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Utilization of Phyto-resources for Sustainable Man-plant Relationship to Ensure the Biodiversity Conservation and Development of Rural Economy

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Abstract

India is one of the significant megadiversity country with great cultural heritage and secured its position among the top ten largest countries of the world in terms of ecosystem, biodiversity, phyto-resources and forested landmass. It is the land of eternal peace and joy where the main motto of social life is to live in harmony with nature. But, for the recent ongoing trends of urbanization and civilization with many other anthropogenic activities, India lost its forested area and biomass. Human endeavours should remember that the journey towards the modern civilization initiated from the forest ground and even our life style fully dependent on either raw or artificial use of phyto-resources till now. The science deals with the study, survey and documentation of the direct relationship between man and biological organism, known as 'Ethnobiology' and the branch of ethnobiology deals with the study of direct man-plant relationships in all aspects, known as 'Ethnobotany'. Tribal communities or indigenous group of people still associated with forest and spend sustainable livelihood by using forest products with sociological, cultural and religious facts of human life. Our mother nature would be conserved by proper utilization and judicious application of bioresources. According to the indigenous knowledge, different plant parts have been offered to God in different ceremonies and festivals on the basis of their religious belief. So, according to this spiritual faith of ethnic people, it is the one of the vital strategies of biodiversity conservation. Young generation of this communities will be employed themselves to manufacture the herbal products and their marketing for the development of rural economy. The present study aims to display the different mode of man-plant relationships and utilization of phyto-resources in context to their conservation, environmental protection and sustainable livelihood.

Keywords: Phyto-resources, Ethnobiology, Biodiversity-conservation, Indigenous group, Rural economy.

Introduction

'Man-plant relationship' is not a trendy concept or idea rather it is intimately involved with the society of human beings in every step of lifestyle since the beginning of civilization (Acharya, 2024). The great geographical and ecological diversities in our country nurture a rich diversity of forests with several morpho-physiological and anatomical adaptations and ethnic populace. Indigenous societies in India possess the treasure houses of bioresource knowledge. It can be developed with community engagement and need an old traditional practice using local genetic resources. They have the commendable role in universal environmental security. There is no doubt that plants are our closest neighbour and best friend because without their oxygen, we can't think about life. Thereafter, life is also impossible without food, fodder and shelter that is completely depends on phyto-resources. Not only these three or four basic needs, human life completely rely upon plant life in every term, conditions and multipurpose objects. Different mode of relationships between plant kingdom and human beingis described below in the following categories:

- **Relationship useful/beneficial both in man and plants:-** Oxygen-Carbon dioxide (O_2-CO_2 ratio) balance in the environment, agricultural and horticultural practices of economically important crops and wild flowering plants respectively, application of biotechnological approach to boost up the reproductive capacity and survival rate of threatened and endangered plant species, and anthropochory (one kind of seed dispersal strategy of plants by human beings normally happened through their natural activities either intentionally or not).

- **Relationship useful/beneficial to man but harmful to plants:** -Overexploitation of plant resources without any conservational approach and sustainable use, negligence of herbaceous plant species to prepare agricultural field and monocultural forestry (cultivation of single economically important plant species) and allelopathic effects of some specific plants (The biological phenomenon that inhibits the growth, survival and reproduction of others plant speciesby producing/synthesizing some special biochemicals called allelochemicals).

- **Relationship useful/beneficial to plants but harmful to man: -**Increasing rate of invasive alien plant species (IAPs) in both terrestrial and aquatic field like *Lantana camara*, *Parthenium hysterophorus* and *Eicchornia crassipes* respectively is a serious threat to others biological organism in agricultural and wetland ecosystem. Several seeds, spores and pollen grains have shown serious allergic effects on human being even some leads to death stage also. Uncontrolled use of fungicides, pesticides and insecticides for the disease management of plants have serious life threating toxic effects on human.

