TNAU & MANAGE, Hyderabad

Natural Farming for Sustainable Agriculture

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NATURAL FARMING FOR SUSTAINABLE AGRICULTURE

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This e-book is a compilation of resource materials obtained from various subject experts in the collaborative training program on "Natural Farming for Sustainable Agriculture" which was conducted from 09-13 October, 2023 by MANAGE and Nammazhvar Organic Farming Research Centre, Tamil Nadu Agricultural University, Coimbatore. This e-book is designed for researchers, academicians, extension workers, research scholars and students in the field of agriculture and allied sectors. The information published in this e-book is useful for educational and knowledge sharing purpose only. Neither the publisher nor the contributors, authors and editors assume any liability for any damage or injury to persons or property from any use of methods, instructions, or ideas contained in the e-book. No part of this publication may be reproduced or transmitted without prior permission of the publisher/editor/authors. Publisher and editor do not give warranty for any error or omissions regarding the materials in this e-book.

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MESSAGE

National Institute of Agricultural Extension Management (MANAGE), Hyderabad is an autonomous organization under the Ministry of Agriculture & Farmers Welfare, Government of India. The policies of liberalization and globalization of the economy and the level of agricultural technology becoming more sophisticated and complex, calls for major initiatives towards reorientation and modernization of the agricultural extension system. Effective ways of managing the extension system needed to be evolved and extension organizations enabled to transform the existing set up through professional guidance and training of critical manpower. MANAGE is the response to this imperative need. Agricultural extension to be effective, demands sound technological knowledge to the extension functionaries and therefore MANAGE has focused on training program on technological aspect in collaboration with ICAR institutions and state agriculture/veterinary universities, having expertise and facilities to organize technical training program for extension functionaries of state department.

Natural farming, heralded as a beacon of regenerative agriculture worldwide, advocates for the cultivation of safe, premium crops while nurturing a symbiotic relationship with the environment. It champions techniques minimizing chemical intervention, such as the consistent use of cow dung and urine-based blends, efficient recycling of crop residues, intercropping with legumes for robust soil coverage, pre-monsoon dry sowing, judicious irrigation, and targeted watering at noon to harmonize soil-air-moisture equilibrium. By placing soil and ecosystem well-being at the forefront, this approach aims to slash input expenses while amplifying farm vigor and crop yields. Moreover, it endeavors to fortify agroecosystems against the onslaught of climate change.

It is a pleasure to note that Nammazhvar Organic Farming Research Centre, TNAU, Coimbatore, Tamil Nadu and MANAGE, Hyderabad is coming up with a joint publication as e-book on “Natural Farming for Sustainable Agriculture”. I wish the program be purposeful and meaningful to the participants and the e-book will be useful for stakeholders across the country. I extend my best wishes for the success of the program and also I wish NOFRC, TNAU, Coimbatore, Tamil Nadu, many more glorious years in service of Indian agriculture and allied sector ultimately benefiting the farmers. I would like to compliment the efforts of Dr. M. Suganthy, Professor, TNAU, Coimbatore, Dr. B. Renuka Rani, Deputy Director (NRM), MANAGE, Rajendranagar, Hyderabad and Dr.N. R. Sharma, MANAGE, Hyderabad for this valuable publication.

Dr. P. Chandra Shekara
Director General, MANAGE

PREFACE

Amidst a growing concern for our environment, climate change, and the urgent need for sustainable development, the spotlight on natural farming has never been brighter. This comprehensive volume aims to be a cornerstone in the discourse on agriculture and sustainability, shedding light on the intricate tapestry of natural farming. As the editors of this collaborative effort, we have strived to bring together a diverse range of perspectives, insights, and research findings from experts and practitioners deeply committed to unraveling the potential and challenges inherent in natural farming.

This book's inception arises from a keen recognition of the pressing need to address the evolving landscape of agriculture. Natural farming, with its emphasis on harmony with nature, regenerative practices, and minimal environmental impact, emerges as a beacon of hope in navigating the complexities of our time. Standing at the intersection of environmental degradation and the imperative for food safety, natural farming presents itself as a viable and sustainable alternative.

Drawing upon the contributions of a diverse group of experts, this book serves as a comprehensive resource for understanding the principles, practices, and advancements in natural farming. Structured to provide a holistic view, it encompasses the current status of natural farming methods, their impact on agricultural ecosystems, and the potential they hold for the future of global food production.

Each chapter is a testament to the dedication of the contributors, who have explored various facets of natural farming. The book covers a wide range of topics, including the evolution of natural farming, the underlying principles guiding its practices, case studies showcasing successful implementations, and discussions on the role of technology and innovation in advancing natural farming methods. Through their expertise, the contributors offer a balanced perspective on the challenges and opportunities associated with transitioning to and promoting natural farming at local, national, and global levels

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We extend our heartfelt gratitude to MANAGE for their recognition of the importance of natural farming and their support in offering training to scientists, students, stakeholders, extension officials and farmers across the country to enrich their knowledge on natural farming, thus facilitating the publication of this book.

As editors, we trust that this book will serve as a valuable reference for researchers, educators, policymakers, and practitioners dedicated to promote sustainable and environmentally friendly agricultural practices. We express our deepest appreciation to all the contributors who have generously shared their expertise, experiences, and research findings, enriching the tapestry of this book. May this volume titled "Natural Farming for Sustainable Agriculture" inspire and guide individuals and institutions towards embracing and championing natural farming for the betterment of our planet and the well-being of future generations.

M. SUGANTHY
B. RENUKA RANI
N. R. SHARMA

FOREWORD

Natural farming, a form of regenerative agriculture, is gaining global advocacy and promotion as a means to produce safe, high-quality crops while maintaining harmony with nature. It emphasizes chemical-free or minimal intervention methods to enhance soil biological fertility without relying on external inputs. Key strategies include the continuous application of cow dung and urine-based concoctions, effective recycling of crop residues, intercropping with legumes for soil cover, pre-monsoon dry sowing, minimal irrigation, and maintaining soil-air-moisture balance by irrigating at noon. Natural farming prioritizes soil and ecosystem health, aiming to reduce input costs while improving farm health and crop yields. Additionally, it seeks to bolster resilience within agroecosystems to withstand the adverse effects of climate change.

The Indian government supports natural farming through initiatives like the National Mission on Natural Farming, which promotes traditional indigenous practices that free farmers from dependence on external inputs. Approximately 6.5 lakh hectares in India are under natural farming, with major adoption in states like Andhra Pradesh, Himachal Pradesh, Chhattisgarh, and others. Andhra Pradesh leads in promoting Community-Managed Natural Farming (APCNF) through the Rythu Sadhikara Samstha (RySS), followed by Himachal Pradesh's Prakritik Kheti Khushhal Kisan (PK3) Yojana. Zero Budget Natural Farming aims to develop the human and social capital necessary for sustainable agricultural production.

This book aims to document traditional natural farming practices across India, their scientific background, production methods, benefits to soil health, crop-specific practices, waste recycling techniques, composting methods, soil fertility enhancement, and natural pest management. Such documentation facilitates soil quality assessment, carbon footprint analysis, and economic evaluation of agroecosystem services, aiding policy decisions at local and national levels. The book serves as a valuable resource for teachers, researchers, and extension personnel involved in natural farming education, validation of practices across different crops and agroecological regions, and skill development for farmers and entrepreneurs.

I congratulate the editors, M. Suganthy, B. Renuka Rani and N.R. Sharma for their dedicated efforts in compiling this book titled "Natural Farming for Sustainable Agriculture".

18/3/2024

(V. GEETHALAKSHMI)

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FOREWORD

Under this backdrop, various concepts such as Return towards Nature, Family Farming, Alternative Agriculture, Eco-friendly Agriculture, and Natural Farming have gained traction nationally and internationally as pathways to sustainable agriculture. These alternative approaches are now integrated into agricultural education curricula at different levels, from undergraduate to doctoral studies, aiming to foster a deeper understanding and practical application of natural farming principles.

