtra, Karnataka, Andhra Pradesh, Kerala, and also in the prosperous states, like Punjab. The present study has been conducted in the highly suicide-prone (of farmers and laborers) districts of Punjab, namely Sangrur and Mansa, which come under the Malwa region of the state. An attempt has also been made to understand the socio-economic characteristics of the sample farmers and agricultural laborers. Findings revealed that the spread of suicide victims was largely concentrated in the age group below 35 years, which seems to be generally prone to suicides. The findings of the present study also verified the prevailing myth that agrarian distress affects only males, but this is not true. Female farmers have also committed suicide in the study area. The level of literacy is also very low among the sample farmers and agricultural laborers. To remedy this, it is recommended that supplementary occupations should be promoted among the farmers and agricultural laborers. There is a need to

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Worldwide Circulation through Authorspress Global Network
First Published in 2023
by
Authorspress
Q-2A Hauz Khas Enclave, New Delhi-110 016 (India)
Phone: (0) 9818049852
E-mail: authorspressgroup@gmail.com
Website: www.authorspressbooks.com

A Handbook of Mental Health and Wellbeing

ISBN 978-93-5529-670-2

Printed in India at Thomson Press (India) Limited

Preface

Mental health refers to a positive term associated with the social and emotional well-being of an individual and society. It determines how an individual thinks, acts, and reacts. It can be said that mental health makes us enable to decide how we pact with our situations, problems, and challenges in different circumstances. Many emotional factors have a vast impact on our fitness stage like despair, aggression, poor thinking, frustration, and worry, and so on. Good mental health indicates a state of psychological nicely-being. A physically and mentally healthy person is constantly in a terrific temper and might without difficulty cope with situations of misery and despair ensuing in normal education contributing to good physical health well known which denotes having an effective sense of ways we experience, assumes, and act which improves one's capability to enjoy our lifestyles. It also contributes to the inner capacity to be self-decided. Mental health is vital in each degree of lifestyle, from childhood to the geriatric stage. In the modern era and lifestyle, stress, anxiety, and depression cases are increasing day by day and many professionals, psychologists, social workers, and practitioners focused on mental health are increasingly intervening in it to reduce the issues and promote well-being.

This book presents a deep understanding of mental health and disorders along with mental health care services and intervention strategies. It is also providing the professional's work experiences illustrations along with chapters for better understanding. This is a handbook to guide the teachers, students, psychologist, professionals, and social workers as a helping tool in concept clarity as well as good practice in the field. It contains ten chapters that cover basic concepts, causes, symptoms, factors, and treatment of mental health, psychiatry, personality theories, pathological theories, mental disorders, mental health care services, and social work intervention in mental health wellbeing.

Seema Rani and Neeraj

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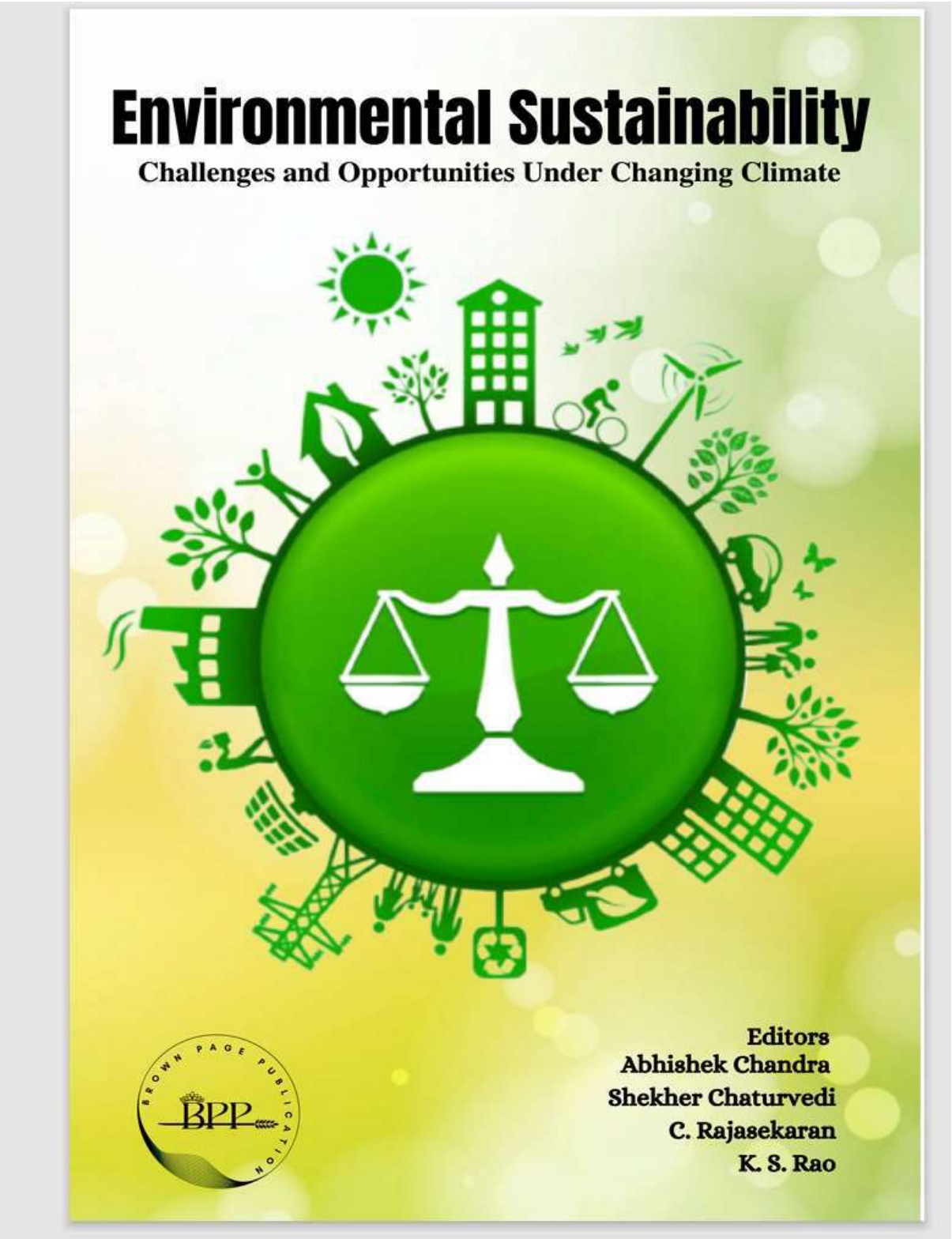
1. **Dr. Hardeep Rai Sharma**



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Chapter: 8

Bioremediation of Metal ions: Current Trends and Future Prospects

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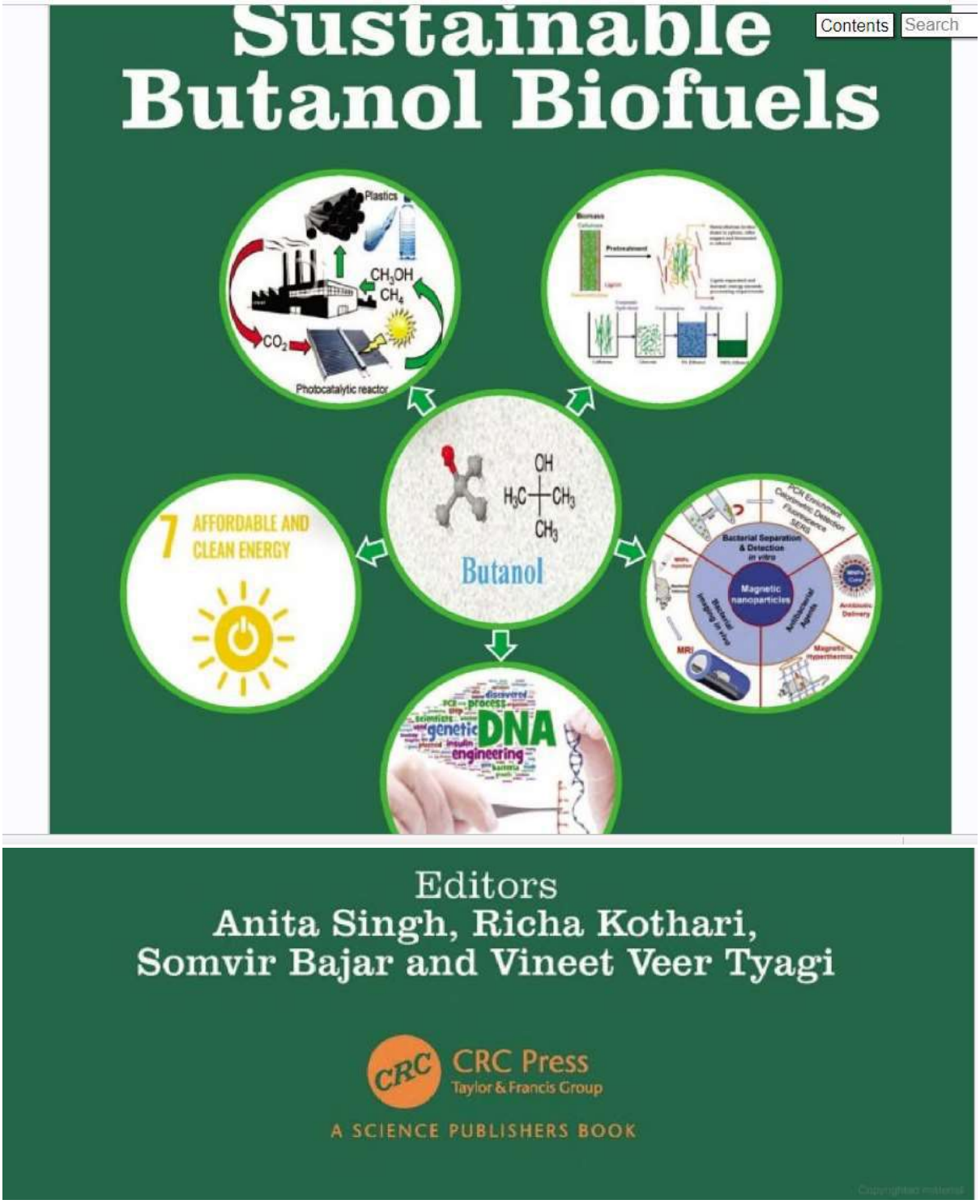
Abstract
Naturally, heavy metals are found in trace amounts and generally cause no significant impact on living organisms. The anthropogenic activities concentrate the heavy metals like copper, zinc, nickel, cadmium, lead, etc. in very narrow points and disrupt the ecosystem. Prolonged and acute exposure to such contaminants causes certain ailments in plants and animal life. Certain living organisms (plants and animals) can absorb these contaminants or reduce them to less harmful ions and clean the ecosystem, and these findings are well documented. In the present chapter, bioremediation of heavy metals by algae, fungi, bacteria etc., are investigated, and their capacities and mechanism of sorption are explained. Some case studies for heavy metals bioremediation are included in the chapter. The status of the current techniques, their limitations and suggestions for future research has also been included in the study.
Keywords: heavy metals; algae; fungi; bacteria; adsorption mechanism

1. Introduction

Heavy metals are the micro-pollutants having density more than 5 $g.cm^{-3}$. They are found in nature in small quantity and some of them act as micro-nutrients for the development and growth of organisms (e.g. magnesium, nickel, chromium, copper, calcium, manganese, sodium and zinc). Due to disturbance in ecological system (volcanic eruptions) or by human interference, the quantity of heavy metals increased which results certain ailments in plants and animal. The industrialization has significantly added various heavy metals in our environment which are rarely found in concentrated form. Industries like tannery, textile, paint, mining and electronic waste etc. discharge large amount of industrial effluents containing heavy metals. Metals like lead, cadmium, mercury, chromium and silver have no role in plants and animals biological activity.