- **Relationship harmful both to plants and man: -** Environmental pollution in terms of soil, water and air is harmful to all kinds of flora and fauna of our ecosystem. Deforestation for civilization is the direct destruction of phyto-diversity and plant products and indirect invitation of greenhouse gases, global warming and acid rain that directly brings the intolerable effects in human life. Shifting cultivation is another traditional agricultural practice, known as slash and burn agriculture have negative impacts on environment as it accelerates deforestation, soil degradation, reduction of the fertility rate of soil and increasing the rate of air pollution for burning of old vegetation.

Rest of the above-mentioned categories, man-plant relationship is also involved in daily routine of our every individual or social life including medicinal purposes, socio-cultural and religious activities, festivals and ceremonies, manufacture of herbal products and their commercialization to promote rural economy etc. Sustainable use and judicious application of plant-based resources must be prioritized in context of their conservation as well as protection to prevent their extinction.

Significance of the present study:

- To bring the consciousness about the different and various aspects of man-plant relationship among the society.
- Understanding the importance of different plant species in socio-cultural activities, rural festivals and religious based human culture.
- To concern about the indigenous and traditional knowledge of ethnic communities and its scientific application for sustainable livelihood.
- To initiate the application of plant-based products instead of modern technology for pollution free green environment.
- Documentation of ethnomedicinally important plants with their proper mode of administration and commercialization of herbal products for the promotion of rural economy.
- Different mode of traditional ways to ensure biodiversity conservation such as sacred groves, religious taboos and believe in the existence of God in several forest areas.
- To explore the unidentified wild floral elements in different natural habitat.
- Preservation of tree species which are responsible for the production of non-timber forest products (NTFPs).
- To promote organic farming and eco-friendly agriculture.
- To give more emphasis on green synthesis of biofertilizer and plant-based pesticides for paste management and disease-free high yielding crops.

Material and Methods

The study used a mixed approach: 50% primary data from field surveys, farmer interviews and case studies in different districts of West Bengal like Jhargram, Sundarbans (Sarberia), Darjeeling (Mungpoo and adjoining areas), Hooghly (Chinsurah); and 50% secondary data from relevant research articles on different disciplines such as Ethnobotany, Taxonomy, Ecology, Pharmacognosy and Agricultural sciences; AYUSH/CSIR/FRI reports and NGO documentation. Collected data were analyzed both qualitatively (traditional knowledge, cultural value) and quantitatively (usage frequency, economic benefits), linking traditional practices with scientific validation.

Figure 1. Location map (taken from internet) of study areas (Chinsurah, Sarberia, Jhargram and Mungpoo)

Literature Review and Experimental Findings

Table 1: Various utilization aspects of different number of plant species in India **(More than 15,000 sp., Ethnobiology in India: AICRPE, MoEFCC)**

Utilization aspect	Number of plant species (Wild)
Food	3900
Fodder	400
Fibre	525
Medicinal uses	7500
Dyes, Gums and Resins	300
Cosmetics and perfumes	100
Pesticidal use	300
Socio-cultural use	700
Buds/Flowers	101
Fruits	647
Leafy vegetables	521
Roots/Tubers	145
Seeds and Nuts	110

Figure 2: Graphical representation of the number of useful plants species in various aspects **(Ethnobiology in India: AICRPE, MoEFCC)**