The transformation of agricultural education is essential for raising awareness, enhancing skills, and promoting experiences in natural farming, which emphasizes the harmonization of the five basic elements of the universe. While challenging, educating society towards a commitment to nature holds the potential to revolutionize farming practices worldwide.

In this context, this book stands as a paramount scientific compilation on natural farming. It serves as a comprehensive resource for educators, researchers, and extension workers striving to improve agroecosystems and human health. By covering the principles and success stories of natural farming, this book is invaluable to farmers and entrepreneurs transitioning to this sustainable approach.

I extend my congratulations to the editors for their diligent work in compiling this handbook. I am confident that "Natural Farming for Sustainable Agriculture" will be an indispensable resource for the technical and learning community, contributing to the advancement of sustainable agriculture.

(S. K. SHARMA)

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NATURAL FARMING: SCOPE AND IMPORTANCE

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Introduction

The present generation of human beings is enjoying the bountiful benefits from prosperity through economic development and scientific advancement in agriculture. Modern intensive farming has played a vital role in increasing the crops' productivity viz., 109% for rice, 208% for wheat, 157% for maize, 78% for potatoes, and 36% for cassava which helped to feed the exploding population and to overcome the crisis of food deficits (Wiebe *et al.,* 2021). Such expansion in food production and economic growth triggered a greater threat to the natural environment. As conventional agriculture is mainly dependent on synthetic chemicals and petrol energy, the excessive use of chemical fertilizers and pesticides has caused environmental pollution and degradation, impaired food safety and quality,and posed an adverse effect on human and animal health. FAI (2020) reported that fertilizer consumption in India increased by about 13 times from 1970 to 2020. This has adversely impacted the crop response ratio and created an imbalance of nutrients in the soil. The crop response ratio has reduced from 58 percent in the last six decades. The ideal ratio of the three major plant nutrients viz., Nitrogen, phosphorus, and Potassium of 4:2:1 is disrupted. Besides, it has greatly increased the quantity of greenhouse gases in the environment. Moreover, it causes an unstable production with an unsustainable agroecosystem. Increased farmer indebtedness due to costly agricultural inputs like chemical fertilizers, pesticides, and herbicides, increased cultivation cost with low farm produce prices, have aggravated the country's farm crisis. The concerns of such problems against the environmental and agricultural sustainability in the country prompted the scientists and policymakers to seek appropriate alternative strategies to ensure more sustainable food production with a pollution-free environment.

What is Natural Farming?

In the Indian context, natural farming is a local low-input climate-resilient farming system that advocates the complete elimination of synthetic chemical agro-inputs. Instead, it encourages farmers to use low-cost, locally sourced inputs such as natural mixtures made using cow dung, cow urine, jaggery, pulse flour, mulch, crop covers, and symbiotic intercropping to stimulate the soil's microbial activities. It emphasizes the enhancement of soil conditions through improved organic matter and biological activity; crop diversification; enhanced biomass recycling with enriched biological interactions in the farm. Natural farming allows for a wide range of agroecological practices - composting, mulching, green manuring, crop rotations, intercropping, tree intercropping, livestock integration - and takes a holistic approach to farming systems.

A set of principle, guides the natural farming as: (i) the farm should be based on poly-cropping, where trees are integrated with various arable and perennial crops; (ii) No synthetic agro-inputs (fertilizers, pesticides, or herbicides) should be applied; (iii) soil should remain covered at all times and for the entire year using cover crops or mulch; (iv) local seeds, which are less costly and more resilient than hybrids, should be used; (v) bio-stimulants, should be used as a catalyst agent to enhance microbial activities of the soil, and botanical extracts for pest management; (vi) minimal tillage; and (vii) integration of livestock with crops for biological and economic synergies.

The top states encouraging natural farming are Andhra Pradesh, Himachal Pradesh, and Gujarat. Other States like Uttar Pradesh, Madhya Pradesh, Odisha, Chhattisgarh, Himachal Pradesh, Jharkhand and Tamil Nadu are also practicing this type of farming (Figure 1). Central government launched a natural farming promotion scheme during 2020-21; *Bharatiya PrakritikKrishi Paddhati* (BPKP) a sub scheme under PKVY. Nearly 6.1 lakh ha has been covered in above said states with total fund of 49.8 crore. There are many opportunities for starting natural farming in our nation because of the varied agro-climates and the richness of farmers' traditional knowledge (Kumar *et al.,* 2019).

Figure 1. Prominent states practicing Natural Farming in India (Source: NITI Aayog)

Natural Farming- the need of the hour

A report from NITI Aayog says that natural farming is the need of the hour as the cost of production of food grains has escalated drastically due to increased cost of agricultural inputs *viz.,* chemical fertilizers, pesticides, fungicides and herbicides. Besides, it is the best way to restore degraded lands, enhance soil health, conserve water and reduce the usage of chemical inputs while improving the nutritional quality of crops and supporting the local food systems.

Features of Natural Farming

- According to natural farming principles, plants get 98% of their supply of nutrients from the air, water, and sunlight. And the remaining 2% can be fulfilled by good quality soil with plenty of friendly microorganisms as like in forests and natural systems
- The soil is always supposed to be covered with organic mulch during a maximum period of the year, which creates humus and encourages the growth of friendly microorganisms
- Farm made bio-cultures namely Beejamrit as seed treatment, Jeevamrit as foliar application and Ghanjeevamrit as soil application instead of any chemical fertilizer to improve the soil microflora. These bio-cultures are derived from very little cow dung and cow urine of desi cow breed which is the purest as far as the microbial content of cow dung and urine is considered
- It holds the promise of enhancing farmers' income while delivering many other benefits, such as restoration of soil fertility and environmental health, and mitigating and/or reducing greenhouse gas emissions
- In natural farming, neither chemical nor organic fertilizers are added to the soil. The decomposition of organic matter is encouraged by microbes and earthworms right on the soil surface itself, which gradually adds nutrition to the soil, over the period
- Natural farming is just the way it would be in natural ecosystems as there is limited tilling of soil, no fertilizers, and no weeding done. Weeds are considered essential and used as a living or dead mulch layer
- Natural, farm-made bio pesticides like Neem Astra are used to control pests and diseases
- Multi-cropping is encouraged over a single crop method

The following table differentiates the practice of natural farming from organic farming based on the techniques, practices and philosophies adopted

Natural Farming	Organic Farming
Relies on natural processes without using any external inputs	Avoids synthetic chemicals, relying on natural inputs, crop rotation, and biodiversity

No external inputs; relies purely on nature's cycle	Uses natural and organic inputs, like organic composts and natural pesticides
Soil fertility is maintained through natural processes like mulching and microbial activity	Soil fertility is enhanced using organic composts, manures, and green manuring
Pest management through beneficial insects and natural predators	Uses organic, non-synthetic pesticides and encourages beneficial insects for managing pests
Depends on natural processes and manual methods for weed control	Weed control through manual weeding, mulching, and sometimes natural herbicides
Seeds are typically untreated or fermented with natural solutions	Seeds can be soaked in organic solutions or used as-is if non-GMO
Low cultivation cost, as known for being low-cost, especially in "zero budget" approaches	Might involve some costs for organic inputs, certification, and labour
No standardized certification process worldwide	Strict certification processes, often regulated by national/international bodies
Can be less time-intensive due to fewer interventions	Might be more time-consuming due to specific organic practices and rotations
Adopts the philosophy of "Work in harmony with nature"	Emphasizes avoiding synthetic chemicals while actively managing farm health

Importance of Natural Farming

There is an urgent need to increase 60-70% food production to feed the estimated 10 billion strong population of 2050. At present, the focus is not just on increasing crop yields, but also on being environmentally conscious in the process. Climate change is considered a major threat to agricultural production affecting the crops' productivity and environment. After the COVID pandemic, health matters a lot, and the consumers too are more aware of what they eat, going back to the old remedies and natural methods. Hence, today's focus is on providing comprehensive sustainable solutions to the humankind through complementary farming practice namely natural farming, which gains popular in agriculture.

