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From the Editor's

Dear Readers,

In the August issue of our Newsletter, we received several popular articles from diverse fields. All the authors deserve great appreciation for sharing articles in huge numbers. Please continue sending articles to our Publication team and share published newsletter with your friends also.

I would like to thank the Editorial team including Print, Designer and Publication committee for their efforts throughout the edition.

Your suggestions are always welcomed for improvement.

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## **COMPARATIVE ASSESSMENT OF MINOR MILLETS AND THEIR NUTRACEUTICAL SIGNIFICANCE FOR HUMAN HEALTH**

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Millets, also known as “Nutri-cereals” are group of underutilized cereal crops with varying percentage of biomolecules like proteins, carbohydrates, fat, crude fiber, and minerals. Recently certain scientific studies have adopted these neglected crops due to their great nutritional benefits and demand for their value-added products. In India, generally eight millets species (Sorghum, Pearl millet, Finger millet, Foxtail millet, Kodo millet, Proso millet, Barnyard millet and little millet) are found. Millets are being used to treat a variety of health problems, including diabetes, obesity, cardiovascular disease and cancer. Nowadays multigrain and gluten-free cereals are considered as modern meal developed by using millets. Millets helps in lowering fat absorption and slowing sugar release helps to prevent cardiovascular disease. Micronutrients, dietary fibers, vitamins, polyphenols, pigments, and phytates are abundant in millets. Apart from mineral and vitamin content, these neglected crops are comparable to other cereals such as rice and wheat in terms of protein, fat, carbs and crude fiber. Millets also include phytochemicals including phenolic acids, flavonoids and tannins, which act as natural antioxidants. Millets are also renowned for anti-nutrient compounds such as alpha-amylase inhibitors, trypsin inhibitors, phytate, and tannins. The majority of millets are three to five times more nutritious than rice, wheat and maize, in terms of vitamins, fiber, proteins, and minerals (calcium and iron).

**Keywords:** Minor Millets, nutritional significance, classifications, comparative assessment

Millets are considered as “minor cereals” and are the world's sixth most important cereal grains, which along with maize, sorghum, oats and barley are known as “coarse cereals”. Millets account for only 2% of the world cereal

production and 95% of the world millet production comes from Asia and Africa. Millets are commonly referred as “small seeded grasses” and currently referred as “Nutri Cereals” due to their extraordinary nutritional values. Several classes of minor millets have been included in that category i.e., pearl millet (*Pennisetum glaucum* L), finger millet (*Eleusine coracana* L), foxtail millet (*Setaria italica* L), barnyard millet (*Echinochloa* spp.), kodo millet (*Paspalum scrobiculatum* L), proso millet (*Panicum miliaceum* L.), and little millet (*Panicum sumatrense* L) (Fig 1). Among them, pearl millet occupies 95% of the production. Foxtail millet [*S. italica* (L.) P. Beauv] is the second largest crop among the millets, finger millet is the sixth largest crop under cultivation, Proso millet is a short-season crop, and Barnyard millet is the fastest growing among the millets with short harvesting period of six weeks. Millets are comparable to rice and wheat in protein and fat and are superior to them in other nutrients as they contain a high proteins, dietary fibres, vitamin, calcium, iron, zinc, phosphorus, potassium, and other essential amino acids.

In India, eight millets species (Sorghum, Pearl millet, Finger millet, Foxtail millet, Kodo millet, Proso millet, Barnyard millet and little millet) are generally found, as they have potential to grow in adverse climate. They are mainly cultivated under rainfed conditions in India. Madhya Pradesh has highest area under small millets (33.4%) followed by Chhattisgarh (16.5%), Uttarakhand (9.5%), Maharashtra (8.4%), Gujarat (5.6%) and Tamil Nadu (4.8%), (Directorate of Economics and Statistics, 2015). In India the minor millets are found in most of the central and southern states and in few parts of Rajasthan, Gujarat, Assam, Haryana etc. especially in dry land areas where annual rainfall is under 350 mm, possibly where no other cereal crop can grow in such climatic conditions. Madhya Pradesh has the highest area under millets in India. Mandala and Dindori districts were the major minor millets producing areas in Madhya Pradesh. The state government introduced an International Fund for Agricultural Development in 2013, for farming the two minor millets in forty-one villages of Dindori's Mehadwani block as the cultivation of these traditional crops is forgotten due to low price and yield than rice and wheat after green revolution despite of its extra ordinary nutritional and climate re-silencing features.

#### Comparative assessment of different minor millets

Millets are small seeded cereals of the grass family Poaceae. cereal species growing in an equally broad range of environments. The most widely cultivated millets are finger millet (*Eleusine coracana*), foxtail millet (*Setaria italica*), pearl millet (*Pennisetum typhoideum*), proso millet (*Panicum miliaceum*), kodo millet (*Paspalum scrobiculatum*) and barnyard millet (*Echinochoia colona*)

(Fig 1). Millets are considered the least important of cereals, with annual production less than 2% of the world's grain. However, they are of great local importance as staples and as reserve crops in marginal areas. The use of millets not only provides farmers with a market for their products but also saves foreign exchange, which would otherwise be required to import cereals (Tiwari et al., 2018, Rana et al 2023, Makwana et al., 2021, 2025). So far, five genomes, namely foxtail millet, finger millet, proso millet, and Japanese barnyard millet, have been sequenced, and genome of foxtail millet is the smallest (423-510 Mb) while the largest one is finger millet (1.5 Gb).

#### Proso Millet

Proso millet (*Panicum miliaceum* (L.)) is an annual grass, growing from seed each year. Its origin goes back in history at least as far as 2000 B.C. when it is reported to have been grown in the Central regions of Europe. This plant is especially well suited to dry climates such as Central Russia, the Middle East, Northern India, Africa, Manchuria, and the Great Plains area of North America. Proso millet was first introduced to Canada in the 17th century, and was used in a limited way as a forage crop in the early 1900's. Proso millet is a relatively low demanding crop and diseases aren't known. That's why Proso millet is often used in organic farming systems in Europe. In the United States it is often used as an intercrop. Thereby, Proso millet can help to avoid a summer fallow, and continuous crop rotation can be achieved. Its superficial root system and its resistance to atrazine residue make Proso millet a good intercrop between two water and pesticide demanding crops. The stubbles of the last crop, by allowing more heat into the soil, result in a faster and earlier millet growth.

#### Finger Millet

Finger millet (*Eleusine coracana* (L.) Gaertn) is a cereal grass belongs from family Poaceae grown mostly for its grain. Finger millet is a robust, tufted, tillering annual grass, up to 170 cm high. The inflorescence is a panicle with 4-19 finger-like spikes, hence the name finger millet. The spikes bear up to 70 alternate spikelets, carrying 4 to 7 small seeds. The seed pericarp is independent from the kernel and can be easily removed from the seed coat. Finger millet is a staple food in many African and South Asian countries. It is also considered a helpful famine crop as it is easily stored for lean years. The grain is readily digestible, highly nutritious and versatile, and can be cooked like rice, ground to make porridge or flour, or used to make cakes. Sprouted grains are recommended for infants and elderly people. Finger millet is also used to make liquor (arakeorarek in Ethiopia) and beer, which yields by-products used for livestock feeding. Finger millet grain is not widely used for livestock: it is primarily a food grain, but it is of lesser quality for livestock than maize, sorghum and pearl millet. In India, it is sometimes used for feeding



**Fig 1: Different types of minor millets being used in India.**

infant calves, growing animals, as well as sick and convalescing animals.