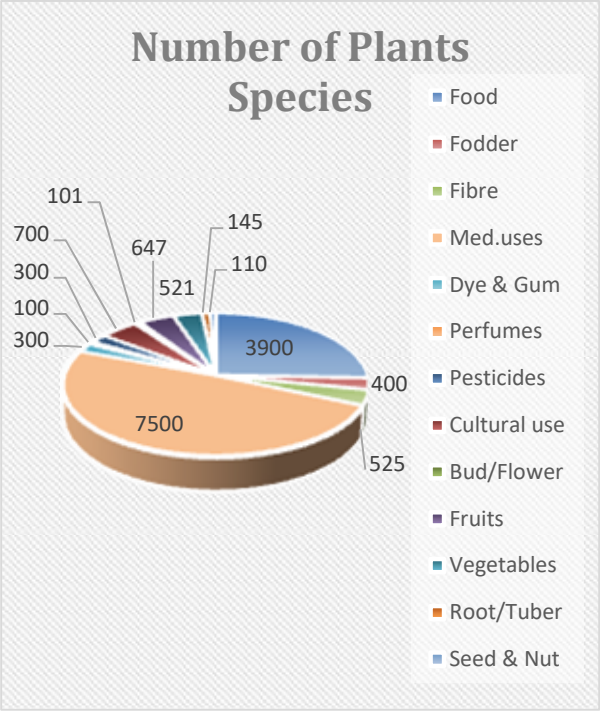

Table 2: An item-wise enumeration of most common and selected plant species having commercial prospectus.

Item of Plant products	Names of the most common and selected plant species
Food	*Oryza sativa, Triticum aestivum, Zea mays, Eleusine coracana, Hordeum vulgare, Echinochloa frumentacea, Cicer arietinum, Phaseolus aureus, Lens esculenta, Cajanus cajan, Glycine max.*
Fodder	*Vigna unguiculata, Desmanthus virgatus, Medicago sativa, Trifolium repens, Stylosanthes guiaenensis, Leucaena leucocephala, Gliricidia sepium, Sesbania grandiflora.*
Fiber	*Corchorus olitorius, Gossypium hirsutum, Crotalaria juncea.*
Medicinal uses	*Aloe vera, Adhatoda vasica, Andrographis paniculata, Atropa belladonna, Abroma augustum, Bacopa monnieri, Cinchona cercinalis, Croton bonplandianus, Digitalis purpurea, Ephedra gerardiana, Glycyrrhiza glabra, Holarrhena antidysenterica, Plantago ovata, Rauvolfia serpentina, Taxus brevifolia, Terminalia arjuna, Withaniasomnifera, Myristica andamanica, Saracaasoca, Rhizophora mucronata, Ceriops decandra, C. tagal, Bruguiera gymnorhiza, Kandelia candel.*

Dye, gum and resins	*Abies balsamea, Acacia nilotica, Acacia catechu, Bixa orellana, Crocus sativus, Gardenia gummifera, Heveabras siliensis, Ferula asafoetida, Indigo tinctoria, Pinusrox burghii, Shorea robusta, Tectona grandis.*
Cosmetics and Perfumes	*Aloe vera, Cymbopogon flexuosus, Cocos nucifera, Eucalyptus sp., Lawsonia inermis, Nyctanthes arbor-tristis, Lavendula officinalis, Mentha piperita, Jasminium odorum.*
Pesticides	*Azadirachta indica, Nicotiana tabacum, Schoenocaulon officinale, Tagetes patula, Tephrosia vogelii, Vitex negundo*
Socio-cultural uses	*Aegle marmelos, Cynodon dactylon, Musa paradisiaca, Ficus religiosa, Ocimum sanctum, Punica granatum, Curcuma longa, Santalum album, Pterocarpus santalinus, Opuntia dillenii*
Buds/Flowers	*Butea monosperma, Crotalaria retusa, Hibiscus rosa-sinensis, Hibiscus mutabilis,Polyanthes tuberosa, Nelumbo nucifera, Catharanthus roseus, Datura metel, Plumeria pudica, Thevetia peruviana.*
Fruits	*Annona squamosa, Annona reticulata, Anacardium occidentale, Artocarpus heterophyllus, Borassus flabellifer, Citrus maxima,Dillenia indica, Lepisanthes rubiginosa, Limonia acidissima, Mangifera indica, Morinda citrifolia, Psidium guajava, Phoenix sylvestris, Tamarindus indica, Zizyphus oenoplia.*
Vegetables	*Abelmoschus esculentus, Brassica oleracea var. capitata, Boerhavia diffusa, Coriandrum sativum, Diplazium esculentum, Marsilea quadrifolia, Moringa oleifera, Murraya koenigii, Spinacia oleracea, Vicia faba.*
Roots/Tuber	*Daucus carrota, Beta vulgaris, Raphanus sativus, Solanum tuberosum, Zingiber officinale, Chrysopogon zizanioides*