- Numerous studies have shown that natural farming is more productive, sustainable, water-efficient, and better for the ecology of farms and the soil. It is regarded as a profitable agricultural method with the potential to boost employment and rural development (Devarinti,2016; Tiwari & Raj, 2020)

- Natural farming seeks to address food hunger,farmer distress, health issues brought on by pesticide and fertilizer residue in food and water, global warming, climate change, and natural disasters. Additionally, it may provide jobs, which would stop young people from rural areas from moving. As the name implies, natural farming is the art, practice, and science of working with nature to accomplish much more with less.

In addition, the following facts also endorse the importance of natural farming and its practice in India:

- **Ecological balance:** With increasing concerns about environmental degradation, natural farming is essential to maintain and restore ecological balance by prioritizing biodiversity and healthy ecosystems.
- **Sustainable agriculture:** For agriculture to be sustainable in the long run, we need farming practices that don't deplete the earth's resources. Natural farming emphasizes such regenerative practices.
- **Health implications:** The rising health issues associated with chemical residues in food highlight the importance of natural farming practices that ensure food safety and nutrition.
- **Resilience in changing climate:** With the unpredictability brought about by climate change, natural farming builds resilience in crops and soil due to its inherent biodiversity and holistic approach.
- **Cultural and traditional preservation:** Natural farming often integrates indigenous knowledge and practices, ensuring the preservation and continuation of invaluable traditional wisdom.

Scope of Natural Farming

Natural farming, with its emphasis on sustainable and eco-friendly practices, holds significant promise for the future of agriculture and its role in a balanced ecosystem. The scope of natural farming extends far beyond just the fields, offering numerous advantages across various dimensions.

1. Environmental scope

Soil health: Natural farming techniques improve the soil health through enhancing the organic matter in soil, promoting microbial activity and improving soil structure.

Biodiversity: By avoiding monocultures and chemicals, natural farming supports a diverse range of flora and fauna, thus maintaining a diversified agro-ecosystem.

Water conservation: With practices like mulching and no-till farming, there's a significant reduction in water evaporation, promoting efficient water use.

Reduced pollution: Non-addition of synthetic chemicals in natural farming helps in maintaining the purity of water bodies including groundwater without pollution

2. Economic scope

Cost efficiency: Natural farming often requires very fewer external inputs, thus reducing the production costs towards fertilizers, pesticides, other chemicals and machinery.

Premium pricing: Produce cultivated through natural farming can often fetch higher prices in niche markets and among health-conscious consumers.

Resilience: With diverse cropping and natural resilience building, natural farming can better handle market fluctuations and crop failures.

3. Health scope

Nutrient rich produce: Crops grown in naturally nourished soil often possess a richer nutrient profile.

Reduced chemical residues: The avoidance of synthetic chemicals means lesser residues on food, approaching towards safer consumption.

4. Social Scope

Empowered communities: As natural farming leans on traditional knowledge, it empowers local communities and encourages collaborative efforts.

Connection with nature: Natural farming promotes a deepened connection between farmers, consumers, and the earth, fostering respect for the environment.

5. Innovation and research scope

New techniques: As the demand for natural farming grows, there is increasing research on refining techniques, discovering new practices, and integrating traditional knowledge with the modern science.

Technological aids: Modern technologies of digital agriculture can be employed to support natural farming, right from apps that aid in pest identification to tools that help monitor soil/crop health and quality.

6. Global scope

Climate change mitigation: With its potential for carbon sequestration, natural farming can play a role in global efforts to combat climate change.

Sustainable Development Goals: Natural farming aligns well with several United Nations Sustainable Development Goals, including good health and wellbeing, responsible consumption and production, climate action, life on land, and clean water and sanitation.

Current scenario of Natural Farming in India

Natural farming is gaining popularity in India.As of 2023, it is estimated that about 4.09 lakh hectares of land in India (Figure 2) are under natural farming and total fund of Rs. 4587.17 lakh has been released in 8 States across the country including the State of Tamil Nadu.

The leading states in terms of area under natural farming through the scheme BPKP:

- Andhra Pradesh (1.00 lakh hectares)
- Madhya Pradesh (0.99 lakh hectares)
- Chhattisgarh (0.85 lakh hectares)
- Kerala (0.84 lakh hectares)
- Odisha (0.24 lakh hectares)
- Himachal Pradesh (0.12 lakh hectares)
- Jharkhand (0.034 lakh hectares)
- Tamil Nadu (0.02 lakh hectares)

Among the various models of natural farming, the zero-budget natural farming (ZBNF)and Andhra Pradesh Community based Natural Farming (APCNF) models are widely used in India. As per the report of Niti Aayog, India can double the acreage of chemical-free farming to 15% immediately and grow it to 30% by 2030. The report says that this practice would not hurt national food security as the resultant loss in output and exports would be compensated by the reduction in fertiliser subsidies.

The National Institute of Agricultural Extension Management (MANAGE), Hyderabad is the Nodal agency for promotion of natural farming in the country. The agency creates a large pool of natural farming experts through conduct of several capacity building programmes to the officials from different Central and State level institutes/ Departments of agriculture, SAUs, private sector organisations and also through various awareness campaigns to the farmers across the country. The Government of India has also launched a National Mission on Natural Farming (NMNF) during 2023 with the aim of motivating farmers to adopt chemical free farming and to enhance the reach of natural farming in the country to cover 10 million hectares of land under natural farming by the year 2025.

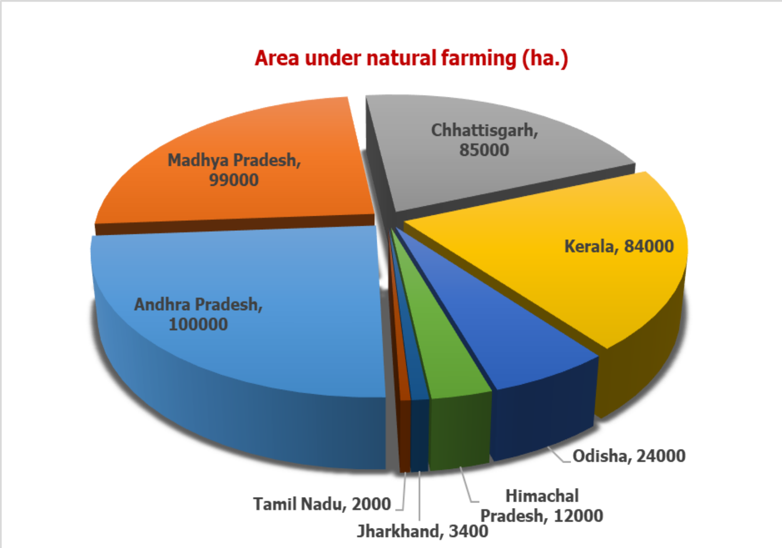

Figure 2. State-wise area under natural farming, (Source: NITI Aayog)

Benefits of Natural Farming

Yield Improvement

Natural farming increases crop yields by taking maximum use of available labour, soil and equipment. It keeps away the need for chemical inputs like fertilizers, herbicides and pesticides.

Healthy Soil

Various natural inoculants in natural farming lead to the fast build-up of soil microbiota and soil aeration. Jeevamrit helps to improve organic matter and stimulate microbial activity in the soil. Beejamrit treats the seed and alleviates in shielding seedlings from soil-borne diseases and young roots from the fungus. Mulching improves humus formation through enhanced decomposition activity in the soil.

Conservation

Agricultural activities produce the largest share of global methane and nitrous oxide emissions. The use of fertilizers in conventional farming is a major contributor to global greenhouse gas emissions. Natural farming works on an agro-ecology framework and does not rely on chemical fertilizers and pesticides at all thus conserves the environment from harmful and toxic gases.