**Kodo Millet**

Kodo millet (*Paspalum scrobiculatum* L.) is widely distributed in damp habitats across the tropics and subtropics of the world. It is indigenous cereal of India and is grown today in Uttar Pradesh in the North and Kerala and Tamilnadu in the South. This cereal is also known as varagu, haraka and arakalu. It forms the main stay of the dietary nutritional requirements. It has high protein content (11%), low fat (4.2%) and very high fibre content (14.3%). Kodo millet is very easy to digest, it contains a high amount of lecithin and is excellent for strengthening the nervous system. Kodo millets are rich in B vitamins, especially niacin, B6 and folic acid, as well as the minerals such as calcium, iron, potassium, magnesium and zinc. Kodo millets contain no gluten and is good for people who are gluten intolerant. Regular consumption of kodo millet is very beneficial for postmenopausal women suffering from

signs of cardio vascular disease, like high blood pressure and high cholesterol levels.

**Foxtail Millet**

Foxtail millet (*Setaria italica* (L.) P. Beauvois) is regarded as a native of China, it is one of the world's oldest cultivated crops. Foxtail millet ranks second in the total world production of millets and continues to have an important place in the world agriculture providing approximately six million tons of food to millions of people, mainly on poor or marginal soils in southern Europe and in temperate, subtropical and tropical Asia. It will grow in altitudes from sea level to 2000 m. It cannot tolerate water logging. Foxtail millet is fairly tolerant of drought; it can escape some droughts because of early maturity. Due to its quick growth, it can be grown as a short-term catch crop. It is adapted to a wide range of elevations, soils and temperatures. Its grain is used for human consumption and as feed for poultry and cage birds.

**Barnyard Millet**

Barnyard millet (*Echinochloa crusgalli* L.) P. Beauvois) is a multi-purpose crop which is cultivated for food and fodder. It is also called by several other names viz., Japanese barnyard millet, ooda, oodalu, sawan, sanwa and sanwank. Nutritionally too, it is a good source of protein, which is highly digestible and is an excellent source of dietary fiber with good amount of soluble and insoluble fractions. The carbohydrate content of barnyard millet is low and slowly digestible, which makes the barnyard millet a nature's gift for the modern mankind who is engaged in sedentary activities. In barnyard millet the major fatty acid is linoleic acid followed by palmitic and oleic acid. It also shows a high degree of retro gradation of amylase, which facilitates the formation of higher amounts of resistant starches. Hence it can be potentially recommended for the patients with cardiovascular disease and diabetes mellitus. Barnyard millet is most effective in reducing blood glucose and lipid levels.

**Little Millet**

Little millet (*Panicum sumatrense*) was domesticated in India. It grown throughout India to a limited extent up to altitudes of 2100 m, but is of little importance elsewhere. The seeds of little millet are smaller than those of common millet. This species of cereal is similar in habit to the Proso millet except that it is smaller. It is an annual herbaceous

plant, which grows straight or with folded blades to a height of 30 cm to 1 m. The leaves are linear, sometimes with hairy lamina and membranous hairy ligules. The panicles are from 4 to 15 cm in length with 2 to 3.5 mm long awn. The grain is round and smooth, 1.8 to 1.9 mm long. It can withstand both drought and water logging. It can be cultivated up to 2000 m above sea level. Little millet is another reliable catch crop in view of its earliness and resistance to adverse agro-climatic conditions and a good fodder for cattle.

Nutraceutical Significance of millets for human health  
 Millets are not only comparable to major cereals with respect to their nutritional features but are very good sources of micronutrients, carbohydrates, and phytochemicals with nutraceutical properties. They are rich source of Vitamin B groups and Minerals (Fig 2). Millet exhibits several kinds of the antioxidants having advantageous impact on defusing the free radicals, which can cause cancer and also clear the additional contaminants from body. Other than that, anti-carcinogenic properties of sorghum have been well documented. There are few reports on comparative assessments of minor millets for nutritional or anti-nutritional parameters. Barnyard millet is comparable with other cereals, such as rice and wheat as a source of protein, fat, carbohydrates and crude fiber apart from mineral and vitamins. It also contains phytochemicals, such as phenolic

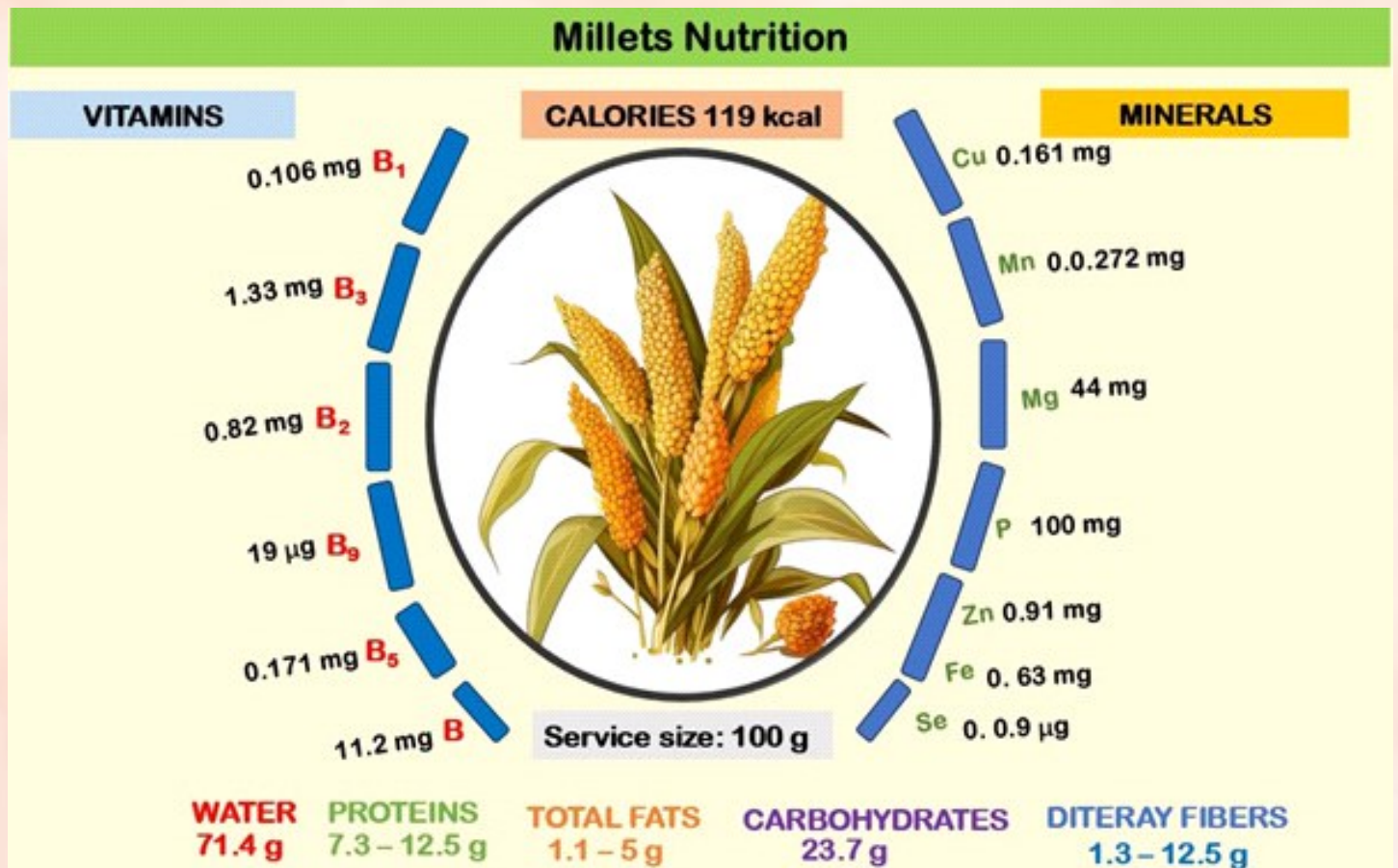


Fig 2. Nutritional values of millets for human health.

acids, flavonoids and tannins which serve as good source of natural antioxidants. Although barnyard millet like any other minor millet is nutritionally superior to cereals, yet it is underutilization. Finger millet and barnyard millet are also well known for their anti-nutrient constituents such as  $\alpha$ -amylase inhibitor, trypsin inhibitors, phytate and tannins. Anti-nutritional factors in plant-based foods are in focus to understand their potential health benefits. Barnyard millet varieties are found nutritionally superior compared to finger millet varieties. Many vitamins, minerals, essential fatty acids are also presenting millet which benefits in terms of prevention of degenerative diseases besides their identified functions of preventing nutritional deficiency diseases. Being gluten free, millets are safe for persons suffering from gluten allergy and celiac disease. Amino acid and micro-nutrient present in small millet can be used to fight against micro-nutrient deficiency diseases like rickets and anemia particularly in infants and pregnant women. As they are non-acid forming, easy to digest and non-allergenic. Millets have potential to defense against age linked degenerative diseases such as metabolic disorders. Utilization of millets decrease risk of heart disease, defends from diabetes, recovers digestive system, depresses the risk of cancer, detoxifies the body, rises immunity in respiratory health, rises energy levels and improves muscular and neural systems.