2. **Dr. Meenakshi Suhag**



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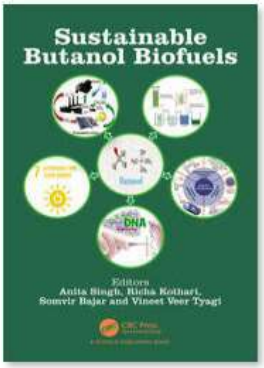
    Arti Devi, Anita Singh, Somvir Bajar and *Deepak Pant*



Chapter

Genetic Engineering in Butanol Production: Recent Trends

By Japleen Kaur, Zaheer Ud Din Sheikh, Anita Singh, Somvir Bajar, Meenakshi Suhag

Book Sustainable Butanol Biofuels

Edition	1st Edition
First Published	2023
Imprint	CRC Press
Pages	20
eBook ISBN	9781003165408

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ABSTRACT

Microbial engineering enables biologically emanated alternates concerning diesel, gasoline, and aviation fuel. Butanol-producing strains are broadly classified into two different categories: the wild type and the genetically modified butanol-producing strain. Various genetic and metabolic engineering pathways have been integrated in the non-native butanol-producing strains. Many of the non-native hosts for butanol production are very advantageous as they require simple nutrients, grow rapidly, and are easy to manipulate because of their known genetic background, but all these conditions differ from strain to strain. Microorganisms that are metabolically engineered to switch renewable carbon sources to desired fuel products are considered as the best choice to obtain high volumetric productivity and yield. Butanol is confirmed to be an essential biofuel. Nowadays, it is produced by genetically modified organisms. It has been extrapolated from various analyses that the presence of bioinformatical data, omics data, and computational biology approaches make it easier to reconstruct non-native strains of microorganisms that produce the desired amount of butanol.

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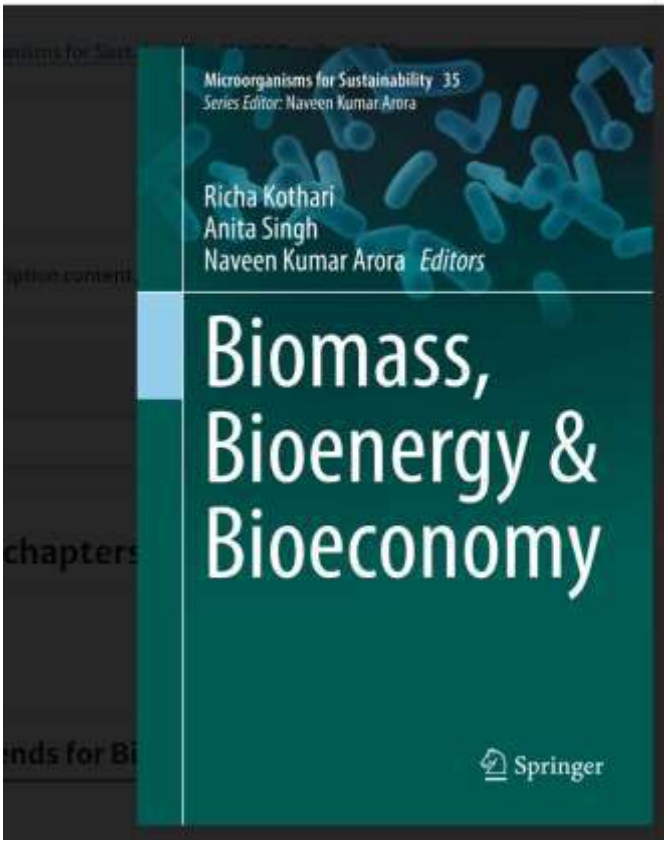
production and challenges from bio-economy perspective



Biomass: Progressive Trends for Bioenergy

Bioenergy: Sustainable Solution for Bioeconomy

Bio-economy: Policy Trends, Challenges and Implications

Bioethanol Production Technologies: Commercial and Future Perspectives

Chapter | First Online: 14 October 2022

pp 117–139 | Cite this chapter

Meenakshi Suhag

Part of the book series: Microorganisms for Sustainability ((MICRO,volume 35))

Abstract

The demand of energy is continuously increasing, which is also increasing the demand of conventional fuel. The major demand of any country till date is fulfilled by conventional fossil fuels, however, the use of renewable energy, waste to energy and other non-conventional energy technologies are in progress. The conventional source of liquid fuels is limited to few countries and sources are getting exhausted in near future, so the alternate source of liquid fuel is current need of research. One such fuel is ethanol which is gaining importance nowadays due to its wide range of substrate and production methods. Ethanol is one of the most acknowledged engine fuels capable of partially substituting gasoline for the purpose of making gasoline-ethanol mixture in different ratios. Bioethanol production is one of the renewable methods of producing ethanol from different biological substrates and various routes. Bioethanol can be produced from various substrates such as sugar cane, wheat, corn, etc. Various countries are producing bioethanol from different routes and substrates. This chapter deals with all such possible technologies available for bioethanol production through different routes. The chapter also provides knowledge about the consequences and benefits of all generations of bioethanol.


Basic Concepts
in Environmental
Biotechnology
Edited by
Neetu Sharma
Abhinashi Singh Sodhi
Navneet Batra
CRC Press

TABLE OF CONTENTS

Chapter

Solid Waste Management

Source and Treatment

By Meenakshi Suhag

Book Basic Concepts in Environmental Biotechnology

Edition	1st Edition
First Published	2021
Imprint	CRC Press
Pages	17
eBook ISBN	9781003131427

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ABSTRACT

Rapid development, growing population and transforming lifestyle have significantly enhanced the generation of waste residues, especially in the larger cities. United States Environmental Protection Agency (USEPA) regulations describe solid waste as "garbage or refuse, sludge from a wastewater treatment plant, water supply treatment plant, or air pollution control facility and other discarded material, including solid, liquid, semisolid or contained gaseous material resulting from industrial, commercial mining, agricultural operations and from community activities". Inappropriate waste disposal degrades our natural environment by contaminating water, soil and air and poses risk to human life. The escalating generation of solid waste and its management are among the most significant challenges being faced by the world today. In developing countries like India, these services (solid waste management) are mainly provided by municipal authorities. High management cost and lack of understanding of effective management techniques, policies and treatment methods are the key issues to be focused upon. Furthermore, waste disposal is the most ignored part of solid waste management practices, and existing methods are not up to the mark. The present chapter provides an overview of solid waste as problem, sources, management/disposal and treatment practices, waste-to-energy generation technologies based on literature and studies carried out so far.

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Environmental Sustainability

Challenges and Opportunities Under Changing Climate

Editors
Abhishek Chandra
Shekher Chaturvedi
C. Rajasekaran
K. S. Rao

BROWN PAGE PUBLICATION
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Contents

Chapter: 15

Green Taxes and Climate Funding

Sandeep Gupta, Meenakshi Suhag, Anuradha and Shant Kumar
Institute of Environmental Studies, Kurukshetra University, Kurukshetra, Haryana - 136119, India
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Abstract
Green taxes and climate funding are two vital economic instruments that are linked to the environmental policy. Green taxes are introduced by governments around the world assuming, it will change the behaviour of the polluter, however its design like rationalization of tax rate and a careful policy implementation remains at the core of its success. It has been observed in some cases that when green taxes are applied together with other policy instruments it is more effective in achieving its goal. However, such taxes sometimes lead to opposition due to lack of public awareness about the objective of the tax/penalty, or lack of transparency about the utilization of revenue generated through such taxes. On the other hand, the higher objective of green funding is to develop an economy that is based on green initiatives and supports firm actions on sustainable development projects. In this, climate financing is an important instrument that includes the financing of technological and capacity-building needs towards climate change activities, especially in the developing countries. In green financing, funding through government and public-private partnership is more common and sources of corporate funding is still under-utilized. In the context of developing countries like India the quantity and time of green funding are two important indicators that will determine the strength and length of the component 'green' in their economy.
Keywords: *Environmental Tax*; *Economic Incentive*; *Green Financing*; *Climate Finance*; *Green Banking*.

1. Introduction

Climate change has become an important issue since the last century. The severity of its impact is gradually increasing and this increase is directly related to the increase in human population, industrialization, modernization, land cover conversion. There is a lot of reluctance in implementing policies related to minimize the adverse impact of greenhouse gases emissions and climate change, particularly by developed nations (Beckerman, 1992). However, a shift in approach to enforce green taxation has shown positive results a) in reducing the pollutants, b) in promoting new and alternative energy sources in producing goods and providing services, c) in