Resiliency Enhancement

Climate change can be felt throughout the world in the form of droughts, heat waves, and flooding. Crops grown under natural farming have shown greater resilience in the face of these conditions. This is mainly due to the enhanced soil and plant diversity. A report by CEEW ("Zero Budget Natural Farming for the Sustainable Development Goals Andhra Pradesh, India") showed that paddy crops withstood the winds and water-logging brought on by the cyclonic winds at Vishakhapatnam in the year 2017. The crops cultivated through natural farming also weathered the Pethai and Titli cyclones of 2018 in much better condition than conventionally cultivated crops.

Reduction of Water Consumption

70% of the total accessible freshwater in the world is used for agricultural purposes. In India, groundwater is used for irrigating 60% of the total irrigated area. The natural farming is popular for minimal water consumption and has been shown to improve the water retention capacity of the soil too. This ultimately impacts groundwater reserves.

Native livestock sustainability

Cow dung and urine are used extensively to create the natural fertilizers (Jeevamrit and Beejamrit), herbicides, and pesticides required in natural farming. Most farmers who take up natural farming rely on manure and urine from indigenous cows rather than crossbred cows, bullocks, and buffaloes. The growing trend can revive the livestock sector in India

Hike of farmer's income

Natural farming reduces the cost of farming towards the purchase of chemical farm inputs or irrigation. Farmers prepare concoctions of essential plant fertilizers and pesticides with easily available local materials. Irrigation costs are cut down with natural farming. The practice of *Whapasa* and mulching in natural farming helps to increase the humus content in soil, thus increasing the soil aeration and inturn the soil moisture retention benefitting the crops growth without any stress. All these ultimately contribute to more profits.

Farmer's health Improvement

In conventional farming, the use of pesticides and fertilizers can be toxic not just to the crops, but to the person applying it too. Farmers exposed to high levels of chemicals increase the occurrence of non-communicable diseases like chronic neurotoxicity, respiratory illnesses, and even cancer. Natural farming replaces the chemical inputs with natural ones that do not harm the health of the farmer or the community in any way.

Conclusion

Natural farming is an agricultural revolution that will not only improve crop yields at minimum costs but will also help to increase farmers' incomes. With the pace at which soil degradation is happening globally, only 30 years of the harvest will remain for consumption. In order to save the world from a food crisis in the future, natural farming is considered to be an ideal solution. It is believed that the Government of India's long-term vision on sustainable agriculture with doubling the farmers' income could be achieved through the natural farming practice. Also, it is viewed that it is the right time to bring about this transition from chemical farming to natural farming by creation of vast awareness among the farming community through several schemes and capacity building programmes.

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FOURS PILLARS OF NATURAL FARMING

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Introduction

Green revolution has made the country self sufficient in food production. Even it made us to export food grains to other countries. But it made the soil hungry as the depleted nutrients are not replenished in full. Moreover, unmindful and imbalanced application of inorganic chemicals as fertilizer and pesticide made more harm rather than the chemicals itself. The latest high yielding and hybrid crop varieties are more responsive to the application of concentrated nutrients and hence the application of inorganic fertilizers becomes compulsory. These fertilizers can supply only few nutrients which are required in macro quantity but we failed to apply the secondary and micro nutrients which are required in lesser and smaller quantity but are also essential for crop production. Application of organics taken care of these secondary and micro nutrients which was not taken care in the intensive agriculture. As a result, the soil system becomes unhealthy and uncapable of producing the yield as it was and required now.

In this context the holistic approach of crop production through natural way become order of the day to restore and sustain the soil health and crop production. "Natural farming is a chemical-free traditional farming method. It is considered as an agroecology based diversified farming system which integrates crops, trees and livestock with functional biodiversity". Natural farming adopts the neo-Gandhian values of self-reliance, autonomy and promotes growing crops in harmony with nature. The principle is collaborating with natural forces rather than opposing them. The ultimate goal is to foster agricultural systems that are both sustainable and in equilibrium with nature.

The uniqueness of Natural Farming:

1) An approach towards sustainability;
2) Expense-free farming;
3) Farming with minimum electricity and water consumption;
4) Producing quality and poison free food stuff;
5) Reducing external labour requirement;
6) Techniques of multi cultivation for higher net income under bio-entrepreneurship.

Principles of Natural Farming

- No external inputs

- Minimal disturbance of soil
- Use indigenous seed
- Mixed cropping
- Integration of trees into the farm
- Soil and moisture conservation
- Integration of animals in to farming
- Increasing organic residues on the soil
- Pest-management through botanical extracts
- No synthetic fertilizers, pesticides, herbicides & GMO

The main aim is to increase the steady build-up of organic matter in a natural way as if in forest eco system. The main moto is "Once the soil health is taken care it will take care of all the life on the earth".

Four main pillars of zero budget Natural Farming

In natural farming it is expected that the nutrient required for the plant growth is available in the soil. If we allow the microbial cycles to operate as in natural ecosystem it will take care of the nutrient requirement of plants. The only thing the farmer is expected to do is to add as much quantity of organic matter, that too from the same farm land, back to soil. Even composting need not be attempted by the farmers. On the soil surface the organic matter has to decompose gradually over a period of time. For the successful natural farming there are four main components (pillars) are proposed and are as follows.

1) Bijamrita / beejamrutha for seed treatment
2) Jivamrita / jeevamrutha to supply of nutrient to plants through enhanced microbial activity
3) Acchadana - mulching - crop residue management for weeds, nutrients and water
4) Whapasa - soil aeration and moisture conservation

1. Bijamrita/beejamrutha

Beejamrutha is for treating the seeds and protecting from the soil borne pathogens and to give an initial thrust to the plants to grow faster and healthier. By soaking the seeds in Beejamrutha, it gives a protection to the seeds or act as a defence mechanism against seed-related diseases, leading to improved germination rates.

Beejamrutha is a proportionate mixer of water, cow dung, cow urine, lime, and forest soil. In the content of Beejamrutha the action of local cow dung is a potent natural fungicide, cow urine is having robust antibacterial properties and soil give the required microbial load.

Application of Beejamrutha:

- Coat the crop seeds by hand-mixing with Beejamrutha.
- Shade dry the seeds before sowing.

- For pulse crops, a quick dip in Beejamrutha followed by shade drying is enough
- For medicinal or ornamental propagating materials, dip the vegetative parts in Beejamrutha before planting.
- Grafts for fruit crops should be dipped in beejamrutha before planting.

Research indicates that beejamrutha enriched with beneficial microorganisms offers protection against harmful soil-borne pathogens. It also shields young seedling roots from fungal infections and common soil and seed borne diseases. Moreover, beejamrutha has been found to generate auxins (IAA) and gibberellins (GA3) promoting plant growth.

Preparation

The composition includes 20 liters of water, 5 kg of cow dung, 5 liters of cow urine, 50 g of lime, and a handful of soil.

1. In a plastic or cement tank, mix all the ingredients. Stir the mixture with a wooden stick, rotating it clockwise to infuse positive energy.
2. Cover the tank with a jute sack or poly net, ensuring it's positioned in a shaded area, shielded from direct sunlight and rain.
3. After a day, the beejamrutha will be ready for seed treatment.

Preparation Time: 12-24 hours

Storage: Use the beejamrutha for seed disinfection. It can be stored for up to 7 days.

Research findings on beejamrutha

Presence of naturally occurring beneficial microorganisms predominantly bacteria, yeast, actinomycetes, photosynthetic bacteria and certain fungi were detected in cowdung (Swaminathan, 2005) which is one component of beejamrutha.

