RATIONAL DISCOURSE

Vol. 30 No. 1 December 2024

A Multidisciplinary Journal
of Current Research
and Studies

Mar Thoma College, Tiruvalla
Kerala - 689 103
Tel: 0469 - 263 0342

Rational Discourse

A Multidisciplinary Refereed Journal of Current Research and Studies

December 2024

ISSN 0972 – 2955

Edited by Dr Remi Cherian George, Chief Editor of Rational Discourse on behalf of Mar Thoma College, Tiruvalla.
Typesetting and Printing : Evangel Press, Tiruvalla.
Ph. 0469 2630223

Rational Discourse

National Reg. No. 2493/96

ISSN: 0972-2955

RATIONAL DISCOURSE is a peer-reviewed, multidisciplinary research journal of Mar Thoma College, Tiruvalla, which has been re-accredited with an A grade by NAAC. Original research articles adhering to the latest APA guidelines are invited from faculty members and research scholars of university departments and affiliated colleges.

CONTENTS

A Discussion on the Impact of Electromagnetic Waves on Flora and Fauna

Kezia Mariam Reji, [1] Ens Mathews, [*, 1, 2] and Samuel Mathew [2, 3]

Abstract: The increasing use of wireless technologies is raising health concerns among the public. Low-frequency electromagnetic fields affect seed germination, plant growth and stress resistance. Research indicates that the non-thermal effects of electromagnetic radiation disrupt various biological systems, leading to significant changes in biological processes and overall body function. Many review papers have concluded that observational studies on long-term effects focusing on EMR are scarce as they are very challenging to conduct, and more studies must be performed before drawing specific conclusions. We must continue to investigate the long-term effects of EMR on flora and fauna, particularly regarding the impacts of new technologies, such as 5G networks, on flora and fauna.

Key words: Electromagnetic waves, Wireless technology, Flora, Fauna

Introduction

Electromagnetic waves (EMWs) are fundamental aspects of the physical world and play an important role in many natural phenomena and technological applications. EMWs are electric and magnetic fields oscillating through space and have a broad spectrum ranging from low-frequency radio waves to high-frequency gamma rays. Natural sources of EMWs include celestial bodies such as stars and other astronomical phenomena like pulsars and black holes, lightning strikes that generate radio waves, and thermal radiation from heated objects that produce infrared waves. Artificial sources of EMWs include radio transmitters, microwave ovens, light bulbs, and medical imaging equipment. In this paper, we explore the findings of various studies conducted on the effects of EMWs on flora and fauna.

[1] Department of Physics, Bishop Abraham Memorial College, Mallappally, Thuruthicad PO, India.
[2] Department of Physics Mar Thoma College, Tiruvalla, India
[3] University Institute of Technology, University of Kerala, Karuvatta PO, Alapuzha – 690517, Kerala, India
[*] Correspondence: Tel: +91 9447116906, E-mail: ens.mathews@bamcollege.ac.in

Historical Context

James Clerk Maxwell's groundbreaking work laid the foundation for understanding electromagnetic radiation (EMR). His formulation of the classical theory of electromagnetism in the 19th century remains a cornerstone of our understanding of EMWs (Maxwell, 1865). As the 20th century progressed, new technologies and methodologies allowed researchers to explore the effects of EMR on living organisms. Early investigations focused on the potential health impacts of radiofrequency radiation, particularly with the proliferation of radio and later television broadcasts. In the latter half of the 20th century, sophisticated tools, such as spectrophotometers and advanced imaging techniques, enabled scientists to study mechanisms by which EMR interacts with biological tissues. This period saw an increased interest in the effects of non-ionising radiation, including microwaves and radiofrequency fields, as mobile communication technologies emerged (Hauf & Wiesinger, 1973; Markov, 1988; Michaelson, 1974).

A significant shift in research focus occurred in the 21st century. Now, studies mainly concentrate on the effects of electromagnetic exposure due to rapidly expanding wireless technologies and their environmental implications. The effects of Wi-Fi radiation have evolved with each generation of technology, from GSM to 5G, primarily due to changes in frequency and power levels. Earlier generations, like GSM and 2G, operated at lower frequencies and power levels, causing thermal effects (Kouzmanova et al., 2010). However, as technology advanced to 3G, 4G, and 5G, the frequency bands have increased, introducing new biological effects beyond thermal impacts. This shift has raised concerns about potential health risks, particularly with the introduction of 5G, which uses higher-frequency millimetre waves (Perov & Lifanova, 2024).

Effects on Flora

Low-frequency electromagnetic fields (LF-EMFs) have been studied for their potential effects on seed germination, plant growth and stress resistance. These effects of EMR on plants are believed to be due to its influence on biochemical pathways and alteration in gene expression (Kostyn et al., 2023; Vian et al., 2016). Some studies indicate that exposure to LF-EMFs can lead to faster germination, enhanced growth rates, and improved anatomical characteristics of plant stems (Sabu et al., 2018). According to Mshenskaya et al. (2023), LF-EMF exposure

can protect against environmental stressors like drought. Heredia-Rojas et al. (2023) report that LF-EMF exposure can potentiate the plant's oxidative defence system. Some studies also indicate the harmful effects of plant exposure to non-thermal, weak radiofrequency electromagnetic fields (RF-EMFs) due to their varied effects on calcium metabolism and stress proteins (Halgamuge, 2017). Adverse effects on seed germination and other growth-related parameters like root and shoot length, leaf length, leaf width, leaf area index and fresh weight are also reported (Nikalje & Rajam, 2021). Another study showed that continuous exposure to RF-EMF radiation can potentially cause cytotoxic and genotoxic effects in root meristems of onions (Chandel et al., 2019).

Effects on Fauna

Theoretical and experimental evidence suggests that even weak interactions between EM energies and cells can significantly affect cell function and development (Rouleau & Dotta, 2014). Research indicates that the non-thermal effects of electromagnetic radiation (EMR) disrupt various biological systems, including sexual, nervous, endocrine, and immune systems, leading to significant changes in biological processes and overall body function (Karipidis et al., 2023). Birds and marine animals rely on the Earth's geomagnetic fields for navigation. Interference from artificial EMF sources can lead to disorientation and impaired migration patterns (Levitt et al., 2022). When exposed to RF waves, birds have been observed to exhibit erratic flight patterns (Surendran et al., 2020). EMF exposure has been linked to reduced reproductive success in various species, including impacts on mating behaviours, nest building, and overall reproductive health (Levitt et al., 2022).

Though many studies report the harmful effects of EMR, it is observed that they can have therapeutic effects in controlled conditions. Pirogova et al. (2009) report that non-ionising EMR stimulates physiological processes like bone repair, nerve stimulation, tissue regeneration, wound healing, and immune system stimulation.

Status of Regulatory Framework

Since 1998, the International Commission on Non-Ionizing Radiation Protection (ICNIRP) maintains that there is no evidence of adverse biological effects of RFR, other than tissue heating at exposures above prescribed thresholds. In contrast, in 2011, an expert working group of

the International Agency for Research on Cancer (IARC) categorised RFR emitted by cell phones and other wireless technology devices as a Group 2B human carcinogen. At the time of writing this paper, 45 countries have issued policies and health recommendations concerning exposure to RFR. Countries like India, China, and Russia have lower allowed limits as they recognise the biological effects of EMR. In 2012, India dropped its RF limits by 1/10th of what they were previously after an inter-ministerial report documented that most research studies found damage to birds and bees. Numerous countries have set maximum permissible RFR limits 10 to 100 times below ICNIRP and FCC limits for cell tower networks or have policies to reduce exposure near sensitive areas. As the transition to higher frequencies in 5G has raised significant health concerns, it is important to note that safety guidelines established by regulatory bodies like ICNIRP and IEEE are designed to protect against known thermal effects, though the non-thermal effects remain a topic of ongoing research and debate (Makharadze et al., 2023). Karipidis et al. (2023) note that there is a lack of international guidelines to protect plants and animals from RF-EMF exposure, unlike the guidelines for human protection.

Discussion

Studies have reported negative and positive effects of EMR on flora and fauna. Many review papers have concluded that observational studies on long-term effects focusing on EMR are scarce as they are very challenging to conduct, and more studies must be conducted before drawing specific conclusions (Dongus et al., 2022). As electromagnetic environments and biological systems are complex, more investigation is required to understand the biological effects of EMR (Liu et al., 2024). It is important to consider the potential benefits these technologies bring to our society and find a balance through regulations that ensure the protection of our ecosystem (Surendran et al., 2020).

Conclusion

Studies have provided many results that help to understand the effects of RF-EMF on flora and fauna. However, due to shortcomings in methodology and focus on a few species and frequencies of EMRs are limitations. The full extent and mechanisms of these effects are not fully understood. There remains a need for further research, particularly regarding the non-thermal effects of long-term exposure. While there

is evidence of potential adverse effects of low-intensity EMF on flora and fauna, the increasing use of wireless technologies may raise health concerns among the public. We must continue to investigate the long-term effects of EMR on flora and fauna, particularly regarding the impacts of new technologies, such as 5G networks, on flora and fauna.

References

Calvente, I., & Núñez, M. I. (2024). Is the sustainability of exposure to non-ionizing electromagnetic radiation possible? *Medicina Clínica, 162*(8), 387–393.

Chandel, S., Kaur, S., Issa, M., Singh, H. P., Batish, D. R., & Kohli, R. K. (2019). Exposure to mobile phone radiations at 2350 MHz incites cyto- and genotoxic effects in root meristems of Allium cepa. *Journal of Environmental Health Science & Engineering,* 17(1), 97–104.

Dongus, S., Jalilian, H., Schürmann, D., & Röösli, M. (2022). Health effects of WiFi radiation: A review based on systematic quality evaluation. *Critical Reviews in Environmental Science and Technology, 52*(19), 3547–3566.

Halgamuge, M. N. (2017). Review: Weak radiofrequency radiation exposure from mobile phone radiation on plants. *Electromagnetic Biology and Medicine, 36*(2), 213–235.

Hauf, R., & Wiesinger, J. (1973). Biological effects of technical electric and electromagnetic VLF fields. *International Journal of Biometeorology, 17*(3), 213–215.

Heredia-Rojas, J. A., Gallardo, E., & Quistian-Martínez, D. (2023). Low-frequency electromagnetic fields increase oxidative stress in tobacco plants. *Emirates Journal of Food and Agriculture*, 139–144.

Karipidis, K., Brzozek, C., Mate, R., Bhatt, C. R., Loughran, S., & Wood, A. W. (2023). What evidence exists on the impact of anthropogenic radiofrequency electromagnetic fields on animals and plants in the environment: A systematic map. *Environmental Evidence, 12*(1),9.

Kostyn, K., Boba, A., Kozak, B., Sztafrowski, D., Widu³a, J., Szopa, J., & Preisner, M. (2023). Transcriptome profiling of flax plants exposed

to a low-frequency alternating electromagnetic field. *Frontiers in Genetics, 14*, 1205469.

Kouzmanova, M., Dimitrova, M., Dragolova, D., Atanassova, G., & Atanassov, N. (2010). Effects of prolonged exposure to GSM900 electromagnetic fields on enzyme activity in leaves of peas (PISUM SATIVUM L.). *Agricultural Sciences, II*(4), 109–114.

Levitt, B. B., Lai, H. C., & Manville, A. M. (2022). Effects of non-ionizing electromagnetic fields on flora and fauna, Part 2 impacts: How species interact with natural and man-made EMF. *Reviews on Environmental Health, 37*(3), 327–406.

Liu, L., Huang, B., Lu, Y., Zhao, Y., Tang, X., & Shi, Y. (2024). Interactions between electromagnetic radiation and biological systems. *iScience, 27*(3), 109201.

Makharadze, S., Mikashavidze, R., Gvagvalia, T., & Eradze, G. (2023). Electromagnetic radiation safety issues of the fifth generation (5G) mobile networks. *Georgian Scientists, 5(4), 322–334.*

Markov, M. S. (1988). Electromagnetic Fields—A New Ecological Factor. In M. Markov & M. Blank (Eds.), *Electromagnetic Fields and Biomembranes* (pp. 135–140). Springer US.

Maxwell, J. C. (1865). VIII. A dynamical theory of the electromagnetic field. *Philosophical Transactions of the Royal Society of London, 155,* 459–512.

Michaelson, S. M. (1974). Effects of Exposure to Microwaves: Problems and Perspectives. *Environmental Health Perspectives, 8,* 133–155.

Mshenskaya, N. S., Grinberg, M. A., Kalyasova, E. A., Vodeneev, V. A., Ilin, N. V., Slyunyaev, N. N., Mareev, E. A., & Sinitsyna, Y. V. (2023). The Effect of an Extremely Low-Frequency Electromagnetic Field on the Drought Sensitivity of Wheat Plants. *Plants, 12*(4), 826.

Nikalje, G., & Rajam, P. (2021). Wi-Fi Radiation Negatively Influences Plant Growth and Biochemical Responses of *Capsicum annuum* L var. Pusa Jwala. *Current Chemical Biology, 15*(2), 182–187.

Perov, S. Yu., & Lifanova, R. Z. (2024). 2-5G electromagnetic field biological effect by oxidative stress investigation on animals: Exposure and aftereffects. *"Radiation and Risk" Bulletin of the National Radiation and Epidemiological Registry, 33*(2), 57–64.

Pirogova, E., Vojisavljevic, V., & Cosic, I. (2009). Biological Effects of Electromagnetic Radiation. In C. A. B. De Mello (Ed.), *Biomedical Engineering.* InTech.

Rouleau, N., & Dotta, B. T. (2014). Electromagnetic fields as structure-function zeitgebers in biological systems: Environmental orchestrations of morphogenesis and consciousness. *Frontiers in Integrative Neuroscience, 8.*

Sabu, A., Dave, P., &J ain, N. K. (2018). Static electromagnetic field (emf) of low frequency enhances seed germination and plant growth at early stages of development. *Journal of Experimental Biology and Agricultural Sciences, 6*(6), 966–972.

Surendran, N. S., Siddiqui, N. A., Mondal, P., & Nandan, A. (2020). Repercussion of Electromagnetic Radiation from Cell Towers/ Mobiles and Their Impact on Migratory Birds. In N. A. Siddiqui, S. M. Tauseef, S. A. Abbasi, & F. I. Khan (Eds.), *Advances in Air Pollution Profiling and Control* (pp. 193–202). Springer Singapore.

Vian, A., Davies, E., Gendraud, M., & Bonnet, P. (2016). Plant Responses to High Frequency Electromagnetic Fields. *BioMed Research International, 2016,* 1–13.

A Checklist of Fish Species in the Achankovil River in the Upper Kuttanad Region, Kerala

Ruby Thomas[1] and Raju Thomas K.[2]

Abstract: We conducted a survey on the fish species present in the Achankovil River between February and July 2022, with a focus on the Upper Kuttanad area. Our study revealed a total of thirty freshwater fish species, belonging to ten orders, fifteen families, and twenty-one genera. We classified these species into three groups, namely cultivable fishes, food fishes, and ornamental fishes. Cyprinidae was the most abundant with seven species, followed by Bagridae (three species). As per the IUCN Red List, most of the identified species were Least Concern (25 species), while three species were classified as Vulnerable, and one as Near Threatened. Additionally, three percent of the species were considered data deficient.

Key words: Ichthyofauna, Achankovil River, Upper Kuttanad, Conservation status

Introduction

Fishes represent the highest species diversity among vertebrates and inhabit a wide range of aquatic habitats. Freshwater fish play vital roles in aquatic ecosystems, influencing nutrient cycling, species interactions, and ecosystem stability. They are excellent indicators of environmental integrity and respond to various stressors such as pollution and habitat degradation. The Achankovil River, flowing through the Upper Kuttanad region of Kerala, India, is a vital aquatic ecosystem renowned for its rich biodiversity and ecological significance. The Upper Kuttanad region, characterised by its intricate network of rivers, streams, and backwaters, provides a unique habitat mosaic for freshwater organisms. Despite its ecological importance, the fish diversity of the Achankovil River in the Upper Kuttanad region remains relatively understudied.

[1]Research Scholar, Department of Zoology, Mar Thoma College, Tiruvalla
[2]Associate Professor and Research Guide in Zoology, Mar Thoma College, Tiruvalla
*Correspondence: rubythomas92@gmail.com

Numerous studies have been conducted on the diversity of fish fauna in water bodies located in Kerala. The Kabini River in the Wayanad region of the Western Ghats is home to 136 different species of fish, representing 29 families, 13 orders, and 69 taxa (Dencin *et al.,* 2021). 35 fish species were identified by Sobha *et al.,* (2016) in the upper Kuttanad area. There are 60 species of fish reported by Renjith et al., (2011) from the Pamba River; 26 species from 5 orders and 21 genera made up the exploited fishery. Vijayasree and Radhakrishnan (2014) identified 62 freshwater fishes from 17 families from the River system of Kuttanad. According to Athira et al., (2020), fish species from the Anjarkandy River in the Kannur District were found to number about sixty-three, and they belonged to 40 genera and 28 families. Swapna (2009) and Sojomon (2022) studied the ichthyofaunal diversity of the Achankovil and Meenachil Rivers, respectively. The present study aims to investigate the freshwater fish diversity in the Upper Kuttanad areas of the Achankovil River and determine the conservation status of collected fishes.

Materials And Methods

Study Area

The Achankovil (or Achenkovil) is one of the major rivers in Kerala, originating from the southern tip of the peninsula by the Rishimala, Pasukidamettu, and Ramakkalteri rivers. Achankovil is a 128 km long west-flowing river that flows through Kollam, Pathanamthitta, and Alappuzha districts. During the ichthyofaunal survey, two stations (Karichal and Cheruthana) from the downstream region of the Achankovil, located in the Upper Kuttanad region of Kerala were selected. Ichthyofaunal samplings were conducted from February to July 2022.

Ichthyofaunal Survey

Fish sampling was conducted using both a gill net and a cast net. After collection, the fish were washed in water to remove any sand or mud particles that were attached to them. Next, they were preserved in a 10% formalin solution. The identification of the fish was carried out using the references Talwar and Jhingran (1991), Jayaram (2010), and Froese and Pauly (2022). The status of threat for fish was determined by referring to the IUCN's (2022) classification. The economic status of fish (cultivable/ornamental/food fish) was also noted.

Result And Discussion

A total of 30 fish species from 10 orders, 15 families, and 21 genera were found in the Karichal and Cheruthana stations of the Achankovil River during the study period. Vishnu et al., (2023) listed 35 fish species from a perennial tributary of the Achankovil River in Kerala. The list of collected fish, their economic importance, and their current status as per IUCN criteria is given in Table 1.

Table 1: Systematic list, economic importance, and threat status of fishes recorded from study stations of Upper Kuttanad of Achenkovil River, Kerala.

Sl. No.	Name of Species	Cultivable/ Ornamental/ Food fish	Threat Status (as per IUCN)
	Order: Siluriformes		
	Family: Heteropneustidae		
1	Heteropneustes fossilis	F	LC
	Family: Siluridae		
2	Ompok bimaculatus	F	NT
3	Wallago attu	F	VU
	Family: Bagridae		
4	Horabagrus brachysoma	F	VU
5	Mystus gulio	F	LC
6	Mystus vittatus	F	LC
	Order: Anabantiformes		
	Family: Pristolepididae		
7	Pristolepis marginata	F	LC
	Family: Channidae		
8	Channa marulius	F	LC
9	Channa striatus	F	LC
	Family: Nandidae		
10	Nandus nandus	O	LC
	Family: Anabantidae		
11	Anabas testudineus	F	LC
	Order: Cypriniformes		
	Family: Cyprinidae		

12	Catla catla	C	LC
13	Labeo rohita	F	LC
14	Cirrhinus mrigala	F	VU
15	Amblypharyngodon melettinus	F	LC
16	Rasbora daniconius	O	LC
17	Puntius chola	O	LC
18	P. filamentosus	O	LC
19	P. fasciata	O	LC
20	P. sarana	F	LC
	Order: Cichliformes		
	Family: Cichlidae		
21	Etroplus suratensis	F	LC
22	E. maculatus	O	LC
	Order: Beloniformes		
	Family: Hemiramphidae		
23	Hyporhamphus limbatus	F	LC
	Family: Belonidae		
24	Xenentodon cancila	F	LC
	Order: Elopiformes		
	Family: Megalopidae		
25	Megalops cyprinoides	F	DD
	Order: Synbranchiformes		
	Family: Mastacembelidae		
26	Mastacembelus armatus	F	LC
	Order: Clupeiformes		
	Family: Engralidae		
27	Stolephorus commersonni	F	LC
28	S. indicus	F	LC
	Order: Perciformes		
	Family: Ambassidae		
29	Ambassis sp.	O	LC
	Order: Gobiiformes		
	Family: Gobiidae		
30	Glossogobius giuris	F	LC

The present study indicates that the fish fauna of the river Achankovil is composed majority of cyprinids. Fibin et al., (2011) also reported dominancy of Cyprinids from the Achankovil River. Seven species from the Cyprinidae family, out of the thirty collected species, formed a major portion of the fish fauna. Bagridae constituted three fish species. Majority of the ichthyofaunal families are composed of one species each. The collected ichthyofauna from the study area constituted most of the edible, cultivable, and ornamental fishes. Eight species are found to be ornamental, one species cultivable, and 19 species were food fishes. Catla catla and Labeo rohita are popular among food fishes and cultivable fishes. Nandus nandus from family Nandidae is considered as an ornamental fish. The state fish of Kerala Etroplus suratensis is endemic to Penisular India and Sri Lanka (Padmakumar et al., 2012).

According to IUCN criteria, fish species such as Cirrhinus mrigala, Horabagrus brachysoma, and Wallago attu are vulnerable (VU), while Ompok bimaculatus is the only species noted as nearly threatened (NT) from the stations. Megalops cyprinoides categorised under the data deficient (DD) group. The majority of the ichthyofaunal members were grouped under the least concern (LC) category in the present diversity study in the Achankovil River system. From the thirty species identified, the dominant portion was Least Concern (25), followed by Vulnerable (3), and near threatened (1). The percentage compositions of the Least Concern, Vulnerable, and near threatened and data deficient categories were found to be 83%, 10%, 4%, and 3%, respectively. No species with endangered status were found at the stations studied. Alarmingly, no species with critically endangered status were noticed during the study period.

Parental care was found in some of the identified fishes from the family Cichlidae. They construct shallow, basin-like nests by removing pebbles and stones from the bottom. In cichlids, usually, male and female parents guard the egg till hatching. Young orange chromides feed on the mucous coating of their parents; this is essential for the small fry's survival. During the feeding period, the parent fish mucous glands increase by 34% (Balshine and Abate, 2021).

Conclusion

The ichthyofaunal survey of the Achankovil River in the Upper Kuttanad region of Kerala revealed a diverse assemblage of fish species,

with representatives from multiple families, genera, and orders. Analysis of the collected data highlighted the importance of the Achankovil River as a critical habitat for freshwater fish biodiversity in the region. The river's ecological significance extends beyond its role as a waterway, serving as a refuge for numerous fish species and contributing to the overall health and resilience of the aquatic ecosystem. The ichthyofaunal survey of the Achankovil River represents a crucial step towards better understanding and conserving the freshwater biodiversity of Kerala's Upper Kuttanad region.

Acknowledgement

We express our gratitude to the natives whose invaluable assistance greatly facilitated the fish collection process throughout the study. Additionally, we extend our heartfelt appreciation to Devika D., a postgraduate student at St. Aloysius College, Edathua, for her significant contribution to this fish survey.