### Conclusion

Millets are a major food source in arid and semi-arid parts of the world. Millets are good sources of energy. They provide protein, fatty acids, minerals, vitamins, dietary fibre and polyphenols. The millets are source of antioxidants, such as phenolic acids and glycosylated flavonoids. Millet foods are

characterized to be potential prebiotic and can enhance the viability or functionality of probiotics with significant health benefits. The nutritional significance of millets demands for an examination of the nutritional characteristics and functional properties of different millet cultivars as well as developing value-added products from millets.

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## PROTECT WILDLIFE, EMPOWER LIVES: INVEST IN PEOPLE AND PLANET

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Biodiversity, the intricate web of life encompassing plants, animals, fungi, and microorganisms, forms the foundation of Earth's ecosystems. It ensures food security, climate regulation, clean water, and overall ecological balance. However, the rapid degradation of natural habitats, pollution, climate change, and overexploitation of species threaten global biodiversity at an unprecedented scale. To counter these challenges, the emerging field of Conservation Finance is playing a pivotal role.

Conservation finance refers to mechanisms and strategies for raising, managing, and deploying financial resources to support long-term conservation of ecosystems and biodiversity. It involves both public and private investments to fund environmental projects, such as reforestation, habitat restoration, species protection,

sustainable agriculture, and the establishment of protected areas.

Conservation finance aims to make biodiversity conservation economically viable by integrating it into development planning and business strategies. It includes diverse tools such as green bonds, biodiversity offsets, conservation trust funds, payments for ecosystem services (PES), and impact investments.

One of the major hurdles in biodiversity conservation is the significant funding shortfall. According to global estimates, hundreds of billions of dollars are required annually to protect and restore biodiversity. Conservation finance provides innovative avenues to bridge this gap, especially in low-income and biodiversity-rich countries.

Investing in conservation creates opportunities for local and indigenous communities by promoting sustainable livelihoods such as eco-tourism, agroforestry, and organic farming. These income-generating models reduce dependency on destructive practices like logging or poaching, thereby indirectly preserving biodiversity.



Conservation finance enables the private sector to engage in biodiversity preservation through profitable, sustainable ventures. For example, green bonds allow companies to raise capital specifically for environmental projects, while impact investors fund initiatives that generate both

financial returns and ecological benefits. Financial investments often come with policy reforms and improved governance mechanisms. This leads to the establishment of legal protections, better resource management, and long-term strategies for biodiversity conservation.

Climate finance and conservation finance can work together to address global challenges. Forest preservation projects, supported through carbon credits and REDD+ (Reducing Emissions from Deforestation and Forest Degradation) initiatives, protect biodiversity while mitigating climate change. One of the world's most successful examples, has been demonstrated by Costa Rica. The government pays landowners to preserve forests, which has helped increase the country's forest cover from 21% in the 1980s to over 50% today. Africa's Wildlife Conservation Bonds is another potential example. Issued by the World Bank, these bonds provide funding for wildlife conservation while offering returns linked to conservation

performance. India's CAMPA Funds (Compensatory Afforestation Fund) is allocated to states for afforestation and biodiversity conservation, sourced from industries requiring forest land diversion.

Implementing Conservation Finance at the grassroots level in India requires a combination of financial innovation, community engagement, and institutional support. Below are practical strategies to ensure successful implementation for biodiversity preservation.

The community-based conservation models like empowering local communities (especially forest-dwelling, tribal, and farming communities) to manage natural resources sustainably are some of the time-tested approach that has been very successful in promoting conservation. Using Joint Forest Management (JFM) and Community Forest Rights (CFRs) to direct conservation funds to grassroots stakeholders. In Odisha and Madhya Pradesh, CFR funds are used to protect sacred groves and regenerate forests. Microfinance & Green SHGs (Self Help Groups) in the format of eco-focused SHGs, particularly women-led, and funding them through conservation finance for native seed banks, organic farming, medicinal plant cultivation, sustainable forest products are important investment strategies to facilitate efficient ground level conservation efforts.

Banks and NABARD can offer green microloans with lower interest for conservation-linked activities to further promote conservation initiatives across various states. Payment for Ecosystem Services (PES) can be introduced by providing various incentive based programs where local communities are financially rewarded for protecting water sources, conserving pollinator habitats, and preventing forest fire. Village communities could receive payments for maintaining Bee Gardens or Butterfly Gardens or establishing Pollinator Sanctuaries. Tapping into Compensatory Afforestation Fund Management and Planning Authority (CAMPA) funds could also be an efficient strategy to attract investments for conservation.

Linking local projects with state biodiversity boards and international conservation finance schemes like GEF or Green Climate Fund can support ground level conservation programs. NGOs and village panchayats can jointly apply for biodiversity conservation grants. Green livelihood

models such as development of sustainable rural enterprises like eco-tourism, beekeeping and apiculture, and organic certification ventures can attract rural communities towards biodiversity conservation initiatives. Conservation finance can seed-fund such enterprises while creating economic incentives to preserve biodiversity. Capacity building and financial literacy is important in training villagers and local youth on conservation finance tools, biodiversity-friendly income generation, accessing government and CSR funds. Involving local institutions like Krishi Vigyan Kendras (KVKs), forest schools, and Gram Panchayats are highly efficient tools to engage local communities in biodiversity conservation drive.

CSR and Public-Private Partnerships (PPP) can mobilize Corporate Social Responsibility (CSR) funds under environmental mandates to support village-level conservation projects. Using PPP models for creating biodiversity parks, buffer zones, or sustainable agriculture zones. Proper monitoring and transparent governance can be established in village biodiversity committees (VBCs) for accountability in fund usage. Using GIS, mobile apps, and community reporting tools for monitoring biodiversity outcomes and finance flow can be highly effective in promoting conservation.

### Challenges and the Way Forward

Despite its promise, conservation finance faces several challenges including lack of investor awareness, weak regulatory frameworks, and difficulties in measuring ecological returns. Steps necessary to follow include:

Ensuring transparency, accountability, and community participation is critical.

Going forward, scaling up conservation finance requires:

Stronger collaboration between governments, NGOs, and the private sector.

Development of robust biodiversity metrics and reporting systems.

Incorporation of conservation into national financial systems and climate action plans.