Application of Phyto-resources instead of modern technology:

A. Vetiver Grass ('Khas–khas') as a Natural Alternative to Air-Conditioning

The demand for indoor cooling in tropical countries like India is steadily increasing, creating heavy dependence on electricity and synthetic refrigerants (Shah & Laubscher, 2019). Traditional ecological knowledge, however, provided natural alternatives long before the invention of mechanical air-conditioning. Vetiver grass (*Chrysopogon zizanioides*), popularly known as 'Khas-khas', offers a traditional, eco-friendly, and low-cost substitute for cooling. Vetiver grass roots, valued for their strong fibrous structure and aromatic properties, have historically been used in mats and blinds to cool homes in summer months. Today, institutions and researchers are reviving this knowledge for eco-architecture and green building technology (Lavania, 2003). Vetiver ('Khas-khas') mats and screens operate on the principle of evaporative cooling. When water is sprinkled over woven vetiver roots, evaporation absorbs heat from the surrounding air, lowering indoor temperature. Unlike mechanical AC, this method consumes negligible energy and simultaneously releases a soothing earthy fragrance, which is known to have calming and air-purifying effects (Grimshaw, 2016).The use of vetiver in cooling has been explored by various scientific and cultural institutions: IIT Delhi incorporated vetiver blinds in sustainable building projects to reduce energy load (IIT Delhi, 2015). NBRI, Lucknow promoted the use of vetiver root panels for eco-architecture and natural cooling (Singh &

Singh, 2012). CSIR recommended "khas tatties" as a practical energy-saving option in semi-urban housing (CSIR Report, 2017). FRI, Dehradun experimented with vetiver mats in heritage buildings, finding them effective in passive cooling (FRI Bulletin, 2018). Traditional Systems in Rajasthan and Gujarat relied on 'khas tatties' in havelis and temples, showing their deep-rooted cultural application (Chaudhuri, 2003).

Vetiver-based cooling not only reduces electricity consumption but also contributes to cultural preservation and rural livelihoods, as vetiver cultivation generates economic opportunities (Truong, 2008). However, its effectiveness is more suited to dry climates, limiting large-scale replacement of AC. Thus, it should be promoted as a complementary system within green building strategies. Vetiver grass serves as a sustainable, culturally relevant, and cost-effective alternative to conventional AC. Its adoption by leading institutions demonstrates its potential to support India's sustainability agenda. Scaling up such eco-friendly practices can significantly reduce carbon emissions while reviving traditional ecological wisdom for modern living (Lavania, 2003).

B. Use of Phytoresources for domestical purposes: Native people of rural areas and indigenous group show different mode of application of plant parts in their domestical activities of daily life to avoid plastic-based products or by-products which is harmful to nature. In general, leaves of *Musa paradisiaca* (Kala), *Shorea robusta* (Saal), *Tectona grandis* (Segun) are widely used as plate to serve food instead of plastic plate. In Garo hill of Meghalaya, indigenous tribe of that area used *Sida acuta* plant to prepare brooms for cleaning rooms and local areas (Shil and Shaw, 2025). In our West Bengal, dry rachis of the leaves of *Cocos nucifera*, used in broom preparation and shows wide application in almost every houses. Preparation of 'Chatai' is one of the important products of cottage industry which is made by leaves of *Phoenix dactylifera* and *Borassus flabellifer,* and widely used as mat in village for sitting or sleeping purposes. Some native people of hilly area used the bracts of giant bamboo (*Dendrocalamus giganteus*) in form of cap.

Fig 3. Roots (from *Chrysopogon zizanioides*) -made curtain popularly known as 'Khas-khas': Natural AC machine (Photois taken from internet).