References

Athira, N., and Jaya, D.S. (2020). Fish Diversity of Anjarakandy River in Kerala, South India. *Journal of Aquatic Biology & Fisheries,* 8: 19-25.

Balshine, S., and Abate, M.E. (2021). Parental Care in Cichlid Fishes. *In:* Abate, M.E., Noakes, D.L. (eds) The Behavior, Ecology and Evolution of Cichlid Fishes. Fish & Fisheries Series, vol 40. Springer, Dordrecht. https://doi.org/10.1007/978-94-024-2080-7_15

Dencin, T., Sethu, M.R., Paul, M., and Shaji, C.P. (2021). Ichthyofaunal diversity in the upper-catchment of Kabini River in Wayanad part of Western Ghats, India. *Journal of Threatened Taxa,* 13: 17651-17669.

Fibin, B., Josin, T., Siby, P., Anvar, A., and Rajeev, R. (2011). Checklist of the fishes of the Achankovil forests, Kerala, India with notes on the range extension of an endemic cyprinid Puntius chalakkudiensis. *Journal of Threatened Taxa,* 3: 1936-1941.

Froese, R. and Pauly, D. (2022). Fishbase. World Wide Web electronic publication. Available at online http:/fishbase.in/.

IUCN. 2022. The IUCN Red List of Threatened Species. Version 2022-1. Available at online https://www.iucnredlist.org.

Jayaram, K.C. (2010). The Freshwater Fishes of the Indian Region. Narendra Publishing House, Delhi.

Padmakumar, K., Bindu, L.K., and Manu, P. (2012). *Etroplus suratensis* (Bloch), the State Fish of Kerala. *Journal of biosciences,* 37: 925-931.

Renjithkumar, C.R., Harikrishnan, M., and Madhusoodana Kurup, B. (2011). Exploited fisheries resources of the Pampa River, Kerala, India. *Indian J. Fish.*, 58(3): 13-22.

Sobha Merina George, Raju Thomas, and Joe Prasad Mathew. (2016). A study on fish diversity of Upper Kuttanad, Kerala. *Journal of Aquatic Biology & Fisheries,* 4: 169-171.

Sojomon, M. (2022). A Study on the Ichthyofauna diversity of Meenachil River, Thazhathangady Region, Kottayam, Kerala. Int. J. Adv. Res. Biol. Sci., 9(2): 42-51.

Swapna, S. (2009). Fish diversity in Achenkovil River, Kerala, India. *J. Bombay Nat. Hist. Soc.,* 34: 56-61.

Talwar, P.K., and Jhingran, A.G. (1991). Inland Fishes of India and Adjacent Countries, Vol. I & II. Oxford and IBH Co. Pvt. Ltd, New Delhi.

Vijayasree, T.S., and Radhakrishnan, M.V. (2014). Fish Diversity of Kuttanad River, Kerala State, India. *International Journal of Fisheries and Aquatic Studies,* 1(6): 55-58.

Vishnu, A.S., Lal, M., Tharian, J.C., Prabhakaran, M.P., and Anvar Ali, P.H. (2023). Diversity, distribution, and conservation status of fish species in Kallar Stream, Achankovil River, Western Ghats of Kerala, India. *Journal of Threatened Taxa,* 15(5): 23

Study on Optimization of Conditions for Phenol-Degradation by Selected *Bacillus cereus strains*

Santhikrishna V[1] and Anilkumar K K[2]

Abstract

Phenol, is a toxic environmental pollutant that is produced naturally as well as synthetically in the environment. In this study, three strains of Bacillus cereus capable of phenol degradation were selected. This study aims to optimize the conditions suitable for maximum degradation of phenol by the selected strains using minimal salt phenol medium (MSPM). Parameters such as p^H, temperature, concentration of substrate, amount of inoculum and the number of incubation days were studied. It was observed that the p^H varies for each strain. Temperature was identified to be ranging from 32^0C to 42^0C. The total number of incubation days was observed to be three days (72 hrs) for all the strain. Optimum substrate concentration was different for the three strains with 10mM/ml for RM23 (65.11%), 60mM/ml for RC29 (38.0%) and 80mM/ml for RM4 (33.33%). The optimum p^H was 5 for RM4 and RM23, and 7 for RC29. It was also observed that there is no strict relationship between the amount of inoculum and the rate of degradation. The capacity of the strains to utilize phenol as a carbon source can be suggested as a promising tool for the biodegradation of phenol contaminated wastewater or effluents.

Key Words: phenols; biodegradation; Bacillus; p^H; temperature; substrate concentration; incubation period

1. Introduction

Phenolic compounds are widespread in the environment. They are formed naturally during the decomposition of various substances of plant and animal origin, mainly polymers containing aromatic rings. Phenolic acids, such as O-coumaric acid, caffeic acid, ferulic acid, P-coumaric acid, P-hydroxy benzoic, syringic and vanillic acids are commonly found in plant tissues and the soil in which the plants are cultivated. Phenolic

[1]Dr. 1Research scholar, Post Graduate and Research Department of Botany, Mar Thoma College, Tiruvalla-689111, Pathanamthitta, Kerala, India; Tel: +91 9645058575; E-mail: santhikrishnakannavathu@gmail.com (Corresponding author)
[2]Associate Professor, Department of Botany, NSS Hindu College, Changanasserry-686102, Kottayam, Kerala, India; Tel: +91 9400231121; E-mail: anilkrish09@gmail.com

compounds are the typical by-products of any industrial process, such as the manufacture of dye and dye intermediate industries, plastics, drugs, explosives, antioxidants, paper and petroleum industries, and rubber production and processing industries. Phenols itself is an established disinfectant and germicide used by household cleaners. These are discharged along with the effluents from several categories of industries such as textiles, woolen mills, coke ovens, pulp and paper industries, iron and steel plants, petrochemicals, paint industries, resins, cosmetics, oil-drilling and gas extraction units, pharmaceuticals, coal washeries, refractory industries etc. and enters into various environmental matrices.

Phenols may be released into the soil or sediments during the manufacturing process when spills occur during loading, transport and leaching from hazardous waste sites and landfills. Phenols that leach through the soil to groundwater spend at least some time in that soil as they travel to groundwater. Organic contamination prompted by high organic content in aquatic ecosystems and eutrophication are the two sorts of substantial and long-lasting pollution dangers of water bodies. Organic pollutants are derived from farm water, industrial effluents, urban run-off and domestic sewage (Muthanna and Afaf, 2018). Phenols are toxic, carcinogenic, mutagenic and teratogenic. Unfortunately, phenols and phenolic compounds have now become a common environmental pollutant found in potable water, soil or sediments and ambient air. Eleven phenolic compounds are included in the list by the United States Environmental Protection Agency (USEPA, 2014) and European Commission (EC) as priority pollutants. Other national-level regulatory bodies, such as the Ministry of Environment and Forests (MoEF) and the Central Pollution Control Board (CPCB) under the Government of India, also listed phenols and phenolic compounds as the priority pollutants. In India, the regulatory actions for phenols and phenolic compounds were contemplated under the Environmental (Protection) Rules, 1986, under which several environmental standards for the discharge of phenols and phenolic compounds in industrial effluent have already been notified. A large number of phenolic compounds are subjected to regulations for air and water pollutants around the world. Many are persistent in the environment. Therefore, it is essential to control and monitor the use of phenols and their proper treatments.

Many microbes are involved in the toleration and degradation of phenols and phenolic compounds. It was identified that the enzyme system of several species of microbes, including algae, fungi, and bacteria, is actively involved in the degradation of phenols. More studies are to be conducted in this area to discover new species or strains causing degradation. Those species can be developed to effectively treat the phenols released into soil and water for a better life. Removal of phenols from the environment improves the quality of natural vegetation. Industrial waste carrying different types of phenolic compounds may transform the normal vegetation, which finally leads to the destruction of the native flora and fauna and thereby imbalances the ecosystem. The accumulation of these toxic chemicals may create mutations in the genes of native species. It may also change the physiochemical and biological properties of the biotic and abiotic systems (soil, water).

Modern environmental biotechnology, together with microbial enzymatic systems for the effective degradation of phenols, can make a dramatic change in the treatment of environmental pollutants like phenols. A lot of microorganisms were found to be tolerant to phenol. Microbial processes can be used for environmental protection and improvement. Bio-separations and bioreactor technologies help in the process of environmental cleaning. Environmental and economic benefits in manufacturing, monitoring and waste management are offered by the field of environmental biotechnology. Treatment methods such as activated carbon adsorption, ion exchange, chemical oxidation, liquid-liquid extraction, etc., are effective, but they often suffer from drawbacks such as high cost. Hence, bio-degradation is considered as an environment-friendly and cost-effective alternative method.

Phenol bio-degradation in soil may take place under both aerobic and anaerobic conditions. Microorganisms (bacteria, fungi, yeasts, algae) use phenols as the sole carbon source for the growth of the organisms. Most of the cases are reported from bacterial species. The degradation process was catalysed by a variety of enzymes such as oxygenases, hydroxylases, peroxidases, oxidases, laccases, and tyrosinases (Nair et al.,2008). Degradation under aerobic conditions is initiated by oxygenation. The aromatic ring is initially monohydroxylated by a mono-oxygenase phenoldehydroxylase at an ortho position to the pre-existing hydroxyl group to form catechol. This includes Pseudomonas, Bacillus,

Acinetobacter, Streptomyces, Desulfobacterium, and Geobacter, among others. Anaerobic degradation of phenol is less advanced than the aerobic process. The first step in this pathway is the carboxylation of phenol at the para position to 4-hydroxybenzoate by the enzyme 4-hydroxybenzoate carboxylase. Thauera aromatica K172 and Clostridium species are examples of anaerobic degradation of phenols (Schie & Young, 2000). Klekner & Kosaric, 1992 investigated the fact that 2,4-dimethylphenol was converted to an isomer of dimethylbenzenediol by a species of Chlorella. It was also capable of degradation and dechlorination of 2-chlorophenol. Scenedesmus species, after an adaptation of a period of 5 days, showed quick degradation of 2,4-dinitrophenol at a concentration of about 190 $mg1^{-1}$. All algae tested by Klekner & Kosaric, 1992 for their study has a mechanism for the degradation of phenolic compounds

Many Bacillus species have been identified as potent phenol-degrading strains such as Bacillus stearothermophilus, B. laterosporus, B. brevis, B. thermoglucosidasius (Krastanov et al.,2012). Bacillus subtilis sp3, a PHB-producing bacteria was found to degrade phenols which can also be used for the laboratory-scale treatment of paper mill effluent containing phenolic compounds (Nair & Prakash, 2017). Two strains of Bacillus cereus (B. cereus MTCC 9817 and 9818) isolated from a petroleum refinery and oil exploration site showed high tolerance to phenol at a concentration of 1000 mg/L, under optimum temperature of 37^0C and p^H 7.0 (Banerjee & Ghoshal, 2010). At an optimum p^H of 8.0, temperature 34^0C, 5% (v/v) of inoculum size, and without any co-substrate, a strain of B.brevis degraded 1750 mg/L phenol in 144 hours (Arutchelvan et al.,2006). Sulfobacillus acidophilus isolated from hydrothermal vents in the Pacific Ocean has a maximum degradation rate of 2.32 mg/L/h of phenol at 38 hours. The degradation is aerobic via meta-pathway under p^H 1.8 and 45^0C temperature. Another strain S. acidophilus can tolerate 1300mg/L phenol and completely degrade 100mg/L phenol in 40 hours (Zhou et al.,2016). The peroxidase enzyme isolated and purified from B. aryabhattai B8W22 exhibits highest degradation (98.47%) at p^H 5.8 with maximum activity at 30^0C and complete thermal stability at 40^0C. The enzyme showed 0.012 U/mg specific activity (Elmetwalli et al.,2023). Bacillus badius follows ortho and meta-catechol pathways. At high concentrations of substrate

(phenol), the rate of degradation by B.badius was more than 70% whereas, 98% was degraded at lower concentrations with alkaline p^H of 9.0 at 37^0C (Sarwade & Gawai, 2014).

However, the process degradation depends upon the optimal conditions of p^H, temperature, concentration of substrate, volume of inoculum, days of incubation, speed of rotation of the shaking incubator etc. The volume of inoculum has a direct impact on phenol-degradation by the bacteria. The p^H value of the medium influences the production of degrading enzymes and finally affects the growth and metabolism of the microbe. An optimum temperature is required for the activity of degrading enzymes (Zhang et al., 2022). The duration of incubation and the concentration of available substrate also have a crucial role in the biodegradation of phenols. In this study, three strains of Bacillus cereus species was used for phenol-degradation studies. The main purpose of this study is to identify the optimum conditions required for maximum phenol-degradation by the strains.

2. Materials And Methods

In this study, soil samples from six different areas of the selected site (an industrial area in the Kottayam district) were collected and pooling method was adopted. Bacterial colonies capable of phenol-degradation were isolated from the soil by continuous-enrichment culture method. The soil samples were then serially diluted into agar plates containing low concentrations of phenol (10mM/ml). The colonies that showed growth in the medium were selected and then transferred to next higher concentration of phenol containing nutrient agar and broth. This process in continued with successive concentrations of phenol, until no growth in the medium and broth were obtained. The colonies that showed growth in both agar plates and broth culture were selected and screened for its maximum phenol degradation capacity. For this, the minimal salt medium containing various concentrations of phenol (MSPM) of p^H 7 was used (Nair, I, C., 2017). 50ml of the MSPM inoculated with each strain were incubated in a shaking incubator at 150 rpm speed and 37^0C temperature for five days. The rate of degradation exhibited by each isolated strains at different concentrations of phenol ranging from 10mM/ml, 20, 40,…..140 mM/ml were studied. Three bacterial strains named RM4, RM23 and RC29 showed maximum degradation at various concentrations of phenol. These three strains

were then identified through morphological, biochemical as well as molecular characteristics (16srRNA sequencing). The strains were identified as Bacillus cereus strains. In this study, the cultural conditions were optimized for these three strains to obtain maximum degradation. For this, the following materials and methods were adopted.

Materials Used

All the chemicals used for the experiment are from HIMEDIA and Nice chemicals. The glassware used is manufactured by Borosil and Nice. Materials used includes: polythene covers, sterile loops, test tubes and racks, measuring cylinders, conical flasks, standard flasks, micropipettes, sterile tips, petriplates, non-absorbant cotton, and various growth media. The equipment and instruments used include a shaking incubator, Laminar Air Flow chamber, incubator, pH meter, weighing balance, hot air oven, autoclave, microscopes, spectrophotometer, PCR machine and HiBacillus rapid test kit.

2.1 Estimation of Phenol

Estimation of phenol was done using the 4-Aminoantipyrine method (4-AAP method, APHA,1978). Aminoantipyrine reacts with phenol in the presence of Potassium ferricyanide to give a red-coloured compound called antipyrine, whose absorbance was recorded at 500nm. The concentration of this dye is directly proportional to the concentration of phenol in the sample. Different aliquots of the stock phenol solution were prepared, and the assay was carried out. The readings were recorded, and a standard graph was prepared.

2.2 Calculation of Percentage Phenol-degradation

The initial and final concentration of phenol in the samples (MSPM with inoculum) and control (MSPM without inoculum) was measured using 4-AAP assay. The percentage of degradation was calculated using the following equation from the standard graph prepared;

$$\text{Percentage phenol-degradation} = \frac{C_i - C_f}{C_i} \times 100$$

Where, C_i = initial concentration of phenol in the medium.

C_f = final concentration of phenol in the medium.

The concentration of phenol in the medium was expressed in millimolar per milliliter (mM/ml) of solution.

2.3 Optimization of p^H

2ml of the bacterial inoculum was added to a 250ml conical flask containing 50ml, 10mM/ml MSPM with different p^H values. A p^H value ranging from 5.0 - 9.0 with an interval of one was selected for the study. The initial p^H of the MSPM was adjusted using 1N, NaOH or HCl. The medium without inoculum is used as the control. The samples along with control were then kept in a shaking incubator at 150 rpm and 37^0C temperature for three days. The OD values were recorded and the percentage phenol degradation was calculated. The p^H value at which the strain exhibits maximum phenol-degradation was selected as the optimum p^H value for maximum phenol-degradation.

2.4 Optimization of Temperature

The temperatures selected for the study are 32^0C, 37^0C, 42^0C, 47^0C and 52^0C. 50 ml of 10mM/ml MSPM (p^H 7) was inoculated with 2ml of each bacterial inoculum and incubated in a shaking incubator for three days at 150 rpm speed. The OD values of the samples along with the control were recorded and the phenolic content was estimated. The percentage phenolic degradation was calculated and analyzed. The temperature at which maximum degradation occurred was regarded as the optimum temperature.

2.5 Optimization Of Concentration Of Substrate

Phenol is the only source of carbon present in the MSPM. The percentage phenol-degradation at various concentrations of substrate (phenol) was studied by inoculating 2ml of each bacterial inoculum into 50ml, MSPM of p^H 7 and incubated at 37^0C and 150 rpm speed in a shaking incubator for three days. The concentration of phenol taken for study ranges from 10mM/ml, 20, 40, 60, 80, 100, 120, and 140 mM/ml.

2.6 Optimization Of Amount Of Inoculum

Different amount of bacterial inoculum was taken for the study such as 1ml, 2ml, 3ml, 4ml, and 5ml. 50ml of 10mM/ml MSPM of p^H 7 was inoculated with different amount of inoculum and the medium without inoculum was kept as the control. The samples were incubated at 37^0C for three days in a shaking incubator at 150 rpm speed. The amount of

inoculum that gives maximum degradation was selected as the optimum amount of inoculum.

2.7 Optimization Of Incubation Period

50 ml of 10 mM/ml MSPM was inoculated with 2 ml of inoculum and incubated in a shaking incubator at 150 rpm speed and 37^0C temperature for five days. The percentage degradation was recorded at regular intervals of two days (48 hrs), three days (72 hrs), and five days (120 hrs) respectively. The incubation time at which maximum percentage of phenol-degradation obtained was regarded as the optimum incubation period.

In all the above optimization study, MSPM without bacterial inoculum is used the control. Each study was conducted three times.

3. Results And Discussion

3.1 Estimation Of Phenol

Estimation was done by 4-AAP assay. A standard graph was plotted with concentration of phenol in the X-axis and absorbance values measured at OD_{500} in the Y-axis. More or less, a straight line was obtained. From the standard graph, the initial and final concentration of phenol in the control and samples was estimated to calculate the percentage phenol-degradation exhibited by each Bacillus strain.

3.2 Optimization Of p^H

p^H has a significant role in degrading phenol. The optimum p^H for the effective degradation of phenol ranges between 5 and 7. The strain RM4 and RM23 showed good degradation to phenol at an initial p^H of 5. This finding was supported by Elmetwalli et al.,2023 The strain RM4 showed 22.22% degradation to phenol and RM23 showed complete degradation (100%) to phenol at an initial p^H of 5 (Fig.1). RC29 showed a maximum of 20% degradation at an initial p^H of 7 (Khleifat & Khaled, 2007; Banerjee & Ghoshal, 2010). The initial p^H value of the medium will affect the synthesis of microbial enzymes and their catalytic activity, further affect the growth of microorganisms and their ability to degrade pollutants (Zhang et al.,2022). The enzymes of Bacillus species are active at a wide range of p^H. Degradation was showed by the three strains in a range of selected p^H. Too high or too low p^H values, often leads to the inactivation of most degrading enzymes of the bacteria and there by inhibit degradation of phenol

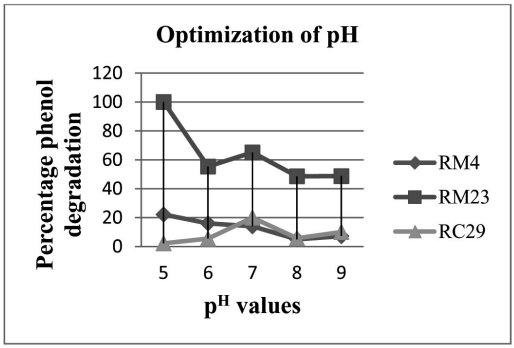


Fig.1. Optimization of p^H for phenol-degradation

3.3 Optimization Of Temperature

Another important factor that affects the ability of a microbe to degrade an organic substance is the temperature. In this study the optimum temperature required for maximum degradation was found to be ranging from 32^0C to 42^0C. The strain RM23 give complete degradation at 37^0C. Maximum degradation was at 42^0C for RM4 and RM29 (Fig.2). At a higher temperature the activity of degrading enzyme may get inactivated. It was also reported that, at very low temperature the activity of enzymes decreases and thereby results in slow microbial metabolism. Zhang et al.,2022 reported that, an optimum temperature of 37^0C is suitable for efficient phenol degradation and maximum cell growth by B cereus ZWB3strain, B.badius (Sarwade & Gawai, 2014), and 34^0C for B brevis (Arutchelvan et al.,2006). A phenomenon has been reported by Meena et al., 2016, that if the temperature is too low or too high, the pollutant removal ability of a microorganism became deteriorative.

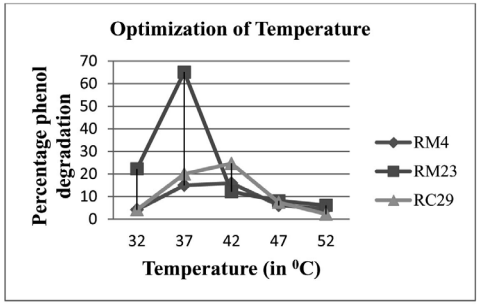


Fig.2. Optimized temperature for phenol degradation

3.4 Optimization Of Period Of Incubation

The period of incubation is another aspect that controls biodegradation. The minimum period of incubation that promotes maximum phenol degradation is regarded as the optimum incubation period. In the study, an incubation period of three days (72 hrs), was found to be the optimum (Nair et al.,2008) and was given in Fig.3. Above this period, the rate of degradation decreases. This result stay close with the findings reported by Long et al., 2019; Wen et al., 2020 and Gong et al., 2021, that the time required for complete degradation of phenol by microbes ranges between 32-75 hrs. Degradation studies conducted in Klebsiella oxytoca strain by Shawabhek et al (2007), found that 75% of the initial phenol concentration of 100 ppm was degraded by the strain within 72 hrs.

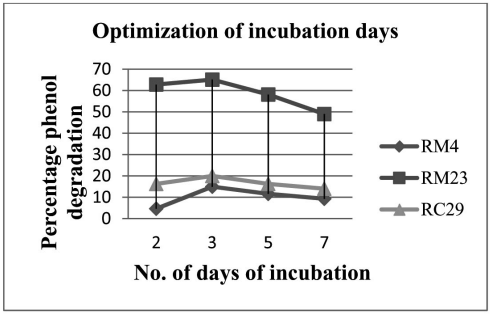


Fig.3. Days of incubation optimized for phenol-degradation

3.5 Optimization Of Amount Of Inoculum

The volume of inoculum has a direct effect on the degradation of phenol by microorganisms. The strain RM23 could completely degrade phenol when the inoculation volume was 3 ml. Gong et al.,2021, studied biodegradation of phenol using Candida tropicalis SDP-1. He noticed that, a smaller volume of inoculum will extend the lag phase and inhibits the growth of the microbe. In contrast, high volume of inoculum may lead to the intra-specific competition between the microorganisms. In this study, the inoculation volume of 2 ml and 4 ml was found to be a better choice for the strains RC29 and RM4. Also, an inoculation volume of 2 ml gives a stable growth phase for all of the strains (Fig.4).