Table 1. Nutrient status of beejamrutha

S. No.	Parameter	Content
1	pH	8.2
2	EC (Soluble salt)	5.5 dSm-1
3	Total Nitrogen	40 ppm
4	Total Phosphorus	155.3 ppm
5	Total Potassium	252.0 ppm
6	Total Zinc	2.96 ppm
7	Total Copper	0.52 ppm

8	Total Iron	15.35 ppm
9	Total Manganese	3.32 ppm

Srinivasa *et al*. (2009) stated that beejamrutha contains not only general microflora, but also certain beneficial biochemical groups such as free living N_2 -fixers, P- solubilizers and bacteria producing plant growth promoting substances as well as bacteria having biological deterrent activities. Presence of such beneficial microbial biomass and nutrient status will result in improved seed germination, seedling length and seed vigour as an efficient plant growth stimulant.

2. Jivamrita/Jeevamrutha

The soil contains nutrients, but they are inaccessible to plant roots. Jeevamrut, an organic fertilizer, contains beneficial microorganisms that convert these nutrients to a usable form when added to the soil. It can be sprayed or added to irrigation every 10-15 days until the soil improves.

Jeevamrutha is an organic alternative to chemical fertilizers, rich in nutrients like carbon, nitrogen, phosphorus, and calcium. It boosts soil microorganisms, enhancing soil fertility and crop yield. It's made from cow dung and urine, promoting nutrient availability and microbial activity. This leads to more earthworms and fertile soil.

Jeevamrutha is a bio-fertilizer that enhances plant growth by stimulating soil microbes and earthworms. It includes important microorganisms like rhizobacteria, cyanobacteria, mycorrhizal fungi, and nitrogen-fixing bacteria. This product catalyzes nutrient conversion and helps fight plant diseases.

Subash Palekar recommends Jeevamrutha for nutrient conversion in plant roots. It contains PGPR, cyanobacteria, Solubilizing Bacteria (PSB), mycorrhizal fungi, and Nitrogen-fixing bacteria, aiding nutrient absorption and disease control. It's effective for the first 3 years, after which the system stabilizes.

Soil microorganisms actively impact fertility by cycling nutrients like carbon and nitrogen essential for plant growth. Jeevamrutha is a fermented culture that not only provides nutrients but also stimulates microbial activity and earthworms. It's beneficial against fungal and bacterial diseases. According to Palekar, it's necessary for the initial 3 years of transition to a self-sustaining system.

Types of jeevamrutham

1) The liquid state of Jeevamrutham.

2) The semi-solid state of Jeevamrutham.

3) Dry Jeevamrutham (Ghana jeevamrutham).

Method and application of liquid jeevamrutham

Preparation: To make jeevamrutha, follow these steps: Fill a barrel with 200 liters of water. Add 10 kg of fresh local cow dung and 5 to 10 liters of aged cow urine. Include 2 kg of natural jaggery, 2 kg of pulse flour, and a handful of soil from the farm's bund. Mix the solution thoroughly and let it ferment for 48 hours in the shade. Now, your jeevamrutha is ready to be applied. For one acre of land, 200 litres of jeevamrutha is sufficient. Apply it to the crops twice a month either through irrigation water or as a 10% foliar spray. This process should continue every 15 days until the soil is enriched. During the 48-hour fermentation process, aerobic and anaerobic bacteria in the cow dung and urine multiply as they consume organic ingredients, including pulse flour. Adding a handful of undisturbed soil serves as an inoculate of native microbes and organisms to the mixture.

Precautions to be taken: Avoid using brass or copper materials for the barrel. After fermentation, Jiwamrita should be applied within 15 days, but it's most effective when used between 7 to 12 days after fermentation.

Preparation of Jiwamrita (Ghan-Jiwamrita)

This method is suitable for regions with limited water availability in dryland or rainfed areas for Jiwamrita application.

- Gather 100 kg of local cow dung, 2 kg of jaggery, 2 kg of pulse flour, and a handful of soil from the bund.
- Thoroughly mix the ingredients, adding a small quantity of cow urine.
- Spread the mixture in a shaded area for drying.
- Once dried, manually sieve it to create a powdered form and store it in gunny bags. This powdered mixture remains viable for up to a year.

For application:

- During ploughing or prior to the final ploughing for every acre of land, spread 200 kg of Ghana-Jiwamrita evenly across the soil.

- During the last ploughing, ensure the soil covers it like a mulch. If applying during ploughing isn't feasible, use it as a basal application during sowing.

- For each acre, use 100 kg of Ghana-Jiwamrita for broadcasting.

Uses of Jeevamrutha

Jeevamruth enriches the soil with nutrients and increases the soil fertility. Soil application of Jeevamruth create favourable conditions for the availability of nutrients by increasing pH in acidic soils and decreasing the pH in alkaline soils and maximizing nutrient availability at pH 6.5 to 7.8 (Kulkarni S.S 2019).

Table 2. Different microbial populations present in Jeevamrutha

Organisms	Colony count (cfu/ml)
Bacteria	20.4×10^5
Fungi	13.8×10^3
Actinomycetes	3.6×10^3
Phosphate solubilizing organisms	4.5×10^2
Free living N_2-fixers	5.0×10^2

Source: (https://agritech.tnau.ac.in/org_farm/orgfarm_ofk_soil.html)

Jeevamruth showed increased growth and yield when applied as seed treatment, foliar spray and soil application also. To the tune of 5- 11% yield is increased when Jeevamruth is applied as seed treatment (Devakumar et al, 2008). Spray of Jeevamruth @200-500 liters/acre in fieldbean resulted in 15 to 40% of its yield(Anon, 2010). Jeevamruth with the combination of other liquid formulations such as Panchagavya has yielded good results in capsicum (Boraiah, 2013).

3. Acchadana/Mulching

Grain crops and healthy orchard trees thrive with a ground cover of vegetables, weeds, and white clover. Mulching with straw enhances soil moisture and encourages microorganisms and earthworms, fostering seed germination without tillage. There are three mulching types:

a. Soil mulch: Protects topsoil during cultivation, promoting aeration and water retention within the upper 4.5 to 6 inches (10-15 cm) layer. Avoid deep ploughing as recommended in Natural farming.

b. Straw mulch: Comprising dried biomass waste or any dead organic material, it contributes to soil fertility by decomposing through microbial activity.

c. Live mulch (Symbiotic Intercrops and Mixed Crops): Diverse cropping patterns supply essential elements to soil and crops. Legumes (dicots) fix nitrogen, while monocots like rice and wheat provide other nutrients.

Cover crops like legumes reduce weeds, enhance water infiltration, and fix atmospheric nitrogen for crops. Surface residues increase microbial degradation and nutrient release. It conserves soil moisture, improves seed germination, and regulates soil temperature.

Under natural farming, soil mulching, straw mulching, and live mulching offer numerous benefits:

- Reduces Tillage: Lessens the need for tilling.
- Enhances Biological Activity: Boosts soil biological processes.
- Replenishes Nutrients: Reinvigorates soil nutrient content.

- Retains Moisture: Prevents water loss from evaporation.
- Controls Evaporation: Manages water evaporation.
- Improves Water Holding Capacity: Increases soil's water retention capacity.

4. Whapasa/Moisture

Waaphasa refers to a soil condition with a balanced mixture of 50% air and 50% water vapour between soil particles. This state reduces irrigation needs and is a foundational concept of natural farming. In the "Whapasa" approach, where both air and water molecules are present in the soil, water application is reduced, primarily irrigating at noon in alternate furrows. This technique enhances water use efficiency and has led to decreased irrigation demands among the natural farming farmers.

In natural farming, water conservation and precise water application based on crop requirements are paramount. By focusing on irrigation during noon in alternate furrows, the goal is to maintain a balance of air and water molecules in the soil. This practice capitalizes on the fact that younger, more active roots absorb water and nutrients more effectively.

It's crucial to strike a balance, as excessive water can limit soil aeration and lead to oxygen deficiency, potentially harming plants. Soil aeration is vital for plant growth, so longer intervals between water applications are advisable. Overall, Whapasa aims to optimize water use and foster healthier plant growth while conserving water resources.