Fig 4. P. Parai (Co-author) and Dr. P. K. Ghosh are enjoying to put on cap made up of 'Giant bamboo brackt' (Place-Mungpoo, West Bengal).

C. Ethnomedicines as Substitutes for Allopathic Treatment in India

In many Indian states, ethnomedicine continues to function as a reliable substitute for costly allopathic treatment. In West Bengal, *Azadirachta indica* (Neem) is used as a natural antiseptic and antimalarial, while *Ocimum tenuiflorum* (Tulsi) works as an effective herbal expectorant against cough and asthma. Similarly, *Curcuma longa* (Turmeric) paste is applied on wounds and infections, replacing antiseptic creams.

Mangrove plants of the family Rhizophoraceae are gaining recognition for their antidiabetic potential (Parai, 2025). *Kandelia candel* ('Goria') leaf and bark extracts exhibit strong hypoglycemic activity due to phenolics, flavonoids, and tannins. *Bruguiera gymnorhiza* ('Lal Kankra') has been reported to lower blood glucose by enhancing insulin sensitivity, while *Rhizophora mucronata* ('Garjan') shows α-amylase and α-glucosidase inhibitory action comparable to synthetic drugs. It is also notable that bark and leaves of *Ceriops tagal* ('Math Goran') and leaves of *C. decandra* ('Jele Goran') are used as antidiabetic drug by the people of Sundarbans due to their enhancing insulin secretion property. These plants also display antioxidant properties, reducing oxidative stress linked with diabetes. Such findings highlight mangroves as sustainable bioresources for developing novel traditional herbal antidiabetic drugs. Several popular Indian ethnomedicinal plants with potent antidiabetic activity like *Momordica charantia* (Bitter gourd), *Gymnema sylvestre* (Gurmar), and *Trigonella foenum-graecum* (Fenugreek) were found to regulate blood glucose through insulin mimetic and pancreatic β-cell regenerative effects (Bandyopadhyay, 2025). His studies emphasize the role of polyphenols, saponins, and alkaloids in reducing hyperglycemia. The findings support traditional practices where these plants act as natural alternatives to oral hypoglycemic drugs. Thus, ethnomedicine continues to provide promising leads for developing safer antidiabetic therapies.

For hypertension, *Rauvolfia serpentina* (Sarpagandha) root decoction is prescribed by Bengal's tribal healers, a practice also common in Uttar Pradesh, where its substitutes synthetic antihypertensives. *Zingiber officinale* (Ginger) and *Piper nigrum* (Black pepper) are used in Bengal and Kerala as digestive remedies, substituting for allopathic carminatives and antacids. *Andrographis paniculata* (Kalmegh) is popular in Bengal for liver disorders and fever, while in Assam it is widely used as an antimalarial substitute.

Myristica andamanica, an ethnomedicinally important plant of Myristicaceae family and abundant in the maritime forest of the Andaman-Nicobar Islands, used by 'Jarawa' tribes to inhale the smoke by burning its leaves to reduce fever. A reddish coloured sap is obtained from the cutting region of the stem which is applied on wounds and also mixed with clay and phytoplankton for preparing 'ochre', used in facial purposes (Chakrabarty *et al*., 2020)

Stem bark and unopened floral buds of *Saraca asoca* (Ashok) used in form of decoction or extraction to cure excessive pain during menstruation, irregular menstruation, blood discharge etc. female reproductive disorders (Chatterjee and Mukherjee, 2016).

Cardiac care through *Terminalia arjuna* (Arjun) bark is practiced not only in Bengal but also in Maharashtra, where it serves as an herbal cardiotonic. *Withania somnifera* (Ashwagandha) roots, used for arthritis and stress in Bengal, are similarly used in Madhya Pradesh as an alternative to painkillers and adaptogens. In Rajasthan, *Aloe vera* is administered for gynaecological disorders and skin diseases, a use echoed in Bengal's folk medicine. *Aegle marmelos* (Bael) fruit is consumed for diarrhoea and dysentery both in Bengal and Bihar, replacing antibiotics and oral rehydration solution (ORS).