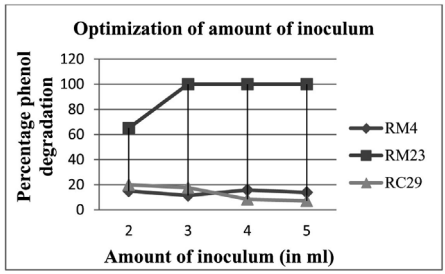


Fig.4. Optimized amount of inoculum for phenol-degradation

3.6 Optimization Of Concentration Of Substrate

Phenol is the only available substrate used by the microorganism for their growth and metabolism. The growth was found to be negligible on applying higher concentration of phenol (Sachan & Hussain, 2019). From the study, it was found that, for the strain RM4, 80 mM/ml phenol concentration was optimum which gives a degradation rate of 33.33%. The optimum phenol concentration for RM23 was identified to be 10mM/ml, with a degradation rate of 65.11%. RC29 gives a maximum degradation rate of 38.38% at an initial phenol concentration of 60 mM/ml. Above 120 mM/ml phenol concentration, the rate of degradation by the strains decreases to very low levels (Fig.5). High concentration of phenol reduces the degradation power of the bacteria. This is due to the toxic effect of phenols on microorganisms. Geng & Lim, 2007 stated that, high concentration of phenol can inhibit bacterial growth by reducing the expression of ATP synthase and inhibits electron transport chain phosphorylation. Due to its toxicity, phenols have an inhibitory effect on cell growth and can cause substrate-level inhibition (Yang & Lee, 2007; Paisio et al.,2013; Hussain et al., 2015; Zhang et al.,2022).

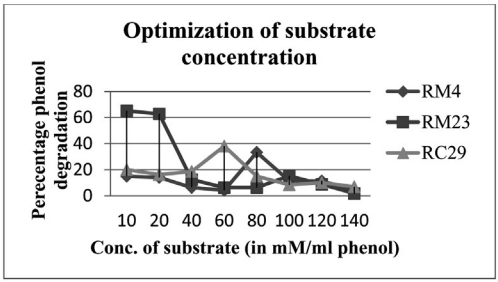


Fig.5. Conc. of substrate optimized for phenol-degradation.

4. Conclusion

Phenol is a significant pollutant being discharged from the effluents of various industrial sources. Native microbial species in polluted settings were more adaptable than non-indigenous microorganisms, and their dominance aided the bio-remediation of phenol-contaminated ecosystems. A critical analysis of the literature reveals that biological treatment is economical, practical and the most promising and versatile approach as it leads to the complete mineralization of phenols, producing non-toxic end products (Dankaka & Abdullahi, 2021).

The Bacillus cereus strains RM4, RM23, and RC29 could effectively degrade phenols under optimized conditions of p^H, temperature, amount of inoculum, concentration of substrate and incubation days. Strain RM4 could effectively degrade phenol to a concentration of 80mM/ml, p^H 5, 42^0C temperature and 4ml inoculum size. RM23 could completely remove phenol in the medium having a concentration of 10mM/ml, p^H 5 and temperature 37^0C and an inoculum size of 3 ml. At a substrate concentration of 60mM/ml phenol, p^H 7, temperature 42^0C and an inoculum size of 2 ml, the strain RC29 could efficiently degrade phenol. All the strains could effectively degrade phenol in three days (72 hrs). The results showcase that, the strains has the capacity to utilize an organic pollutant like phenols as the sole carbon source for their growth and metabolism, suggesting that, these strains of B. cereus can be applied in the biological treatment of wastewater contaminated with phenol, to remove the pollutants. This study provides findings that are strongly supported by the data reviewed during the course of study, and can be contributed to the biodegradation studies on phenols.

Acknowledgements

This work acknowledges support from the Post Graduate and Research Department of Botany, Mar Thoma College, Tiruvalla.

Data availability statement

All the relevant data are included in the paper or it's supplementary information.

Conflict of interest

The authors declare there is no conflict.

References

Alexander, M., 1965.Biodegradation: Problems of molecular recalcitrance and microbial infallibility. *Advances in Applied Microbiology,*7,35-80.

Antai, S., Crawford, D.,1983. Degradation of phenols by *Streptomyces setonii. Canadian Journal of Microbiology*. 29(1).

APHA, 1978. phenolics-spectrophotometric, manual 4-AAP.

Arutchelvan et al., 2006. Kinetics of high strength phenol degradation using *Bacillus brevis. Journal of Hazardous Materials.* 129(1-3):216-222.

Banerjee, A., & Ghoshal, A.K., 2010. Isolation and characterization of hyper phenol tolerant Bacillus sp.from oil refinery and exploration sites. *Journal of Hazardous Materials.* 15.176(1-3): 85-91.

Castillo et al., 2012. Self-bioremediation of cork-processing wastewater by (chloro)phenol-degrading bacteria immobilized on to residual cork particles. *Water Research.* 46,1723-1734.

Central Pollution Control Board (CPCB) ,2016. Phenols and Phenolic Compounds. Parivesh. Delhi. www.cpcb.nic.in.

Dankaka, S.M. & Abdullahi, N., 2021. Isolation and molecular identification of phenol tolerating bacteria from petroleum contaminated sites. *Bayero Journal of Pure and Applied Sciences.* 14(2), 206-213.

Elmetwalli et al.,2023. Evaluation of *Bacillus aryabhattai* B8W22 peroxidase for phenol removal in wastewater effluents. *BMC Microbiolgy.* 23, 119.

FDA, U.S.,1998. Bacteriological Analytical Manual, 8th ed, Gaithersburg, MD: AOAC International.

Geng, A. & Lim, C. J., 2007. Proteome analysis of the adaptation of a phenol-degrading bacterium Acinetobacter sp. EDP3 to the variation of phenol loadings. *Chinese Journal of Chemical Engineering.* 15 (6), 781-787.

Gong *et al.*,2021. Biodegradation of phenol by a halotolerant versatile yeast *Candida tropicalis* SDP-1 in wastewater and soil under high salinity conditions. *Journal of Environmental Management.* 289, 112525-112534.

Harrison, R.B.,2008.Composting and Formation of Humic Substances. *Encyclopedia of Ecology,* 713-719.

Hoostal, M.J., & Bouzat, J.L., 2008. The modulating role of dissolved organic matter on spatial patterns of microbial metabolism in Lake Erie sediments. *Microbial Ecology,* 55 (2), pp: 358-368.

Hussain & Dubey.,2014. Specific methanogenic activity test for anaerobic treatment of phenolic waste water. *Desalination and Water Treatment.* 52 , 37-39.

Hussain, A., Dubey, S. K. & Kumar, V.,2015. Kinetic study of aerobic treatment of phenolic wastewater. *Water Resources and Industry.* 11, 81-90

Jim & Reyes., 2008. Microbial degradation of chlorinated phenols. *Reviews in Environmental Science and Biotechnology,* 7(3). pp: 211-241.

Kafilzadeh, F. & Mokhtari, S. 2013. Isolation and Identification of Phenol Degrading Bacteria from Mangroove Sediments in the Persian Gulf and their Growth kinetics Assay. *Biomed Pharmacol,* 6(2) http://dx.doi.org/10.13005/bpj/402

Khleifat & Khaled, M.,2007. Biodegradation of phenol by *Actinobacillus sp.*; Mathematical interpretation and effect of some growth conditions. *Bioremediation Journal.* 11, 103-104

Klekner & Kosaric, 1992. Degradation of phenols by algae. *Environmental Technology,* 13(5), 493-501, DOI: 10.1080/09593339209385176.

Krastanov et al., 2013. Microbial degradation of phenols and phenol derivatives. *Engineering in Life Sciences,* 13(1),76-87.

Kumaran, P. & Paruchuri, Y.L., 1996. Kinetics of phenol bio-transformation. *Water Resource,* 31(1), 11-22.

Lowry et al., 2009. Isolation and characterization of phenol degrading soil bacterium, *Xanthomonas flavus. Bioremediation Journal,* 13(1), 1-6.

Mahgoub, S.A., et al., 2023. Characterization and biodegradation of phenol by P*seudomonas aeruginosa and Klebsiella variicola* strains isolated from Sewage Sludge and their effect on soybean seeds germination. *Molecules.* 28.

Malaviya,P. & Rathore, V.S., 2007. Bioremediation of pulp and paper mill effluent by a novel fungal consortium isolated from polluted soil. *Bioresource Technology,* 98, 3647-3651.

Meena, S. S., et al.,2016. Isolation and identification of *Bacillus megaterium* YB3 from an effluent contaminated site efficiently degrades pyrene. *Journal of Basic Microbiology* 56 (4), 369-378.

Min et al., 2015. The regulation of phenolic compounds by soil organic matter dynamics under a changing environment. *Biomed Research International.* Article 10. 825098.

Mohanty, S.S., Satpathy, G.R., Jena, H.M., 2012. Microbial degradation of phenol: A comparative study. Department of Biotechnology and Medical Engineering. NIT. Rourkela.

Muthanna & Afaf., 2018. Biodegradation of phenolic components in the wastewater by micro algae: a review. *MATEC Web of Conferences,* 162(4):05009.

Nair, I.C., 2007. Treatment of paper factory effluent using a phenol degrading *Alcaligenes sp.* under free and immobilized conditions. *Bioresource Technology,* 98 (3), 714-716.

Nair, I.C., & Prakash, S., 2017. Degradation of phenol using a PHB producing *Bacillus subtilis sp3. World Journal of Pharmaceutical Research.* 1127-1142.

Nair, I.C. et al., 2008. Biodegradation of Phenol. *African Journal of Biotechnology.* 7(25), 4951-58.

Nuhoglu, N., & Yalcin, B., 2005. Modeling of phenol removal in a batch reactor. *Process Biochemistry.* 40 (3-4), 1233-1239.

Paisio et al., 2013. Characterization of phenol degrading bacterium isolated from an industrial effluent and its potential application for bioremediation. *Environmental Technology.* 34(4), 485-493.

Raj, A., & Reddy, M.M.K., 2007. Decolurization and treatment of pulp and paper mill effluent by lignin-degrading *Bacillus sp. Journal of Chemical Technology and Biotechnology.* 82(4), 399-406.

Sachan, P., Madan, S., & Hussain, A.,2019. Isolation and screening of phenol-degrading bacteria from pulp and paper mill effluent. *Applied Water Science*. 9:100. https://doi.org/10.1007/s13201-019-0994-9

Sarwade, V., & Gawai, K., 2014. Biodegradation of phenol by Alkaliphilic *Bacillus badius* D1. IOSR *Journal of Environmental Science, Technology and Food Technology*.

Schie & Young., 2000. Biodegradation of phenol: Mechanisms and Applications. *Bioremediation Journal.* 4(1), 1-18. https://doi.org/10.1080/10588330008951128.

Shawabhek, R., Khaled, M. & Khleifat.,2007. Rate of biodegradation of phenol by *Klebsiella oxytoca* in minimal medium and nutrient broth conditions. *Bioremediation Journal.* 11, 13-19.

Shourian, M. et al., 2009. Efficient phenol degradation by a newly characterized Pseudomonas sp.SA01 isolated from pharmaceutical wastewater. *Desalination.* 246(1-3), 577-599.

The Environmet (Protection) Act, 1986, Government of India https://www.indiacode.nic.in

The United States Environmental Protection Agency (USEPA). 2014. https://www.epa.gov.in

Wen *et al.*, 2020. Biodegradation of phenol by *Rhodococcus sp*. strain SKC: characterization and kinetics study. *Molecules.* 25 (16), 3665-3676.

Yang, C. F. & Lee, C. M., 2007. Enrichment, isolation and characterization of phenol-degrading *Pseudomonas resinovorans strain* P-1 and *Brevibacillus sp. strain* P-6. *Int Biodeterior Biodegrad.* 59, 206-210.

Zhang et al., 2022. A study of highly efficient phenol biodegradation by a versatile *Bacillus cereus* ZWB3 on aerobic condition. *Water Science & Technology.* 86 (2), 355

DOI: 10.2166/wst.2022.209.

Zhou *et al.,* 2016. Phenol degradation by *Sulfobacillus acidophilus* TPY via the *meta*-pathway. Microbial Research. 190:37-45.

Solar Activity Influencing Rainfall in Regions of Heavy and Scarce Rainfall in India

Elizabeth Thomas[1] and Noble P. Abraham[2]

Abstract: Understanding the solar activity cycle is increasingly crucial since fluctuations in solar activity can impact the Earth's space environment in various ways. In this study, the influence of solar activity on regions receiving heavy and scarce rainfall in India is investigated. Coastal Karnataka and West Rajasthan are identified and their rainfall values along with sunspot number for a period of 116 years are used. Wavelet cross-spectrum and wavelet coherence analyses are performed. Region receiving less rainfall, i.e., West Rajasthan is observed to have a greater solar influence on its rainfall than in regions receiving heavy rainfall like Coastal Karnataka.

Key words: Solar activity, sunspot numbers, wavelet analysis, rainfall

Introduction

In recent years, the global climate has undergone significant changes, raising considerable concern due to its impact on human existence. Radiations from the Sun play a crucial role in influencing climate, along with the effects of human activity. Solar activity encompasses all variations in the Sun's appearance or energy output. The most common indicators of solar activity are sunspots. These temporary dark regions on the Sun's surface are linked to strong magnetic activity and appear darker due to their lower temperatures than the surrounding photosphere.

Figure 1. Location map of Coastal Karnataka and West Rajasthan regions

[1]Research Scholar, Mar Thoma College, Kuttapuzha P.O., Tiruvalla, PIN:689103, Kerala, India. E-mail: shinuelz@yahoo.co.in
[2] Assistant Professor and Research Guide, Mar Thoma College, Kuttapuzha P.O., Tiruvalla, PIN:689103, Kerala, India. E-mail: noblepa@gmail.com

The Sun's influence on Earth's precipitation has long been a concern. Solar activity affects rainfall in a wide variety of ways, and they vary depending on the time scale and region considered (Tsiropoula, 2003; Zhao, Han, and Li, 2004; Wasko and Sharma, 2009; Mauas, Buccino, and Flamenco, 2011; Rampelotto et al., 2012). Recent studies on sun-rainfall connections were performed in China (Zhai, 2017; Yu et al., 2019; Song et al., 2022), the United States (Nitka and Burnecki, 2019), Europe (Laurenz, Lüdecke, and Lüning, 2019), Argentina (Heredia et al. 2019), Nepal (Tiwari et al., 2021) and Northeast Asia (Song et al., 2022).

The variability of rainfall in India significantly impacts agriculture and industry, putting considerable pressure on the country's economy. To date, numerous studies have explored the potential connection between solar activity and rainfall patterns in India (Jagannathan and Parthasarathy, 1973; Hiremath, 2006; Bhattacharyya and Narasimha, 2007; Lihua et al., 2007; Selvaraj et al., 2009; Selvaraj and Aditya, 2011, 2012; Selvaraj et al., 2013; Hiremath et al., 2015). Indian Meteorological Department (IMD) has divided the country into 36 meteorological sub-divisions. Coastal Karnataka and West Rajasthan were found to be the regions receiving the highest and lowest rainfall, by calculating the seasonal (JF, MAM, JJAS, and OND) and annual rainfall.

There is a lot of interest in exploring whether solar influence affects rainfall in these regions. So, this study examines the relationship of solar activity with rainfall in areas of heavy and scarce rainfall in India using cross-wavelet spectrum and wavelet coherence analyses.

Data and methods

This study used 116 years (1901-2016) of rainfall data over Coastal Karnataka and West Rajasthan regions and sunspot numbers. The sunspot number data was obtained from the World Data Center SILSO, Royal Observatory of Belgium, Brussels (http://www.sidc.be/silso/data _files). Rainfall (in mm), corresponding to Coastal Karnataka and West Rajasthan subdivisions, was taken from IITM Research Report No. RR-138 (Kothawale and Rajeevan, 2017). The location of these regions is shown in Figure 1.

The rainfall and sunspot data were grouped into four seasons (JF, MAM, JJAS, and OND). Figure 2. shows the time series of sunspot

number (SSN) and rainfall over West Rajasthan (WR-RF) and Coastal Karnataka (CK-RF) corresponding to the JF, MAM, JJAS and OND seasons respectively.

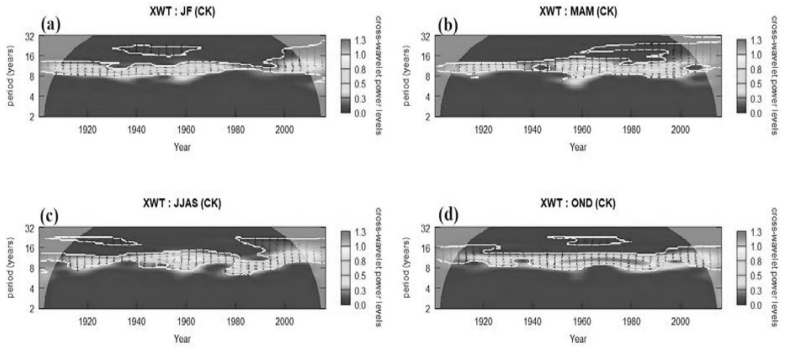
The rainfall over Coastal Karnataka and West Rajasthan regions and sunspot data were smoothed using a Savitzky-Golay Filter, which was used throughout the study. Data is filtered using this filter to increase the signal-to-noise ratio (Laurenz et al. ,2019; Luo et al., 2005). The filter used in this study has a frame size of 11 and a polynomial order of 5.

2.2 Methodology

In the present study, Cross-Wavelet Transform (XWT) and Wavelet Transform Coherence (WTC) analyses were done to explore the possible relationship between sunspot number and rainfall over Coastal Karnataka and West Rajasthan subdivisions.

The wavelet transform can be used to analyse time series that contain non-stationary power at different frequencies. Continuous wavelet transforms of a time series, x_n, n = 0, 1, 2, …, N-1 is given by

$$W_n^X(s) = \sum_{n'=0}^{N-1} x_{n'} \; \psi^* \left[\frac{(n' - n)\delta t}{s} \right]$$



3. Wavelet cross-spectrum between sunspot number (SSN) and rainfall over Coastal Karnataka (CK) during (a) JF (b) MAM (c) JJAS and (d) OND seasons. The white contour line indicates significance at the 10% level.

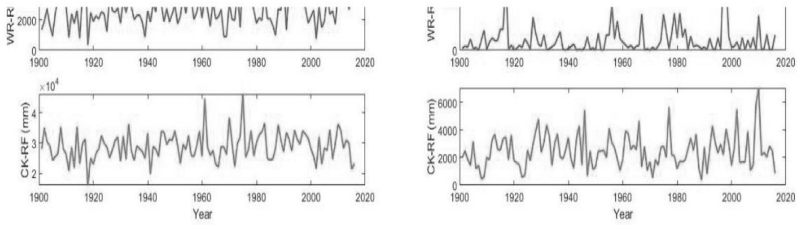


Figure 2. Time series of sunspot number (SSN) and rainfall over West Rajasthan (WR-RF) and Coastal Karnataka (CK-RF) during (a)JF (b)MAM (c)JJAS and (d)OND seasons

2.2.1 Cross -Wavelet Spectrum and Wavelet Coherence

From two continuous wavelet transforms it is possible to construct a wavelet transform that can present their common power and relative phase in time-frequency. According to Grinsted et. al (2004), a cross-wavelet transform of two time series $\mathbf{x_n}$ and $\mathbf{y_n}$ is defined as

$$W_n^{XY}(s) = W_n^X(s)\, W_n^{Y*}(s)$$

The cross-wavelet power is given by $|W_n^{XY}(s)|$.

Using wavelet coherence, the localized correlation between two variables time series in time–frequency space is determined. It is a quantity between 0 and 1 and is defined as the square of the cross-spectrum normalized by the individual power spectra. Wavelet coherence (WTC) of two time series $\mathbf{x_n}$ and $\mathbf{y_n}$ is defined as

$$R_n^2(s) = \frac{\left|S(s^{-1}\, W_n^{XY}(s))\right|^2}{S(s^{-1}\, |W_n^X(s)|^2).\, S(s^{-1}\, |W_n^Y(s)|^2)}$$

where S is a smoothing operator (Torrence and Compo, 1998; Grinsted et. al, 2004).

Figure 3. Wavelet cross-spectrum between sunspot number (SSN) and rainfall over Coastal Karnataka (CK) during (a) JF (b) MAM (c) JJAS and (d) OND seasons. The white contour line indicates significance at the 10% level.

These filtered values of sunspot number and rainfall were subjected to Cross Wavelet Transform (XWT) and Wavelet Transform Coherence (WTC), to evaluate the relationship between the given data. The R package 'Waveletcomp' is used for analysing Cross Wavelet Transform and Wavelet Coherence analyses (Roesch and Schmidbauer, 2018).

3. Results and Discussions

3.1 Cross-Wavelet Spectrum

Wavelet cross-spectrum between sunspot number (SSN) and rainfall over West Rajasthan (WR) during (a) JF (b) MAM (c) JJAS and (d) OND seasons. The white contour line indicates significance at the 10% level.

Cross-wavelet transform was carried out between the seasonal values of sunspot number and rainfall over Coastal Karnataka and West Rajasthan to estimate statistically the level of covariance between them. The white contour line indicates a 10% significance level and the arrows show the relative phase relationship between them. Right (left) pointing arrows show an in-phase (anti-phase) relationship. Figure 3. gives the wavelet cross-spectra between sunspot number and rainfall values over Coastal Karnataka, for all seasons. Significant cross-power was observed at 8-16 years scale during all the seasons. During the OND season, high cross-wavelet power was visible for a longer time, around 1950-1990. During this period, solar activity was comparatively high, except during Solar Cycle 20. Similarly, Figure 4. denotes the wavelet cross-spectra between sunspot number and rainfall values over West Rajasthan, for all seasons. Visual inspection showed significant cross-power at 8–16 years scale for all the seasons. During the JF, JJAS, and OND seasons, the high cross-wavelet power is observed but at different time intervals. This was often during times when solar activity was high.

A possible link between sunspot number and rainfall over these regions is suggested. Considering the arrows, no particular information about the phase could be interpreted for both regions. The reversal of phases was visible at different times. Coastal Karnataka, receiving high rainfall, showed high power only during the OND season. Low rainfall in West Rajasthan revealed high cross-power during the JF, JJAS, and OND seasons. Thus, solar activity influences regions with less rainfall.

Cross-wavelet results were reported at Pelotas (Souza Echer et al., 2008) and Santa Maria (Rampelotto et al.,2012) in southern Brazil while studying rainfall variability and its possible link with solar activity. Significant cross-power was reported at the 11-year solar cycle period. Similar cross-power results were reported while analyzing different

stations in Iran (Nazari-Sharabian and Karakouzian, 2020). Even in Kerala, related results were noted (Thomas and Abraham, 2022; Thomas et al., 2023).