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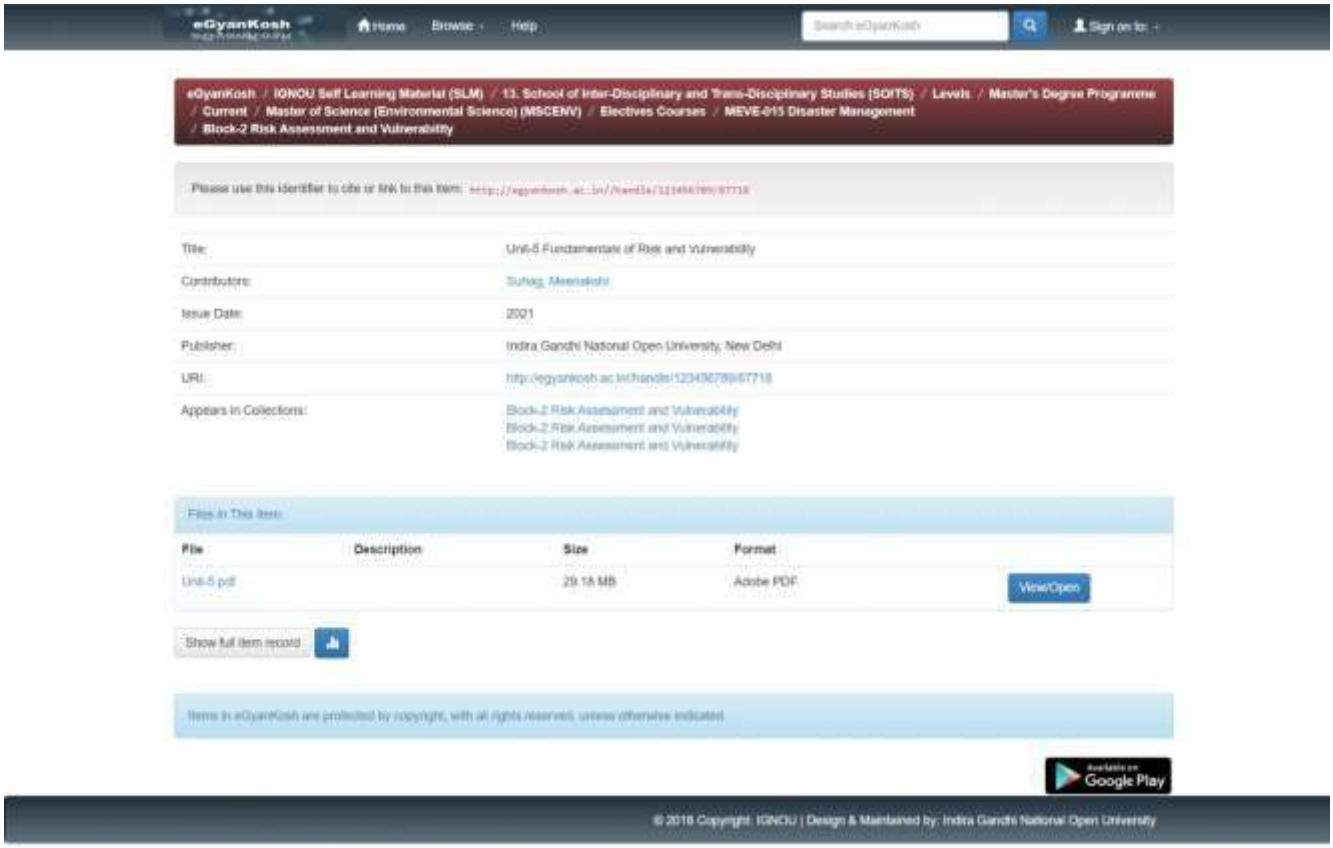
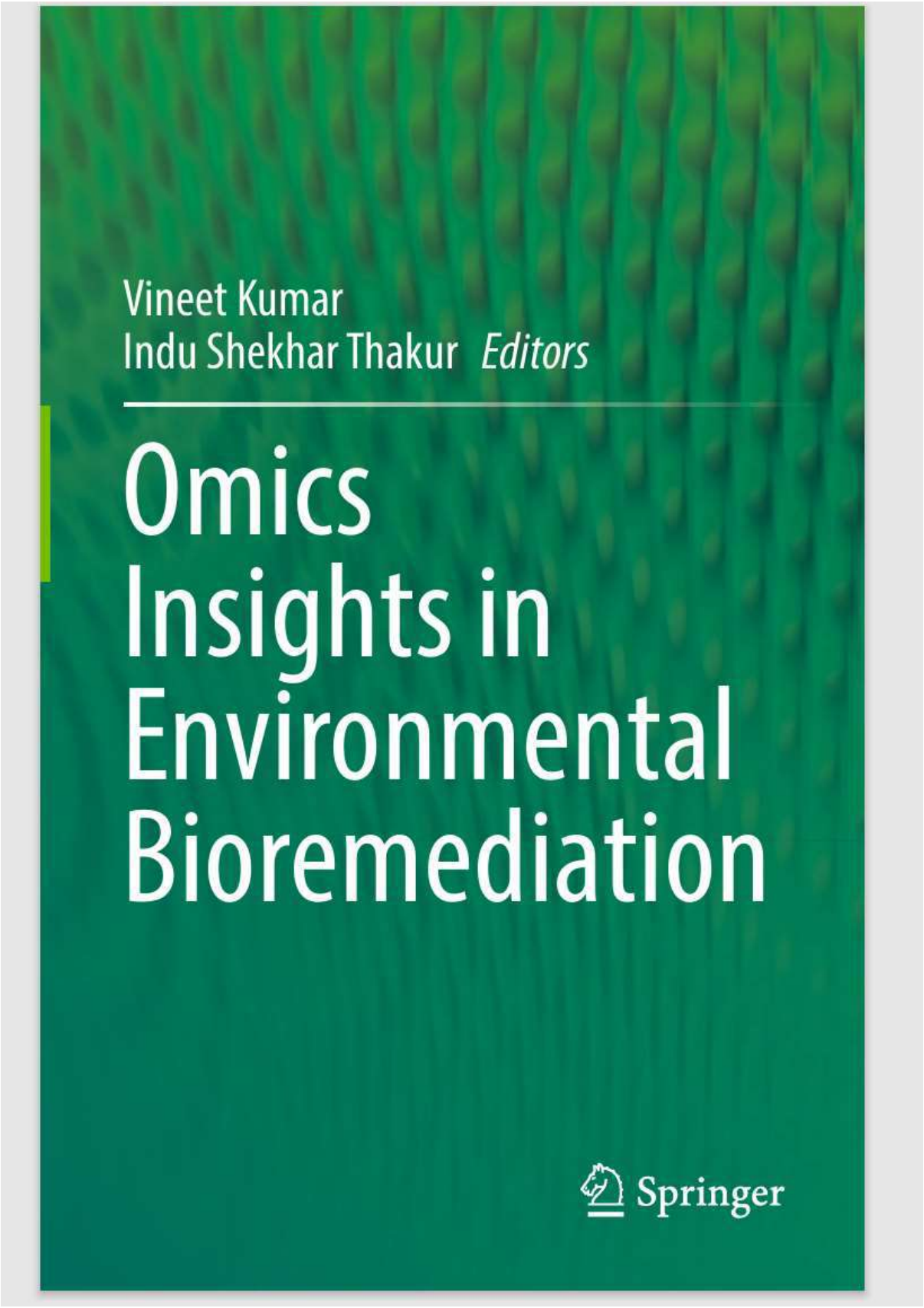


3. **Dr. Pooja Arora**



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Recent Trends in Bioremediation of Heavy Metals: Challenges and Perspectives

5

Pooja Arora, Rashmi Paliwal, Nitika Rani, and Smita Chaudhry

Abstract

Heavy metal pollution is a matter of serious concern worldwide. Movement of heavy metals starting from the extraction processes to their applications in a variety of industrial activities, results in their indiscriminate release in the environment. Prolonged exposure to these heavy metals can cause detrimental health effects in human as well as other living organisms. Heavy metals include a class of some highly toxic metals such as, Hg, Cd, Cr, Pb, Ni, Cu, and Zn. that are reported to have cytotoxic, carcinogenic, teratogenic, and mutagenic effects. Since, these heavy metals are nondegradable and have a tendency to accumulate in environment, their removal from aquatic and terrestrial system is required. Bioremediation is one of the promising techniques which can be used to remove these contaminants from water and soil using biological agents, including microorganisms (bacteria, fungi, and microalgae) and plants (phytoremediation). Microorganisms and plants are capable of taking up heavy metals from nature and use these toxic contaminants in their metabolic activities, or convert them to less/nontoxic forms. Thus, the microorganism- and plant-mediated treatment processes are widely accepted since these methods are based on natural mechanisms and also reduce the chances of generation of secondary pollutants as in the case of various conventional processes. This chapter thus studies the various bioremediation techniques for the removal of heavy metal from nature and will discuss the mechanisms of different biological agents used for the transformation of toxic heavy metals. Different methods for the assessment of heavy metals have been

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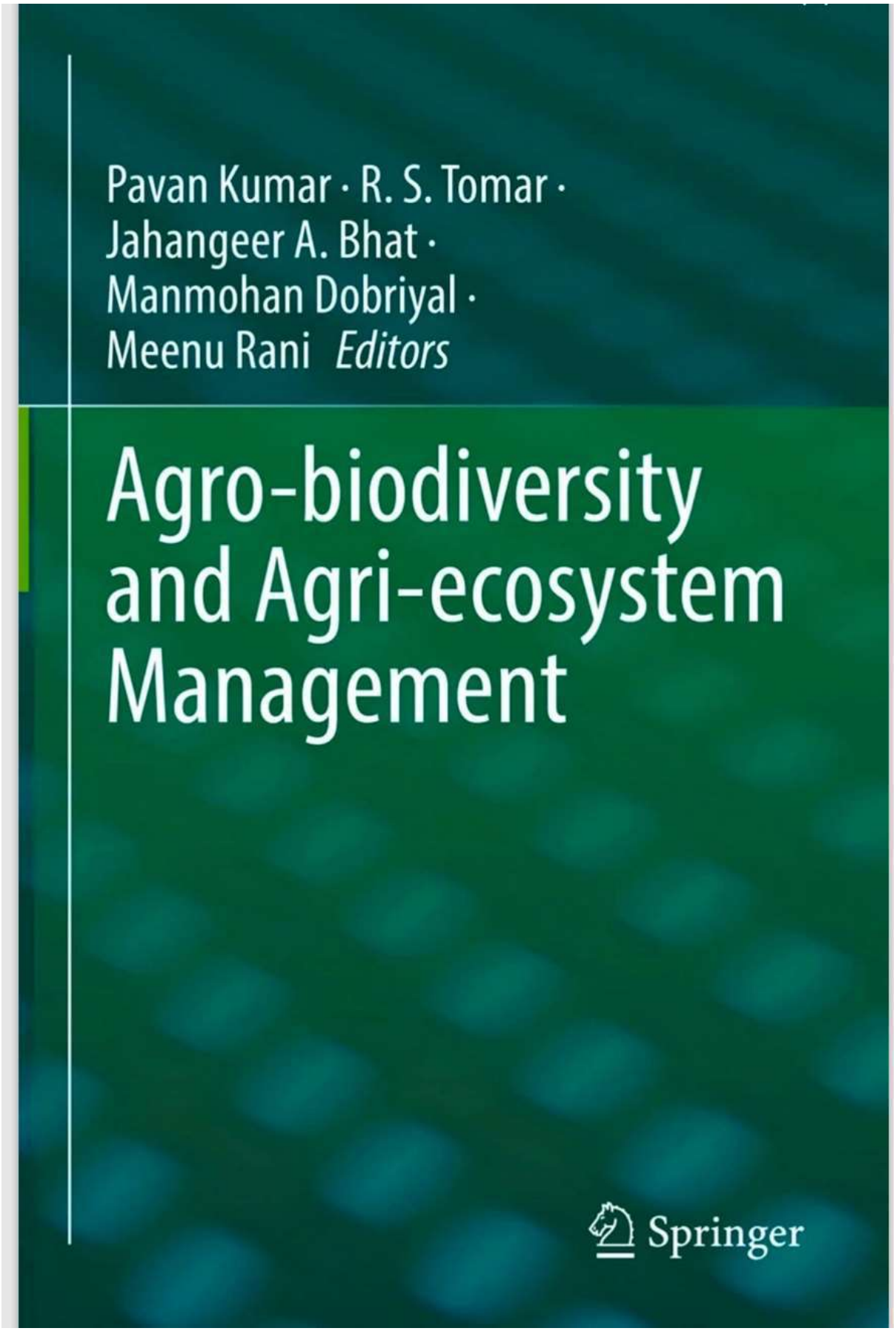
V. Kumar, I. S. Thakur (eds.), *Omics Insights in Environmental Bioremediation*,
https://doi.org/10.1007/978-981-19-4320-1_5