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NUTRIENTS MANAGEMENT AND INPUTS FOR SOIL HEALTH ENHANCEMENT UNDER NATURAL FARMING

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1. Introduction

The soil health is pivotal for sustainable and regenerative agriculture namely natural farming. It emerges as a holistic approach that encourages diverse plant communities and microorganisms enhances soil structure, nutrient cycling, and water retention etc through the application of various soil health based inputs. It boosts farmers' income while restoring soil fertility, aiding to reduce greenhouse gases and provide ecosystem services. Hence, the soil health management through natural farming emerges as a unifying solution.

Soil health most often refers to *the* ***"ability of the soil to sustain agricultural productivity and protect environmental resources"*.** A healthy soil provides many functions that support plant growth, including nutrient cycling, protect the soil from erosion, biological control of plant pests, and enhances water holding capacity and drainage. These functions are influenced by the interrelated physical, chemical, and biological properties of soil, many of which are sensitive to soil management practices.

Soil Health and natural farming:

The soil health in NF is taken care by all the four wheels of natural farming *viz.,* Whapasa, mulching, jeevamirt and beejamirt as they helps to enriching the soil physical, chemical and biological properties through retaining moisture, reducing soil loss, harboring and expanding the wide range of microbes. These microbes aids in cycling of nutrients in soil. Specifically the application of cow dung and cow urine based concoctions helps to ensure the soil fertility and productivity.

2. Principles of soil health management in natural farming:

The soil health management is the key factor for getting higher yield and the principles of organic farming could be very well adopted to NF provided no input is from the outside of farm and indigenous to the location or site or area. The following are the five fundamental principles for effective management practices aimed at preserving and enhancing soil health and nutrients availability.

i) Soil shielding

- Keeping soil surface covered year around with the help of live crops and crop residues of own farm.
- Serves multiple purposes including preventing soil erosion, suppressing weed growth, and stabilizing soil temperatures, reducing compaction, and providing a better environment for soil organisms to thrive.

ii) Less disturbance

- Reducing the mechanical disturbance (e.g., tillage), chemical disturbance (e.g., pesticide application), and biological disturbance (e.g., overgrazing) to soil.
- Conservation tillage, IPM, and rotational animal grazing are effective management practices- minimize soil disturbance, reduce erosion, & enhance biodiversity

iii) Diverse/Multiple crops

- Growing diverse and mixture of crops on the same land helps to sustaining a balanced and functional soil food web beside control the occurrence of diseases and pests.

iv) Continual live plant/root

- Keeping a living root growing throughout the year for increasing soil biodiversity, achieving high microbial activity, and controlling soil erosion

v) Livestock Integration

- Including animal grazing in cover crop, crop residue, and weed management.
- Effective for improving animal well-being, reducing herbicide uses, promoting nutrient cycling, and decreasing crop land nutrient export.

3. Soil Health Enhancement and Inputs

It becomes imperative to adopt effective soil health management practices in order to preserve and improve the nutrients availability and uptake by the crops in natural farming. This could be achieved by increasing and maintaining the soil organic carbon and or matter in soil at higher level. For enhancing the soil health and nutrients supply in natural farming, the following, techniques and inputs needs to adopt.

i). Cover crops for enhancing organic matter and nutrients availability

Cover crops are essential and important part of soil fertility and health management in natural and organic farming. Cover crops are any crops that are cultivated together with or after the primary crop and is often removed prior to planting the subsequent crop. A cover crop can function as a green manure when it is ploughed under and incorporated into the soil while still green or at maturity.

Benefits of cover crops

- ✓ Provides ground cover and serve as green manure
- ✓ It increase plant residues retained on the soil surface, minimize soil disturbance and erosion, reduce the risk of erosion
- ✓ Enhances organic matter levels in soil returning their biomass
- ✓ Leguminous cover crops fix and enrich soil with nitrogen
- ✓ Organic acids of their decomposition facilitates cycling and mineralization of nutrients in soil
- ✓ Improve soil structure and water-stable aggregates
- ✓ Cover crops with taproots can create macro-pores and alleviate soil compaction
- ✓ Provide forage for livestock
- ✓ Support pollinators and beneficial insects
- ✓ Retain nitrate and other nutrients that are susceptible to leaching losses and hence reduce water and air pollution
- ✓ Help to control various pests and weeds by acting as live mulch
- ✓ Diverse cover crop maximize water and nutrient use efficiencies of crop production systems
- ✓ Enhance net ecosystem productivity and longer-term carbon (C) sequestration.

Suitability of cover crops

- ➢ Taproot crops - create macro pores and alleviate compaction.
- ➢ Fibrous-rooted -promote aggregation and stabilize the soil.
- ➢ Species of cover crops that host mycorrhizal fungi can sustain and increase their population
- ➢ Legume cover crops - add nitrogen

Cover crops type and key benefits to soil

Types	Suitable crops	Benefits
Non Leguminous	Brassicas, rooted vegetables like beet root, radish, turnip etc	Controls soil erosion, add organic matter to soil, improves soil structure, Breaks sub soil compaction
Leguminous	Cowpea, sun hemp, Sesbania, horse gram, Bengal gram, cluster bean, etc	Source of nitrogen fixation, add organic matter to soil, improves soil structure, cycles the nutrients

Allelopathic cover crops	Mustard, brassicas, wheat, rye, sorghum, radishes etc	Increase soil organic matter, enhance soil microbes, weed suppression, reduce soil erosion
Mixed / multi species cover crops	In addition to all above crops, the crops like coriander, peas, bean etc	Grass cover crops- prevent erosion and nutrient loss; Legumes- supply N to a subsequent crop. Brassicas, which include turnips, radish, and mustards, are fast-growing, scavenge nitrogen and supply fodder to livestock; Flowering –benefits the pollinators and add organic matter

Multi species cover crops and soil health

Growing single or double species of plants as cover crops, the benefits to soil, crop and ecosystem is limited. Hence in recent decade, growing multispecies cover crops specifically during the period between two primary crops is recommended to have multiple benefits in organic and natural farming. They helps to meet all the above said benefits and the plant species belongs to wide range of groups differ in the rooting pattern, biomass production, allopathic effect, nitrogen fixation etc can used as multi-species cover crops.

Crop mixture for cover crops

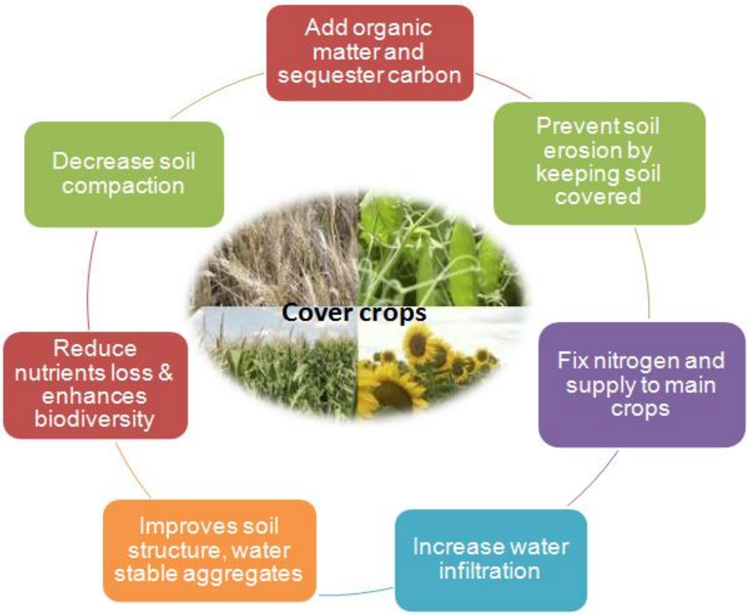
Cereals	Sorghum, Pearl millet, Finger millet
Pulses	Black gram, green gram, cowpea
Oilseeds	Groundnut, Sesame, sunflower, castor
Spices	Coriander, Cumin, anise, Mustard
Green manures	Dhaincha, Sun hemp, naripairu, horse gram

Growing multi species cover crops

The seeds of above crops are to be selected and mixed in different proportion (2.5 kg from each group) based on their growth habit and seasonal requirement. Mixed seeds are to be sown in the ploughed field. These plants are allowed to grow till the maximum biomass developed. Then cut the whole biomass during flowering of any one species or at full vegetative growth and incorporate into the same field. Leave the field for 15 days to get proper decomposition. This could be repeated two to three times to improve the soil fertility and health. After the incorporation of first set of cover crops, 2nd sowing with same mix of seeds must be taken within 2 weeks and allowed to grow for 45 days and incorporated. 3rd frequency is to be taken but should be incorporated within 30 days. This continuous frequency for three times enriches the soil nutrients and improves the health.