3.2 Wavelet Coherence

Wavelet coherence was determined to statistically study the relationship between

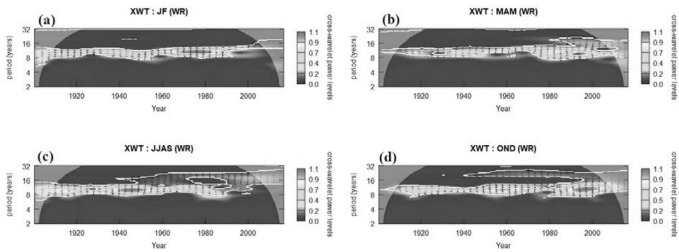


Figure 4. Wavelet cross-spectrum between sunspot number (SSN) and rainfall over West Rajasthan (WR) during (a) JF (b) MAM (c) JJAS and (d) OND seasons. The white contour line indicates significance at the 10% level

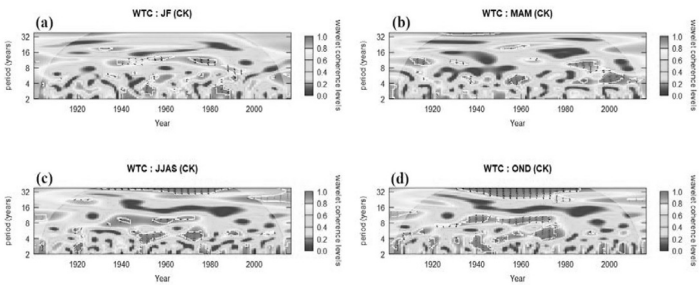


Figure 5. Wavelet coherence spectra between sunspot number (SSN) and rainfall over Coastal Karnataka (CK) during (a) JF (b) MAM (c) JJAS and (d) OND seasons. The white contour line indicates significance at the 10% level.

sunspot number and rainfall over Coastal Karnataka and West Rajasthan regions. It shows statistical significance only when both data share significant periods. The white contour line indicates a 10% significance level and the arrows show the relative phase relationship between them. Figure 5. gives the results of wavelet coherence between sunspot number and rainfall over Coastal Karnataka, corresponding to all seasons. The JJAS and OND seasons showed high significant coherence power during

different periods, compared to other seasons. During JF, JJAS, and OND seasons, Coherence power at lower periods like 2-8 years was observed in almost all seasons. Higher periods at 8-16 years were observed in JF seasons, and between 12-32 years during JJAS and OND seasons. Coherence was lowest during the MAM season.

Figure 6. gives the wavelet coherence in the case of West Rajasthan region. Significant coherence was observed at lower periods at 2-8 years during all the seasons. During MAM seasons, wavelet coherence at higher periods of 16-32 years was visible. OND season showed coherence almost during all the periods and gets maximum at 16-32 years.

West Rajasthan showed high significant coherence values during the JJAS and OND seasons, compared to other seasons. Here again, significant phase information was not detectable. Wavelet coherence results corresponding to annual rainfall over Kerala and sunspot data showed less coherence power at different periods between 2–16 years scale at different intervals of time (Thomas and Abraham, 2022; Thomas et al., 2023).

The wavelet analyses (cross-spectrum and wavelet coherence) corresponding to Coastal Karnataka and West Rajasthan regions gave significant results. Comparing all the results it was observed that solar activity showed more influence on the rainfall over West Rajasthan than Coastal Karnataka. In the case of the West Rajasthan region, the JF, JJAS and OND seasons showed significant cross-spectrum power while only the OND season showed in the case of Coastal Karnataka.

Figure 5. Wavelet coherence spectra between sunspot number (SSN) and rainfall over Coastal Karnataka (CK) during (a) JF (b) MAM (c) JJAS and (d) OND seasons. The white contour line indicates significance at the 10% level.

The JF and OND seasons of rainfall over West Rajasthan showed an in-phase relation with sunspot number for a longer period. The JF and OND seasons, corresponding to both regions

Figure 6. Wavelet coherence spectra between sunspot number (SSN) and rainfall over West Rajasthan (WR) during (a) JF (b) MAM (c) JJAS and (d) OND seasons. The white contour line indicates significance at the 10\% level showed significant coherence power. It was also noted

that the rainfall corresponding to the OND season in particular has a greater solar influence than other seasons.

4. Conclusion

This study attempted to understand how rainfall in regions of heavy rainfall and scarce rainfall in India is related to solar activity. Coastal Karnataka and West Rajasthan meteorological sub-divisions were identified and their rainfall was analysed along with sunspot numbers for 116 years (1901-2016). The rainfall and solar data were grouped into different seasons, i.e., winter (JF), pre-monsoon (MAM), monsoon (JJAS), and post-monsoon (OND). The data were subjected to cross-wavelet spectrum and wavelet coherence to determine the possible relationship between them. Significant cross-wavelet power was observed at an 8- 16-year scale for all seasons but was high during the winter, monsoon, and post-monsoon seasons, in the case of the West Rajasthan region.

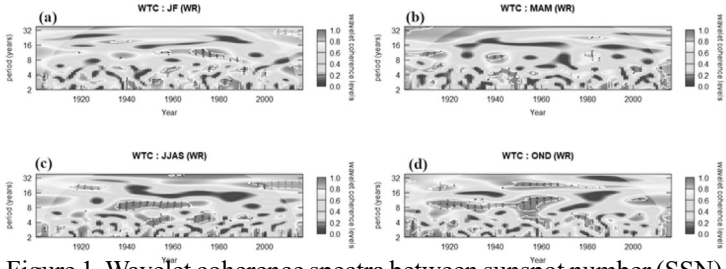


Figure 1. Wavelet coherence spectra between sunspot number (SSN) and rainfall over Coastal Karnataka (CK) during (a) JF (b) MAM (c) JJAS and (d)OND seasons. The white contour line indicates significance at the 10% level

In the case of the Coastal Karnataka region, highly significant cross-power was visible only during the post-monsoon season. Visually examining the phase difference image of sunspot number over rainfall, from cross-wavelet results, in-phase relation was identified during the winter and post-monsoon seasons (over West Rajasthan region) and the pre-monsoon season (over Coastal Karnataka region). Wavelet coherence power was high during the monsoon and post-monsoon seasons at 8-16 years scale, for both the regions. In both regions, the post-monsoon season showed high cross-wavelet spectrum power, high coherence, and even high nonlinear correlation. According to all the

results, solar activity had a greater effect on rainfall over West Rajasthan than Coastal Karnataka. It appears that solar activity has a greater influence on rainfall in areas with low rainfall, here in West Rajasthan, than in areas with heavy rainfall.

5. Acknowledgement

The authors are thankful to the Royal Observatory of Belgium for the sunspot numbers data and the Indian Institute of Tropical Meteorology (IITM) for the rainfall data. The first author acknowledges the financial assistance from the University Grants Commission (UGC), India, under Savitribai Jyotirao Phule Fellowship for Single Girl Child (SJSGC) Fellowship.

References

Bhattacharyya, Subarna, and Roddam Narasimha. (2007). Regional differentiation in multidecadal connections between Indian monsoon rainfall and solar activity. J. *Geophys. Res. Atmos*., 112 (24): –10. https://doi.org/10.1029/2006JD008353.

Grinsted, A., Moore, J., Jevrejeva, S. (2004). Application of cross wavelet transform and wavelet coherence to geophysical time series. *Nonlinear Process. Geophys*. 11, 561-566. http://dx.doi.org/10.5194/npg-11-561-2004.

Heredia, Teresita, Flavia M. Bazzano, Rodolfo G. Cionco, Willie Soon, Franco D. Medina, and Ana G. Elias. (2019). Searching for solar-like interannual to bidecadal effects on temperature and precipitation over a southern hemisphere location. J. Atmos. Sol.-Terr. Phys 193:105094. ISSN: 1364- 6826. https://doi.org/https://doi.org/10.1016/j.jastp.2019.105094.

Hiremath, K.M. (2006). The influence of solar activity on the rainfall over India: Cycle-to-cycle variations. *J. Astrophys. Astron*. 27, 367–372.

Hiremath, K.M., Manjunath, H., Soon, W., (2015). Indian summer monsoon rainfall: Dancing with the tunes of the sun. *New Astron.* 35, 8–19. http://dx.doi.org/10.1016/j.newast.2014.08.002.

Jagannathan, P., Parthasarathy, B., (1973). Trends and periodicities of rainfall over India. *Mon. Weather Rev.* 101 (4), 371–375. http://dx.doi.org/10.1175/15200493(1973)101<0371:taporo>2.3.co;2.

Kothawale, D. R. & Rajeevan, M. (2017). Indian Institute of Tropical Meteorology (IITM) Earth System Science Organization, Ministry of Earth Sciences 02, 1–164.

Laurenz, Ludger, Horst Joachim Lüdecke, and Sebastian Lüning. (2019). Influence of solar activity changes on European rainfall. *J. Atmos. Sol.-Terr.Phys.* 185:29–42. https://doi.org/10.1016/j.jastp.2019.01.012.

Laurenz, L., Lüdecke, H.J., Lüning, S. (2019). Influence of solar activity changes on European rainfall. *J. Atmos. Sol.-Terr. Phys.* 185, 29–42. http://dx.doi.org/10.1016/j.jastp.2019.01.012.

Lihua, M., Yanben, H., Zhiqiang, Y. (2007). The possible influence of solar activity on Indian summer monsoon rainfall. *Appl. Geophys*. 4 (3), 231–237. http://dx.doi.org/10.1007/s11770-007-0029-4.

Luo, J., Ying, K., He, P. & Bai, J. (2005). Digital Signal Processing: A Review Journal 15, 122–136. https://doi:10.1016/j.dsp.2004.09.008.

Mauas, Pablo J.D., Andrea P. Buccino, and Eduardo Flamenco. (2011). Long-term solar activity influences on South American rivers. *J. Atmos. Sol.-Terr. Phys*. 73 (2-3): 377–382. ISSN: 13646826. https://doi.org/10.1016/j.jastp.2010.02.019.

Nazari-Sharabian, M., Karakouzian, M. (2020). Relationship between sunspot numbers and mean annual precipitation: Application of cross-wavelet transform—A case study. *J. Multidiscip. Sci. J*. 3 (1), 67–78. http://dx.doi.org/10.3390/j3010007.

Nitka, W., Burnecki, K. (2019). Impact of solar activity on precipitation in the United States. *Physica A* 527, 121387.

Rampelotto, P.H., Rigozo, N.R., da Rosa, M.B., Prestes, A., Frigo, E., Souza Echer, M.P., Nordemann, D.J. (2012). Variability of rainfall and temperature (1912–2008) parameters measured from santa maria (29o 41's, 53o 48'W) and their connections with ENSO and solar activity. *J. Atmos. Sol.-Terr. Phys.* 77, 152–160. http://dx.doi.org/10.1016/j.jastp.2011.12.012.

Roesch, A. & Schmidbauer, H. WaveletComp: Computational Wavelet Analysis (2018). URL https://CRAN.R-project.org/package=WaveletComp. R package version 1.1.

Selvaraj, R.S., Muthuchami, A., Nancharaiah, M. (2009). Influence of sunspot activity on the annual rainfall of Tamil Nadu, India. *Indian J. Phys.* 83 (9), 1251–1258.http://dx.doi.org/10.1007/s12648-009-0106-z.

Selvaraj, R.S., Aditya, R. (2011). Study on correlation between Southwest and Northeast Monsoon rainfall over Tamil Nadu. *Univ. J. Environ. Res. Technol.* 1 (4).

Selvaraj, R.S., Aditya, R. (2012). The solar influence on the monsoon rainfall over Tamil Nadu. *J. Ind. Geophys.* Union 16 (3), 107–111.

Selvaraj, R.S., Umarani, R., Mahalakshmi, N., May, M.A. (2013). Correlative study on solar activity and all India rainfall: Cycle to cycle analysis. J. Ind. Geophys. Union 17 (1), 59–63.

Song, Yan, Zhicai Li, Yu Gu, and Ziniu Xiao. (2022). Impact of solar activity on snow cover variation over the tibetan plateau and linkage to the summer precipitation in china. *Front. Earth Sci.* 9. ISSN: 2296-6463. https://doi.org/10.3389/feart.2021.756762.

Souza Echer, M.P., Echer, E., Nordemann, D.J., Rigozo, N.R., Prestes, A. (2008). Wavelet analysis of a centennial (1895-1994) southern Brazil rainfall series (pelotas, 31o46′ 19′ s 52o 20′ 33′′ W). Clim. Change 87 (3–4), 489–497. http://dx.doi.org/10.1007/s10584-007-9296-6.

Thomas, E., and Abraham N.P. (2022) Relationship between sunspot number and seasonal rainfall over Kerala using wavelet analysis. *J. Atmos. Solar–Terres.* Phys. 240, 2022, 105943. https://doi.org/10.1016/j.jastp.2022.105943.

Thomas, E., Joseph, l., and Abraham, N.P. (2023). Wavelet analysis of annual rainfall over Kerala and sunspot number. New Astron. 98, 2023, 101944. https://doi.org/10.1016/j.newast.2022.

Tiwari, Babu, Jiyao Xu, Binod Adhikari, and N. Chapagain. (2021). Wavelet and cross correlation analysis on some climatology parameters of nepal. *BIBECHANA* 18 (June): 105–116. https://doi.org/10.3126/bibechana.v18i2.33805.

Tsiropoula, G. (2003). Signatures of solar activity variability in meteorological parameters. *J. Atmos. Sol.-Terr. Phys.* 65 (4): 469–482. ISSN: 13646826. https://doi.org/10.1016/S1364-6826(02)00295-X

Wasko, Conrad, and Ashish Sharma. (2009). Effect of solar variability on atmospheric moisture storage. Geophys. Res. Lett. 36 (3). ISSN: 00948276.https://doi.org/10.1029/2008GL036310.

Zhai, Qian. (2017). Influence of solar activity on the precipitation in the North-central China. *New Astron.* 51:1339–1351. ISSN: 13841076. https://doi.org/10.1016/j.newast.2016.09.003.

Zhao, Juan, Yan-Ben Han, and Zhi-An Li. (2004). The Effect of Solar Activity on the Annual Precipitation in the Beijing Area. *Chin. J. Astron. and Astrophys*. 4 (2): 189–197.

Yu, Xuefeng, Yi Wang, Shiyong Yu, and Zhihai Kang. (2019). Synchronous droughts and floods in the southern chinese loess plateau since 1646 ce in phase with decadal solar activities. *Glob. Planet Change* 183:103033. https://doi.org/https://doi.org/10.1016/j.gloplacha.2019.103033.

A Review on the Phytochemical and Therapeutic Potential of *Olea Dioica* Roxb. Infected with *Zaghouania Oleae* (E.J. Butler) Cummins

Susan Kuriakose[1] and Jacob Thomas[2]

Abstract: The health industry relies heavily on traditional remedies, which include medicinal plants and plant materials. Nevertheless, it is imperative to preserve this invaluable knowledge for future generations, as traditional knowledge is diminishing due to evolving lifestyles. Fungal infections of plants, such as Zaghouania oleae can produce bioactive natural products that can supplant conventional molecules. The chemical composition of the host is influenced by the complex interaction between fungi and plants, which function as biotransformers or biocatalysts. The ancient therapeutic framework of India, which spans over 5,000 years, comprises more than 9,500 distinct types of wild flora that communities have employed for various purposes. Various bioactive secondary metabolites, such as alkaloids, benzopyranones, and phenolic acids, are produced by fungi that infect plants. Rust fungi, also called Pucciniales, have evolved in conjunction with their hosts and have undergone host switching. In the Western Ghats region of India, the tree Olea dioica Roxb. is renowned for its traditional Siddha medicine and ethnomedicinal properties. Nevertheless, it is susceptible to fungal infections caused by Zaghouania oleae, which result in infertility and hypertrophy. A study conducted by Dr. Vimal Kumar assessed the anti-infertility potential of Olea dioica Roxb. that had been infected with the fungus.

Key words: secondary metabolites, hypertrophy, coevolution, alkaloids, Saponins, Tannins, Flavonoids, Steroids, Glycosides, Phenols, Sterols.

Introduction

Most therapeutic medicines used today are the results of research on traditional knowledge. Traditional medicines include medicinal plants, plant materials, herbal preparations, prepared herbal products containing plant parts, and other plant materials or combinations of them as active ingredients (WHO, 2013a). As traditional knowledge is rapidly eroding due to the changing lifestyles of people, there is an urgent need to

[1]Assistant Professor, Department of Botany, Mar Thoma College, Tiruvalla
[2]Associate Professor and Research Guide, Department of Botany, Mar Thoma College, Tiruvalla

systematically document such valuable knowledge for the welfare and development of posterity (Lalitha et al., 2011).

Certain fungal infections of plants, which trigger the production of many secondary metabolites, have been considered an excellent source of bioactive natural products. Once the properties of secondary metabolites are known, they will be used to replace conventional molecules, ultimately benefiting the health industry. Olea dioica Roxb., a member of the "Oleaceae" family, is a tree species infected by the rust fungus Zaghouania oleae (E.J. Butler) Cummins. Infection with Z. oleae is limited to leaves and tender shoots and causes leaf blistering, hypertrophy, shrinkage, thickening, and abnormal elongation of the infected shoot. In Andhra Pradesh, Chenchu tribal women cook and eat the hypertrophied sensitive twigs of Zaghouania oleae infected Olea dioica to treat women's infertility issues.

Together with other abiotic elements of nature, the interaction between fungi and plants represents a distinctive, well-balanced, multipartite ecological relationship that creates a complex interplay of the elements. The host's chemical composition is altered by fungus infection, and fungi also function as biotransformers or biocatalysts. The relationship between plants and fungi appears to go beyond just a straightforward interaction to a highly complex genome-level interaction. One finding is that some genes are exclusively expressed in fungus-infected plants (Johnson et al., 2003). The coevolution of fungus and their host plants is the result of this long-term genetic connection (Germaine et al., 2004)

Fungi in Ethnomedicine

India’s old therapeutic framework dates back roughly 5,000 years and could be invaluable to our country’s history. Atreya Samhita is considered the most seasoned restorative book on the planet. Our ancient texts, such as the Rigveda, Yajurveda, and Atharvaveda, also make mention of medicinal plants (Anil,2013). These texts were written between 3000 and 2500 BC. In Ayurveda (600-100 BC), medicinal plants are documented in writing. The properties and applications of medicinal plants were later described in detail in the Charaka Samhita (700 BC) and Sushruta Samhita (200 BC).

According to research done by the Indian Ministry of Environment and Forests as part of the All-India Co-ordinated Research

Study on Ethnobiology, over 9,500 different types of wild plants are used by Indian tribes to fulfill a variety of needs. In addition to using 7,500 different wild plant species for medicinal purposes, they also use 3,900 different species for food, 525 different species for cordage and fiber, 400 different species for fodder, about 300 different species for pesticides and piscicides, 300 different species for gums, resins, and dyes, 100 different species for incense and perfumes, and 700 different species for cultural and other needs. Purkayastha and Chandra (1985) reported that some ethnic groups in India are considered mycophilous and possess extensive traditional mycological knowledge.

As a result of fungal infection, many medicinal plants develop additional secondary metabolites, which boost their therapeutic effects. Tribes have employed the herb Potentilla fulgens infected with the fungus Talaromyces flavus to cure excessive blood sugar levels. Osbeckia stellata, a toothache treatment, has been shown to be infected with the fungus Mortierella hyaline. For the treatment of dysentery and excessive sputum, Osbeckia chinensis infected with the fungus Paecilomyces variabilis and Penicillium pinophilum have been employed. Infected with the fungus Syncephalastrum racemosum and Trichoderma harzianum, Camellia caduca has been used as an astringent, digestive, carminative, and diuretic. The fungus Aspergillus chrysogenum has invaded Schima khasiana, which is used to cure stomach aches and allergies.

From time immemorial, fungi have been used to treat human reproductive diseases. The Amazonian Jývaro women consumed Balansia carecis infecting the inflorescence of Carex sp to treat infertility (Lewis and Lewis,1990). Ergometrine is formed during the infection process of a perennial grass Secale cereale by a smut fungus Claviceps purpurea and has long been used for strong uterine contraction and control of postpartum haemorrhage (Tudzynski et al. 2001). The ascomycete fungus, Ophiocordyceps sinensis which develops on the larva of an insect, the 'Himalayan bat moth' is one of the most prized herbs used since ancient periods. It is said to be a highly efficient herbal treatment for a variety of disorders, such as cancer, hypoglycemia, asthma, hypercholesterolaemia, sexual dysfunction, immunodeficiency, and so on. It is widely recognised for its tonic, aphrodisiac, cardiotonic, and expectorant properties (Shrestha et al., 2010).

Secondary Metabolites and plant-fungal interaction

Plants and fungi produce a vast array of secondary metabolites. The genetic capacity for creating these compounds, the triggers for their production, and specific phytotoxins fundamentally shape the interactions between microscopic fungi and host plants, as well as the pathogenic behaviour of fungi.

Mycophenolic acid, a crystalline fungus product from Penicillium glaucoma, was identified by Gosio in 1896, and it is regarded as the first secondary metabolite found in microorganisms (Demain & Fang, 2000). According to Tan and Zou (2001), fungi that infect plants produce a wide range of bioactive secondary metabolites with distinctive structural characteristics, such as alkaloids, benzopyranones, chinones, flavonoids, phenolic acids, quinones, steroids, terpenoids, tetralones, xanthones, phenols, isocoumarins, benzopyranones, cytochalasines, and other compounds.

Microorganisms appear to be innately capable of creating considerably more natural compounds than have been seen in the lab, according to Bode et al. (2002). According to Schulz et al. (2002), fungi that infect plants can create the same critical and uncommon bioactive chemicals as their host, making the fungi a potential source of alternative plant secondary metabolites.

Biology of Zaghouania oleae (E.J. Butler) Cummins

The Pucciniales, commonly known as rust fungi, are among the most expansive fungal groups, with over 8,000 species documented. These captivating pathogens can affect a diverse range of plants, including ferns, monocots, gymnosperms, and angiosperms, indicating a deep-rooted evolution towards a biotrophic way of life. Rust fungi exhibit intricate life cycles and are pathogens specific to their hosts. Some can necessitate two distinct host plants to finish their life cycle, while others might have a simpler life cycle, lacking certain spore-producing phases. Numerous rust fungi go through life cycles encompassing five varied spore forms or phases: pycniospores, aeciospores, urediniospores, teliospores, and basidiospores.

The evolutionary patterns and diversification of rust fungi have long been a topic of keen research, particularly in relation to their coevolution with host plants. Historically, rust fungi, being obligate

parasites, were believed to have evolved in tandem with their hosts, initially infecting ferns, then gymnosperms, and finally angiosperms. However, recent phylogenetic studies challenge this view, indicating that fern rust fungi weren't ancestral and that some angiosperm-infecting rust fungi trace back to a primordial family. Notably, the discovery of Caeoma torreyae on gymnosperms suggests a more recent origin for rust fungi. Current data highlights rust fungi diversification primarily through host switching, emphasizing the evolutionary role of a primary host in the Pucciniales order. It's also noted that certain rust fungi, which switch between unrelated plants, require these hosts to exist in the same environment. This suggests potential unknown alternate hosts might cohabit in the same environment as identified hosts or have vanished due to ecological shifts.

Many species of Zaghouania are known to produce basidia, which can be called semi-internal basidia and sessile basidiospores. "semi-internal" refers to the unique structure of the basidia wherein they are partially formed from the inside of the teliospores but also have portions extending outside of them. Most basidia create structures called sterigmata, and on the tips of these sterigmata, they produce basidiospores. However, species from the genus Zaghouania don't have these structures. Instead, they produce basidiospores directly on the basidia.

Phytochemical estimation of Olea dioica Roxb. infected with Zaghouania oleae

The Olea dioica Roxb. is a tree that belongs to the Oleaceae family and is known for its ethnomedicinal properties. It's found in open forests ranging from fully evergreen to partly evergreen and even moist deciduous forests up to 1200 meters high, primarily in India's Western Ghats region. Traditional Siddha medicine uses its roots and leaves to treat cancer and snake bites.

In the state of Kerala, Olea dioica is colloquially designated as 'Edana.' Historically, this plant has been recognized for its intermittent medicinal applications. Notably, during the winter months, the tree is susceptible to fungal infections by Zaghouania oleae (E.J. Butler) Cummins, a fungus from the Pucciniaceae family. The manifestations of this fungal infection are predominantly observed on the leaves and nascent shoots, resulting in blisters, hypertrophy, and anomalous growth

patterns. It is noteworthy that the hypertrophied young branches, post-infection, are consumed by the Chenchu tribal women of Andhra Pradesh, purportedly as a remedy for female infertility disorders.