4. **Dr. Dipti Grover**



Agri Ecosystem Services and Climate Resilience

Chapter

Carbon Sequestration Potential in Agricultural Systems

July 2022

DOI: 10.1007/978-981-19-0928-3_6

In book: Agro-biodiversity and Agri-ecosystem Management

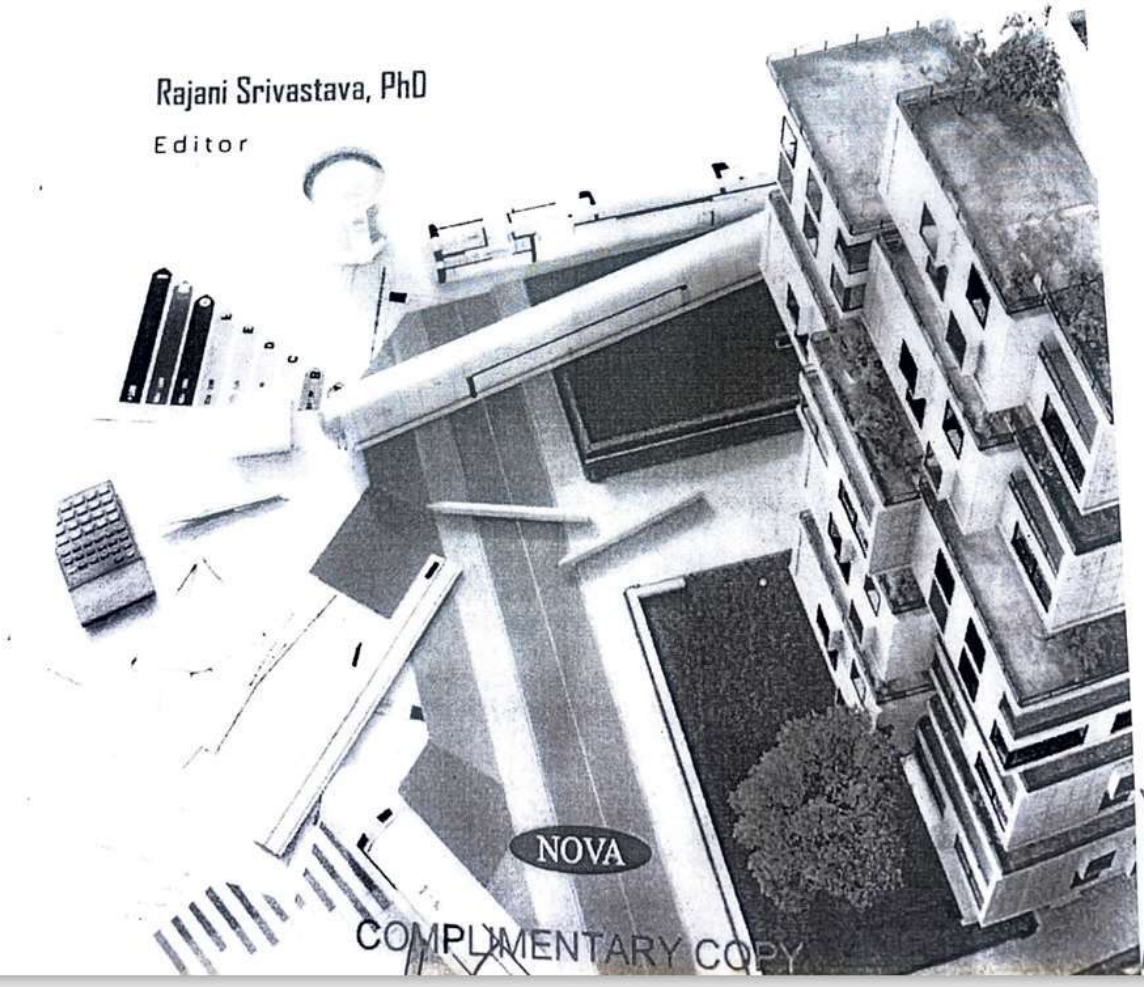
 Ajay Kumar Mishra ·  Dipti Grover ·
 Rajeswari Das · Show all 5 authors ·
 Bisworanjita Biswal

AGRICULTURE ISSUES AND POLICIES

Strategies to Achieve Sustainable Development Goals (SDGs)

A Road Map for Global Development

Rajani Srivastava, PhD
Editor



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Chapter 8

Natural Farming Systems as Hotspots of Eco-Tourism and Their Potential for Sustainable Development

Ajay Kumar Mishra[1,*], Sheetal Sharma[1], Pinaki Chattopadhyay[2], Dipti Grover[3], Pallavi Chattopadhyay[4] and Jyotiprakash Mishra[5]

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Abstract

Eco-tourism is a newly emerging concept in tourism, fusing environmental protection, cultural awareness, and low impact travel with the provisioning of employment generation. Over the past decade, it has become increasingly popular to conserve resources, especially biological diversity, and maintain sustainable resources. This chapter highlights the significance of Agri-ecotourism, pathways for up-scaling it to the village level and scope for developing climate resilience through eco-tourism. Eco-tourism offers a balance between economic,

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In: Strategies to Achieve Sustainable Development Goals (SDGs)
Editor: Rajani Srivastava
ISBN: 978-1-68507-836-2

Meenu Rani
Bhagwan Singh Chaudhary
Saleha Jamal
Pavan Kumar *Editors*

Towards Sustainable Natural Resources

Monitoring and Managing Ecosystem Biodiversity

Springer

Chapter

Regenerative Agriculture as Climate Smart Solution to Improve Soil Health and Crop Productivity Thereby Catalysing Farmers' Livelihood and Sustainability

September 2022
DOI: 10.1007/978-3-031-06443-2_16
In book: Towards Sustainable Natural Resources
Lab: Ajay Kumar Mishra's Lab

Ajay Kumar Mishra · Devi Dayal Sinha · Dipti Grover · Show all 8 authors · Sheetal Sharma

Biostimulants for Crop Production and Sustainable Agriculture

Edited by
Mirza Hasanuzzaman,
Barbara Hawrylak-Nowak,
Tofazzal Islam and Masayuki Fujita

CABI

| Chapter | 22 September 2022

19

Biological Trace Elements Confer Abiotic Stress Tolerance in Plants

Authors: Aditi Shreeya Bali, Gagan Preet Singh Sidhu, Dipti Grover, Bhawna Dahiya | AUTHORS INFO & AFFILIATIONS

Publication: Biostimulants for Crop Production and Sustainable Agriculture

https://doi.org/10.1079/9781789248098.0019

Abstract

Abiotic stresses have become a major concern now a days as they act as the limiting factors in plant growth and development. Due to the advancement of science, inten rch has been carried out globally to explore the

| Chapter | 22 September 2022
30

Plant–Microorganism Interactions Remediate Heavy Metal-contaminated Ecosystems

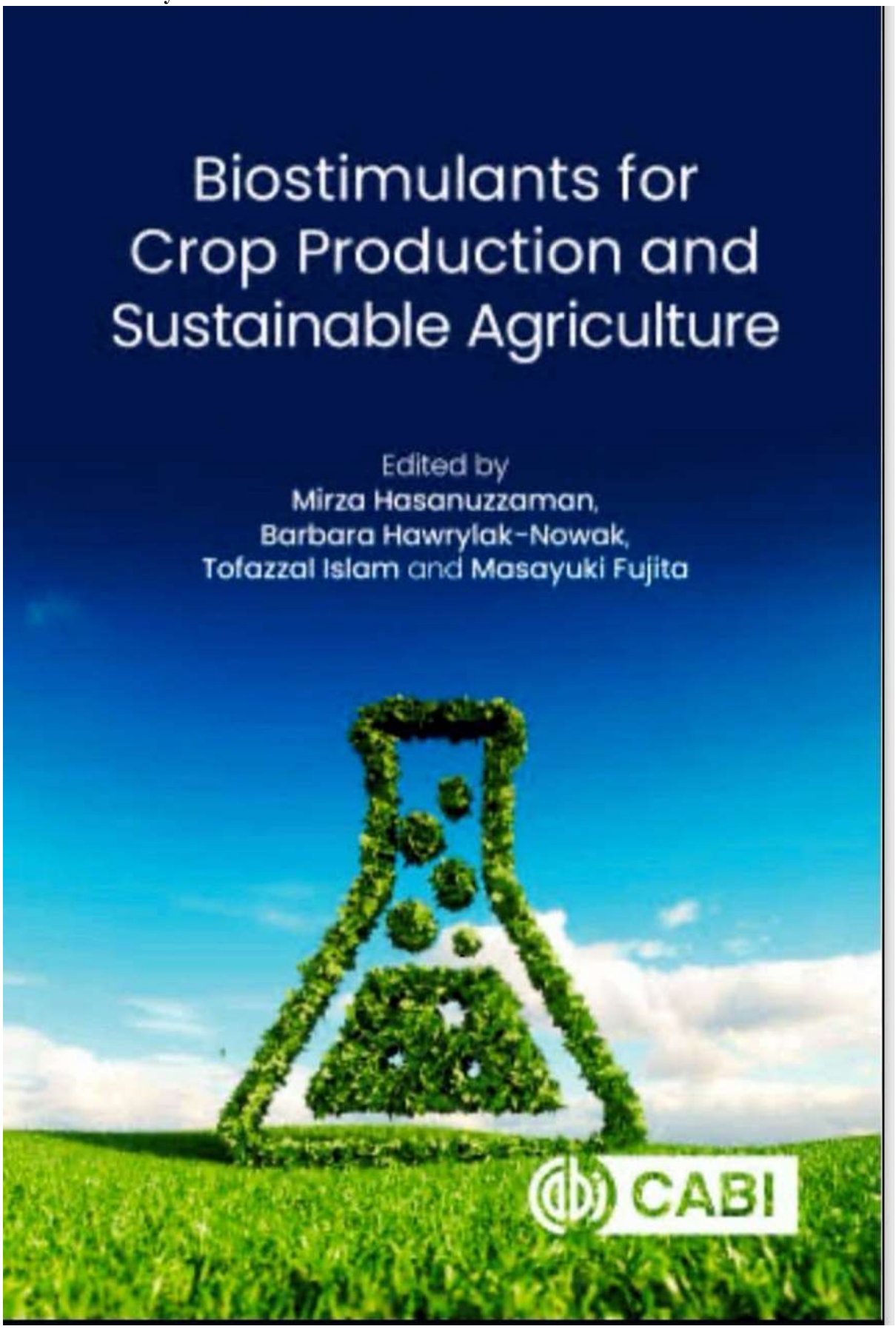
Authors: Aditi Shreeya Bali, Gagan Preet Singh Sidhu, Bhawna Dahiya, Dipti Grover | AUTHORS INFO & AFFILIATIONS