Advantages

More diverse crop species as cover crops have better soil quality and nutrients supply. Growing multiple species with different rooting pattern has ability to mobilize and lift the nutrients from sub surface to surface and helps the ensuing crops.



ii). Reduced or zero tillage

Conventional tillage practices breaks down soil aggregates and produces a bare soil that is vulnerable to erosion and more subject to temperature changes than soils. This also enables the soil organisms to break down soil organic matter rapidly which further increases when tillage breaks soil aggregates into smaller pieces, increasing their surface area and exposure to oxygen. Whereas the adoption of zero or minimum tillage practices keeps the soil always covered, disturbing little by growing of different kind of species together. This helps to preserve soil organic matter, enhancing soil structure markedly by improving aggregation, curtailing soil erosion, and reducing greenhouse gas emissions and less disturbances to soil organisms and often their diversity (Babu *et al.,* 2023).

ii). Non invasive tillage as a remedy for soil compaction

Excessive tillage causes soil compaction and related changes in soil physical-chemical properties viz., poor infiltration, poor soil structure, increased bulk density, reduced porosity etc. Hence adoption of non inversion tillage is highly needed in natural farming. This cause less soil disturbance and less direct mortality to beneficial soil organisms which intern offset the organic matter decomposition and nutrients availability. Integrating several years of a perennial forage crop into a rotation with annual crops is one way to reduce tillage intensity over time in natural farming

Benefits of reduced tillage practices to soil health

Tillage types	Advantages & disadvantages
No-tillage	• Soil undisturbed; reduced erosion, increases water infiltration • Retains crop residues on soil surface • Requires more N
Strip tillage	• tillage done in the rows at planting • minimizes soil moisture loss, preserves crop residue on the soil surface
Ridge tillage	• tillage to form raised ridges or beds in rows • reduces soil erosion and increase water infiltration

iii). Crop Rotation and Intercropping

Crop rotation entails the sequential cultivation of two or more crops on the same plot within a farmland, aimed at optimizing nutrient management and ameliorating soil health. Integral to successful crop rotation is the stipulation that succeeding crops belong to distinct species or sub-species relative to the preceding crop. The incorporation of legumes after cereals or wheat exemplifies this principle (Shah *et al.*, 2021). The capacity of pulses to fix atmospheric nitrogen within root system contributes to their self-reliant fulfilment of nitrogen requirements. Whereas the monocropping trends exhaust soil health and curtail yields. Leguminous crops not only transfers nitrogen to non leguminous plants, but also mobilizes organic P and insoluble P in soil by secreting phosphatases, or exudation of carboxylates or protons and also through mycorrhizal network (Li *et al.*, 2014; Homulle *et al.*, 2020). Also they help for hydraulic lift and transfer of water to component crops which intern mobilizes immobile elements. Over all soil fertility and health was improved by the intercropping with leguminous and non-leguminous species.

iv). Maximizing living roots Incorporating a living root year-round change the soil biology and structure. Plants feed carbon to soil microbes, enhancing nutrient cycling at the root surface. This can be achieved through planting cover crops, reducing fallow and using diverse crop rotations.

Keeping living roots in the soil - feed the soil-feed the plants - feed soil life!.

Benefits of maintaining year around living roots

Soil with living roots	Without living roots
Good soil structure Increased porosity, Low bulk density & increased water holding capacity	Soil compaction decreased porosity, High bulk density & Decreased water holding capacity

v). Addition of organic sources of nutrients

Plant and animal based organic sources serve as crucial input for soil health management and nutrients cycling in natural farming. They yield multifaceted benefits, encompassing improved soil structure, nutrient availability, water retention, microbial activity, and overall soil fertility.

Manures and Compost

Animal-derived manure and compost are valuable sources of organic matter and nutrients. These materials not only enrich the soil's nutrient content but also enhance its water-holding capacity and aggregate formation by adding organic matter. Moreover, the fostering of microbial activity contributes to nutrient cycling and soil organic matter decomposition. The only point to remember is the manures and compost must be of on farm in nature and should not be outsourced.

NPK Content of different animal manures

Organic Manures	N (%)	P (%)	K (%)
Cow Manure	0.5 - 0.7	0.2 - 0.4	0.5 - 0.6
Poultry Manure	2.0 - 2.5	1.0 - 1.5	1.0 - 1.5
Buffalo manure	1.23	0.55	0.69
Goat Manure	0.7 - 1.0	0.3 - 0.5	0.5 - 0.8
Horse Manure	0.4 - 0.7	0.2 - 0.4	0.5 - 0.7
Sheep Manure	0.7 - 1.0	0.3 - 0.5	0.7 - 1.0
Farmyard Manure	0.5 - 1.0	0.2 - 0.5	0.5 - 1.0

Crop residues and green manures

Incorporating plant-based manures such as crop residues and green manures, into the soil imparts organic matter and nutrients, thereby enhancing the soil fertility. Green manures, comprising cover crops facilitate nitrogen fixation and nutrients assimilation besides enhancing the soil biological fertility.

NPK Content of crop residues and green manures

Organic Material	N (%)	P (%)	K (%)
Crop Residues			
Rice Straw	0.4 - 0.7	0.1 - 0.3	0.6 - 1.0
Wheat Straw	0.5 - 0.8	0.1 - 0.4	0.5 - 0.8
Maize Stalks	0.5 - 0.9	0.2 - 0.4	0.6 - 1.0
Sugarcane Residues	0.3 - 0.6	0.1 - 0.3	0.4 - 0.7
Green Manures			
Dhaincha (Sesbania)	2.5 - 3.5	0.2 - 0.4	1.0 - 1.5
Sun Hemp	2.0 - 3.0	0.2 - 0.5	1.0 - 1.5
Cowpea	2.0 - 3.0	0.2 - 0.5	1.0 - 1.5
Green Gram	2.0 - 2.5	0.2 - 0.4	1.0 - 1.5
Mustard	2.0 - 2.5	0.3 - 0.5	1.0 - 1.5

Concoctions as special manures

Application of cow based on farm preparations is an excellent source for sustaining soil health and nutrients cycling in natural farming. Wide range of concoctions recommended or in practice for NF are jeevamirt, ghanajeevamirt etc. They have to be prepared in the farm itself (Samlash et al., 2022; Kumar et al., 2023) and applied at fort night interval which facilitates nutrients cycling and increase microbial diversity (Barakzai et al., 2021) in soil. The average nutrients content of concoctions (Choudhary *et al.*, 2022) are given below.

Concoctions	N (%)	P (%)	K (%)
Beejamirt	0.72-2.38	0.12-0.14	0.23-0.49
Jeevamirt	0.25-1.40	0.13-0.42	0.26-0.31
Ghanjeevamirt	1.05-1.80	0.16-0.30	0.68-0.85

Saharan et al. (2023) found that the continuous application of jeevamirt for three consecutive years from 2017-2019 increase has increased the organic carbon, available P, and available K up to 46%, 439%, and 142%, respectively, while micronutrients, such as Zn, Fe, Cu, and Mn, increased up to 98%, 23%, 62%, and 55%, respectively. Also through whole genome metagenomic analysis that the bacterial phyla including Bacillus, Pseudomonas, Rhizobium, and Panibacillus etc were presented in the jeevamirt treated soils.