The phytochemical analysis showed the presence of Saponins, Tannins, Flavonoids, Steroids, Glycosides, Phenols, and Sterols in Olea dioica (Ashwathanarayana et al., 2015). The leaf extract from the fungus-infected leaves of O. dioeca contains notably higher levels of phenolics and flavonoids compared to their uninfected counterparts (Vimalkumar et al.,2014). This discovery is pivotal for a multitude of reasons. Firstly, this study stands as the inaugural comparison of the chemical composition between fungus-infected and healthy leaves of O. dioeca. Secondly, extracts with flavonones and phenols derived from fungus-infected plants have historically been employed to address infertility disorders. This research not only aims to substantiate the indigenous tribes' medicinal claims about these infected plants but also underscores the broader medicinal potential of such extracts. Earlier studies have ascertained that many of these phenolic compounds and flavonoids act as potent natural antioxidants, invaluable for human health both in preventive and therapeutic capacities. Beyond their antioxidative qualities, flavonoids and phenolic compounds have been recognized for a spectrum of medicinal properties, including but not limited to liver protection, inflammation reduction, immune system enhancement, cancer prevention, and infertility treatment.

In a comprehensive study aimed at elucidating the anti-infertility potential of Olea dioica Roxb. infected with the fungus Zaghouania oleae (E.J. Butler) Cummins, Dr. Vimal Kumar employed the reproductive indices model as a diagnostic tool. Their exploration focused on discerning the reproductive sequelae in female Wistar rats' post-administration of extracts isolated from infected O. dioica (Plate – 1). A holistic evaluation of the plant's reproductive impact was undertaken by juxtaposing the reproductive outcomes of subjects treated with both mycosis-compromised and non-compromised plant extracts against a standard control cohort. The model was meticulously curated to quantify the variance in reproductive efficacy induced by the different plant extract treatments. Key parameters assessed included uterine and ovarian mass, implantation site enumeration, offspring progeny counts, metrics pertaining to post-implantation attrition, and an array of salient

reproductive indices. These encompassed gestational tenure, fertility ratios, delivery dynamics, neonatal viability ratios, prevalence of external congenital malformations, standardized litter dimensions, and neonate mass distribution metrics. In light of the observed results, it can be deduced that the enhancement in reproductive indices is attributable to the estrogenic activity elicited by the fungus-infected O. dioica. All these observations align with the augmented pharmacological potency of the plant extract derived from the fungus-infected specimen.

PLATE - 1

Zaghounia oleae **(**Butler) Cummins on the leaves of *Olea dioica*
1-4 Infected stem and leaves showing, 5. Uredospores

References

Anil K G. Role of Ethnobotany in drug development. J Trad Folk Practices 2013; 1(1):39-46.

Ashwathanarayana, R., & Raja Naika. (2015). Preliminary phytochemical and antimicrobial properties of Olea dioica Roxb bark extract collected from Western Ghats, Karnataka, India. Journal of Pharmacognosy and Phytochemistry, 4(4), 156-160.

Bode H B, Bethe B, Hofs R, Zeeck A. Big effects from small changes: Possible ways to explore nature's chemical diversity. Chem Biochem 2002; 3:619– 627.

Demain A L and Fang A. The natural functions of secondary metabolites. Adv Biochem Eng Biotechnol. 2000; 69: 1-39.

Germaine K, Keogh E, Garcia C, Borremans L, Barac O, Vangronsveld M, Moore E R B, Campbell C D, Ryan D D. Colonization of poplar trees by gfp expressing bacterial endophytes. FEMS Microbiol Ecol 2004; 48:109- 118.

Johnson L J, Johnson R D, Schardl C L, Panaccione D G. Identification of differentially expressed genes in the mutualistic association of tall fescue with Neotyphodium coenophialum. Physiol Mol Plant Pathol 2003; 63: 305-317.

Lalitha R S, Kalpana D V, Tresina S P, Maruthu P A, Mohan V R. Ethnomedicinal plants used by Kanikkars of Agasthiarmalai Biosphere Reserve, Western Ghats. J Ecobiotech 2011; 3(7):16-25.

Lewis W H, Lewis M. Obstetrical use of the parasitic fungus Balansia cyperi by Amazonian Jivaro women. Econ Bot 1990; 44:131-133.1.

Purkayastha R P, Chandra A. Manual of Indian edible mushrooms. Jagendra Book Agency, New Delhi, India. 1985.

Rommert A K, Oros-Sichler M, Lange T, Aust H J, Schulz B. Growth promoting effect of endophytic colonization of Larch seedlings (Larix decidua) with Cryptosporiopsis sp. and Phialophora sp. In: Book of Abstracts, the Seventh International Mycological Congress 2002; University of Oslo, Oslo. pp. 309.

Shrestha B, Zhang W M, Zhang Y J, Liu X Z. What is Chinese caterpillar fungus Ophiocordyceps sinensis (Ophiocordycipitaceae)? Mycol 2010; 1: 228- 236.

Tan R X, Zou W X. Endophytes: a rich source of functional metabolites. Nat Prod Rep 2001; 18:448-459.

Tudzynski P, Correia T, Keller A. Biotechnology and genetics of Ergot alkaloids. J Psychedelic Drug 2001; 57:65-93.

Vimalkumar, C.S., Hosagaudar, V.B., Suja, S.R., Vilash, V., Krishnakumar, N.M., & Latha, P.G. (2014). Comparative preliminary phytochemical analysis of ethanolic extracts of leaves of Olea dioica Roxb., infected with the rust fungus Zaghouania oleae (E.J. Butler) Cummins and non-infected plants. JPP, 3(4), 69-72.

WHO. "WHO Traditional Medicine Strategy 2014-2023". World Health Organization. 2013a.

Role Of Kudumbashree Project in Women Empowerment through Micro Financing – with Special Reference to Niranam Panchayat

Ancy Mary Ninan1 and Liji Samuel2

Abstract: Kudumbashree, launched in 1998 by the Government of Kerala, is a pioneering initiative aimed at poverty eradication and women s empowerment through a community-driven approach. Functioning under the Department of Local Self-Government, the mission operates on a three-tiered structure involving Neighbourhood Groups (NHGs), Area Development Societies (ADS), and Community Development Societies (CDS). This study focuses on the Kudumbashree project in Niranam Panchayat, examining its role in empowering women through microfinancing. Using primary and secondary data, it assesses strengths, weaknesses, opportunities, and challenges while offering recommendations for improvement. Kudumbashree represents a unique socio-economic model fostering self-sufficiency and grassroots development.

Introduction

The Government of Kerala established Kudumbashree in 1998 with the goal of reducing poverty in Kerala's rural and urban communities through community development initiatives .One of India's most significant initiatives for women's empowerment is currently known as Kudumbashree. The Kudumbashree Mission is also known as "Ayalkootam," which is Malayalam for gatherings or meetings held in the neighbourhood. The Ayalkootam was born out of an experiment conducted in the 1970s in the Gandhian village of Kanjippadam in the Alappuzha District by D Pankajakshan, a teacher. The three levels of this experiment were also present. The members of the first tier, known as "Tharakootam," came from ten to fifteen nearby families. Every evening, they gathered in one of the homes' courtyard. The Ayalkootam, composed of five Tharakootam, was the following level. The Gramakootam or village assembly was the third level, made up of ten

[1] Former PG STUDENT, Research Centre, Department of Economics, Mar Thoma College, Tiruvalla

[2] Assistant Professor, Department of Economics, Mar Thoma College, Tiruvalla

Ayalkootams. The State Poverty Eradication Mission of the Government of Kerala has been implementing the Kudumbasree Poverty Alleviation and Women Empowerment Program."Prosperity of family" is the meaning of the word Kudumbasree in Malayalam. The Kudumbasree Community Network is represented by the name "Kudumbasree Mission" or "SPEM."

The Kudumbashree scheme seeks to raise the standard of living for underprivileged women in rural areas by establishing microcredit and profitable businesses. It is a poor women's self-help project centred in the neighbourhood. The National Bank for Agriculture and Rural Development (NABARD) and the Government of Kerala together created the Kudumbashree initiative, which was carried out through Community Development Societies (CDSs) of Poor Women, the neighbourhood arm of local governments.

The Mission is managed, supervised, and directed by the Department of Local Self-Government of the Kerala Government. The National Bank for Agriculture and Rural Development (NABARD), a bank owned by the Government of India, also provides support for the Mission in addition to the monies that the Kerala Government allots for it in its annual budget.The Kerala Government's Department of Local Self-Government oversees, manages, and directs the Mission. In addition to the funds that the Kerala Government allots for the Mission in its annual budget, the National Bank for Agriculture and Rural Development (NABARD), a bank owned by the Government of India, also offers assistance for the Mission.

There is a mission underway for Kudumbasree Mission. The three-tiered community network of the mission focuses mostly on saving and credit. However, they also help local governments create and carry out programmes for reducing poverty, empowering women, and fostering the overall economic growth of their region of operation. The Community Development Society (CDS), in a similar manner, creates a "CDS Action Plan" in response to a "demand plan" put out by their local government. The action plan was created over the course of several sittings when neighbourhood groups prepared their "micro-plans," which were then integrated into all "Mini-Plans" at the level of the Area Development Society. The CDS Action Plan, please.

Kudumbashree was designated as the State Rural Livelihoods Mission (SRLM) under the National Rural Livelihoods Mission in 2011

by the Ministry of Rural Development (MoRD), Government of India (NRLM).

Statement Of the Problem

Study on Kudumbasree Project in Niranam Panchayat will enable us to know the role of this project in women empowerment through micro financing. It also helps us to identify the strengths, weaknesses, opportunities and threats of this project and provide suggestions for improvements and remedial action where necessary.

Objectives Of the Study

1. To understand the structure, working and progress of kudumbashree project in Kerala.
2. To examine the role of Kudumbashree Project in women empowerment through micro financing in Niranam Panchayat
3. To give suggestions for the improvement of the performance Kudumbashree Project.

Methodology

Information will be collected mainly through primary and secondary data. Primary data is collected from small scale entrepreneurs of Niranam panchayath of Pathanamthitta District.

Primary data has been collected through questionnaires and direct enquiry method secondary data are collected from published books, report, periodicals, websites, etc. Comparative analysis of their economic conditions is undertaken. The sample will be collected from 50 people through convenience sampling method.

Kudumbashree, the Kerala State Poverty Eradication Mission was launched on 17th May 1998 inaugurated by the Prime Minister, Shri Atal Bihari Vajpayee. The Mission aims to eradicate absolute poverty within a definite time frame of 10 years under the leadership of Local Self Governments formed and empowered by the 73rd and 74th Amendments of the Constitution of India. The Mission launched by the State Government with the active support of Government of India and NABARD has adopted a different methodology in addressing poverty by organizing the poor in to community-based organizations. The Mission follows a process approach rather than a project approach.

Kudumbashree, a community organization of Neighbourhoods Groups (NHGs) of women in Kerala, has been recognized as an effective strategy for the empowerment of women in rural as well as urban areas:

bringing women together from all spheres of life to fight for their rights or for empowerment. The overall empowerment of women is closely linked to economic empowerment. Women through these NHGs work on a range of issues such as health, nutrition, agriculture, etc. besides income generation activities and seeking micro credit.

Kudumbashree differs from conventional programmes in that it perceives poverty not just as the deprivation of money, but also as the deprivation of basic rights. The poor need to find a collective voice to help claim these rights.

Kudumbashree was conceived as a joint programme of the Government of Kerala and National Bank for Agricultural and Rural Development (NABARD) implemented through Community Development Societies (CDSs) of Poor Women, serving as the community wing of Local Governments. Kudumbashree is formally registered as the "State Poverty Eradication Mission" (SPEM), a society registered under the Travancore Kochi Literary, Scientific and Charitable Societies Act 1955. It has a governing body chaired by the State Minister of LSG. There is a state mission with a field officer in each district. This official structure supports and facilitates the activities of the community network across the state. Kudumbashree differs from conventional programmes in that it perceives poverty not just as the deprivation of money, but also as the deprivation of basic rights. The poor need to find a collective voice to help claim these rights.

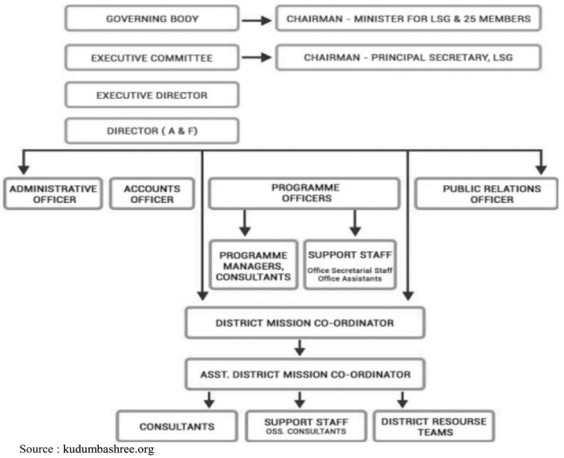
The grassroots of Kudumbashree are Neighbourhood Groups (NHG in short) that send representatives to the ward level Area Development Societies (ADS). The ADS sends its representatives to the Community Development Society (CDS), which completes the unique three-tier structure of Kudumbashree. It is this network that brings women to the Grama Sabhas and helps them bring the needs of the poor to the attention of the local governments. The Community Development Societies are also very active in Government programmes and play significant roles in development activities ranging from socio-economic surveys and enterprise development to community management and social audit. Though its efforts to engage women in civil society in development issues and opportunities, Kudumbashree in association with the local self government of Kerala is charting out new meaning and possibilities for local economic development and citizen centric governance.

The Community Development Societies (CDSs) of Poor Women, the community arm of Local Governments, were used to implement the Kudumbashree programme, which was created as a collaborative initiative of the Government of Kerala and NABARD. Kudumbashree is officially recognised as the "State Poverty Eradication Mission" (SPEM), an organisation registered under the Travancore Kochi Literary, Scientific and Charitable Societies Act 1955. Its Executive Committee is presided over by the Additional Chief Secretary of the Department of Local Self Government, and its Governing Body is led by the state minister of local self government.

The Governing Body and Executive Committee are responsible for the Mission's governance. The Governing Body makes decisions at the policy level and routinely assesses the Mission's performance. While the Executive Committee makes the executive decisions for the creation and implementation of the programme. Thiruvananthapuram is home to the State Mission Office for the Mission, while the 14 District Mission Teams are each based at the district's administrative centre. The state-wide community network's activities are supported and made easier by this formal structure.The State Poverty Eradication Mission's (SPEM) organisational chart is displayed below:

Figure 1

Structural Body of State Poverty Eradication Mission (SPEM)



Source : kudumbashree.org

Kudumbashree is essentially a community network that covers the entire State of Kerala. It consists of a three tier structure with Neighbourhood Groups (NHGs) as primary level units, Area Development Societies (ADS) at the ward level, and Community Development Societies (CDS) at the local government level. It is arguably one of the largest women s networks in the world. While the community network is formed around the central themes of poverty eradication and women empowerment, its main features include democratic leadership, and support structures formed from the „Kudumbashree family .

Neighbourhood Groups (NHGs)

Neighbourhood Groups (NHGs) are the primary units of the Kudumbashree community organisation. Ten to twenty women from a neighbourhood form a NHG. The membership, structure, and functions of the NHGs are bound by the byelaws of Kudumbashree CDS.

Area Development Society (ADS)

Area Development Society (ADS) is the middle tier of the Kudumbashree community organisation. An AD is formed at the ward level of the local governments. There is a one-to-one correspondence between the wards and ADSs except for the tribal ADSs which are formed with special permission of the government.

Community Development Society (CDS)

Community Development Society (CDS) is the apex body of the three-tier Kudumbashree community organisation. It functions at the local government level, in both rural and urban areas. While typically there is a CDS per local government, there can be more CDSs for urban government institutions with relatively large number of NHGs and ADSs.

Micro Finance Activities

Thrift and micro credit, bank linkage, Matching Grant to thrift and credit facilities, interest subsidy, the Kudumbashree Accounts & Audit Service Society(KAAS), Financial Literacy Campaign, E-Shakti, and Yuva sree

Bank Linkage

NHGs initiate steps to establish bank linkage on completing six months of functioning with regular meetings and savings. The NHGs undergo grading to qualify for bank linkage. Once an NHG is linked

with banks, it can avail loan and use the funds to lend to its members. For loans extended to members out of bank loans, repayment terms are fixed based on the repayment requirements of the bank

Women drivers

As part of ensuring safe journey of women, Kudumbashree developed a pool of 226 women drivers in 2018-19.Some of the examples for this are She taxi, Palliative ambulance, etc…

Haritha Karma Sena

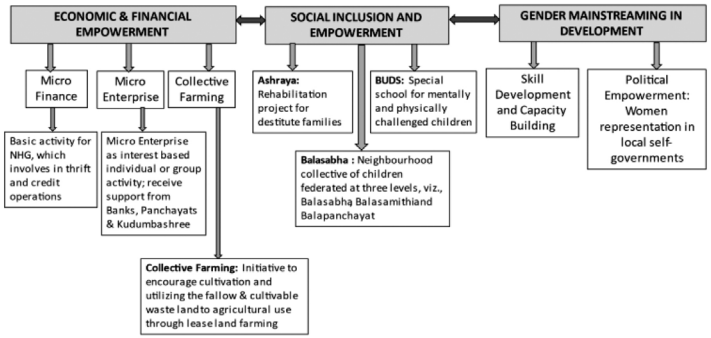
The Haritha Karma Sena collects **non-biodegradable waste from houses and establishments to shredding units for recycling**. ... Each Kudumbashree worker will visit minimum 250 houses to collect non-biodegradable waste. The collection will be based on user fee.

Prathyasha

"Prathyasha" is an innovative programme launched as a joint venture amid Individuals, Corporate and Kerala Social Security Mission (KSSM).As a part of this programme girls belonging to poor families are provided with a marriage assistance dole of Rs 50,000 each using the funds raised by Individuals, Corporate and Kerala Social Security Mission. The individuals / corporate can donate amount in multiples of 25,000 and equivalent amount contributed by the government which will be used by the Mission to meet the requirements. Depositors would have an option to select the beneficiaries.

Figure: 2

Kudumbashree and Multi Diametrical Empowerment



Source: kudumbashree.org

Study Area

Niranam village is situated in Teshil Thiruvalla, District Pathanamthitta and in State of KERALA India. Village has population of 10770 as per census data of 2011, in which male population is 5084 and female population is 5686. Total geographical area of Niranam village is 1101 Hectares. Population density of Niranam is 10 persons per Hectares. Total number of house hold in village is 2837. Gram Panchayat name of the Niranam village is Niranam. CD Block name is Pulikkeezh (Part) and Teshil/Taluk or sub-district is Thiruvalla. Data Reference year is 2009 of Census 2011. Sub District HQ Name is Thiruvalla and Sub District HQ Distance is 10 Km from the village. District Head Quarter name is Pathanamthitta and its distance from the village is 40KM. Nearest Town of the Niranam village is Thiruvalla and nearest town distance is 10 km. Out of total population total 9452 people in Niranam Village are literate, among them 4456 are male and 4996 are female in the village. Total literacy rate of of Niranam is 96.01%, for male literacy is 96.91% and for female literacy rate is 95.22%.

Kudumbashree -NIRANAM

The kudumbashree unit in Niranam started in 1998 with 800 members in the panchayat .In Niranam there are 68 kudumbashree units with 2438 members and the self employed members in the Niranam panchayat is 95.Akudumashree unit must only contain minimum 10 member to maximum number and 20lakh Rs have been allotted to them. There are also many micro enterprises under a kudumbashree unit. Some of the micro enterprises in the units are poultry farm, cow rearing, duck farming, duck rearing ect.

A Profile Of the Niranam Panchayat

Description	Census 2011 Data
Village Name	Niranam

Description	Census 2011 Data
Teshil Name	Thiruvalla
District Name	Pathanamthitta
State Name	KERALA
Total Population	10770
Total Area	1101 (Hectares)
Density (P/Ha)	10
Total No of House Holds	2837
Total Male Population	5084
Total Female Population	5686
0-6 Age group Total Population	925
Total Person Literates	9452
Total Person Illiterates	1318
Scheduled Cast Persons	1318
Scheduled Tribe Persons	5

Niranam Kudumbashree Description

Description	Data
Kudumbashree started	1998
Members(Start)	800
Members(Now)	2438
Unit	168

Description	Data
Self employed	95

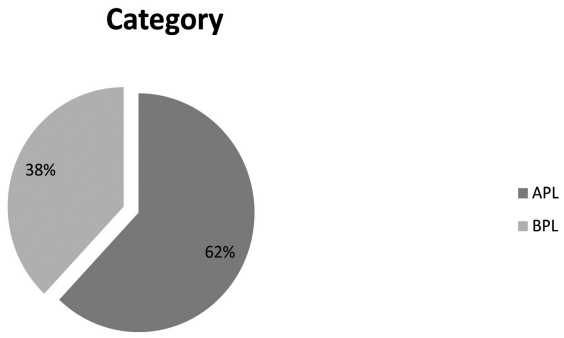
In Niranam the kudumbashree started in 1998 with 800+ members now there are actively 2438 members. The Niranam panchayat have 168 unit active now each unit can have maximum 20 members (in each unit).The 95 members in the panchayat is self employed.
Source: Primary data

A Profile of Kudumbashree Members

The profile shows the age wise distribution of the kudumbashree members. In total 50 samples have been collected from the KDS members in that 46 percentage of the respondents are in the age group of 41-50. The age group between 31-40 and 50 above (that is 28% and 22%) are not actively participating in KDS and only 4% or 2members are participating in the kudumbashee out of 50 samples taken.

Figure 3

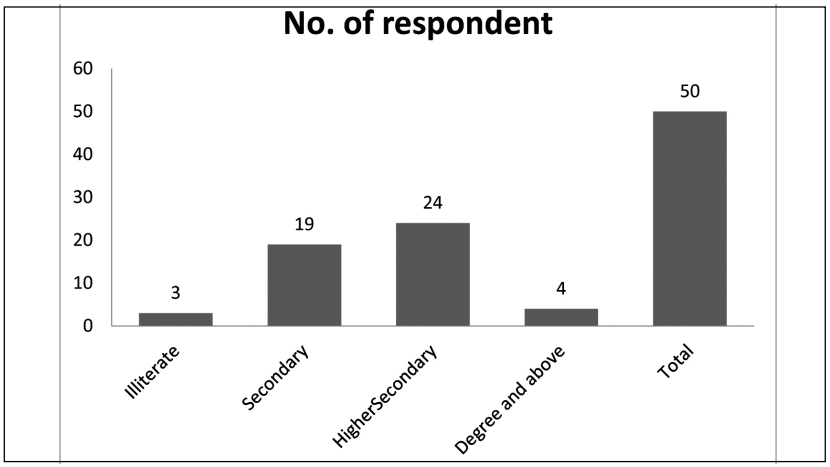
Pie Diagram Showing Category of the Respondent



Source: Primary data

The figure 3 show the category (APL, BPL) of the respondent. The 62 percent or the 31 member of the Kudumbashree out of 50 samples are APL category and the 38% or the 19 members are BPL.