Thus, ethnomedicines across states show remarkable regional diversity, yet share a common principle: substituting expensive or inaccessible allopathic medicines with locally available, culturally trusted, and ecologically sustainable plant-based remedies.

Traditional methods of biodiversity conservation: Indigenous communities understand the importance of biodiversity conservation because plant products and forest resources fulfill almost all kinds of requirements in their every day's life through generation after generation. Not only the basic needs, they have many kinds of religious belief, existence of almighty, symbol of God and availability of supreme power around the forest areas with associated trees. These kind of forest regions with socio-cultural or religious importance and hence maintained by the native people of ethnic communities, known as **Sacred groves**. There is no doubt that it is one of the oldest and ideal way of biodiversity conservation practices, preserved by different group of people of various communities without any costs but only the basis of their spiritual faith and awareness.

Sacred groves: A religious mode of conservation- Sacred groves, a promising approach of traditional and spiritual mode of conservational strategies of both flora and fauna, unique phyto-resources, soil conservation and indigenous knowledge of age-old practices may directly or indirectly help in the preservation of biodiversity (Singh *et al.,* 2017). Ethnobiologists reported that India has highest and maximum numbers of traditionally or religiously conserved forest patches in compare with other countries of the world having more than 1,00,000 sacred groves according to several state reports. It is indeed an important part of regional biodiversity and dynamic ecosystem services to different groups of local community. Applied Environmental Research Foundation (AERF), Pune, Maharashtra is actively engaged to explore different sites of Sacred groves from last three decades. Till now more than 650 sacred groves are identified only in the Pune and Maharashtra area by this non-governmental organization (NGO), AERF. Near about 20 sacred groves of Pune are marked as the source of non-timber forest products (NTFPs). Odissa state has more than 2000 sacred forests (Rath and Ormsby, 2024) and Assam has approximately 300 forests conserved by native people with their religious believes (Baidya and Devi, 2024).In our traditional Hinduism culture of West Bengal, many unique plant species are recognized as the God and Goddess by common people of Bengal and worshipped by them with full of spiritual faith and religious belief. In this present study, we are going to highlight some very common plants of Bengal, abundantly grown here and there, having this kind of significant. Some of them are- *'Opuntia dillenii'* (Family. Cactaceae) is the symbol of 'Devi Manasha'; *'Aegle marmelos'* (Family. Rutaceae) is the signof 'Shiva'; '*Ocimum sanctum'* (Family. Lamiaceae) and *'Ficus religiosa'* (Family. Moraceae) are worshipped as 'Vishnu' in almost every house of Bengal even in different sociocultural or religious festivals (Bandyopadhyay and Ghosh, 2023). The existence of God in the mentioned plant species is highly controversial and there are several opinions regarding this, but these kinds of concepts are the key points of biodiversity conservation without any extra efforts.

Fig 5. Devoted to a specific local deity in a village at Dahanu Taluka, Palghar, Maharashtra (Photo courtesy: Dr. Suchandra Ranjit Dutta).

Fig 6. Tulsi Mancha: Traditional Hinduism Culture of West Bengal for evening prayer.

Fig 7. Sacred area of Pirtala, Chinsurah, Hooghly, West Bengal(D. Bandyopadhyay).

Fig 8. Sacred tree, Pirtala, Chinsurah, Hooghly, West Bengal (D. Bandyopadhyay).

Fig 9. Worship of *F. religiosa* in form of 'Shiva', at Pearabagan, Chinsurah, Hooghly, West Bengal (D. Bandyopadhyay).