Publication: Biostimulants for Crop Production and Sustainable Agriculture
https://doi.org/10.1079/9781789248098.0030

Abstract

Technogenic advances have led to the exploitation and contamination of soil/water ecosystems. The alleviation of heavy metal contaminants from polluted so gh non-conventional methods is a cost-effective and

5. **Dr. Bhawna Dahiya**



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19 Biological Trace Elements Confer Abiotic Stress Tolerance in Plants

Aditi Shreeya Bali[1], Gagan Preet Singh Sidhu[2,*], Dipti Grover[3] and Bhawna Dahiya[3]

[1]Dyal Singh College, Karnal 132001, India; [2]Gautam Buddha University, Greater Noida, Uttar Pradesh, India; [3]Institute of Environmental Studies, Kurukshetra University, Kurukshetra 136119, India

Abstract

Abiotic stresses have become a major concern now days as they act as the limiting factors in plant growth and development. Due to the advancement of science, intensive research has been carried out globally to explore the underlying mechanisms of plant nutrient uptake, their metabolism, homeostasis and protection against abiotic stresses. Plants require trace elements at very low concentrations for growth and other physiological activities. Exogenous supplementation of trace elements in plant systems mitigates various stress conditions of plant species. Trace elements not only improve plant physiological processes and growth, but also play vital roles in improving plant tolerance toward varied abiotic stresses. The addition of trace elements ameliorates plant antioxidant response to counter oxidative stress. This chapter presents the plant responses to different abiotic stresses and the beneficial effects of different trace elements in conferring plant tolerance against various abiotic stresses.

19.1 Introduction

Rapid industrialization, globalization and increased human population have elevated the demand of plants as a source of food, oil, fiber, medicine, timber, etc. However, plants being immobile are bound to grow within their natural habitat and are exposed to a wide range of environmental stresses that hamper their morphology, physiology, biochemistry and molecular functions (Sharma *et al.*, 2019). Abiotic stresses can reduce the productivity and yield of crop plants by more than half (Dhankher and Foyer, 2018). A few plants have naturally adapted through various morphological changes against stress; however, some plants undergo physiological and molecular adaptations to avoid abiotic variations. The combined effect and longer duration of all these stresses and plant species drastically effect the plant growth and productivity (Pandey, 2015). The increased abiotic stress leads to overproduction of reactive oxygen species (ROS) in plants such as hydrogen peroxide (H_2O_2), superoxide anion ($O_2^{\bullet-}$), hydroxyl radical (•OH), and singlet oxygen ($^1O_2$), causing oxidative stress (Choudhury *et al.*, 2017). It adversely affects the synthesis of biomolecules such as DNA, proteins, carbohydrates and the antioxidant network, and may cause severe damage to cellular processes and other membrane systems. To cope with abiotic stress, plants have developed various mechanisms that help to mitigate stress-induced

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 Biostimulants for Crop Production and Sustainable Agriculture (eds. M. Hasanuzzaman *et al.*)
DOI: 10.1079/9781789248098.0019

30 Plant–Microorganism Interactions Remediate Heavy Metal-Contaminated Ecosystems

Aditi Shreeya Bali[1], Gagan Preet Singh Sidhu[2,*], Bhawna Dahiya[3] and Dipti Grover[3]

[1]Dyal Singh College, Karnal, India; [2]Gautam Buddha University, Greater Noida, Uttar Pradesh, India; [3]Institute of Environmental Studies, Kurukshetra University, Kurukshetra, India

Abstract

Technogenic advances have led to the exploitation and contamination of soil/water ecosystems. The alleviation of heavy metal contaminants from polluted soils through non-conventional methods is a cost-effective and eco-friendly approach. Phytoremediation is a prominent green technology employed to remediate contaminated soil/water ecosystems. Rhizospheric microorganisms are omnipresent and can tolerate a wide range of contaminants, hence they can facilitate the removal of noxious contaminants. Microorganism-assisted phytoremediation is a safe and innovative method for remediation of toxic substances. Microorganisms like bacteria and fungi in the rhizosphere can sense signals and enable the plants to tolerate metal-induced toxicity along with growth promotion. These rhizosphere microbes can accumulate, transform or detoxify the toxic substances. In this chapter, we discuss heavy metal-induced toxicity, microorganism–plant interactions and microorganism-assisted phytoremediation of contaminated ecosystems. This chapter is also intended to give an overview of the recent findings, challenges and opportunities in microorganism-assisted plant-based reclamation of contaminated soils.

30.1 Introduction

Environmental contamination by heavy metals is a serious environmental concern worldwide. Heavy metals have been reported to cause severe health concerns in humans (Bali *et al.*, 2020; Sidhu *et al.*, 2020). Heavy metals are non-biodegradable and persistent in nature (Kumar *et al.*, 2019a, 2019b). They are known to cause soil/water pollution, inducing toxicity, genotoxicity and mutagenic effects on the living organisms. Heavy metals have the atomic number greater than 20 and have an elemental density greater than 5 g cm^{-3}. Heavy metals such as Pb, Cd, As, Cr and Hg do not have any biological function and are known as non-essential elements (Ali and Khan, 2018). A number of environmental protection agencies has listed heavy metals as priority pollutants that are liable to cause serious health hazard to humans (Sarwar *et al.*, 2017). Therefore, there is an urgent need to employ environmentally sound strategies to alleviate the heavy metals from the contaminated ecosystems.

Conventional approaches are costlier and environmentally destructive in nature (Sidhu

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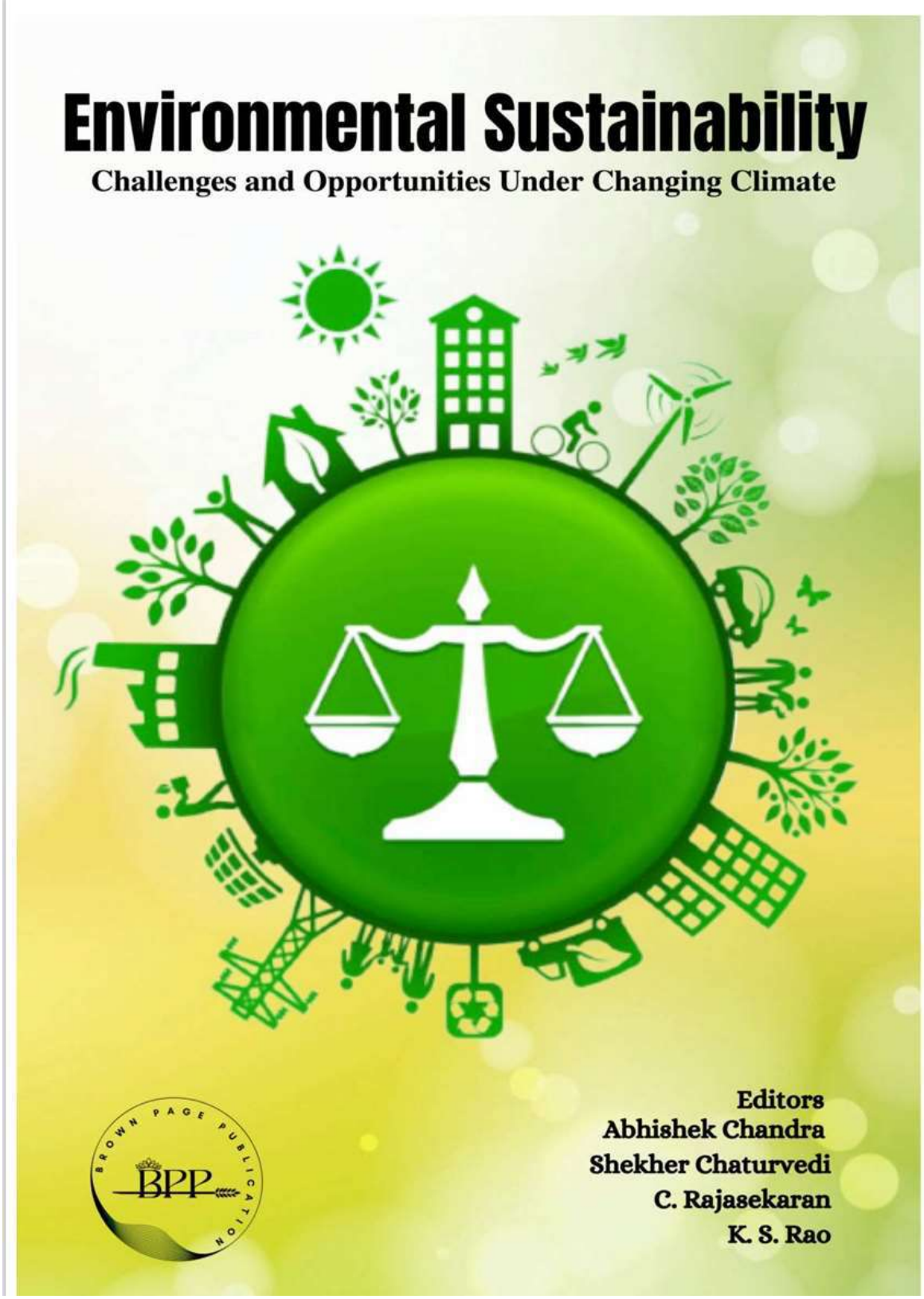
 Biostimulants for Crop Production and Sustainable Agriculture (eds. M. Hasanuzzaman *et al.*)
DOI: 10.1079/9781789248098.0030

6. **Dr. Sandeep Gupta**



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Chapter: 15

Green Taxes and Climate Funding

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7. Shivani Garg

Emerging Contaminants in Water and Remedial Techniques

| Chapter | First Online: 04 June 2022

| pp 203–229 | Cite this chapter

Legacy and Emerging Contaminants in Water and Wastewater

Smita Chaudhry & Shivani Garg

Part of the book series: Emerging Contaminants and Associated Treatment Technologies ((ECAT))

Abstract

Emerging contaminants (ECs) occur in extremely small concentrations; have a broad distribution, especially in water bodies; and have been identified to cause potential environmental and health risks. ECs comprise of chemical and biological micro-pollutants such as fertilizers and pesticides, pharmaceuticals, cosmeceuticals, nutraceuticals and other personal care products (PCPs), disinfectants, plastics, polycyclic aromatic hydrocarbons (PAH), dioxins, etc. that even in minor concentrations cause serious environmental threats and risks to the associated flora and fauna. The treatment of these ECs poses a major challenge to researchers, engineers and academicians. This chapter hence describes the types of ECs; the hazards associated with their widespread distribution in various fresh water bodies, groundwater and industrial wastewater; and also the associated modern remedial techniques. In order to tackle the bio-geo-environmental threats, various research efforts have been made to increase the efficiency of remediation techniques. Aerobic and anaerobic treatments, adsorption processes with activated carbon and clay minerals, hydrothermal carbonization of biomass, coagulation- flocculation, ozonation, advanced oxidation process (AOPs), UV irradiation, ultrafiltration (UF) membrane treatments, nanofiltration (NF), etc. are some effective treatment techniques for emerging contaminants in water and wastewater.