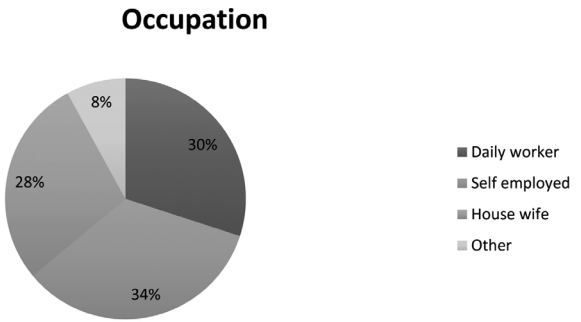
Figure 4
Bar Diagram Showing the Education Qualification of the Respondent



Source: Primary data

The above figure 4 shows the Educational Qualification of the respondent. From the above table it is clear that the 48% of the members have got higher secondary education and the 38 percent of the members got secondary education. Out of the total sample taken only 6% of the people are illiterate. The above graduated people is low, there are only 8% of the total sample have got degree and above.

Figure 5
Pie Diagram Showing Occupation of the Respondent



Source: Primary data

The figure 5 shows the occupation of the respondent of the kudumbashree units. 34 percentage or the 17 members are self employed and the 30 percent or the 15 members of the KDS are daily worker. 14 members or the 28 percent of the workers are house wife and the other 8 percent of the members are engaged in other sectors

Table 1
Duration of Being Member of kudumbashree

member of Kudumbashree	No. of respondent	Percentage
1-2 year	7	14%
3-5year	13	26%
5-10 y	20	40%
more than 10	10	20%
Total	50	100%

Source: Authors calculation

The above table 1 shows that the duration of a member participating in part of kudumashree. The 40% of the or the 20 members have been the part of kudumbashree for 5 to 10 years and the 26% of the members have been a member of kudumbashree for past 3-5 years. The 20% of the people have been the member of kudumbashree for more than 10 years. Only the 14% of the people have been newly joined kudumbashree for the past 1-2 years.

Table 2
Influencing Factor to Join Kudumbashree

Factor to join kudumbashree	No. of respondent	Percentage
To Obtain Credit Others	14	28%
For promoting savings	22	44%
For employment opportunities	21	42%
Others	5	10%
Total	50	100%

Source: Authors calculation

The above table1 showing the influencing factor to join kudumbashree. The 44% or the 22 members join kudumbashree to promoting saving and the 42 %of the members or the 21 members join for getting more employment opportunity. The remaining 28% and 10% of the members are joining kudumbashree for obtaining credit and other purpose.The above table 1 shows the after joining kudumbashree unit. The 48% or the 24 members of the unit got the benefit of increased saving and the 42% of the members join kudumbashree to get loan to meet emergencies. The 26% and 8% of the members got the benefit of becoming a part of social group and other benefits were also there.

Table 3

Personal bank account

personal bank account	No of respondent	Percentage
Yes	50	100%
No	0	0%
Total	50	100%

Source: Authors calculation

The table 3 shows how many kudumbashree members have got personal bank in account. Out of 50 samples taken the 100% of the members have personal account in bank.

Table 4

Loan through Kudumbashree

Loan facility	No. of respondent	Percentage
Yes	37	74%
No	13	26%
Total	50	100%

Source: Authors calculation

The above table 4shows the loan facility that is availed through kudumbashree.the 774%of they have been availed loan facility through the kudumbashree and the 26%of the members havet availed loan facility through kudumbashree. The majority of the members have availed loan facility through kudumbashree for various uses.

Table 5
Purpose of Micro Finance Availed by you

purposes micro finance	No of respondent	Percentage
House maintenance	9	18%
Framing	15	30%
Starting micro finance	20	40%
Other	6	12%
Total	50	100%

Source: Authors calculation

The table 5 is showing the micro finance availed by KDS members .the 40%of the members availed micro finance for the purpose of starting micro enterprises. The 20% of the people availed loan for the purpose of housing maintenance and the 185 and the 12%of the members availed micro finance for farming and other purpose

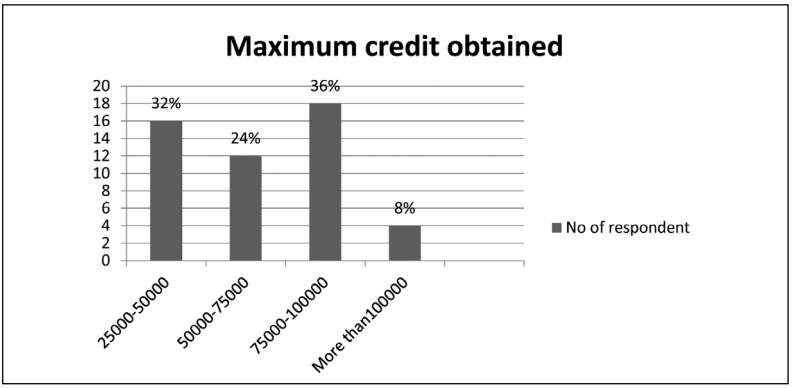
Table 6
Banking Service Improved After Joining Kudumbashree

Banking service	No of respondent	Percentage
Yes	47	94%
No	3	6%
Total	50	100

Source: Authors calculation

The table 6 shows the banking service improved after joining kudumbashree. The 94% or the 47 members of the kudumbashree members say the banking services have improved and the 6% or the 3 members says that the banking service haven t improved

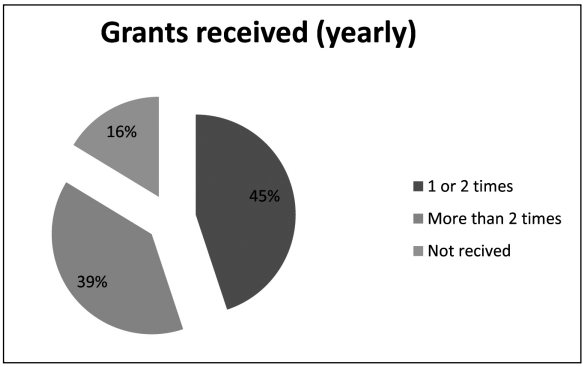
Figure 6
Bar Diagram Showing Maximum Credit Obtained by KDS Member



Source: Primary data

The figure 6 shows the maximum credit obtained by KDS member. The 36% of the members obtained 25000-50000 credit yearly and the 32% of the members obtained 75000-100000. The 24%of the members obtained 50000-75000 and only the 8% of the members obtained the credit of one lakh above.

Figure 7
Pie Diagram Showing Subsidy Received Through KDS

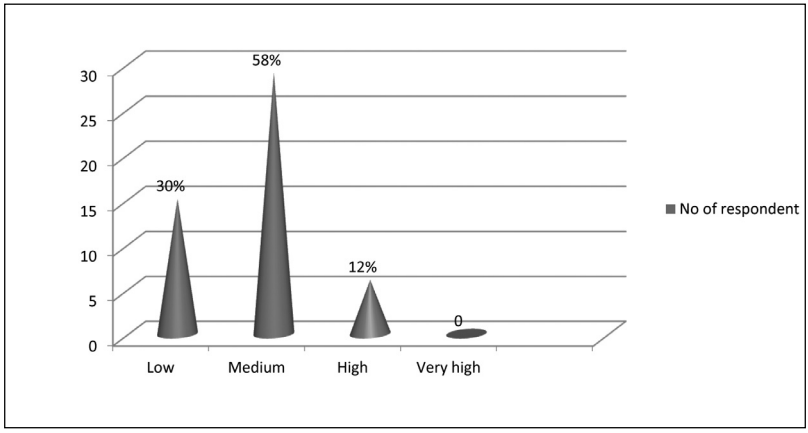


Source: Primary data

The above figure 7 shows the grants receive yearly by a KDS member. The 44% of the members received grand through kudumbashree 1 or 2 times and the 38% of the members have received more than 2 times. The 16% haven t received grants through kudumbashree in a year.

Figure 8

Cone Diagram Showing the Participation of Government Offered Programmers



Source: Primary data

From the above figure 8 ,we can understand that the government participation is not that much in KDS the 58 percent of the people say that the participation of the government is medium. There isn t much participation by the government. The 305 say that the participation of the government is very low.

Table 7

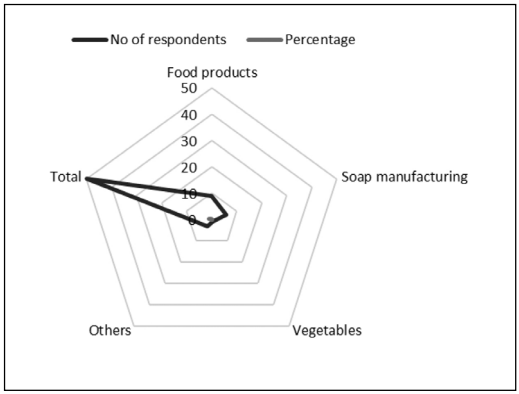
Business in Kudumbashree Business in KDS No of respondents Percentage

Yes	19	38%
No	31	62%
Total	50	100

Source: Authors calculation

The above table 7 showing the business that runs in kudumbashree. The 68% of the people doesn t run business in through kudumbashree. The 38% of the people run business in kudumbashree.

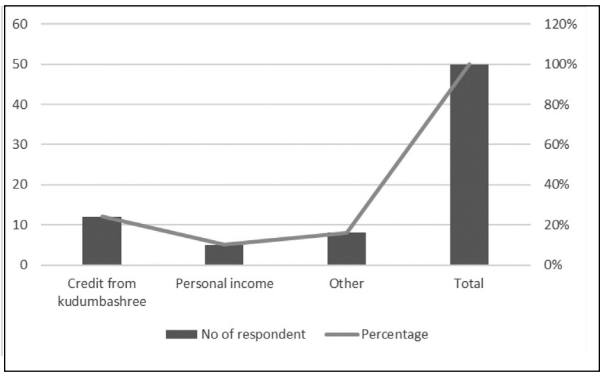
Figure 9
Pie Diagram Showing Business Run in Kudumbashree



Source: Primary data

The above figure 9 shows the products or the businesses that runs through the kudumbashree. The 47%of the members run business of food product and the 32% of the members run business in soap manufacturing. The 16% and 5% of the members engaged in vegetables and other businesses.

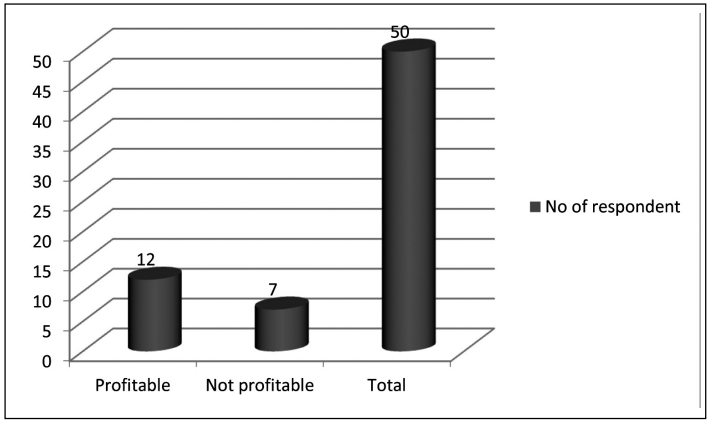
Figure 10
Pie Diagram Showing Source of Finance



Source: Primary data

From the above table it is clear that the majority run business through the credit taken from the kudumbashree and the16 % and the 10% of the members run business through personal source and other sources.

Figure 11
Cylinder Diagram Showing the Impact



Source: Primary data

The above figure shows the impact of business run by the KDS members From the above table it is clear that the 24% if the members run a profitable business but the 14 %of the members run a non profitable business.

The kudumashree has played an important role in women empowerment and poverty eradication. This programme is implemented by the state poverty eradication mission SPEM) by the government of Kerala. The kudumbashree programme was set up in 1977 by the government of Kerala .Kudumbashree is a community network covering the entire state of Kerala. The kudumbashree consist of three tier structure Neighbourhood Groups NHGs as a primary group Area Development societies ADS at the ward level and the Community development societies CDS at local government level.

The findings of the study are displayed below:

- In 1977, the government of Kerala launched the Kudumbashree initiative in an effort to empower women and end poverty.
- There were numerous microfinance initiatives to encourage women's participation.
- The Kudumbashree missions have mostly fully covered all facets of social and economic activity, including industry, agriculture, etc.

- The Kudumbashree Mission is now a major organisation for carrying out numerous state and federal government anti-poverty programmes.
- The vast majority of the Kudumbashree members are married and in the 40+ age bracket.
- From the total sample taken the 48% of the members have Higher secondary education.
- From the total sample taken the 38% of the members are self employed, while the others are daily worker and house wife.
- According to the total sample taken from the Niranam panchayat the most of the members are the part of the kudumbashree for the past 5-10 years.
- Most of the members join kudumbashree for increase their saving.
- According to the total sample taken the each member have personal bank account.
- From the total sample we can understand that taken the 74% of the members have been facilitated loan from the kudumbashree.
- The 40%of the people have availed the loan for starting microfinance and the 30% and 18% have been availed loan for farming and house maintenance and some member s availed l oan for the other sector.
- The majority of the members have obtained credit above 75000.
- From the total sample taken the 44% of members have gotten grant 1 or 2 times.
- From the total sample taken only 20 members are included in business in that the majority are included in the food products. The some of the members are included in the soap manufacturing and the vegetable.
- The 24% run business through credit taken through kudumbashree.
- From the total sample taken 14% of the members run a non profitable business

Conclusion

The study is an attempt to evaluate role of kudumbashree project in women empowerment through micro financing – with special reference to Niranam panchayat. Kudumbashree, the poverty eradication mission has evolved as a strategic tool for poverty eradication and women empowerment. Many poor women in Kerala, particularly in the Pathanamthitta and Idukki districts, became a lifeline for Kudumbasree. It is a massive anti-poverty programme of the Kerala government that aims to eradicate poverty and rescue the destitute from the clutches of extreme deprivation. The relative success of Kudumbasree enterprises demonstrates widespread acceptance of community-based activities aimed at uplifting the poor and oppressed. Poor women have truly been empowered by their participation in Kudumbasree organs such as neighbourhood groups and micro-enterprises. The Kudumbasree State Alleviate Poverty Mission, launched by the Government of Kerala State in India, is the largest poverty eradication programme in modern history.

References

Robins Jose et al.(2021)Study on Women Empowerment through Kudumbashree with reference to Kottayam District, Kerala Nat. Volatiles & Essent .Oils journal

Vijaykumar et al.(2021) The Impact of Kudumbashree Scheme on the Marginalized Women with Reference to Alappuzha District, Kerala. IUP Journal of Entrepreneurship Development

R Shehnaz, S Suresh Kumar.(2019) Women entrepreneurship enticed family prosperity - an empirical evaluation of performance of microenterprises under Kudumbashree mission in Kerala, India inderscienceonline.comVol. 38, No. 1-2

M AmritKiran, A Suresh.(2018) A Study on Kudumbashree in Kerala, International Journal of Pure and Applied Mathematics

Nehajoan Panackal, et al.(2017) Kudumbashree and Women Empowerment in Kerala – An Overview and Theoretical Framework, Indian Journal of Commerce and Management Studies

Siji .S R (2014): Role of Kudumbasree in waste management a study of Ernakulam district, shodhganga.inflibnet.

Liji Santosh(2013). Empowering women through micro financing and micro enterprising a study of Kudumbashree in Kerala, shodhganga.inflibnet.a

P. Johnkutty(2012) Kudumbashree in Kerala An Evaluation, shodhganga.inflibnet

KBNidheesh (2009). Study on the changing process of Kerala women through Kudumbashree in Kerala, International NGO Journal

Tlikhitha(2018). Report On Inter District Comparision Of Micro Enterprises Of Kudumbashree, Spb.Kerala.Gov.In

Shehnaz SR(2018). Women entrepreneurship enticed family prosperity - an empirical evaluation of performance of microenterprises under Kudumbashree mission in Kerala, India

https://www.kudumbashree.org/pages/8

https://etrace.in/census/village/niranam-thiruvalla-district-pathanamthitta-kerala-628292

A Search for Female Freedom in Shauna Singh Baldwin's *The Selector of Souls*

[1]Krishna Jyothi. K.S and [2]Remi Cherian George

Abstract: This paper delves into Shauna Singh Baldwin's The Selector of Souls, highlighting post-colonial feminist concerns. It scrutinizes women's fight for liberation in India, where all women encounter systemic injustices, notably gender-specific abortion and infanticide. The novel illustrates women's search for identity within patriarchal confines and justifies their responses to societal oppression. It explores prevalent domestic violence and female foeticide, shedding light on the protagonists' justified reactions.

Key words: post-colonial feminism, India, gender injustice, abortion, infanticide.

In *The Selector of Souls*, Shauna Singh Baldwin delves deeply into a wide range of social challenges and religious catastrophes that Indian society faces in the form of gender discrimination, gender selection, domestic violence, birth control etc. Going through the experiences of the two main characters Damini and Anu the novel is thought to provoke a tale of injustice that Indian women face right from the womb.

Relating to the second generation of diasporic writers Shauna Singh Baldwin's world is not a limited one because her writing encompasses the women's stories related to three countries India, Canada and North America. Her life exceeds women's experiences and so in her writings, she is very well aware of the different facets of social, political and cultural manifestation which directs women to the secondary and marginalized position. Whether Baldwin is discussing Sikh women of colonial India, a Muslim woman in the Second World War, portraying a Hindu and Christian women's story in 1990's India or exploring the lives of women of different countries, she makes the reader listen to the different women's voices who are on their quest of self-discovery

Postcolonial feminist writers especially talk about the subjectivities and efforts of women in the various Third World countries and try to

[1]Student of MBA in Human Resources Management from Coventry University, London.
[2]Assistant Professor, Department of English, Mar Thoma College, Tiruvalla, Kerala

capitalize on the women of such countries with voice by representing their ordeal in works of literature. Shauna Singh Baldwin is a major South Asian diasporic writer who opposes the traditional cultural and patriarchal definition of women in South Asia. Shauna Singh Baldwin's works unite the concepts of Postcolonial Feminism and give voice to the struggles of women of the Third World about the Indian context. Indian Feminism is evident in Indian English diasporic women's writing. Shauna Singh Baldwin leaves no stone unturned in depicting the confrontations that women face in the form of gender discrimination. In her works, she takes up feminist issues like the quest for selfhood, societal marginalization of women, patriarchal oppression, female sexuality, man-woman relationships, traditional hegemonic structure, the role of women as a daughter, sister, wife, mother etc.

The voices of revolt can be heard from her works because she creates living breathing identities that are aware of their female consciousness which urge them to voice their feelings. Indian scenario forms the basis of many of her writings and directly she focuses the attention of her readers on many problems which ruin the sanctity of lives of Indian women. Be it the problem of marital discord, widowhood, the problem of infertility, the choice to have children or not, fighting abortion, humiliation at the hands of in laws, financial depravity, domestic abuse, consent in marriage or making self-sustaining choices, to mention a few.

The novel is generally dedicated to the women audience in a patriarchal society. Women, their issues; bodies; emotions; their bonding together; their position in war; their babies, sexual inequalities and the pressures on women to not give birth to their gender. In her book, Shauna Singh Baldwin tells of women's lives and stories that are strangely intertwined. "Their silent voices and bold choices shuffle the minds of the readers to think twice for the problems of discrimination that women face under the guise of societal pressures and their ordeals to define their own lives in a patriarchal society" (Friedan, 1963).

The novel *The Selector of Souls* begins in 1994, with Damini, a Hindu widowed grandmother who returns to live in her daughter's home in Gurkot after serving as a loyal maid in a household in Delhi after her mistress dies. It is the time when Damini's daughter Leela is expecting her third child. Leela delivers a baby girl and thus bad news for the family. The father Chunilal refuses to name the child and the mother

Leela refuses to feed her. Unattended by both parents, Damini decides to perform an ugly but necessary deed.

She prepares to kill the new-born baby with the tobacco feeding and this is the sacrifice that characterizes one of the many unexpected, unwanted, unthinkable choices thrust upon women who must protect and care for their dependents because her daughter once again gives birth to a female baby as a third child. Baldwin exactly points out through the following words how the parents neglect the female babies,

Leela (the newborn baby's mother) turned away from her again and bound a long Dupatta about her breasts. And despite Damini's pleading, her son-in-law Chunilal is making no preparations for her naming. "He is not worth naming, he says …. Naming this baby will proclaim her a girl. She'll be like a rotti, a chair, a sandal, a pencil, a dhurrie, a rope-bed, a furrow, a lentil seed, a small box, a pot" (Baldwin, 2012, p. 190).

The parents do not want this child and consider it as an object, due to the social system that a baby girl carries with them the economic burden for the parents who need to pay dowry at the time of marriage. The poor cannot afford it and hate the girl babies. Baldwin records this cultural practice of infanticide and the abortion of foetuses and there itself the deadly exploitation of women occurs. The following lines further explain the pathetic state of women who must face many problems throughout life: "And so this soul came, bringing all the desires of a being. Because it became a girl, along with it came all the expectations and demands of her someday husband and family" (Baldwin, 2012, p. 151).

She takes the baby girl before the huge clay pot of the unnamed goddess Anamika Devi and pushes tobacco into the tiny mouth. After murdering newborn, Damini proclaims, "Because it became a girl, along with it came all the expectations and demands of her someday husband and family... Release this atman, girl- body. Let it return to the place that continues long before and long after this world. Let it take shape when this world is a better place for girls" (Baldwin, 2012, p. 140).

Again, and again, Damini explains her deed but later on full of remorse for the brutal act she committed and escorting many women of the village of Gurkot for the cleaning of the girl child, making her realise that this is not the right path she has chosen for herself and others. Full

of repudiation she confines her unclaimed acts and in future works for the advancement of women of Gurkot. Disappointed by the deeds of her son Suresh who took part in the demolition of Babri Masjid, burned down a Christian house of God and raped a poor woman, realisation dawns upon her that she gave much importance to her son and her son-in-law who are none the fewer representatives of the headstrong patriarchal mindset. Damini strongly defies her deeds and gives voice to her feelings.

> Men, women — all of us have lost out true honour because we think our sons are gold. "I tried to indulge my son and son-in-law so they would look after me in old age. I forgave my son the first time he attacked a house of worship and that made him bolder. I was so afraid my son-in-law would send me away or tell people Leela's baby girl was mine, I did bad things. If you promise not to tell Sisterji, I promise to find a way to heal men and women here" (Baldwin, 2012, p. 140).

Damini is aware of the plight of women in her society and community at large. She knows that women who are not able to bear sons have to face constant humiliation. When Damini was born after four daughters, her father took for the second bride to bear him sons and her mother lit her own funeral pyre. Throughout her life, Damini blames herself for her mother's death. She gives expression to her feelings while talking to Goldina. She says, "And I knew then, that I killed my mother by taking shape; entering the world when I did couldn't I have waited? Why didn't I listen to her wishes and die in her womb? Couldn't I have gone to some other woman and not added to the burdens of a woman who already had four daughters?" (Baldwin, 2012, p. 130).

The novel discusses this dreadful problem of gender selection which blemishes the image of multicultural society like India where the preference for son is something that only matters. But still, her women characters work hard to voice the unspoken feelings of a broken heart and works to create a better world for their daughters so that they have an equal opportunity of survival in a male world. Vrinda Nabar, an eminent writer dealing with women's issues in her works, comments in her book Caste as A Woman:

> The birth of a daughter is a let-down in some absolute sense. A woman who bears a son, on the other hand, is exalted as someone

> who has fulfilled her mission as a female. She is conditioned into experiencing a sense of achievement at having done so. If the other aspects of bearing a daughter (her presence being temporary and therefore an alleged source of grief) enter the picture at all they do so at a later stage. Moreover, they are wilfully regarded as an unalterable situation and in this way the whole boy-girl syndrome is perpetuated and rationalised. (Nabar, 1995, p.10)

Nabar believes that it is the traditional thinking which is to be questioned because tradition carries power and an individual in society is bound to follow these traditions. If a woman tries to challenge these traditions, she seems to a person from another world. The same is the condition of Anu in The Selector of Souls, another strong female character in the novel who boldly challenges the norms of society which treats women as inferior to men.