## PRESENCE OF MICRO AND NANO PLASTICS IN VEGETABLES

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### Introduction

Micro-plastics are transferred to human through various ways. The consumption of food contaminated with these particles is one of the ways. Although it is well-known that some additives [Bisphenol-A (BPA), Phthalates, Polybrominated diphenyl ethers, etc.] are used in the production of plastics which have harmful effects on human, there are still limited information on the effects of micro plastics to human health and their toxicity. Nevertheless, their occurrence in the human body was concerning and reported even in the placenta, brain and in blood. Despite this, no international food standard limit is

available for plastic contamination control. Hence, it is very important to investigate the presence of micro plastics starting from the bottom of the food chain and to evaluate the possible risks on human health. To date, the occurrence of micro-plastics was mainly reported in seafood (e.g., mussels, fish, and zooplankton). Many other land based foods as well as processed food were found to be contaminated with micro plastics. In land/terrestrial ecosystems especially in agriculture land, application of huge loads of sewage sludge is also a major source of micro and nano-plastics in soil (Fig 1). One of the main sources of micro-plastics in food originates from plastic packaging materials that come into direct contact with food items during the production processing and marketing chain. With regards to fruits and vegetables, to date, only a few studies aiming to investigate the occurrence of micro-plastics in these highly consumed healthy food items were carried out globally. In very recent time some scientific evidences are floating in the scientific platforms regarding uptake of micro and nano plastics into vegetables from soil during their growing stage.



**Fig 1: Micro-plastics isolated from sewage sludge that are subjected to application in farm soil.**

Case study as evidence that vegetables which cultivation; can uptake nano-plastics through roots from soil.

This study from the University of Plymouth, published in Environmental Research, could reshape how we think about plastic pollution is limited not just in oceans and soils, but in the food we eat.

- **Breakthrough discovery:** For the first time, researchers have shown that nano-plastics are some plastic particles which are as small as one millionth of a centimeter that can be absorbed by crops during growth and accumulate in their edible parts.
- **Radish experiment:** The study used radishes to demonstrate how these particles enter through the roots and spread throughout the plant.
- **Food chain concerns:** This adds to growing evidence that nano-plastics can move through the food chain from one trophic level to another through vegetables, unlike previously shown in mollusks and fish.

- **Human exposure risk:** The findings suggest a new route by which human and animals may unknowingly ingest nano-plastics, raising concerns about long-term health effects.
- **Call for further research:** Scientists emphasize the urgent need to investigate the environmental and health impacts of this emerging issue.

#### **Crisp findings from the Radish hydroponic experiment**

- **Hydroponic setup:** Radishes were grown with their non-fleshy roots immersed in a solution containing polystyrene nano-particles labeled with radiocarbon for tracing.
- **Particle uptake:** After five days, about 5% of the nano-particles originally in the solution were absorbed by the roots translating to millions of tiny plastic particles entering each plant.
- **Distribution within the plant:** Of the absorbed nano-plastics:
  - Approximately 25% traveled into the edible fleshy roots the part we commonly eat.
  - Another 10% accumulated in the leaves, showing that nano-plastics can spread beyond just the roots.
- **Implications:** This uptake and internal transport mean that nano-plastics can bio-accumulate in crops, potentially making their way into the human diet.

Dr. Nathaniel Clark's insights highlight just how surprising and concerning this discovery is. The Casparian strip, a natural root barrier, is meant to protect plants by filtering out harmful particles but this study shows nano-plastics can by-pass it, infiltrating plants in a way never proven before. This means the issue isn't just limited to radishes; countless other crops worldwide could be accumulating these tiny plastic particles, quietly entering into our food supply.

The University of Plymouth's decades-long micro-plastics research is remarkable, tracing plastic pollution from the ocean's depths all the way to remote mountain regions. Their work has uncovered major pollution sources, like tire wear, laundry wastewater, and peeling paint, emphasizing how widespread and persistent micro-plastic contamination is. Importantly, their findings have helped shape global environmental policies, underscoring the vital role science plays in tackling pollution. This new evidence pushes the urgency to further investigate how nano-plastics move through ecosystems and food chains, and what impact they might have on human health in the long run. It's a powerful reminder that pollution is not just

an environmental issue but a direct concern for our daily lives.

The work underscores the increasing need to understand how these tiny plastic particles accumulate over time and the ways they might impact human health. While much remains to be uncovered about the specific effects, the evidence is building that micro- and nano-plastics are more than just an environmental nuisance; they could have real implications for food safety and public health. This deepening insight encourages both scientific investigation and the development of strategies to mitigate exposure across ecosystems and food chains.

### Understanding International and National Standards and Relevant Regulations

#### Lack of Specific Regulations for Fruits and Vegetables

- There are no strict international or national regulations specifically monitoring MPs in fresh produce like fruits and vegetables.
- This absence leads to limited surveillance and data on MP contamination levels and associated health risks 2.

#### Existing Guidelines Focus on Packaging

- The European Commission Directive 2002/72/EC and Regulation (EU) No. 10/2011 set Specific Migration Limits (SMLs) for chemicals leaching from plastic packaging into food.
- These limits assume an average adult consumes 1 kg of packaged food per day, but they do not account for MPs in unpackaged or naturally contaminated foods.

#### India's Emerging Response

- The FSSAI (Food Safety and Standards Authority of India) launched a project in 2024 to:
  - Develop validated methods for detecting MPs and nano-plastics in food.
  - Assess their prevalence in various food matrices, including fruits and vegetables.
  - Generate exposure data to inform future safety standards.

- This initiative involves collaboration with institutions like CSIR-IITR, ICAR-CIFT, and BITS Pilani, aiming to fill the data gap and guide policy development.

#### Conclusion

Despite global recommendations for healthy eating such as the World Health Organization's (WHO) endorsement of diet, which advises a daily intake of at least 300 grams of fruits and vegetables there remains a pressing concern regarding food safety. Specifically, the presence of micro-plastics in produce is a growing issue that cannot be overlooked, regardless of whether the cultivation method is conventional, integrated, or organic. The lack of comprehensive data on micro-plastic emissions across these agricultural practices underscores the need for vigilant monitoring throughout the food supply chain. To safeguard consumer health, it is essential to identify and mitigate potential sources of contamination. Given the widespread occurrence of micro-plastics and the absence of robust regulatory frameworks, the development of standardized methodologies for assessing and managing micro-plastic contamination in fruits and vegetables is strongly recommended.

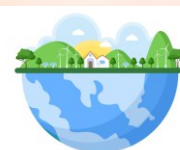
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## EXPLORING CULTURES: A JOURNEY THROUGH ANTHROPOLOGY

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An integrated anthropology workshop, entitled 'Exploring Cultures: A Journey Through Anthropology' was conducted at Miraloke by a prominent NGO called Howrah Suparna dedicated towards educational and social empowerment. Howrah Suparna conducted the one-day interactive anthropology workshop at Miraloke School aimed at introducing students to the fascinating world of human cultures, traditions, and societies.

"Meera Lok" located in New Alipore locality of South Kolkata is a school beyond the school with the Rishi Aurobinda's School of Thoughts and Directly Related to

the ideals and principles of the famous "Aurobindo Ashram Pondicherry ". According to Miraloke Principal Partha Sarathi Bose "Miraloke, not a school or a coaching center but a learning community based on the thoughts of Sri Aurobindo and The Mother on education." The program was designed to cultivate cultural awareness, critical thinking, and a respect for diversity among students from class 7 represented as the Aspiration Group.



The major objectives of this particular workshop were as follows:

1. To introduce students to the basics of anthropology and its importance in understanding human societies
2. To create awareness about local and global cultural diversity.
3. To encourage dialogue about identity, tradition, and social change.

The program started around 10:00 -10:30 AM through inauguration and welcome address by Mr. Partha Sarathi Bose, the honourable Principal of Miraloke. The keynote address was delivered by Dr. Suparna Sanyal Mukherjee (Head of the Department ic Education; and Departmental-In-Charge for Sociology and Anthropology, Seacom Skills University, Bolpur, Birbhum) as well as the Secretary and Chief Functionary of Howrah Suparna. She provided a brief introduction to Howrah Suparna's mission. She conducted the entire workshop in assistance with Miraloke staff members.

The Session 1, entitled 'What is Anthropology?' was conducted between 10:30- 11:30 AM. It was a fun and visual presentation on the various branches of anthropology (cultural, social, linguistic, archaeological) by Dr. Mukherjee followed by an interactive question/answer session with the students.