Advanced Applications of Biobased Materials
Food, Biomedical, and Environmental Applications
2023, Pages 231-243

Chapter 7 - Biobased materials for increasing the shelf life of food products

Preeti Tyagi [a], Nelson Pynadathu Rumjit [a], Shivani Garg [b], Shakeel Ahmed [c d], Chin Wei Lai [a]

https://doi.org/10.1016/B978-0-323-91677-6.00031-3

Abstract

With the increase in urban population and busy lifestyles, the demand for fresh and healthy food is also increasing. The food industry must ensure food safety and search for sustainable solutions to increase the shelf life of food and decrease food waste. Using a biobased material as a packaging material is a possible alternative, wherein sustainability and real-time observation of food quality provide the combined assurance of health safety and economic and environmental benefits. Moreover, biobased packaging materials obtained from renewable resources could potentially replace plastic or fossil-based materials. This chapter outlines the use of three different types of biobased and biodegradable polymers, i.e., polymers derived by the chemical synthesis of bioderived monomers, natural polymers derived from raw materials such as cellulose, and starch-based polymeric materials derived from primitive plastics. Such biobased biopolymers can produce coatings and films with decent thermal, chemical, and mechanical properties to store food items and thus increase their shelf life. The objective of using renewable biomass is to first reduce the responsibility of fossil resources and second use them for food packaging applications.

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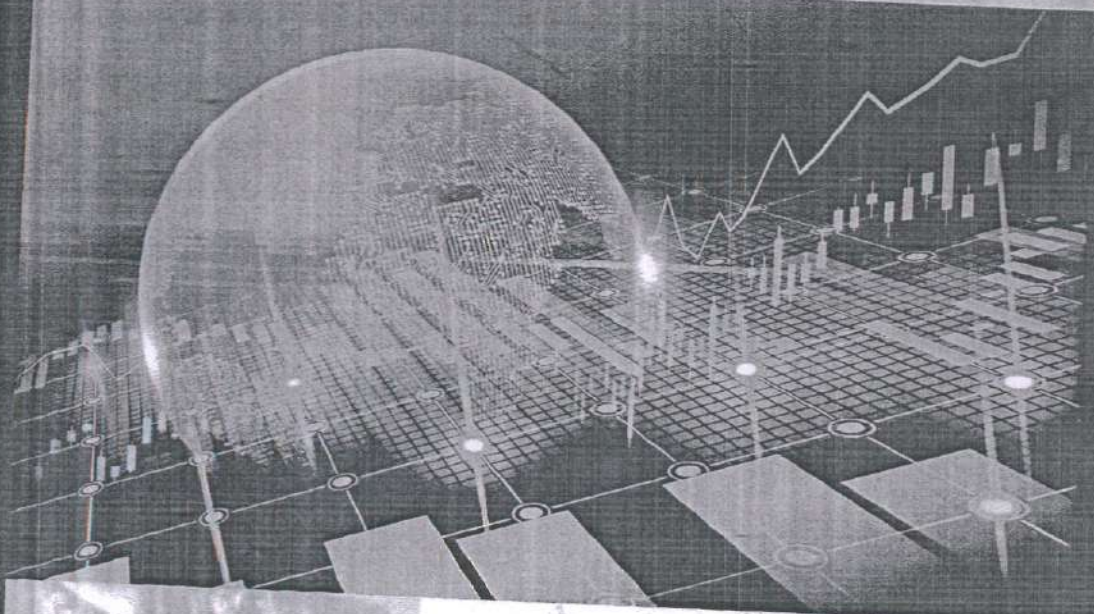

Editors

Dr Shravan Kumar | Dr Ramveer Tanwar

Dr Harleen Kaur | Dr Akash Singh

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munication. Dr Kumar is a Professor & Dean,
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carrying the responsibility of National Vice-
sidentship of the English Language Teachers'
sociation of India. He has also received the
icher Excellence Award by UGC in 2020. He has
ivered more than 125+ lectures as Plenary
eaker/ Resource Person in National and
ernational Seminars, Conferences, Workshops,
d Webinars. He has organised more than 50
ternational academic and more than 350+
tracurricular mega-events.

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He has been invited as Chairperson, Co- Chairperson
and Moderator in many Technical Sessions of
International Conferences. He has Authored and
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Classification" by ESS ESS Publication Delhi,
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Professionalism and Accessibility in Libraries

Editors
Dr. Shravan Kumar
Dr. Ramveer Tanwar
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Navjagran Prakashan

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Awareness And Use of Social Media Among Postgraduate Students of Punjabi Department of Kurukshetra University: A Study

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Kurukshetra University, Kurukshetra

Dr. Manoj Kumar Joshi
Professor, Department of Library & Information Science,
Kurukshetra University, Kurukshetra

Abstract

Social media has become an integral part of modern life and students are no exception to it. All the postgraduate students of the Punjabi Department of Kurukshetra University were aware of various social media platforms. 90.91% respondents were aware of WhatsApp and one fourth of the respondents had started using social media during last one year. Almost two thirds of the total respondents used social media up to two hours a day. All respondents were accessing social media through their smartphones and WhatsApp (90.91%) along with Youtube (68.18%) were the most used platforms. Respondents mainly used social media for 'group discussion with classmates' and 'as a source for material to read for

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distinguished five primary areas of public arrangement, or authoritative reaches, where public libraries have an effect: training, social approach, data, social improvement and financial turn of events.

Conclusion

The motivation behind open libraries is still to additional vote based system, uniformity and civil rights, increment admittance to data, scatter culture and information, add to a significant and useful relaxation time, and go about as a shared establishment and a social gathering place. To satisfy this reason today, notwithstanding, there is a need to reconsider the public libraries' job by concentrating completely on the difficulties of the computerized society. This article has zeroed in on an enlarging of the computerized hole and a debilitating of social support and contribution and highlighted the capability of reinforcing the public libraries' majority rule job by facilitating social comprehensiveness and citizenship.

There is a need, moreover obvious, to report public library esteem in financial terms too. At a time where the monetary strain is proceeding and expanding, the need to show the financial significance of public libraries is critical

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Role of Academic Libraries in the Psychological Well-Being of Students: A Proposal for the Alleviation of Library Anxiety

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Kurukshetra University, Kurukshetra

Manoj Kumar Joshi
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Kurukshetra

Abstract

Every person has the desire to live a happy life filled with success, good physical, and mental health. Good mental health includes both the absence of mental illness and the presence of psychological well-being. But nowadays mental disorders/ health issues are at their peak and this has affected the overall quality of an individual's life. Therefore, it is essential to overcome mental health issues and promote psychological well-being as it enhances overall happiness and contentment in an individual's life. It has been seen in the existing literature that students have more mental health issues than others and these have a negative impact on their academic performance. Educational institutions, particularly

Spatial Distribution of the Gutenberg-Richter Parameters and Fractal Dimension and Their Correlations in Northeast India and Its Vicinity

R. B. S. Yadav, P. Chauhan, M. Sandhu, R. Kumar, and V. Singh

Abstract The study aims to estimate the Gutenberg-Richter parameters (a and b) and fractal dimension (Dc) using the maximum likelihood estimation (MLE) method in 18 shallow (≤70 km) and 5 intermediate (>70 km) depth seismic zones in northeast India and its vicinity. Scaling relations have been developed among the estimated hazard parameters. A unified and comprehensive earthquake catalogue spanning the period from 1897 to 2016 is used for the purpose. The regions associated with the low b-value and high Dc value have been considered the utmost potential regions for the incidence of big events in the examined area. The b-values in the examined region vary from 0.59 to 1.31 in shallow zones and from 0.88 to 0.98 in intermediate zones. Similarly, the Dc values vary from 1.81 to 2.65 in shallow zones and 2.22 to 2.71 in intermediate zones. The low b-values (less than 0.9) and the high Dc values (greater than 2.0) are related to shallow zones 3 (Arunachal Himalaya), 6 (Eastern Himalayan syntaxis), 13 (Burmese region), 17 (south of Shillong Plateau) and all intermediate zones in Indo-Burmese regions. This makes these zones the most vulnerable to high earthquake hazards. The associations between D_c and b, and D_c and a/b illustrate a positive and negative correlation, respectively. The spatial variations of these parameters can be used as important parameters of earthquake hazard levels in the region.

Keywords b-value · Fractal dimension · Earthquake hazard · Northeast India

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R. Kumar
National Centre for Seismology, New Delhi, India

M. Shrikhande et al. (eds.), *Proceedings of 17th Symposium on Earthquake Engineering (Vol. 4)*, Lecture Notes in Civil Engineering 332,
https://doi.org/10.1007/978-981-99-1459-3_12

Annexure - 16
Pages 1 - 13

महाकाव्य

श्री ब्रह्मानंद दर्शन भास्कर

अनुक्रमणिका

--उपन्यास

धरतीपुत्र

किसान - क्रांति

आचार्य शीलक राम

BlueRose ONE

का उद्देश्य किसी भी
खिलाड़ी, उद्योगपति,
उन, तर्क, सम्प्रदाय,
ूजा–पद्धति, आस्था,
ी, योगी, संन्यासी,
कर्त्ता, मुनि, मौलवी,
ा, भाषा, भूषा, भूषण,
ाक, राजनीतिक दल,
, सभ्यता, सभ्याचार,
तेकता, विषय, राष्ट्र,
क्षा–पद्धति आदि का
क गुण–दोष–समय–
–विवेक के अनुसार

उपन्यास **'धरतीपुत्र**
। दिव्य–आत्माओं के
सदियों से शोषित,
ग्रस्त, दास, गुलाम,
क्षित तथा आत्महत्या
बदहाल जीवन की
। उपन्यास में अनेक
यक्ति आदि आए हैं
आन्दोलन को केन्द्र में
इतिहास नहीं।

अनुक्रमणिका

भारत की खोज

(दार्शनिक निबन्ध-संग्रह)

आचार्य शीलक राम

rkp

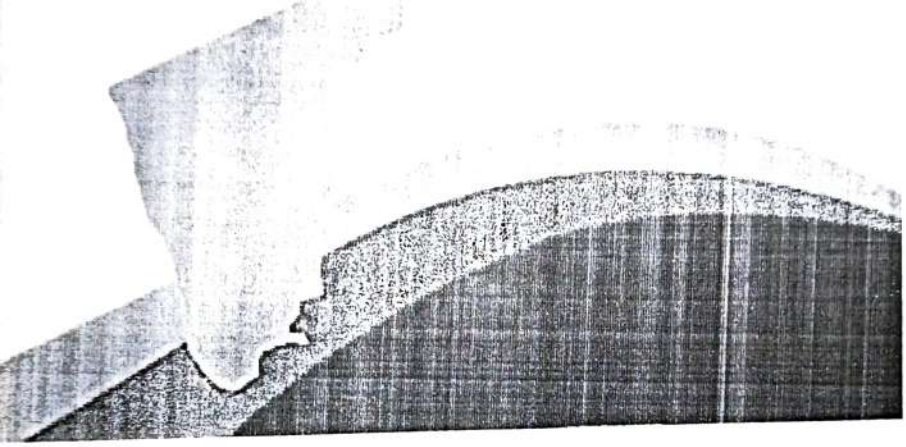
आर.के. प्रकाशन

नई दिल्ली

विषयानुक्रम

(दार्शनिक निबन्ध-संग्रह)