Damini's story is intertwined with that of Anu, a well-educated Hindu - Christian who wants to remain unmarried and childless but is forced into marriage and became the victim of marital rape. When marriage proves to be a misery for Anu, she desperately seeks to escape her abusive husband through a divorce and becomes a nun. She sends her daughter to live in Canada with her sister Rano. The choices she makes in her life show how important it is for her to voice her feelings.

Anu has created a belief system for herself but still, she has to give in to the demands of the family and marry Vikas; the ambitious, well-mannered, well-educated son of Mrs Pammy and Mr Lalit Kohli who owned Kohl's Media. But theirs were not the marriage made in heaven. Vikas's attitude and behaviour harassed Anu so much that she thought of killing him on many occasions. Kohli's house is a place where Anu feels suffocated. She is sexually violated by Vikas and as a result, she gives birth to an unwanted child. Before giving birth to her daughter Anu thinks that "having children was a selfish act of self-perpetuation, an imposition of Indian's resources and a sacrifice of a woman's independence" (Baldwin, 2012).

But when Anu gave birth to Chetna, she fell in love with her. Vikas, a person of a traditional patriarchal mindset, could not accept Chetna because he was longing for a son. Vikas saw Chetna two days after she was born and remarked: "I wanted a boy. A boy, a boy, everyone

wants a son. An heir and a spare if your wife does her duty" (Baldwin, 2012, p. 129).

The woman is often regarded as a sex object and a means of procreation. She is known and recognized only through her relationship with a man and is not expected to have an independent identity. Even in modern times, when women have achieved economic independence and high educational standards, they are still regarded as inferior to men (Baldwin, 2012).

Anu decision to join St. Anne's convent in Shimla, is not a decision that she made in haste, it is her choice to liberate herself from the world she is part of and to become unreachable, unknowable. It is a kind of sweet revenge as she unveils her thoughts to readers. It is Anu's exceptional will to overcome odds like her younger brother Bobby's death and later on her father's death which make her character a symbol of strength. Anu's faith in reincarnation shows how much longing is there in her heart to see her brother and father again.

After joining St. Anne's convent in Shimla, her rendezvous with people of Gurkot, Jalawaaz and hamlets around, where she came with sister Bethany to serve as a nurse in the Bread of Healing clinic, she came across many life-changing experiences. Working under the guidance of Father Pashan she must serve ailing people. Here her path crosses with that of Damini and several other women who due to lack of education, proper care facilities and lack of medical care are suffering in their lives. Living in Urkot, Anu is having the time of her life though sometimes she can't stand Gurkot for another minute because of the lack of basic facilities and unsafe conditions, still, she and Dr Gupta work together to heal the villagers with limited facilities available to them.

Murder is also on the mind of Anu - the murder of her husband. So overwhelming is her desire to kill the vicious man that she decides to convert to Christianity, become a nun and trains to be a nurse. She also files for divorce and takes the heart-wrenching decision to send her young daughter to her cousin in Canada. The two women come together in Gurkot, in a government hospital. Both are working to alleviate the misery of women but in different ways. Whereas Damini is the selector of souls - the one who helps women decide whether or not to give birth to a girl child, Anu wants to improve the health and lot of women, to

educate them to be able to decide to have girl children. Baldwin is the author of the Commonwealth Prize-winning novel What the Body Remembers and the Giller Prize-nominated novel, Tiger Claw. After chequered lives and trying times in the lives of the women in the book, there is a resolution, though not in a traditional way. There is some independence for women, a voice, not loud, but allowed to be heard, some breathing space that they win for themselves and their sisterhood.

Shauna Singh Baldwin writes for a global audience. So, her works reflect the amalgamation of Eastern and Western thoughts. Baldwin is acquainted with concepts of Western feminism and being a South Asian writer, her works reflect her consciousness of Third World Feminism. Her writing incorporates the experiences of women from three countries and many more voices who dare to choose a trackless path for themselves to create a space of their own. Baldwin's female empathy is reflected in her own words in her book of essays Reluctant Rebellions: New and Selected Nonfiction "I worry about the Punjabi woman. And the Canadian woman, the American woman. Indeed, all the young women in the world" (Baldwin, 2012).

This sensitivity towards women's issues makes Baldwin create strong female characters who are aware of their space in time and place. Some characters voice their feelings and some characters choose the shroud of silence to hide their feelings. But the struggle is similar, to liberate the soul from the restraints of patriarchal restrictions.

However, the detailed presentation of political, religious and historical facts makes the reading tiresome yet in the presentation of emotions of anger, hatred, love sympathy, and compassion, the work is matchless in connection to the female world and their strong voices which insist on being heard makes the work splendid (Katrak, 1992). The Selector of Souls is a shift from the regular canon of the immigrant novel and explores the details of life in India that incorporate caste, religion and sexism issues. However, primarily its concerned about the epidemic of anti-female sex selection and the status of women in Indian society. The vivid details of the multicultural world and its people are presented in refined and passionate prose, making the novel a fascinating piece of art.

The novel portrays several issues and conflicts of India while it was constantly developing as one of the most competent economic forces in the world during the 1990s. Being an Indo-Canadian writer, Baldwin pinpoints the bitter experiences of women and religious conflicts in India. The setting of the novel runs through primarily in India in the mid-1990s. She has written it with an ambitious attempt to make it more extensive and multifaceted in its themes and treatment.

She narrates through the personal lives of two female characters namely Damini and Anu who battle for their survival in the male-chauvinistic society. Their sufferings are not so different from each other. They come from different backgrounds but at one point meet each other due to the disappointments they met with. Baldwin deals not only with feministic issues but also with the major political events of the time, such as the ongoing fights for authority and power between parties, groups and individuals. All these happenings around them directly influence the personal circumstances of her protagonists.

Shauna Sing Baldwin, being a diaspora novelist depicts with concern the plight of women in this novel and has enabled the Western world to visualize the other side of India. Although we have stepped into the o twenty-first century, these sexual abuses and exploitation of women continue to be a matter of concern and threat to society. This novel is yet another example of feministic voices relevant even in the present scenario.

The stories of Shauna Singh Baldwin picture the lives of women in India from 1919 to today, from India to North America, and their struggles inside and outside the society, from birth to death. This book is primarily about the mistreatment of girls and women in India, a developing, democratic country but one dominated by a patriarchal society which views females as mere objects. The author is writing from her lifelong experience and has done extensive research, but sometimes the novel reads more like non-fiction because it is so crammed with data. The author's voice overshadows the characters' stories. The novel questions the identity of women in the traditional patriarchal mindsets of people.

Singh Baldwin also crosses the lines between religions. Most of her characters are Sikh-Hindus or Hindu-Christians with the innate ability to switch backwards and forwards between religions as the occasion

suits them. She brings up issues of politics, the agony of Partition followed by Indira Gandhi's Operation Bluestar, the vengeance of the Sikhs and the struggle between India and Pakistan coincides with the story's climax. So much so that there seems to be almost an overdose of political and social issues and the main story flounders.

Their discrimination in religious beliefs, age, caste and social standing not overcome, they both can listen and learn. What comes forward fundamental issue in their relationship is their opposing attitude towards birth control and family planning, and by expansion of the treatment of children, especially girls. Both central characters seem to be guided by an inner voice, visually specified through a different print face. While their respective sections focus on their experiences and are written from their viewpoints, one can at times sense the omniscient authorial voice clarifying improvements rather than showing them through the protagonists' behaviour or thinking. For both the moral dilemma is evident and well portrayed. Still, the discussion or elaboration of an important theme seems, at times, to push the narrative progression of the novel into the background.

Postcolonial feminist writers particularly discuss the helplessness and struggles of women in various Third World countries and try to capitalize on the women of such countries by giving a voice to them through works of their literature (Nabar, 1995). Shauna Singh Baldwin is a major South Asian diasporic writer who opposes the traditional cultural and patriarchal definition of women in South Asia.

Shauna Singh Baldwin's works unite the concepts of Postcolonial Feminism and give voice to the struggles of women of the Third World in the Indian context. Indian Feminism is evident in Indian English diasporic women's writing. Shauna Singh Baldwin leaves no stone unturned in depicting the catastrophes that women face in the form of gender intolerance. In her works, she takes up feminist issues like the quest for identity, societal marginalization of women, patriarchal oppression, female sexuality, man-woman relationships, traditional hegemonic structure, the role of women as a daughter, sister, wife, mother etc.

The voices of rebellion as a third world writer can be heard from her works because she establishes living breathing identities who are aware of their female consciousness which urge them to voice their

emotions. Through her writings, she directly focuses to give awareness to her readers on many problems which ruin the sanctity of lives of Indian women. Be it the problem of marital discord, widowhood, the problem of infertility, the choice to have children or not, fighting abortion, humiliation at the hands of in laws, financial depravity, domestic misuse, consent in marriage or making self-sustaining choices, to mention a few.

Shauna Singh Baldwin's novel The Selector of Souls is the best example of what ratifies through the mind of women characters when they are in continuous search of their identity within the male-specified patriarchal set-up of society. Dealing with the troubling issues like gender selection and female foeticide which often dims the possibilities of a better life for the girl child an in a multicultural society like India, Baldwin creates two strong female characters who relentlessly work towards the betterment of not only their selves but also for the women who are part of their lives.

The novel is generally dedicated to the women audience in a patriarchal society. "Women, their issues; bodies; emotions; their bonding together; their position in war; their babies, sexual inequalities and the pressures on women to not give birth to their gender" (Singh, 2014). In her book, Shauna Singh Baldwin tells of women's lives and stories that are strangely intertwined. Their silent voices and bold choices shuffle the minds of the readers to think twice for the problems of discrimination that women face under the guise of societal pressures and their ordeals to define their own lives in a patriarchal society.

Shauna Sing Baldwin, as a diaspora novelist depicts her concern of the plight of women in this novel and it has enabled the western world to visualize the other side of India. Even in twenty-first century sexual abuse and exploitation of women continue to be matters of alarm and seriousness, and the society needs to deal with it seriously. This novel is an example of such feministic voices relevant even in the present scenario

References

Baldwin, S. S. (2016). *Reluctant Rebellions: New and Selected Nonfiction*. Centre for Indo-Canadian Studies, U of the Fraser Valley.

—. (2012). *The Selector of Souls: A Novel.* Simon & Schuster.

—. (2009). *We are So Different Now*. Transatlantic Literary Agency.

Boyce Davies, C. (1994). *Black Women, Writing, and Identity: Migrations of the subject*. Routledge.

Drivedi, O. P. (2011). *The Literature of The Indian Diaspora*. Pencraft International.

Friedan, B. (1963). *The Feminine Mystique*. Norton.

Joseph, M. P. (2014). *Jasmine On String: A Survey of Women Writing English Fiction In India.* OUP.

Katrak, K. (1992). *Indian nationalism, Gandhian 'Satyagraha,' and the engendering of national narratives*. In A. Parker, M. Russo, D. Sommer, & P. Yeager (Eds.), Nationalisms and sexualities (pp. xx-xx). Routledge.

McClintock, A. (1995). *Imperial Leather: Race, Gender, And Sexuality in The Colonial Contest.* Routledge.

Nabar, V. (1995). *Caste as a woman.* Penguin Books.

Said, E. W. (1978). *Orientalism.* Pantheon Books.

Gilbert, S. M., & Gubar, S. (2000). *The madwoman in the attic: The woman writer and the nineteenth-century literary imagination.* Yale UP.

Singh, B. (2014). *Indian writing in English: Critical insights*. Authors Press.

Shibu, K. C. (2015). *Men and Dreams in the Dhauladhar: Indian writing in English*. Niyogi Books.

Lighting the Modernity: An Analysis of Malayalam Film *'Oridathu'*

Mathew Sam[1]

Abstract: Malayalam cinema can be deemed as a potential source to unravel the nuances of modernity in Kerala. The moving images are instrumental in proving the phenomenological understanding of anthropological and topographical data. Moreover, the narrative structure illustrates the discursive practices of the society in which the movie is produced and appreciated. The paper explores the nexus between visual narrative and social history by delving into the visual trajectories of the movie Oridathu. It postulates that the visual narrative of the film highlights the subtle tensions eminated in the modernization process of Kerala society.

Key words: Modernity, Historiography, Visual Narratives

"No other kind of relic or text from the past can offer such a direct testimony about the world which surrounded other people at other times. In this respect, images are more precise and richer than literature"-- John Berger

All images are man-made (Berger 9). It is produced within a given space and time .The time and space bound transform every piece of image as a potential relic of the past. The moving images have been more direct and open up new vistas of historical documentation (or rather picturisation).The historical validity of moving images are of two ways. One, it captures the images of persons or objects directly. Second, continues movement of images narrates a discourse in which the cultural logic of time would be revealed. The paper would labour to historicize the cinematic rendition of reception of a particular variant of modernity by Kerala society. The source of the study is a Malayalam film, titled Oridathu.

Oridathu was released in the year 1987. The film was directed by G.Aravindan, one of the genius filmmaker of Malayalam film industry (Nath 16). The plot revolves around the village life in the years just before the formation of Kerala state. The story narrates the advent of electricity to a village and the changes it brought about in the life of those villagers. The later life of modernity and its social repurcations

[1] Assistant Professor, Department of History, Mar Thoma College, Tiruvalla,
*Correspondence: sampallickal89@gmail.com

are cinematically historicized in this film. Society, nature and time become the central characters of rendition. Many of the Indian films which were released in 1950s had been shown its sincere commitment to the official discourse of nation building. The narrative logic of those films was centered on the nation- in-the making idea. The new nation state and its government were visualized as the agent of modernity. This was the promise of the national movement as well. Thus the filmic discourse of the time ends (or begin?) as the Mother inaugurated a dam, the modern temple of India (Mother India, 1957). The films of that time rendered post- colonial era as the flag bearer of modernity in India. Yet, the historical context as Oridathu was released is different. The narrative time of the film was the early years of post- colonial India. But the film as an artifact lives in the second part of the 1980s.The period witnessed the theoretical and political movements for the rights of women, nature and dalits. Oridathu happened in such a theoretical and political milieu of Kerala society. Thus, the film analyzes the historical life of modernity with the logic of post –colonial discourses.

The filmic accounts portray the dialectical relation of the people with the agencies of modernity. The direct symbolic agent of modernity in this film is electricity. It has been a Brahmin who initiated for the electrification of the village. Hence, the electricity board engineer‘s first visit was to Namboothiri’s illom. The upper caste/class is the pioneers who receive the agents of modernity. After finishing electrification at home, the Namboodiri wants to get electricity to the temple. The traditional spaces are encountered by the new forces of modernity. However the relation has been more of accommodative. The electrification of temple visualizes the complex nexus of modernity with traditional ways of life. The rituals get modified by new possibilities brought about by modernity.

Yet the life of modernity cannot be confined to the terrain of interaction between the hegemonic social classes. It has an alternative historical narration. In Kerala history, elite modernity had been criticized and rectified by subaltern interventions. Social reform movements, national freedom struggle and the communist movement acted as the catalytic force in the subaltern critique of elite modernism. Those social and political movements had demanded just distribution of the fruits of modernity. The film has documented the arguments for fair distribution of resources. When the discussion on the dispension of electricity had

held in the public library, a local level communist activist argued that the electricity should not be limited to temple alone; it should extend to harijan colonies too. The argument historicizes the ideological struggle which made 'Kerala Model' of development possible.

However, the plot explains the minute social realities and makes it more visible. Kuttan (Sreenivasan's character) and his lover (Surya's character) are the dalit representation in the narrative structure. Kuttan is always positioned with the new agents of modernity in the village. He is the loyal servant of contractor. When the allopathy doctor comes to the village, Kuttan gets the role of helper in the hospital. Even when the dalit life moves along with the agencies of modernity, the actual social position still keeps at margins. Kuttan is led by the internalized logic of submissiveness. His masculine body is submissive before the new masters. As he found the illicit relation of his sister with the contractors, kuttan's masculine pride has been challenged. But he remains powerless. His subalternity continues even in the encounter with the modern symbols of development.

The dalit women are more deplorable in the new regime. As the most exploited social fraction in Indian society, dalit women face the exploitation of caste, patriarchy and class simultaneously. The film tells the subaltern life of dalit women in its entire brutality. Dalit women are assimilated as the cheap work force in the construction projects for electrification. The contractor ensures dalit women in his work force trough Kuttan's intermediation. 'This is government's project.if you don't come,they will arrest you'.Kuttan threatened his lover(Surya's character) .He becomes a medium to infiltrate state power to gurantee dalit women labour for the novel modernity projects. Dalit labour is pooled by the government itself to materialize modernization projects. They are uprooted from their traditional source of livelihood. The dalit women in the film used to indulge in local level manual works. When the electrification project advents to the village, she is forced to be a part of the new work force. The new capitalist relations transform the subaltern workforce. The dalit women works under the surveillance of governmental and patriarchal power in the new domain of work. She feels insecure in the gaze of contractor. But the sexual threat has not been confined to the contractor. She is sexually exploited by the dalit man who is her lover. She gets pregnant by Kuttan. Kuttan wants to abort the pregnancy and seeks the assistance of the fake allopathy doctor.

The story ends with the death of her. The contractor and the doctor insecure and annihilate dalit women body. She is the first victim of the modernized village. Her dead body is thrown into temple pond. The Brahmanic logic disdains her for polluting the temple pond. She is contempt even in her death.

In the development trajectory of modernity, the first victim is nature. It extends from there to women and other subaltern existence. As the new electric line is set up, four coconut trees owned by Pothuval have been cut off. It is a source of his meager livelihood. Another scene visualizes that cattles of Madavikuttiyamma are killed after getting shock from the electicity line. Those cattles are the sole source of income for the poor village woman. It is evident that the new development projects demand more from the poor.The path of electricity line is decided in favour of the rich. An argument goes in the film that the proposed path is arranged to save some jackfruit trees of namboothiri. There is a stunning scene in the film which evokes the anti - environmental face of modern development. A flock of Crows is killed by getting shock from the electricity line. .The victimization caused by the new electric line has been a poin of debate in local social gatherings. Many narratives unfold there. Those narratives register the lost of livelihood of the poor. The film problematizes displacement and the socio-economic cost paid by the downtrodden for the successful implementation of modern development initiatives. Oridathu becomes a social history representation by visualizing the victimization of the wretched of the earth.

The film also narrates the progressive public sphere which is definitely an outcome of modernity. The discussions and debates over the electrification of the village are carried out in public spheres like tea shops, barber shops, tailoring shops, library etc. Library comes to a vigorous space of public debate. In the fiery debate on electrification some argues for library as the first place to be lighted. The public sphere has not been secular spaces every time. The film shows caste based social gathering around the temple. The discussions around the banyan tree rather mystify the nature of electricity and loft it to some mythical figure they are familiar with. Another notable feature in this regard is the gendered nature of public sphere. Public sphere and 'high' intellectual discussions are exclusively reserved for men. There is hardly any scene of women who are actively engaged in public discourses. Oridathu, thus, cinematically documented the gendered, caste and class based nature of Kerala public sphere.

The film presents an indigenous resistance to modernity. Theyyam, a traditional art form known for the revolutionary cult of the subaltern communities symbolize the resistance in the film. Eventually, Kuttan, the Theyyam artist, encountered the contractor who represented the agency of modernity in the narrative logic. Hence, it is evident that the indigenous and subaltern cultural- knowledge forms being placed as the critique of modernity in the film Oridathu. The critique of modernity becomes the realization of subaltern consciousness and identity. This is the self- recognition of the victimized community in the modern development regime.

Historically, the film released at a time when the victims of modern development and the social groups hitherto oppressed realized the predicament of their life and being politically mobilized. Oridathu seems to be a cinematic response to the political and intellectual unrest of its time. The film documented its time by narrating a historical event. It travels through/into time. Oridathu inquires the complex history of modernity and development with the current discourses and apprehensions of the time as the film was made. This is not a kind of documentary exploration of the past. Rather the film inquires a given historical experience cinematically. The film made in a given time is reading a historical process with its own theoretical and political devices. Instead of documenting a historical time, Oridathu renders the history of the reading of how the present of the film read the past it narrates. It reveals the historicity of the moving images which can be placed in the domain of the source of historical inquiry.

Filmography

Oridathu(1987), Dir,G.Aravindan, YouTube, Millennium Cinema, Published on 7 May 2015.

References

*Berger, John.*Ways of Seeing. *New Delhi: BBC And Penguin Books, 2008.*

Kumaran,K.P. Vishalathayude, Lokam.Aravindan-Jeevithavum alayum.Calicut:Solar Books,1991

Nath, Rakesh. Aravindhan:Kalyum Darshanavum. *Kozhikodu: Olive Publication, 2016.*

Shanmukhadas, I. Aravindante Anweshangal. *Mathrubhumi Weekly. March 20-26, 2016.*

Comparative Analysis of Cow Dung Inoculant Bio Compost and Vermicompost on the Vegetative Growth of Amaranthus tricolor L.

Ann Mary Jacob[1], Somi Cherian[2], Susan Thomas [3] Sonia Anna Zachariah[4]

Abstract: This study aimed to investigate the comparative effects of cow dung inoculant bio compost and vermicompost on the vegetative growth of Amaranthus tricolor L. The experiment was conducted with ten replications per treatment over a period of 42 days. Analysis of the data revealed significant influences of vermicompost on shoot length and leaf length compared to cow dung inoculant bio compost. Results indicate that the growth performance of Amaranthus spp. was notably enhanced in vermicompost-amended soil pots in comparison to those treated with cow dung inoculant bio compost. The findings underscore the potential of vermicompost as a superior nutrient source for promoting plant growth, offering insights into sustainable agricultural practices.

Key words: Amaranthus tricolor L., cow dung inoculant bio compost, vermicompost, vegetative growth, nutrient source, sustainable agriculture

Introduction

The rapidly growing global population is placing tremendous pressure on land use and natural resources, leading to significant ecological damage (United Nations, 2019). Increased crop production, driven by the need to feed more people, has exacerbated the depletion of soil nutrients, with the rate of nutrient removal from soils having quadrupled over the past four decades (Tilman et al., 2011). While chemical fertilizers have played a crucial role in boosting food production, their continuous use poses long-term risks to soil health and environmental stability. These fertilizers often fail to promote the development of strong root systems and other beneficial plant characteristics, leading to crops that do not mature properly and may accumulate harmful toxins in the human body (Fageria et al., 2011). To mitigate the adverse effects of synthetic

[1]Department of Zoology, Union Christian College, Aluva - 683201
[2]Departurent of Zoology, Bishop Moore College, Mavelikara-690110
[3]Department of Zoology, Mar Thoma College, Thiruvalla-689103
[4]Department of Botany, Mar Thoma College, Thiruvalla-689103
*Correspondence: susanrick72@gmail.com

fertilizers, the adoption of eco-friendly and sustainable practices, such as the use of bio-fertilizers and vermicompost, is essential. Organic waste, which includes agricultural by-products and animal manure, can be transformed into valuable bio-fertilizers through composting processes involving living microorganisms that enhance nutrient availability and promote plant growth (Kumar et al., 2020). Vermicomposting, in particular, utilizes earthworms to convert organic waste into high-quality compost rich in essential nutrients, offering a sustainable alternative to chemical fertilizers (Edwards & Arancon, 2020). Bio-fertilizers such as Rhizobium, Azotobacter, and phosphate-solubilizing microorganisms not only improve soil fertility but also support a balanced ecosystem by enhancing microbial activity and nutrient cycling (Bhattacharyya et al., 2021). Vermicompost, produced through the biodegradation of organic material by earthworms, is rich in nitrogen, phosphorus, potassium, and beneficial soil microbes, making it an excellent growth promoter and protector for crops (Lazcano & Domínguez, 2011). The use of vermicompost has shown to be effective in increasing crop yields, improving soil health, and reducing the reliance on chemical fertilizers (Kale & Bano, 1986). The shift towards organic farming and the use of bio-fertilizers not only addresses the environmental issues associated with synthetic fertilizers but also supports sustainable agricultural practices that are vital for long-term food security (Pretty et al., 2018). As the demand for quality agricultural products grows, integrating bio-fertilizers and vermicompost into farming practices offers a promising path toward sustainable agriculture and environmental conservation (Pimentel et al., 2005). Vermicompost, a nutrient-rich organic amendment, contains plant growth-promoting substances produced by microorganisms and is abundant in available carbon and nitrogen. Soils amended with worm castings are notably richer in water-soluble nutrients and contain two to three times more available nutrients than unamended soils, which significantly enhances plant growth. Bio-waste encompasses biodegradable garden and park waste, as well as food and kitchen waste from households, restaurants, caterers, retail premises, and comparable waste from food processing plants. It excludes forestry or agricultural residues, manure, sewage sludge, and other biodegradable waste such as natural textiles, paper, or processed wood, as well as by-products of food production that never become waste.