Session 2 on 'Our Local Cultures' was conducted between 11:30– 12:30 PM. Students share stories, customs, and festivals from their own families and communities and also were provided a global glimpse on diversity of tribes and tribal communities around the world including India. This was followed by an engaging group discussions on cultural similarities and differences by the students. The students went tir lunch between 12:30-1:30 PM. The post lunch Session 3 on 'Role Play & Simulation' of diverse tribal cultures across different continents. The highly charged students participated in role-play activities simulating traditional life in various continents. The students made masks, weapons and tools of tribes from the continents of Africa, Central and South America. This was followed by a short debriefing and reflection session of what new the students have learnt that day by Dr. Mukherjee and Mr. Bose.





Between 2:30-3:30 PM, Session 4 on 'Anthropology in Action' was conducted that highlighted upon how studying culture helps us solve real-world issues (e.g. climate, migration, gender). Short presentations of case studies by the students as part of their assignment. The Closing Ceremony was completed between 3:30-4:30 with feedback collected from both students and teachers. The workshop sparked curiosity among the students of Miraloke School, who actively engaged with each session. Teachers appreciated the inclusive and participatory approach. Howrah Suparna plans to expand this initiative to other schools in the district.

Dr. Suparna Sanyal Mukherjee inspired the adolescent boys and girls as a speaker and explored Value Education through Indian Knowledge System, concurred the heart of the children with inspirational speech. It was really an excellent opportunity to explore the conscious idiocentric scientific acumen among the youth of modern era for Better Life and Better Educational exposure.

*Photo credit: Saikat Kumar Basu*







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## VERMICOMPOSTING WITH *EICHHORNIA CRASSIPES*: CONVERTING AN AQUATIC MENACE INTO ORGANIC GOLD

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### Water Hyacinth: A Persistent Environmental Challenge

Water hyacinth (*Eichhornia crassipes*) is often called the “Green devil” of water bodies. Water hyacinth is one of the most aggressive aquatic weeds found in tropical and subtropical regions. Initially introduced as an ornamental plant, it has now spread uncontrollably across lakes, ponds, rivers, canals, and wetlands. Its rapid vegetative reproduction enables it to form dense floating mats that obstruct sunlight penetration, deplete dissolved oxygen, and disturb aquatic biodiversity. The weed interferes with fishing, irrigation, navigation, and drinking water supply systems, while also creating favourable conditions for mosquito breeding. Considerable resources are spent every year on its removal, yet the problem persists due to its extraordinary regeneration capacity.



### Nutrient-Rich Biomass with Untapped Potential

Despite being considered a nuisance, water hyacinth is a plant with remarkable nutrient accumulation ability. It

absorbs large quantities of nitrogen, potassium, calcium, and trace elements from polluted and nutrient-rich waters, resulting in rapid biomass production. After removal, however, the plant material is usually discarded along riverbanks or roadsides, where it decomposes, emits unpleasant odours, and releases greenhouse gases, or it is burned, contributing to air pollution. These practices reflect a missed opportunity to utilize this abundant biomass in a productive and environmentally responsible manner.

### Vermicomposting as a Sustainable Waste Management Strategy

Vermicomposting is an efficient biological process that uses earthworms to convert organic waste into a nutrient-rich, stable organic amendment known as vermicompost. This technology is particularly suitable for managing bulky plant residues like water hyacinth. Vermicompost improves soil fertility, enhances microbial activity, and supports sustainable crop production. Using water hyacinth for vermicomposting aligns with the principles of circular economy and waste-to-wealth, turning an invasive weed into a valuable agricultural input.

### Preparation of Water Hyacinth for Vermicomposting

Fresh water hyacinth cannot be used directly for vermicomposting due to its excessive moisture content, fibrous structure, and presence of certain inhibitory compounds. Therefore, the harvested plants are first chopped into smaller pieces and partially dried under the sun to reduce moisture. This is followed by a pre-decomposition period of about ten to fifteen days, during which the material is heaped and mixed with cow dung or farmyard manure.

Pre-decomposition allows microbial action to soften the plant tissues, reduce toxicity, and create favourable conditions for earthworm activity. The hair like root part should be separated out while chopping and should be discarded. After loading the material into the compost bin or pit; rice straw should be layered at the top to avoid direct sunlight, to reduce the loss of moisture from the content. During dry weather watering should be done in each 2-3 days after. To hasten the process of vermicomposting, a solution of Besan (pulse flour) and jiggery can be sprinkled for 2 times during complete duration preferably at initial 15 days and 30 days after loading into the pit.

The vermiwash can be collected through pipes from the bottom of the pit/bin and can be sprayed to different vegetable crops for getting more flower flush as this vermiwash is none other than cocktail of different plant growth hormones secreted from the earthworm and other microbes present during the whole process.



### Earthworm Species and Composting Process

After pre-decomposition, the prepared biomass is placed in vermicomposting beds, pits, or tanks, and suitable earthworm species such as *Eisenia fetida*, *Eudrilus eugeniae*, or *Perionyx excavatus* are introduced. The composting units are maintained under shade with adequate moisture. Over a period of sixty to seventy five days, the earthworms consume and transform the organic matter into fine, dark, granular vermicompost. The process is simple, low-cost, and easily adoptable by farmers and rural communities.

### Quality and Nutrient Value of Water Hyacinth Vermicompost

Vermicompost derived from water hyacinth contains balanced amounts of essential macro and micronutrients, along with beneficial microorganisms and humic substances. It enhances nutrient availability in soil, improves soil structure, and increases water-holding capacity. The presence of plant growth-promoting compounds in vermicompost supports better root development, vegetative growth, flowering, and yield. Farmers using water hyacinth vermicompost have observed improvements in soil health and crop productivity across cereals, vegetables, oilseeds, and horticultural crops.

### Environmental Benefits and Ecosystem Restoration

Vermicomposting of water hyacinth contributes significantly to environmental protection. Regular harvesting of the weed helps restore water bodies by improving oxygen levels and water quality. Controlled biological decomposition prevents methane emission

associated with uncontrolled rotting. The use of organic manure reduces reliance on chemical fertilizers, thereby minimizing soil degradation, nutrient leaching, and contamination of surface and groundwater resources.

### Application and Benefits of Vermicompost Produced from *Eichhornia crassipes* in Vegetable Cultivation

Vermicompost produced from *Eichhornia crassipes* (water hyacinth) is characterized by a well-stabilized organic matrix, narrow C: N ratio (typically 12–18:1), and high biological activity, making it particularly effective for vegetable cropping systems with short growth cycles. During vermicomposting, complex lignocellulosic fractions of *Eichhornia* biomass which are biotransformed by earthworms and associated microbial consortia into readily mineralizable forms, resulting in enhanced availability of nitrogen (1.2–2.0%), phosphorus (0.6–1.2%), and potassium (1.0–1.8%), along with calcium, magnesium, and essential micronutrients such as Fe, Zn, Mn, and Cu. The humified fraction of *Eichhornia* vermicompost is rich in fulvic and humic acids, which act as natural chelators, improving nutrient uptake efficiency and root membrane permeability in vegetable crops.

From a soil physical perspective, application of *Eichhornia*-based vermicompost significantly improves soil aggregation, porosity, and water retention, particularly in light-textured and degraded soils. Studies have shown a reduction in bulk density (by 8–15%) and an increase in water-holding capacity (by 10–25%) following regular vermicompost application. These changes create a favorable rhizosphere environment, promoting extensive root proliferation and enhanced nutrient absorption in vegetables such as tomato, brinjal, chilli, cabbage, spinach, and okra.