मैं भारत
बोल रहा हूँ



आचार्य शीलक राम

मैं भारत बोल रहा हूँ

(निबन्ध-संग्रह)

आचार्य शीलक राम

आर.के. प्रकाशन

नई दिल्ली

भूमिका

इस धरती पर सच बोलना सबसे बड़ा खतरे का कार्य है। खतरे का कार्य इसलिए है क्योंकि कोई भी सच बोलना व सच सुनना पसंद नहीं करते हैं। विज्ञान से लेकर अध्यात्म तक, व्यक्ति से लेकर विश्व तक, भारत से लेकर अमेरिका तक, हिन्दू से लेकर ईसाई तक, चरवाहे से लेकर दार्शनिक तक, गांधीवादी से लेकर आतंकवादी तक सर्वत्र झूठ का बोलबाला तथा सच का विरोध मौजूद है। साधु, महात्मा, संन्यासी, स्वामी, संत, मुनि, योगी, कथाकार, दार्शनिक, चिंतक, विचारक, लेखक, तर्कशास्त्री, सुधारक,मौलवी, पादरी, ग्रंथी, मठाधीश, वैज्ञानिक, शिक्षाशास्त्री, नेता, न्यायाधीश, उच्च–अधिकारी, अपराधी, आतंकवादी सभी के सभी सच से भय खाते हैं। कहते अवश्य हैं लेकिन सच का सम्मान कोई नहीं करता। या यों भी कह सकते हैं कि ये सच व झूठ की व्याख्या अपनी सुविधा–असुविधा तथा अपने हित–अहित को देखकर करते हैं। वैसे सच में इतनी ताकत है कि झूठ भी सच की आड लेकर ही आगे बढ़ता है। झूठ के पास अपना कुछ नहीं होता है। प्रस्तुत पुस्तक के निबंधों में सच लिखने का दुस्साहस किया गया है। आशा है कि पाठकों को पसंद आएगा।

विक्रमी सम्वत-2080
कलि सम्वत्–5124
सनव सृष्टि सम्वत्–1960853124

आचार्य शीलक राम
वैदिक योगशाला
कुरूक्षेत्र (हरियाणा)

विषय-सूची

श्री अरविन्द के विविध पक्ष

डॉ. सुरेन्द्र कुमार

महत्त्वपूर्ण सुझावों एवं मार्गदर्शन हेतु उनका हृदय की अतल गहराई से धन्यवाद। जिन भी लेखकों की पुस्तकों का इस पुस्तक के लेखन में सहयोग लिया गया है। उन सबका आभार प्रदर्शन करना मेरा पुनीत कर्तव्य बनता है, विशेषकर श्री बसन्त कुमार लाल तथा श्रीमती अवधेश कुमारी का धन्यवाद ज्ञापित करने के लिए सभी शब्द छोटे पड़ जाते हैं। इन सभी का बहुत-बहुत धन्यवाद।

दीपावली
विक्रमी सम्वत् 2079

डॉ. सुरेन्द्र कुमार
असिस्टेंट प्रोफेसर
दर्शन-विभाग, कुरुक्षेत्र विश्वविद्यालय
कुरुक्षेत्र-136119
मो. 9466241799

विषयानुक्रमांक

अध्याय-1

श्री अरविन्द दर्शन का प्रवेश द्वार

[illegible] भारतीय संस्कृति, सर्वांगपूर्ण आध्यात्मिक विकास, [illegible] भविष्य के संदेशवाहक महान् भारतीय चिन्तक श्री [illegible] 1872 को पश्चिमी बंगाल में कोननगर के एक [illegible] लिंग, लंदन इत्यादि स्थानों में शिक्षा ग्रहण करने [illegible] और उन्होंने प्राचीन भारतीय वाङ्मय, विशेषतः [illegible] प्रारम्भ किया। इस अनवरत ज्ञान साधना के साथ [illegible] एक अत्यन्त निर्णायक भूमिका अदा की, [illegible] के पश्चात् वे आध्यात्मिक साधना की ओर [illegible] राजनैतिक क्षेत्र को छोड़कर योगसाधना के [illegible] आश्रम की स्थापना कर अतिमानस के [illegible] साधना करते रहे, सन् 1950 में उन्होंने महाप्रयाण [illegible]

[illegible] विस्तृत अध्ययन तथा विभिन्न संस्कृति की [illegible] साथ ही उन्होंने [illegible] में पाश्चात्य दर्शन तथा [illegible] और [illegible] आदर्शवादी तथा [illegible] परिचित थे। [illegible] लेखों में स्पष्ट संकेत [illegible] पूर्वमीमांसीय विचारों की [illegible] भारतीय [illegible] का गहन अध्ययन किया [illegible] विचार पर स्पष्ट प्रभाव [illegible] उन्होंने अपने चिन्तन में [illegible] व्यापक तथा [illegible]

[illegible] है।

[illegible]

Name of Teacher	Topic/Field of Research	Journal/Book
Dr. Sushila Devi Chauhan	Human Rights with Special Reference to Juvenile Justice in India	Book Edited on Human Rights in India Issues and Perspective, 2023 (Ist Ed.), P. 1-13
Pooja, Asst. Professor, Dept. of Law, K.U.K	'Wife's Right To Maintenance Under Protection Of The Women From Domestic Violence Act, 2005	Contemporary Indian Laws: Issues And Challenges (Edited by- Dr. Archana Vashishth, Anuranjan Sharma, Dr. Sakshi) KAAV Publication
Pooja, Asst. Professor, Dept. of Law, K.U.K	'Human Rights For Disable Persons	Human Rights in India: Issues and perspectives' (Edited by Prof.(Dr.) Sushila Devi Chauchan and Dr. Promila)

Name of Teacher	Name of Conference /Seminar	Place and Date	Topic of Lecture
Dr.Preety Jain	Workshop for Law Students	Kurukshetra ,10.2.2022	Gender Discrimination and Constitution of India
	Training on Women Empowerment in agriculture and allied Sector	EEI,Nilokhedi,5.3.2022	Role of Law in Women Empowerment: Issues and Challenges
	Awareness Talk	UIET,Kurukshetra,29.9.2022	Women at Workplace (Prevention,Prohibition and Redressal) Act
	Student Induction Programme-2022	UIET,Kurukshetra,19.10.2022	Human Values
	3 Day ICAR-HRD Training on Emotional and Social Intelligence at Workplace	IIB&WR,Karnal,15.12.2022	Legal wellbeing in Social Sphere
	Workshop on Gender Sensitization	RGSIPR&CD,Nilokhedi,23.12 .2022	Legal Provisions for empowering Women
Prof. Sushila Devi Chauhan	Human Rights: Contemporary & emerging Issues	Sri Sukhmani College of Law, Derabassi, Mohali, Punjab on 12th August 2022.	Alternate Sentencing: A Step Towards Human Right Aspect of Restorative and Reformative Justice

	India @75: Past, Present and Future.	Bharati Vidyapeeth's New Law College, Sangli, Pune on 30/06/2022.	Role of Indian Judiciary on Human Rights of Women.
	Workshop on Awareness against Drug Abuse	"Parayas Sanstha" ITI Kurukshetra, on 07th March, 2022	Drug Abuse and Its Consequences.
	Lecture on Intellectual Property Rights	DAV College for Girls, Yamuna Nagar on 31st March 2022.	Intellectual Property Rights
	Lecture on Women Empowerment	Arya P.G. College, Panipat, on 09th June 2022	Women Empowerment
	Gender Based Victimization – Theory and Practice	Saraswati Institute of Law – Palwal on 30th September 2022	Lecture on Gender Based Victimization – Theory and Practice
	World Peace Harmony: Insights from Shrimad Bhagwadagita	Kurukshetra University, Kurukshetra. on 30th November 2022	Paper Presentation on Sentencing in light of Shrimad-Bhagwat-Geeta: A Transformation
Dr. Promila	Human Rights: Contemporary & emerging Issues	Sri Sukhmani College of Law, Derabassi, Mohali, Punjab on 12th August 2022.	Paper Presentation on Human Rights and Health
	Protection of Women and Children Rights: Issues and Challenges	Law Mantra, ILI New Delhi, MNLU-Nagpur, MNLU-Aurangabad, SRM University Sonipat and VIT-AP University on 23rd July 2022.	Paper Presentation on Emerging Relevance of International Law on Elimination of Violence against Women with Special Reference to Impact of Covid-19 Pandemic
	World Peace Harmony: Insights from Shrimad	Kurukshetra University, Kurukshetra. on 30th	Paper Presentation on Bhagavad Gita and Conscience Building: An Indispensable tool for a Lawful and Just Society.

	Bhagwadagita	November 2022	
Dr. Priyanka Chaudhary	World Peace Harmony: Insights from Shrimad Bhagwadagita	Kurukshetra University, Kurukshetra on 30th November 2022	The Ethical Philosophy of Bhagavada Gita with reference to the Right to Privacy
Dr. Aarushi Mittal	World Peace Harmony: Insights from Shrimad Bhagwadagita	Kurukshetra University, Kurukshetra on 30th November 2022	Paper Presentation on Bhagwad Gita and International Humanitarian Law: An Analogy
Prof.Amit Ludri	Expert speaker	Shooloni University Solan 17th April 2023	Fundamental rights and directive principles
Prof.Amit Ludri	Guest lecture	Mahrishi Markandeshwar university Mullana Ambala 20 Sep 2023	Different Dimensions of civil Rights
Prof.Amit Ludri	Human Rights Centric approach (prospects and challenges) faculty of law	HP University shimla 30 sep 2023	Human rights and its value
Prof. Preety Jain	Student Induction Program	UIET, Kurukshetra University, Kurukshetra 18-09-2023	Prevention of Sexual Harassment of Women at Workplace
Prof. Preety Jain	One Day Workshop on Gender Sensitization	RGSPRCD, Nilokheri 18-12-2023	Legal Provisions for Empowering Women
Prof. Preety	Interactive Session on	IICWBR, Karnal	Status of Women in Post-Independence India