Vermicomposting is an efficient method for the disposal of non-toxic solid and liquid organic wastes through the activity of earthworms. This technique is applicable in both rural and urban settings, offering a cost-effective and energy-efficient solution for recycling animal wastes (such as poultry, horse, cattle dung, and piggery excreta), agricultural residues, and certain industrial wastes (Jambhekar, 1992). The use of vermicompost can increase crop yield, enhance pest resistance, and improve produce quality. Essentially, it employs earthworms to convert organic waste into a valuable product, vermicompost, thus contributing to environmental sustainability. While the use of compost in horticulture can sometimes be limited by high electrical conductivity and excessive ion concentrations, which may cause phytotoxicity due to the chemical nature of the initial waste and/or suboptimal processing, these adverse effects are less common when vermicompost is used as a potting amendment. Continuous application of chemical fertilizers poses significant health and environmental risks, including nitrate leaching that contaminates ground and surface water. Reducing the reliance on nitrogen fertilizers without inducing nitrogen deficiency is a critical challenge in field management. Recycling organic waste presents a viable strategy to decrease the dependence on chemical fertilizers. Amaranth (Amaranthus spp.), originating from the Americas and one of the oldest cultivated food crops with evidence dating back to 6700 BC, consists of nearly 60 species. Many of these species are cultivated as leafy vegetables, grains, or ornamental plants, while some are considered weeds. Amaranth is a common leafy vegetable grown during the summer and rainy seasons in India. However, the current production and consumption levels of vegetables in the country are significantly inadequate, meeting only one-fourth to one-third of the population's needs. Rapid population growth exacerbates issues such as food shortages, malnutrition, and poverty, emphasizing the urgent need to enhance vegetable production.

Materials and Methods

Preparation of Vermicompost

Vermicompost was prepared using earthen pots with a diameter of 50 cm and a height of 60 cm. The base of each pot was layered with broken bricks (approximately 5 cm), followed by a 2 cm layer of sand.

Above this, a 15 cm layer of loamy soil was added, mixed with small lumps of fresh cattle dung to serve as an active growing medium for earthworms. Approximately 100–500 earthworms, including species Eudrilus eugeniae, Perionyx excavatus, and Eisenia foetida, were introduced into the vermibed. A 10 cm thick layer of straw, leaf litter, and various farm residues was then placed above the soil. A slurry of cow dung was sprinkled over this layer. This layering process was repeated until the pot reached a height of 1 meter. Water was sprinkled periodically to maintain moisture content. The vermicompost was harvested on the 42nd day, and earthworms were separated from the vermicast using 3 mm sieves.

Preparation of Biocompost

Biocompost was prepared in a cement ring (diameter: 1 meter, height: 0.5 meters). Campus waste such as shredded paper, used teabags, food waste, and vegetable scraps were sorted and used. The base of the ring was filled with a layer of broken bricks (5 cm), followed by a 2 cm layer of sand. A 15 cm layer of loamy soil was added, and an inoculant of cow dung was sprayed on top. Moisture content was maintained throughout the process. The biocompost was harvested on the 35th day.

Biometric Analysis

For biometric analysis, 10 plants were randomly selected from each triplicate sample. Parameters recorded included plant height, number of branches, leaf length, and stem girth. Height was measured from the ground to the tip of the main stem and expressed in centimeters. The number of branches was counted on the 7th, 14th, 21st, 28th, 35th, and 42nd days. Fully opened leaves were counted to calculate the average number of leaves per plant. Stem girth was measured at the bottom, middle, and top of each plant, and the average girth was calculated.

Observation on Growth Parameters

The height of 10 randomly selected plants was measured from the ground to the tip of the main stem and averaged. The number of branches arising from the main stem was counted at specified intervals (7th, 14th, 21st, 28th, 35th, and 42nd day). Fully opened leaves were counted, and the average number of leaves per plant was recorded. Stem girth was measured at three levels (bottom, middle, top), and an average girth was calculated for each plant.

Shoot Length

Shoots from control and treated pots were washed to remove soil particles. The length from the

root-shoot junction to the shoot tip was measured using a scale and expressed in centimeters. Ten seedlings were randomly selected from each treatment for measurement.

Leaf Length

Leaf length was measured using a scale and expressed in centimeters. Six plants were randomly selected from each treatment for this measurement.

Effect of Vermicompost and Biocompost on Soil Profile

Qualitative analysis of soil organic matter and pH was conducted using soil analysis kits. Samples were taken before and after the application of vermicompost and biocompost to determine changes in soil quality.

Results and discussions

The effects of vermicompost and cow dung compost on the shoot length of plants over a period of 42 days were investigated. The results, presented in Table 1, show a clear trend of increased shoot length in both treatment groups (T1: vermicompost + soil and T2: cow dung compost + soil) compared to the control (soil only).

Table 1: Effect of Vermicompost and Cow Dung Compost on Shoot Length

Days	C	T1	T2
7 days	4.9±0.11cm	5.7±0.14cm	5.4±0.2cm
14 days	5.4±0.24cm	7.3±0.25cm	7.0±0.3cm
21 days	6.9±0.28cm	12.4±0.42cm	10.2±0.21cm
28 days	9.3±0.29cm	14.4±0.1cm	13.4±0.18cm
35 days	13.4±0.37cm	17.8±0.5cm	16.7±0.27cm
42 days	17.2±0.21cm	21.1±0.9cm	20.3± 0.25 cm

Values are mean of ten observations, ± standard error

C – Control (Soil only) T1 - Vermicompost of E. eugeniae + Soil (1:1)

T2 – Cowdung + Soil (1:1)

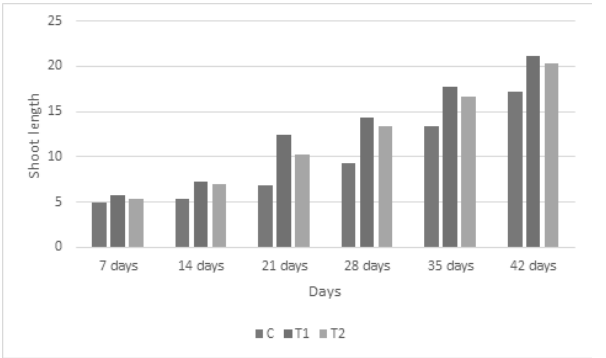


Fig.1 Effect of Vermicompost and Biocompost on shoot length of Amaranthus tricolor

The study demonstrates that both vermicompost and cow dung compost significantly enhance the shoot length of plants compared to the control. From the initial 7 days to the final measurement at 42 days, plants in both treatment groups consistently outperformed those in the control group. At 7th day, shoot lengths in the T1 and T2 groups were 5.7 cm and 5.4 cm, respectively, compared to 4.9 cm in the control. This trend continued with more pronounced differences as time progressed. By 21 days, the shoot length in T1 was 12.4 cm, nearly double that of the control (6.9 cm), while T2 reached 10.2 cm. At 42nd day, T1 and T2 recorded 21.1 cm and 20.3 cm, respectively, compared to the control's 17.2 cm. The results align with previous research, which has shown that organic amendments like vermicompost and cow dung compost improve soil structure, nutrient availability, and microbial activity, thereby promoting plant growth (Arancon et al., 2004; Atiyeh et al., 2002). Vermicompost is particularly known for its rich nutrient content and beneficial microbial populations, which enhance plant growth and yield (Edwards et al., 2010). Similarly, cow dung compost provides essential nutrients and improves soil physical properties, leading to better plant growth (Panda et al., 2012). The application of vermicompost and cow dung compost has a significant positive impact on the shoot length of plants, with vermicompost showing a slightly higher efficacy compared to cow dung compost. These findings suggest that both types of compost can be effective organic amendments for enhancing plant growth in agricultural practices.

Table 2: Effect of vermicompost and cowdung compost on leaf length for 42 Days

Days	C	T1	T2
7 days	3.9±0.40cm	4.2±0.21cm	4.1±0.18cm
14 days	4.3±0.12cm	6.4±0.16cm	5.7±0.24cm
21 days	5.1±0.26cm	8.2±0.27cm	7.1±0.16cm
28 days	6.4±0.3cm	10.3±0.18cm	9.4±0.15cm
35 days	8.2±0.31cm	12.2±0.12cm	11.5±0.81cm
42 days	9.7±0.42cm	13.6±0.34cm	12.8±0.45cm

Values are mean of ten observations, ± standard error

C – Control (Soil only) T1 - Vermicompost of E. eugeniae + Soil (1:1)

T2 – Cowdung + Soil (1:1)

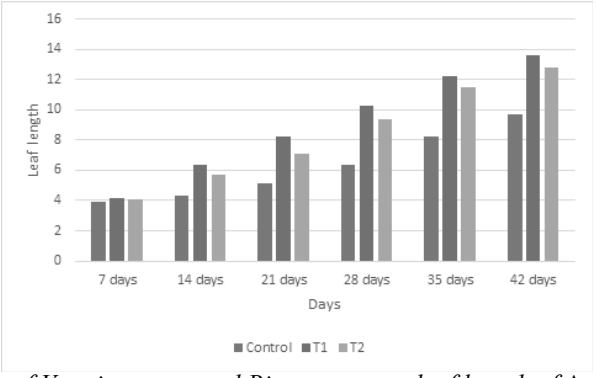


Fig.2 Effect of Vermicompost and Biocompost on leaf length of Amaranthus tricolor

The results indicate that both vermicompost (T1) and cowdung compost (T2) significantly enhance leaf length compared to the control (soil only) throughout the 42-day period. During the first 14 days, the control group exhibited minimal growth with leaf lengths increasing from 3.9 cm to 4.3 cm. In contrast, both T1 and T2 showed a marked improvement. At 14 days, T1 showed a 52.4% increase in leaf length over the control, and T2 a 32.6% increase. This early-stage enhancement suggests that the nutrients in the composts quickly become available to the plants. Between 14 and 28 days, the disparity between

treatments and the control became more pronounced. By 28 days, T1 exhibited a 61.0% increase in leaf length over the control, while T2 showed a 46.9% increase. This suggests that the vermicompost (T1) might be more efficient at providing necessary nutrients or enhancing soil structure compared to cow dung compost (T2).

In the final stages (28 to 42 days), T1 continued to show superior growth, achieving a leaf length of 13.6 cm compared to 9.7 cm in the control (a 40.2% increase), and 12.8 cm in T2 (a 32.0% increase). The significant growth in T1 indicates the sustained release of nutrients from the vermicompost, promoting continuous and enhanced growth. Throughout the 42-day period, T1 consistently outperformed T2, indicating that vermicompost might have a higher nutrient content or better nutrient availability than cowdung compost. The differences could also be attributed to the presence of beneficial microorganisms in vermicompost that aid in nutrient uptake and promote plant growth. In conclusion, the application of both vermicompost and cowdung compost positively impact leaf growth compared to the control, with vermicompost showing a more pronounced effect. This suggests that vermicompost may be a more effective organic amendment for enhancing plant growth in terms of leaf length. Future studies could explore the specific nutrient profiles and microbial compositions of these composts to better understand the mechanisms driving these differences.

Plate-1 Effect of cowdung biocompost on the growth of Amaranthus tricolor L

Cowdung Biocompost

7th Day

14th Day

21st Day

28th Day

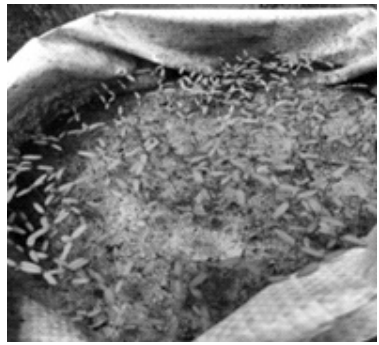
35th Day

42nd Day

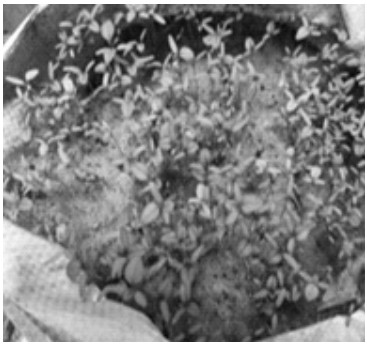
Grown in normal soil (42nd Day)

Plate-2 Effect of vermicompost on the growth of Amaranthus tricolor L.

Vermicompost



7th Day



14th Day

21st Day

28th Day

35th Day

42nd Day

Grown in normal soil (42nd Day)

Qualitative Analysis of NPK and pH of the Soil Profile

The pH values of both cow dung and vermicompost treated soil range from 7.5 to 8. The decomposition of nitrogenous substrates into ammonia may be attributed to overall increases in pH (Cohen & Lewis, 1949). The observed increase in nitrogen (N) in all composts, except for cow dung bio-compost, suggests that the activity of earthworms, along with microorganisms, promoted the mineralization process, making nutrients readily available for plant growth. The increased nitrogen may be due to nitrogenous metabolic products of earthworms. Atiyeh et al. (2000) reported that by enhancing nitrogen mineralization, earthworms significantly impact nitrogen transformation in manure, ensuring nitrogen retention in the nitrate form. Hand et al. (1988) reported that Eisenia foetida in cow dung slurry increased the nitrate-nitrogen content. Phosphate (P) values are higher in vermicompost-treated soil compared to cow dung. The passage of organic residue through the gut of earthworms releases phosphorus. The available forms of phosphate are produced partly by earthworm gut wall microbial phosphatase, and further phosphorus release might be attributed to phosphorus-solubilizing microorganisms present in worm cast (Zhang et al., 2000). Total potassium (K) concentration increased in vermicomposts of all combinations except cow dung. Delgado et al. (1995) reported a higher content of K in new sewage sludge vermicompost. Benitez et al. (1999) observed that leachates collected during the vermicomposting process had higher K concentrations. Kaviraj and Sharma (2003) observed that

the level of K was increased by 10% by Eisenia foetida and 5% by Lampito maturitii during vermicomposting. Most bio-wastes can be converted into valuable products.

However, in India, particularly in Kerala, the potential utilization of biodegradable wastes for human welfare is still neglected. The suitability of Perionyx spp. and Eudrilus eugeniae in vermicomposting has been reported by various researchers. Indiscriminate dumping of wastes degrades soil, water, and air, causing several serious diseases to animals, including humans. Vermibiotechnology may be a suitable option for the biomanagement of most bio-wastes. It is the process by which bio-wastes are converted into nutrient-rich organic manure known as vermicompost using earthworms as biological agents. Environmental degradation has become a major global threat. When the environment was not tampered with, there was harmony, and all living organisms coexisted well with the inorganic components of the environment. Due to improper waste management facilities and treatment, the disposal of organic wastes from domestic, agricultural, and industrial sources has caused severe environmental problems. Rapid population growth in India has led to a significant increase in the generation of municipal solid waste (MSW) over the last few decades. Garbage or organic wastes produced by every household make up the municipal or corporation garbage, which today results in environmental problems. Vermicomposting, an environmentally friendly technique that implies no pollution, can convert all such wastes into wealth. Vermicomposting is a sustainable technique for solid waste disposal. Vermicompost is an eco-friendly, cheap product of the vermicomposting process. Unlike chemical fertilizers, vermicompost has no adverse effects on soil health; rather, it is very useful for the sustainable management of soil health and crop productivity.

However, not all verm species and bio-wastes are equally suitable for vermicompost production. The adverse effects of synthetic fertilizers on humans and the environment have contributed to global economic downturns. Heavy use of chemical fertilizers is altering the physicochemical properties of soil, while plant growth depends entirely on balanced nutrients and agroecological conditions. According to Patil and Maharkar (1989), the vegetative growth of plants depends mainly on the optimum dosage of micro and macronutrients. Establishing

alternative solutions for sustainable development to reduce environmental pollution has become essential. Several scientists have studied the effects of organic manure and vermicompost on the growth of various crop plants. Vermicompost contains microorganisms, organic matter, and inorganic material in a form usable by plants. It is an excellent organic manure, porous, and has moisture-absorbing capacity. Vermicompost is rich in vitamins, antibiotics, and enzymes such as protease, amylase, lipase, and cellulase. These enzymes continue the disintegration of organic matter after excretion from the worms as cast. Worm cast is also rich in nitrates, phosphates, and potash (Jogdand, 1995). Vermicompost is also rich in micronutrients like Fe, Zn, Cu, and Mo, and plant promoters (Bano et al., 1978). Hence, vermicompost has proven to be a good source of growth promoters. The results Indicated that the application of vermicompost increased plant growth and yield compared to conventional compost. Therefore, it should be recommended for farmers to use vermicompost in crop production as it is easily available, nutrient-rich, economical, and improves soil physical properties. Vermicomposting can be a good source of income and self-sustainability, especially when the global market drops due to pandemics or other natural calamities. More research should be conducted to investigate the growth, yield, and nutrient content of other crops.

Conclusion

As the world grapples with the challenges of a rapidly increasing population and the resulting strain on natural resources, it is evident that sustainable agricultural practices are imperative. The detrimental effects of continuous reliance on chemical fertilizers underscore the need for a shift towards organic, eco-friendly alternatives such as biofertilizers and vermicompost. These natural solutions not only enhance soil health and fertility but also mitigate the risks associated with chemical accumulation in the environment and human bodies. Embracing biofertilizers represents a step towards ensuring food security, promoting environmental sustainability, and fostering the renewal of our ecosystems for generations to come.

References

Arancon, N. Q., Edwards, C. A., Bierman, P., Metzger, J. D., Lee, S., & Welch, C. (2004). Effects of vermicomposts on growth and marketable fruits of field-grown tomatoes, peppers and strawberries: The 7th international symposium on earthworm ecology, Cardiff, Wales, 2002. Pedobiologia, 47(5-6), 731-735.

Atiyeh, R. M., Edwards, C. A., Subler, S., & Metzger, J. D. (2000). Earthworm-processed organic wastes as components of horticultural potting media for growing marigold (Tagetes erecta L.). Bioresource Technology, 75(3), 175-180.

Atiyeh, R. M., Edwards, C. A., Subler, S., & Metzger, J. D. (2000). Earthworm-processed organic wastes as components of horticultural potting media for growing marigold and vegetable seedlings. Compost Science & Utilization, 8(3), 215-223. https://doi.org/10.1080/1065657X.2000.10701999

Bano, K., Srivastava, R. K., & Verma, D. C. (1978). Effect of vermicompost on the yield and uptake of nutrients by rice (Oryza sativa L.) under field conditions. Plant and Soil, 50(1-3), 409-414.

Benitez, E., Nogales, R., Elvira, C., & Masciandaro, G. (1999). Influence of earthworm activity on microbial communities during vermicomposting of pig manure. Soil Biology and Biochemistry, 31(7), 859-869.

Bhattacharyya, P., Roy, K. S., Neogi, S., Adhya, T. K., Rao, K. S., & Manna, M. C. (2021). Biofertilizers: An eco-friendly solution for sustainable agriculture. Sustainability, 13(12), 6908.

Cohen, J. J., & Lewis, R. W. (1949). Decomposition of nitrogenous substrates in cow dung by the action of microorganisms. Journal of Agricultural Science, 39(3), 318-329.

Delgado, M., Moral, R., Gomez, I., & Moreno-Caselles, J. (1995). The use of pig slurry and its vermicompost for tomato growth. Bioresource Technology, 54(2), 139-144.

Domínguez, J. (2004). State-of-the-art and new perspectives on vermicomposting research. In C. A. Edwards (Ed.), Earthworm Ecology (pp. 401-424). CRC Press. https://doi.org/10.1201/9781420039719.ch21

Dominguez, J., & Edwards, C. A. (2020). Relationships between composting and vermicomposting. In C. A. Edwards & N. Q. Arancon (Eds.), Vermiculture technology: Earthworms, organic wastes, and environmental management (pp. 11-26). CRC Press.

Fageria, N. K., Baligar, V. C., & Jones, C. A. (2011). Nutrient flux in soil-plant system. In Growth and mineral nutrition of field crops (pp. 57-76). CRC Press.

Hand, S. C., Menzel, R. W., & Cink, C. L. (1988). The presence and activity of nitrate reductase in earthworms (Lumbricus spp.). Comparative Biochemistry and Physiology Part B: Comparative Biochemistry, 91(1), 167-170.

Jogdand, S. V. (1995). Effect of vermicompost on growth and yield of cotton (Gossypium hirsutum L.). Indian Journal of Agricultural Sciences, 65(2), 144-146.

Kaviraj, & Sharma, S. (2003). Municipal solid waste management through vermicomposting employing exotic and local species of earthworms. Biodegradation, 14(4), 283-292.

Kale, R. D., & Bano, K. (1986). Field trials with vermicompost (Vee Comp. E. UAS) on organic fertilizers. Journal of the University of Agricultural Sciences, 24(5), 134-137.

Kumar, A., Bhargava, R., & Reddy, M. S. (2020). Biofertilizers: Present status and future prospects. In M. S. Reddy, M. Kumar, & M. B. Reddy (Eds.), Biofertilizers for sustainable agriculture and environment (pp. 1-24). Springer.

Lazcano, C., & Domínguez, J. (2011). The use of vermicompost in sustainable agriculture: Impact on plant growth and soil fertility. Soil Biology and Biochemistry, 43(4), 1259-1262.

Panda, H., Panda, H. B., & Panda, B. K. (2012). Vermicomposting and organic farming. Organic Farming: Concepts, Applications and Advances, 2, 305-316.

Patil, S. H., & Maharkar, A. R. (1989). Effect of composted organic manures on the growth and yield of tomato (Lycopersicon esculentum Mill.). Journal of Maharashtra Agricultural Universities, 14(1), 75-77.

Pimentel, D., Hepperly, P., Hanson, J., Douds, D., & Seidel, R. (2005). Environmental, energetic, and economic comparisons of organic and conventional farming systems. BioScience, 55(7), 573-582.

Pretty, J., Benton, T. G., Bharucha, Z. P., Dicks, L. V., Flora, C. B., Godfray, H. C. J., & Wratten, S. (2018). Global assessment of agricultural system redesign for sustainable intensification. Nature Sustainability, 1(8), 441-446.