Biologically, *Eichhornia* vermicompost introduces a diverse population of beneficial microorganisms, including nitrogen-fixing bacteria, phosphate-solubilizing microbes, and plant growth-promoting rhizobacteria (PGPR). These microbes accelerate nutrient cycling and stimulate enzymatic activities such as dehydrogenase, phosphatase, and urease in soil, which are directly linked to improved nutrient availability. Additionally, vermicompost contains biologically active substances, including auxin- and gibberellin-like compounds, which enhance seed germination, vegetative growth, flowering, and fruit set in vegetable crops.

In vegetable cultivation, field and pot experiments have consistently reported yield increases ranging from 15–35% when *Eichhornia* vermicompost is applied either alone or in combination with reduced doses of inorganic fertilizers. Fruit quality parameters such as total soluble solids (TSS), vitamin C content, and dry matter percentage have also shown measurable improvement. Importantly, nitrate

accumulation in leafy vegetables is reduced due to the slow and synchronized release of nitrogen from vermicompost, contributing to safer and healthier produce.

From a crop management standpoint, *Eichhornia* vermicompost is most effective when applied as a basal dose (2–3 t ha<sup>-1</sup>) before transplanting or sowing, supplemented with localized side dressing during peak vegetative growth. Integration with 50–75% of recommended chemical fertilizers has been shown to maintain or enhance yields while significantly reducing chemical input costs. This integrated nutrient management

approach improves nutrient use efficiency and supports long-term soil fertility.

In summary, vermicompost derived from *Eichhornia crassipes* functions not merely as a nutrient source but as a soil–plant system regulator, enhancing physical, chemical, and biological soil properties while improving vegetable yield, quality, and sustainability. Its utilization offers a dual benefit of aquatic weed management and environmentally sound nutrient recycling in intensive vegetable production systems.

**Table: Benefits of *Eichhornia* Vermicompost during vegetable cultivation.**

Parameter	Technical Impact
Nutrient content	N: 1.2–2.0%, P: 0.6–1.2%, K: 1.0–1.8% (slow-release)
C:N ratio	Narrowed to 12–18:1, enabling rapid mineralization
Soil physical properties	↓ Bulk density (8–15%), ↑ WHC (10–25%)
Microbial activity	Enhanced PGPR, N-fixers, P-solubilizers
Enzyme activity	Increased dehydrogenase, phosphatase, urease
Crop response	15–35% yield increase; improved quality
Nutrient use efficiency	Reduced nitrate leaching and accumulation
Recommended dose	2–3 t ha <sup>-1</sup> (basal) + split top dressing

**Socio-Economic Opportunities for Rural Communities**

The conversion of water hyacinth into vermicompost offers promising livelihood opportunities, especially for women's self-help groups, landless farmers, and rural youth. Since the raw material is freely available, production costs are low, while market demand for organic manure continues to grow. Community-based vermicomposting units can simultaneously address weed management and income generation, fostering local participation in environmental conservation. Each kilogram of ready produce can be sold off in a range of 15-20 Rupees.

**Need for Awareness, Training, and Policy Support**

Although the technology is simple, its successful adoption requires proper training on biomass preparation, earthworm management, moisture control, and compost quality assessment. Support from agricultural extension agencies, research institutions, and local governance bodies are essential. Integrating water hyacinth vermicomposting with wetland management, watershed development, and organic farming initiatives can significantly enhance its impact and scalability.

**Conclusion: From Problem Weed to Sustainable Resource**  
Water hyacinth, long regarded as an environmental menace, can be transformed into a valuable resource through vermicomposting. This approach provides a sustainable solution to aquatic weed infestation while

producing high-quality organic manure that supports soil health and crop productivity. Vermicomposting with *Eichhornia crassipes* stands as a powerful example of how ecological challenges can be converted into opportunities for sustainable agriculture, environmental restoration, and rural development.

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## WATER HYACINTH: FROM MENACE TO OPPORTUNITY IN WEST BENGAL

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### A Familiar Green Menace in Bengal's Water bodies

In West Bengal, water and life are inseparable. Rivers, canals, wetlands, ponds and beels shape agriculture, fisheries, and transport and everyday livelihoods. Yet across the state, these waterbodies are increasingly choked by a floating green weed 'water hyacinth'. It has become present in almost all rivers here including standing water bodies like ponds as well. The plant spreads rapidly, forming dense mats on the water surface and its boom tendency makes the water bodies choked over time. It hinders fishing, transportations heavily.

For local communities, water hyacinth is often associated with stagnation and dying of water bodies. Fishers struggle to cast nets, farmers face blocked irrigation channels, and stagnant water becomes a breeding ground for mosquitoes. Decomposed water hyacinth reduces the dissolved oxygen of the water bodies and deteriorates water quality for aquatic organisms. During the monsoon, clogged canals worsen flooding, particularly in low-lying deltaic regions. Municipal bodies and panchayats spend significant

resources on periodic removal but the notorious weed returns within weeks.

### The Menace: A Green Invader

Originally native to the Amazon Basin in South America, water hyacinth was introduced to water bodies worldwide for its pretty purple flowers and rapid growth. But that beauty hid a serious threat. Because of its extraordinary reproductive power, a single plant can double its population in just a few weeks and dense mats of hyacinth can spread across entire lakes if left unchecked. Across India, lakes like Powai Lake in Mumbai have been completely covered with hyacinth, making the water surface almost invisible and hindering aquatic life. Civic groups have even launched campaigns to highlight this crisis and urge stronger action. In Kenya's Lake Naivasha and Lake Victoria, the weed has strangled fishing routes, entangled boats, and drastically reduced fish catches; threatening livelihoods and local economies.

### Abundance across West Bengal's Landscape

West Bengal's geography makes it especially prone to water hyacinth infestation. The state's extensive river network, floodplains, wetlands and aquaculture ponds provide ideal conditions for the plant to thrive. Nutrient-rich runoff from agriculture, sewage discharge and industrial effluents further accelerate its growth. Yet this abundance also ensures a steady and low-cost supply of raw material. Unlike cultivated crops, water hyacinth does not compete for land, irrigation or fertilisers. Its availability across districts makes decentralized, small-scale enterprises feasible, particularly in rural and peri-urban areas.



### From Environmental Burden to Economic Resource

Despite its negative impacts, water hyacinth has one remarkable characteristic; it grows extremely fast without any external input. This very trait makes it a valuable biomass resource. Instead of treating it purely as waste, water hyacinth can be reimagined as raw material for livelihood generation, clean energy, organic farming and eco-friendly products. The idea of "waste to wealth" is particularly relevant for this invasive weed because of its vigorous and fast biomass generation behaviour, where population density is high. Utilizing water hyacinth allows

communities to address an environmental problem while simultaneously creating economic value.

### Craft and Handicraft: Reviving Cottage Industries

One of the most visible and accessible uses of water hyacinth lies in handicrafts. The fibrous stalks, once dried and processed, can be woven into a wide range of products baskets, bags, mats, trays, lamp shades, stools and decorative items. These products appeal to urban consumers looking for eco-friendly alternatives to plastic and synthetic materials. West Bengal already has a strong tradition of cottage

industries, including jute crafts, cane and bamboo work, and handloom weaving. Water hyacinth crafts can build on these existing skills. Women's self-help groups (SHGs) in particular can play a central role, as the work is home-based, flexible and requires modest investment. With proper design inputs, branding and market linkage, water hyacinth handicrafts can find space in urban markets, fairs, exhibitions and even online platforms. For rural women, this can mean a steady supplementary income and greater financial independence.

### **Paper and Fibre-Based Products**

Beyond handicrafts, water hyacinth fibre can be used to produce handmade paper and paper-based products. The pulp can be mixed with recycled paper or other natural fibres to make notebooks, gift bags, envelopes and packaging material. In a state like West Bengal, where the education sector and small publishing industries are significant, handmade paper units can cater to niche markets such as eco-stationery and sustainable packaging. These enterprises can be set up at a small scale, providing employment to local youth and artisans.