Jain	Status of Women	07-06-2023	
Prof. Preety Jain	One Day Seminar on Changing Role of Women in Indian Society	CSKM, Fatehpur, Pundri, Kaithal 22-09-2023	Gender Justice in India
Prof. Preety Jain	Two Week Training Programme on Research Methodology in Social Sciences for the Research Scholars/ Faculty Members	ICSSR, Panjab University 09-12-2023	Social Issues in Research in Social Sciences
Prof. Preety Jain	Two Week Refresher Course for Competence Building	Kurukshetra University, Kurukshetra 05-06-2023	Sexual Harassment of Women at Workplace
Prof. Preety Jain	ICC One Day Workshop	Kurukshetra University, Kurukshetra 10-02-2023	Gender Sensitization through Education
Prof. Preety Jain	One Day National Seminar on the Independence of Judiciary vis-a-vis Justice Delivery System in India	IILS, Ghanahatti Shimla 03-11-2023	Independence of Judiciary Introspection and Prospective Vision
Prof. Preety Jain	Lecture Series on Rights of Women	Meerut College, Meerut 05-10-2023	Gender Justice and Indian Constitution

Dr. Sushila Devi Chauhan	Organized by Department of Political Science	DAV College, Pehowa, 28.2.2023 as Resource Person	Right to Information Act, 2002 As a Tool of Good Governance
Dr. Sushila Devi Chauhan	Online Conference	Department of Law, MDU, Rohtak, Technical Session Chair on 2.3.2023	Changing Dimensions of Law and Society in Amrit Call
Dr. Sushila Devi Chauhan	Model Sanskriti School, Kurukshetra.	Department of Law, KUK, 3.4.2023	One day awareness campaign on Gender Sensitisation
Dr. Sushila Devi Chauhan	Global Sumit onSDG Goals (Online)	Swami Devi Dyal Law College, 11.7.2023 14.7.2023, Keynote Speaker	Inclusive Development
Dr. Sushila Devi Chauhan	Radio Station, Kurukshetra	Hello Kurukshetra,Akashwani, Kurukshetra, FM 101.4 Megahat, 21.7.2023, Morning 10 AM	नीति के निर्देशक तत्व और इनका क्रियान्वयन
Dr. Sushila Devi Chauhan	Effective Climate Actions for Sustainable Future (Virtual Mode) organized by Saraswati Law College,	10.8.2023-12.8.2023 Resource Person in Three Days International Conference	Sustainable Development & Environment Protection

	Faridabad.		
Dr. Sushila Devi Chauhan	Two days Training of Trainers (TOT) Programme on Women Friendly Panchayat	HIRD, Nilokheri1.8.2023	Women Empowerment Key-Acts and Constitutional Provisions
Dr. Sushila Devi Chauhan	Bridging Boundariesfor a Better World: Exploring Inclusive of people with Disability through Interdisciplinary Approach	23.9.2023 Organized by Centre for Disability Studies, MDU, Rohtak	Person with Disability in India: Need for Implementation of Right of Dignity as Human Rights
Dr. Sushila Devi Chauhan	Directorate of Prosecution Department, Haryana, Panchkula	23.10.2023, Panchkula	Proposed Amendments in New Criminal Law Bills
Dr. Sushila Devi Chauhan	Institute of Law, Kurukshetra University, Kurukshetra, OneWeek Faculty Development Programme	20.10.2023, Online	Human Rights and Criminal Justice System of India: A Critical Study
Dr. Sushila Devi Chauhan	Economics Department One Week Short Term Course	10.12.2023, Online	Gender Justice in India: Constitutional Prospective

Dr. Sushila Devi Chauhan	Institute of Management, KUK, Faculty Induction, 1.12.2023 to 20.12.2023	13.11.2023, Online	Gender Sensitization in India: Problems and Perspectives
Dr. Sushila Devi Chauhan	Internal Complaint Committee, Kurukshetra	14.12.2023, Girls Hostel Complex, KUK	Sexual harassment of Women at workplace Act, 2023
Dr.C.R.Jilova	National Seminar on Gender Equality and Women's Rights in India,	Women Cell, Ch.Ishwer Singh Mahavidyala,Pundri on dated 24.7.2023	Law Relating to Maintenance to Women in India
Dr. C.R.Jilova	Workshop on New Education Policy	University Sr.Sec.Model School as Resource Person on dated 12.8.2023	New Education Policy and Legal Literacy.
Dr.C.R.Jilova	National Seminar on Human Rights centric approach(Prospects and Challenges	Department of law, H.P. University, Shimla on 30.09.2023	Human Rights
Dr.C.R.Jilova	Refresher Course on Human Rights	Institute of law and MMTTC, K.U.Kurukshetra,dated.21.10.2023	Human Rights in the background of current Socio-Legal Milieu in India
Dr.C.R.Jilova	Refresher Course on Research Methodology in Social Sciences	Department of Economics and MMTTC, K.U. Kurukshetra, dated 30.11.2023	Ragging in India: Understanding, consequences and Remedies

Dr.Mahabir Singh	National Seminar on Human Rights centric approach(Prospects and Challenges)	Department of law, H.P. University, Shimla on 30.09.2023	Role of NHRC in protection of Human Rights
Dr.Mahabir Singh	Refresher Course on Human Rights	Institute of law and MMTTC, K.U.Kurukshetra,dated.21.10.2023	Human Rights
Dr.Mahabir Singh	Refresher Course on Social Sciences	Institute of Management and MMTTC, K.U.Kurukshetra,dated.21.12.2023	Uniform Civil Code
Dr. Dipti Choudhary	Resource Person for One-day National Webinar on 'Gender Equality and Women's Right in India'	Women Cell, Ch. Ishwar Singh Kanya Mahavidyalaya , Fatehpur, Pundri on 27 th April 2023	" Women's Rights and Relevance of Consent in Marital Relations"
Dr. Dipti Choudhary	Resource Person for One -day State -level Student Seminar on 'Expected Economic and Political Outcomes of G-20 Summit 2023'	Organised by Arya Kanya Mahavidyaliya, Shahabad Markanda on 27th September, 2023	"Expected Economic and Political Outcomes of G-20 Summit 2023"
Dr. Dipti Choudhary	Presented Paper in the International Gita Seminar on 'Vasudhaiva	Organised by Department of Social Work , K.U.K on 18th December 2023.	"Ingrained Values of Vasudhaiva Kutumbkam in Indian legal System"

	Kutumbakam: Srimad Bhagavad Gita and Global Unity'		
Dr. Dipti Choudhary	Presented Paper in ICSSR Sponsored International Seminar	Organised by Centre for B.R Ambedkar studies K.U.K on 22nd September 2023	"Significance of Dr B.R Ambedkar's view on Constitutional Morality in Contemporary Bhart"
Dr. Promila	Sustainable Environment: Society, Governance and Law	Rayat College of Law, S.B.S Nagar, Punjab 22nd Feb. 2023	Role of Law and Governance in Technology and Innovation for Sustainable Development
Dr. Promila	Right to Information Act-2005- As a tool of Good Governance	D.A.V. College, Pehowa 28th Feb. 2023	RTI and Consumer Rights
Dr. Promila	Changing Dimensions of Law and Society in Amrit Kaal	M.D.U Rohtak 2nd March, 2023	Role of National Human Right Commission in Amrit Kaal- A Critical Analysis
Dr. Promila	Bridging Boundaries for a Better World: Exploring Inclusion of People with Disability through Interdisciplinary Approach	M.D.U Rohtak 23rd September,2023	Transforming Challenges of Acid-Attack Victims into Triumphs

Dr. Promila	Vasudhaiva Kutumakam: Srimad Bhagavad Gita and Global Unity	K.U.Kurukshetra 17th -19th December,2023	Aiding Nations in Times of Distress: The Spirit of Vasudhaiva Kutumbakam
Dr. Promila	Gender Sensitization	University Sr. Sec. School, K.U.K 3rd April,2023	Gender Sensitization
Dr. Promila	Gender Sensitization	Govt. Sr. Sec. School. Vill. Bilahi, Kurukshetra 4th August,2023	Gender Sensitization
Dr. Aarushi Mittal	One Day National Seminar on Sustainable Environment: Society, Governance and Law	Organized by Rayat College of Law, SBS Nagar, Punjab on 22nd February, 2023	Crimes Against Environment vis a vis Role of International Criminal Law
Dr. Aarushi Mittal	National Conference on Constitutional Law of India: Emerging Issues and Challenges	Organized by Siddhartha Law College, Dehradun on 15th-16th April 2023	Secularism in the Indian Context: An Analysis
Dr. Priyanka Chaudhary	National Conference Organized by Siddhartha Law College	Dehradun15th-16th April 2023	A Comparative analysis of Euthanasia with reference to Article 21 of Indian Constitution
Dr. Priyanka Chaudhary	International Conference on 'Law and the	March 31st and April 1st, 2023	Standard Of Uniform Civil Code in India Vis – a – Vis The Indian Personal Laws: A Critical Analysis

	Contemporary Trends', organized by Sharda School of Law, Sharda University and Adelaide Law School, University of Adelaide, Australia		
Pooja, Asst. Professor, Dept. of Law, K.U.K	2 days International Conference	Bhagat Phool Singh Mahila Vishwavidyalaya March 24-25,2023	Paper presented "Pedagogical Innovation:NEP 2020"
Pooja, Asst. Professor, Dept. of Law, K.U.K	Gender Sensitisation	University Model School ,Kurukshetra, April 3,2023	Gender Sensitisation
Pooja, Asst. Professor, Dept. of Law, K.U.K	Legal Awareness Camp on Gender Senstisation	Government Sr. Sec. School, Balahi,Kurukshetra, August 4,2023	Gender Sensitisation
Pooja, Asst. Professor, Dept. of Law, K.U.K	National E-Seminar on 'Contemprory Indian Laws:Issues and challenges	School of Legal Studies at Apeejay stya University, Gurugram, May 20,2023	Paper presented on "Wife right to maintenance under Protection of Women from Domestic Violence Act,2005
Pooja, Asst. Professor, Dept.	National seminar on "Independence of	IILS Ghanahatti, Haridevi Shimla,	Paper presented on the topic of 'Judicial Activism'

of Law, K.U.K	Judiciary vis-à-vis Justice Delivery System in India"(Introspection and Prospective vision)	Nov. 3,2023	
Pooja, Asst. Professor, Dept. of Law, K.U.K	8th International Geeta Seminar,2023	K.U.K, Dec18,2023	Paper presented 'Srimadbhagvada Gita : A Cornerstone In Global Unity'

CHAPTER 8

Metabolism of Lipids in Malignant Solid Tumors Hypoxia and Drug Targets

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ABSTRACT

The abrupt metabolism of glucose is a well-known hallmark of malignancy in hypoxic cancer cells, whereas little is known about lipid metabolism. Recent work has documented the role of lipid in the pathogenesis of cancer cells. As lipid are the important building blocks of cells like plasma membrane, hence needed in much more amounts in rapidly dividing cancer cells. Lipids are also utilized in energy production for emergencies like starvation, hence stored as triglycerides in the adipose tissue. Lipids also serve as important signaling molecules like steroidal hormones (testosterone, estrogen, progesterone). In normal cells, *de novo* fatty acid biosynthesis and dietary fats are the only sources of fatty acid in which occurs at a normal pace. Extra glucose as if

Therapeutic Platform of Bioactive Lipids: Focus on Cancer. Manjari Singh, PhD (Ed.)