Strategies for the Development of Rural Economy:

Commercialization of Herbal Products in India: Scope and Challenges

The Indian subcontinent is home to thousands of medicinal plants that have historically been used in local healthcare practices (Mukherjee *et al*., 2017). In recent years, global demand for natural remedies has placed India in a strong position to supply herbal medicines, nutraceuticals, and wellness products (Patwardhan, 2014). In the past few decades, this indigenous knowledge has evolved into a structured industry through the commercialization of herbal products. With state support, rising consumer demand, and international recognition, India's herbal sector is now a growing component of healthcare and trade. The Ministry of AYUSH has been instrumental in providing policy support, research encouragement, and export promotion to enhance this sector (Srivastava S, 2018).

The herbal market in India is expanding at a rapid pace, with well-established companies such as Dabur, Himalaya, Baidyanath, and Patanjali manufacturing a wide range of herbal-based health, nutrition, and cosmetic products. Projections indicate a steady rise in both domestic and global markets, with India becoming a significant contributor to the herbal economy (Sharma, 2021). Export-oriented strategies and the cultivation of medicinal plants under government-supported programs such as the National Medicinal Plants Board (NMPB) have further strengthened this growth. But it is still notable that the commercialization of herbal products faces multiple barriers: (i) Quality assurance issues due to lack of uniform raw material standards (Bent, 2008); (ii) Biodiversity pressure from overharvesting of medicinal plants, especially in sensitive regions like the Himalayas (Hamilton, 2004); (iii) Regulatory variations across countries that complicate global trade (Ekor, 2014); and (iv) Insufficient scientific evidence from clinical trials which limit wider medical acceptance (Mukherjee, 2017).

With growing interest in herbal cosmetics and dietary supplements, India has the potential to establish itself as a world leader in herbal commercialization (Patwardhan *et al.,* 2005). The commercialization of herbal products in India is an evolving sector that balances heritage with innovation. Addressing quality, sustainability, and regulatory gaps will be crucial for long-term growth. With coordinated efforts from industry, government, and research institutions, India can meet both national health needs and international demand, positioning itself at the forefront of the global herbal trade.

Phyto-Resources in Organic Farming: An Indian Perspective

Organic farming in India has grown significantly in recent years due to consumer demand for chemical-free food and government initiatives like the *National Programme for Organic Production* (**NPOP**). Unlike conventional farming, organic practices emphasize renewable inputs and ecological balance. Phyto-resources are essential to strengthening India's organic farming system by providing natural, cost-effective, and sustainable inputs.

Plant-based resources are employed in multiple ways in Indian organic agriculture:

Green Manures: Crops like *Sesbania aculeata* and *Crotalaria juncea* enrich soils with nitrogen and organic matter (Yadav *et al*., 2013).

Mulching: Mulching is the practice of covering soil with organic materials such as crop residues, leaves, and seaweed to conserve moisture, regulate temperature, and suppress weeds (Kumar *et al*., 2019). In organic farming, it enriches the soil naturally reduces chemical inputs, and supports soil biodiversity (Bhattacharyya *et al*., 2020). Common phyto-resources include rice straw, neem leaves, sugarcane trash, banana pseudostem, and seaweed biomass (Singh & Kaur, 2018). These materials not only improve soil fertility but also provide scope for bioprospecting of bioactive compounds (Rao *et al*., 2021). Thus, mulching connects sustainable farming with innovations in agriculture, medicine, and industry.

Compost and Vermicompost: Agro-residues from crops such as sugarcane and rice are composted to improve soil fertility. Vermicompost is an excellent odorless organic manure synthesized by excreta (vermicast) of earthworm like *Eisenia fetida*, *Eudrilus eugeniae*, feeding on biological waste and plant material.

Bio-Pesticides: Extracts from *Azadirachta indica* (neem), *Lantana camara*, and *Vitex negundo* are widely used as eco-friendly alternatives to chemical pesticides (Singh & Misra, 2017).