### **Compost and Organic Fertiliser for Sustainable Farming**

Agriculture remains a backbone of West Bengal's rural economy, with paddy, vegetables and horticultural crops dominating the landscape. However, rising input costs and soil degradation are growing concerns. Water hyacinth offers a natural solution through composting. When properly decomposed, water hyacinth produces nutrient-rich compost that improves soil structure, water retention and microbial activity. Vermicomposting further enhances its quality. This organic fertiliser can be used in paddy fields, vegetable farms and homestead gardens. Local production of compost reduces dependence on chemical fertilisers, lowers costs for farmers and promotes environmentally friendly farming practices. Panchayats, farmer producer organisations and SHGs can collectively manage composting units, linking wetland management with agricultural sustainability.

### **Supporting Fisheries and Aquaculture**

Fisheries play a vital role in West Bengal's food security and rural employment. Yet uncontrolled growth of water hyacinth severely affects fish habitats by reducing oxygen levels and sunlight penetration. Systematic harvesting of water hyacinth not only clears water surfaces but also improves pond productivity. Processed hyacinth biomass can be used as a supplementary feed ingredient for certain fish species when combined with other feed materials. While it cannot replace conventional feed entirely, it can help reduce costs when used carefully. Cleaner ponds also lead to healthier fish stocks, benefiting small-scale fishers and fish farmers across the state.

### **Biogas and Renewable Energy Potential**

Energy access remains uneven in rural West Bengal, particularly in remote and flood-prone areas. Water hyacinth can contribute to local energy solutions through

biogas production. When mixed with cow dung or other organic waste, it can be fed into biogas digesters to produce methane for cooking and lighting. Community biogas plants based on locally available biomass reduce dependence on firewood and fossil fuels. They also help manage organic waste in a cleaner manner. The slurry left after biogas production can be used as biofertiliser, closing the loop between energy and agriculture.

### **Environmental Benefits beyond Income**

The benefits of utilizing water hyacinth go beyond economics. Regular harvesting improves water flow, reduces stagnation and helps restore ecological balance. Improved water quality benefits aquatic life, livestock and human health. In urban and peri-urban areas, better-managed water bodies also enhance aesthetics and recreational value. This is particularly relevant for towns and cities where ponds and canals are integral to the cultural landscape.

### **Challenges to Scaling Up**

Despite its potential, water hyacinth-based enterprises face several challenges. Processing requires training, tools and quality control. Products must meet market expectations in terms of durability and design. Transport and storage of bulky biomass can also be difficult.

There are environmental considerations as well. Water hyacinth absorbs pollutants, so biomass collected from highly polluted waters must be handled carefully to avoid secondary contamination. Sustainable harvesting practices are essential to prevent unintended ecological impacts.

### **Role of Government, NGOs and Institutions**

To realise the full waste-to-wealth potential of water hyacinth, coordinated support is essential. Government departments dealing with rural development, fisheries, environment and women's empowerment can play a catalytic role. NGOs and academic institutions can provide training, research and design support. Pilot projects, skill development programmes and assured market linkages can help transform small initiatives into viable enterprises. Integrating water hyacinth utilization into wetland management and rural livelihood schemes can ensure long-term sustainability.

### **Towards a Circular Economy in West Bengal**

Water hyacinth symbolises both a challenge and an opportunity for West Bengal. By converting an invasive weed into useful products, energy and fertiliser, the state can move towards a circular economy where waste is reused, livelihoods are strengthened and ecosystems are restored. What was once seen only as a burden can become a source of resilience environmental, economic and social. With thoughtful planning and community participation, water hyacinth can truly be transformed from a menace into a means of sustainable development for West Bengal.

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## CLIMATE CHANGE AND ITS CHALLENGES IN CHILLI CULTIVATION IN INDIA

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Chilli (*Capsicum annum* L.) is one of India's most important spices vegetable crops, valued not only for its pungency and colour but also for its role in export earnings. India is the world's largest producer, consumer, and exporter of chilli, with major producing states including Andhra Pradesh, Telangana, Karnataka, Maharashtra, Tamil Nadu, and West Bengal. However, climate change has emerged as a serious threat to sustainable chilli cultivation, affecting productivity, quality, and farmers' income.

### Chilli cultivation: highly climate-sensitive

Chilli is a climate-sensitive crop that performs best under moderate temperatures (20-30 °C), well-distributed rainfall, and low humidity during flowering and fruit maturity. Even slight deviations from these conditions can disrupt growth, flowering, fruit set, and quality attributes such as colour, pungency (capsaicin), and oleoresin content. Climate change is altering these delicate balances across India.

### Rising temperatures and heat stress

One of the most visible impacts of climate change is the increase in average and extreme temperatures. Prolonged heat waves during flowering and fruiting stages lead to flower drop and poor fruit set, increased pollen sterility and reduced fruit size and yield. High night temperatures, increasingly common in chilli-growing belts, also affect respiration rates and reduce dry matter accumulation, ultimately lowering marketable yield.

### Erratic rainfall and water stress

Climate change has made monsoon rainfall erratic and unpredictable, with delayed onset, prolonged dry spells, and sudden heavy downpours. For chilli farmers, these results in moisture stress during critical growth stages,

water logging and root damage due to intense rainfall and increased soil erosion and nutrient leaching. Both drought and excess moisture predispose chilli plants to physiological disorders and diseases, making crop management more difficult and costly.



**Fig. 1: Excess rainfall in chilli crop.**

### Increased pest and disease pressure

Warmer temperatures and higher humidity favour the rapid multiplication and spread of pests and diseases. In chilli cultivation, climate change has intensified problems such as thrips, mites, aphids, and whiteflies, viral diseases like Chilli leaf curl virus and mosaic viruses and fungal diseases such as anthracnose, powdery mildew, and fruit rot. Extended pest activity periods and overlapping generations have increased dependence on pesticides, raising production costs and environmental risks.

### Quality deterioration and mycotoxin risk

Climate variability also affects chilli quality, a crucial factor for both domestic consumption and export. High humidity and unseasonal rains during drying and storage encourage fungal growth, particularly *Aspergillus* species, leading to discoloration and reduced pungency, contamination with aflatoxins and rejection of consignments in international markets. Thus, climate change poses not only yield losses but also serious food safety and trade challenges.

### Impact on small and marginal farmers

Most chilli growers in India are small and marginal farmers with limited access to irrigation, weather information, and adaptive technologies. Climate-induced crop failures increase indebtedness and economic vulnerability, making chilli cultivation a high-risk enterprise under changing climatic conditions.

### Rainfall uncertainty and excess moisture stress

Chilli is sensitive to both drought and excess moisture. Excess rainfall during vegetative and flowering stages causes root hypoxia. Waterlogging increases susceptibility to wilt and root rot diseases. Heavy rains during fruit maturity hinder harvesting and drying operations. Delayed or prolonged monsoon spells often disrupt optimal sowing windows, affecting crop establishment.

### High humidity and disease incidence

The persistently humid climate creates a congenial environment for fungal and bacterial diseases in chilli. Common problems include anthracnose and fruit rot, powdery mildew and leaf spot diseases, damping-off in nursery and early crop stages. High humidity also favours insect vectors such as thrips and aphids, increasing the incidence of viral diseases like leaf curl and mosaic.

### Impact on chilli quality and post-harvest losses

Climatic variability not only affects yield but also quality attributes of chilli. Unseasonal rains and high moisture during post-harvest stages lead to poor colour development and reduced pungency, difficulty in sun-drying, resulting in fungal infestation. Higher risk of aflatoxin contamination under improper drying and storage. These factors limit the market value of chilli especially for long-distance trade.

### Implications for farmers and cropping systems

Most chilli growers are smallholders practicing mixed or diversified farming. Climatic uncertainty increases input costs due to repeated plant protection measures, crop failure risks during monsoon-season cultivation and dependence on local markets with limited price realization. As a result, farmers often hesitate to expand chilli acreage despite favourable soil fertility.

### Adaptation strategies for climate-resilient chilli farming

To cope with climate change, a combination of scientific, technological, and traditional approaches is essential

- Development and adoption of heat, drought, and disease-tolerant chilli varieties
- Improved water management through drip irrigation and mulching
- Integrated pest and disease management (IPM)
- Adjustment of sowing dates based on weather forecasts
- Promotion of climate-smart practices such as organic amendments, soil health management, and agroforestry

Strengthening extension services and climate advisories can further help farmers make timely decisions.

### Adaptive approaches

To make chilli cultivation more resilient to climatic variability, region-specific strategies are needed such as

- Selection of short-duration, disease-tolerant chilli varieties suitable for humid climate
- Raised bed cultivation and improved drainage systems
- Protected nursery raising to avoid damping-off
- Mulching and organic amendments to improve soil structure and aeration
- Promotion of off-season or rabi chilli cultivation where irrigation is available

Integration of weather-based agro-advisories and climate-smart practices can significantly reduce production risks.

### Way forward and conclusion

Climate change is no longer a distant threat it is already reshaping chilli cultivation in India. *Chilli, a symbol of India's culinary identity, must now be cultivated with a climate-smart vision to ensure its future in a warming world.* Addressing its impacts requires coordinated efforts from researchers, policymakers, extension workers, and farmers. By integrating climate-resilient technologies with local knowledge, India can safeguard chilli production, protect farmer livelihoods, and maintain its global leadership in spice production.

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## AFLATOXIN CONTAMINATION IN RED CHILLI: A GROWING CONCERN FOR HEALTH, FARMERS, AND EXPORT TRADE

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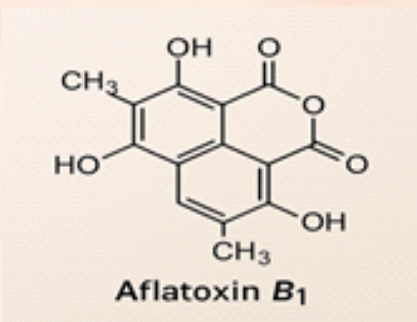
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Red chilli occupies a unique place in Indian agriculture and cuisine. It is an indispensable spice in daily cooking, a major cash crop for farmers, and a valuable export commodity earning substantial foreign exchange. India leads the world in red chilli production and export, with major growing belts spread across Andhra Pradesh, Telangana, Karnataka, Maharashtra, Tamil Nadu, and parts of eastern India. Despite this prominence, aflatoxin contamination in red chilli has emerged as a serious and persistent challenge, threatening food safety, farmer income, and India's reputation in the global spice market.

### Understanding Aflatoxin: The Invisible Enemy

Aflatoxins are naturally occurring toxic compounds produced by certain fungi, primarily *Aspergillus flavus* and *Aspergillus parasiticus*. These fungi thrive in warm and humid environments, conditions that often prevail during the post-harvest handling of red chilli. Aflatoxin contamination is particularly dangerous because it cannot be detected by sight, smell, or taste. Chillies that appear perfectly normal can still carry aflatoxin levels far above safe limits. Among different types, aflatoxin B<sub>1</sub> (AFB<sub>1</sub>) is the most potent and is classified as a Group-1 carcinogen. Once formed, aflatoxin is highly stable and cannot be eliminated by cooking, roasting, or grinding.



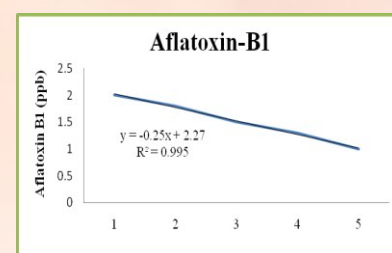
### Why Red Chilli is Highly Vulnerable

Red chilli is especially prone to aflatoxin contamination due to its production and post-harvest characteristics. The crop is harvested during seasons when intermittent rains and high atmospheric humidity are common. Traditional sun drying, though economical, often results in slow and uneven moisture removal, creating ideal conditions for fungal growth.

### Key vulnerability factors include:

- High moisture retention in freshly harvested fruits of chilli
- Drying chillies on bare soil or roadside surfaces
- Mechanical injury during harvesting and handling
- Insect infestation that facilitates fungal entry
- Storage in gunny bags under humid conditions
- Long storage duration before marketing or processing

Powdered chilli is at even greater risk, as contamination in a few mouldy fruits can spread across the entire batch during grinding.



### Health Implications of Aflatoxin Exposure

Aflatoxin poses a serious public health risk, particularly because chilli is consumed regularly, albeit in small quantities. Continuous intake of aflatoxin-contaminated food can lead to:

- Liver toxicity and liver cancer
- Impaired immune function
- Reduced nutrient absorption
- Stunted growth and development in children
- Increased susceptibility to infectious diseases

The risk is higher among populations with poor nutritional status, making aflatoxin a hidden contributor to long-term health problems in developing countries.

### Economic and Trade Consequences

Aflatoxin contamination has significant economic implications. Many importing countries, especially those in the European Union, the United States, and Japan, enforce extremely strict limits on aflatoxin content in spices. Several consignments of Indian red chilli and chilli powder have faced rejection or destruction due to aflatoxin levels exceeding permissible limits.

### Such incidents result in

- Heavy losses to exporters and processors
- Reduced market confidence in Indian produce
- Lower price realization for farmers
- Increased compliance costs for testing and certification

Ultimately, the burden of contamination is borne by the entire value chain, from farmer to exporter.

Critical Points of Contamination along the Value Chain  
Aflatoxin contamination can occur at multiple stages:

1. Pre-harvest – Stress conditions such as drought and pest attack
2. Harvesting – Delayed harvest and damaged pods
3. Drying – Slow drying and exposure to moisture
4. Storage – High humidity and poor ventilation
5. Processing – Mixing of contaminated and clean lots

Among these, drying and storage stages are the most critical and offer maximum scope for intervention.

### Preventive Measures: The Only Effective Solution

Since aflatoxins cannot be removed once formed, prevention is the key strategy.

#### At Farm Level

- Harvest at optimum maturity
- Avoid damaged and diseased pods
- Minimize contact with soil
- Use clean containers for collection

#### During Drying

- Initiate drying immediately after harvest
- Use raised platforms, tarpaulin sheets, or cemented floors
- Turn pods frequently for uniform drying
- Protect from rain and night-time dew
- Reduce moisture content below 10%

#### During Storage

- Store only well-dried chillies
- Maintain dry, cool, and ventilated storage conditions
- Avoid prolonged storage
- Use moisture-resistant packaging materials
- Regularly inspect for mould growth

#### At Processing and Marketing

- Strict sorting and grading before grinding
- Avoid blending old and fresh stocks
- Periodic aflatoxin testing
- Maintain traceability of produce

#### Role of Awareness, Testing, and Policy Support

One of the biggest challenges in managing aflatoxin is lack of awareness, particularly among small and marginal farmers. Strengthening extension services, farmer trainings, and demonstrations on scientific drying and storage is crucial. Establishment of low-cost aflatoxin testing facilities at mandis and processing units will help detect contamination early. Supportive policies, incentives for improved post-harvest infrastructure, and promotion of solar or mechanical dryers can significantly reduce aflatoxin risks.

#### Conclusion

Aflatoxin contamination in red chilli is a silent but severe challenge that affects food safety, farmer livelihoods, and export competitiveness. Addressing this issue requires a farm-to-fork approach, focusing on good agricultural practices, scientific post-harvest management, regular testing, and strong awareness programmes. Ensuring aflatoxin-free red chilli is not only essential for protecting consumer health but also for sustaining India's leadership in the global spice trade.

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**“Our planet is a lonely speck in the great enveloping cosmic dark. In our obscurity, in all this vastness, there is no hint that help will come from elsewhere to save us from ourselves.”**