Botanical Growth Promoters: Plant-based formulations like *'Panchagavya'* and *'Jeevamrutha'* are commonly used by organic farmers to enhance crop growth (Subhashini, 2018). Panchagavya and Jeevamrutha are traditional organic formulations gaining popularity among farmers in West Bengal for their cost-effectiveness and environmental

benefits. Panchagavya is a blend of cow dung, cow urine, milk, curd, ghee, jaggery, banana, tender coconut, and water. It acts as a growth promoter and biopesticide, enhancing soil fertility and plant immunity. Jeevamrutha is a fermented mixture of cow dung, cow urine, jaggery, pulse flour, and water. It promotes microbial activity in the soil, improving nutrient availability and plant growth.

Fig 9: Preparation of 'Panchagavya': An outstanding and traditional organic manure (Photo courtesy: P. Parai).

Fig10:Cultivation field at Sarberia (Sundarbans) using 'Mulching practice' and growth of flowering plant – *Zinnia sp.* (Asteraceae), (Photo courtesy: P. Parai).

The West Bengal government, through various schemes and Krishi Vigyan Kendras (KVKs), supports the adoption of organic farming practices, including the use of 'Panchagavya' and 'Jeevamrutha'. These initiatives aim to reduce dependency on chemical fertilizers and pesticides, promoting sustainable agriculture. Cooch Behar District farmers have adopted Jeevamrutha to enhance soil health and crop yield. Studies from Uttar Banga Krishi Viswavidyalaya indicate that 'Jeevamrutha' outperforms other organic manures in terms of nutrient content and microbial activity. Field examples from different Districts may be cited. Under the guidance of Jhargram Krishi Vigyan Kendra, farmers have implemented Panchagavya and Jeevamrutha preparations, leading to improved crop productivity and soil fertility. Cooch Behar District farmers have adopted Jeevamrutha to enhance soil health and crop yield. Studies from Uttar Banga Krishi Viswavidyalaya indicate that Jeevamrutha outperforms other organic manures in terms of nutrient content and microbial activity. The integration of Panchagavya and Jeevamrutha into organic farming practices in West Bengal demonstrates the potential of traditional knowledge in modern agriculture. With continued government support and farmer education, these practices can contribute to sustainable and eco-friendly farming in the region.

Discussion

Plants have always been central to human survival, culture, and economy, and the utilisation of phyto-resources reflects a deep-rooted man–plant relationship that sustains biodiversity while supporting rural livelihoods. Traditional practices such as the use of vetiver grass (*Chrysopogon zizanioides*) as a natural cooling system, leaf plates of *Musa paradisiaca*, *Shorea robusta*, and *Tectona grandis* to replace plastics, or brooms made from *Sida acuta* and *Cocos nucifera* rachis, illustrate how indigenous knowledge reduces reliance on modern synthetic products while conserving natural resources.

Ethnomedicine further demonstrates the significance of plant-based resources, where species like *Azadirachta indica*, *Curcuma longa*, and mangrove plants (*Kandelia candel*, *Rhizophora mucronata*) act as natural substitutes for costly allopathic drugs, contributing to both community health and biodiversity conservation. Such traditional remedies not only provide affordable healthcare but also open avenues for bioprospecting and development of novel plant-based drugs.

Equally important are sacred groves, which stand as living examples of biodiversity conservation through spiritual faith. These culturally protected patches safeguard unique flora and fauna, linking ecological preservation with religious traditions. They serve as vital reservoirs of non-timber forest products (NTFPs) and ecosystem services. From an economic perspective, the commercialisation of herbal products and the integration of phyto-resources in organic farming systems (mulching, composting, bio-pesticides, Panchagavya, Jeevamrutha) provide farmers with sustainable income opportunities. Government schemes and grassroots initiatives in West Bengal and other states further highlight how traditional plant-based practices can strengthen rural economies while reducing chemical dependence.

In conclusion, the sustainable use of phyto-resources ensures a balanced man–plant relationship where biodiversity conservation and rural economic progress complement each other. By blending indigenous wisdom with modern science, these practices not only safeguard ecological heritage but also pave the way for a resilient, eco-friendly rural economy.

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Conflict of Interest

Authors have no conflict of interest.

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