4. Nutrients cycling and biological Fertility in Natural Farming:

Organic carbon and nitrogen: Nitrogen is often a limiting nutrient and soil organic matter is a key source of nitrogen, achieved by building and maintaining healthy levels of organic matter. Growing leguminous cover crops fix atmospheric nitrogen and enhance soil N fertility. Manure, both raw and composted, contributes nitrogen to the soil. For efficient cycling of nutrients, the crop residues and cover crops must be incorporated to top soil (1 inch) only.

Phosphorus: Soil organic matter contains organic phosphorus compounds that are gradually mineralized into inorganic phosphates through microbial activity. Green manure crops upon decomposition release organic acids which solubilise the organic and inorganic phosphorus pools, aiding its availability. Manure and compost also provide accessible forms of P by slow mineralization.

Potassium: Potassium is vital for plant growth and soil organic matter doesn't contain potassium in large quantities, unlike nitrogen and phosphorus. Green manure, cover crops and compost are effective K sources. Beside the ash available if in the farm could be applied to soil to meet K requirement.

Secondary and micronutrients: Secondary and micronutrients like Mg, S, iron, manganese, and zinc etc are essential for plant health. Organic sources of these micronutrients are managed through diverse inputs such as compost, manure etc. A balanced soil with good organic matter content helps to prevent micronutrient deficiencies.

Natural farming practices promotes diverse ecosystems, enhances soil structure, nutrient cycling, and water retention. It also tackles chemical pollution through reduced external inputs and natural pest control. It offers hope for reviving waste lands, restoring ecosystems, and ensuring food security through a symbiotic partnership with nature. Best on farm practices for sustaining soil health under natural farming is growing leguminous cover crops, adoption of crop rotations and mixed cropping, application of cow dung and cow urine based concoctions not only improves biological fertility of the soil but also cycles the nutrients within the ecosystem by investing less cost and more harmony with nature.

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CROP RESIDUE AND WEED MANAGEMENT UNDER NATURAL FARMING

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Crop Residues

Waste materials derived from various agricultural operations are defined as agricultural wastes. The harvest waste, which is more popularly termed as crop residue can contain both the field residues that are left in an agricultural field or orchard after the crop has been harvested and the process residues that are left after the crop is processed into a usable resource. Stalks and stubble (stems), leaves, and seed pods are some common examples for field residues. Sugarcane bagasse and molasses are some good examples for process residue.

According to the Indian Ministry of New and Renewable Energy (MNRE), India generates on an average 500 Million tons (Mt here after) of crop residue per year. The same report shows that a majority of this crop residue is in fact used as fodder, fuel for other domestic and industrial purposes. However, there is still a surplus of 140 Mt out of which 92 Mt is burned each year. The following table compares the agricultural waste generated by selected Asian countries in Mt/year. It is also interesting to note that the portion burnt as agricultural waste in India, in volume is much larger than the entire production of agricultural waste in other countries in the region.

Table 1. Agricultural waste generation in India compared to other select nations in the same region

Country	Agricultural Waste Generated (million tons/year)
India	500
Bangladesh	72
Indonesia	55
Myanmar	19

Table 2 . Crop Production Estimate of Major Crops in India

Crop	Estimate of Production (Mt)
Rice	105
Wheat	94
Sugarcane	361

Crop	Estimate of Production (Mt)
Oil seeds	30
Cotton	35
Jute	11
Pulses	17

Table 3.Nutrient potential of crop residue for the top ten Crop Residue producing crops in the world

Crops	Area (million ha)	Production million tonnes 2020	Crop residue production in million tons 2020	Nutrient content in crop residue				
				N %	P2O5 %	K2O%	Total NPK %	Total NPK potential in million tonns
Maize	201.98	1162.35	1162.35	0.52	0.18	1.35	2.05	23.83
Wheat	219.01	760.93	1141.39	0.48	0.16	1.18	1.82	20.77
Rice	164.19	756.74	1135.12	0.61	0.18	1.38	2.17	24.63
Sugarcane	26.47	1869.72	467.43	0.40	0.18	1.28	1.86	8.69
Soyabean	126.95	353.46	353.46	0.88	0.14	0.65	1.67	5.90
Barley	5.16	157.03	235.55	0.52	0.18	1.30	2.00	4.71
Seed cotton	31.84	83.11	124.67	0.40	0.10	0.66	1.16	1.45
Rapeseed	35.50	72.38	108.56	0.70	0.22	1.14	2.06	2.24
Potato tube	16.49	359.07	89.77	0.52	0.21	1.06	1.79	1.61
Sorghum	40.25	58.71	88.06	0.52	0.23	1.34	2.09	1.84
Total	867.84	5633.50	4906.36					95.67

Prasad *et al.*, 2020

Stubble management is one of many complex issues that farmers must contend with. Traditionally, grain growers have burnt stubble to manage weeds, diseases and reduce biomass to make sowing easier. This is no longer the preferred option. Numerous other methods can be used to manage stubble. Retaining stubble, rather than burning or cultivating, protects the soil from erosion. It also conserves soil moisture and organic matter to sustain crop production. This is particularly beneficial in dry areas or in dry seasons. Stubble influences many things including the passage of machinery, light penetration, soil temperature, herbicide interactions, frost severity, pests, weeds and diseases.

The quantity and utilization of crop residues exhibit considerable variation across different regions, contingent on factors such as cultivated crops, cropping intensity, and crop productivity. Notably, Uttar Pradesh leads in crop residue generation with 60 Mt, followed by Punjab with 51 Mt, and Maharashtra with 46 Mt. Among the diverse array of crops, cereals account for the highest residue generation (352 Mt), followed by fibers (66 Mt), oilseeds (29 Mt), pulses (13 Mt), and sugarcane (12 Mt). The cereal crops, encompassing rice, wheat, maize, and millets, contribute significantly (70%), with rice alone contributing 34% of the overall residue.

These crop residues serve as a valuable resource for enhancing soil quality within the context of natural farming. Incorporating crop residues into the soil yields benefits such as improved soil structure, enhanced water retention capacity, and increased nutrient availability. Additionally, crop residues can function as effective mulch, serving to suppress weed growth and conserve essential soil moisture.

Residue Recycling

Exploring methods of residue recycling, including decay on field surfaces and repurposing as mulches or composts, highlights their environmental and soil health benefits. Crop residue recycling presents itself through diverse avenues, including allowing residues to decay on the field surface or repurposing them as mulches and composts. These practices not only benefit the environment but also control weeds and enrich soil health.

Role of Crop Residues in the field

Crop residues contribute to soil quality enhancement by preventing erosion, improving structure, increasing organic content, and retaining soil moisture. Crop residues leftovers have a potent influence on soil quality in terms of Physical, chemical and biological properties. Crop Residue utilization is Crop residues contribution to soil enhancement and weed suppression.

Weed Management

Crop residues act as barriers hindering the penetration of light, thereby impeding weed seed germination and emergence. Their role in weed control finds application across diverse agricultural practices.

Conservation Agriculture and Soil Cover

Crop residues play a vital role in conservation agriculture by maintaining soil cover and influencing weed seed germination in no-till practices. Conservation agriculture hinges on minimal soil disturbance, crop rotation, and the maintenance of soil cover through residues.

Challenges and Questions

Certain aspects, such as the response of different weed species to residue-based control methods and the optimal residue quantity, warrant further investigation. Despite remarkable progress, certain aspects remain unexplored, including how different weed species respond to residue-based control and the optimal quantity required. These questions offer fertile ground for future research.

Environmental problems of Crop residue burning

Emission of greenhouse gases (GHGs), Increased levels of particulate matter (PM) Loss of biodiversity of agricultural lands and deterioration of soil fertility

Burning of 98.4 Mt of crop residue has resulted in emission of nearly 8.57 Mt of CO, 90.13 Mt of CO_2, 0.037 Mt of SO_x, 0.23 Mt of NO_x, 0.12 Mt of NH_3 and 1.46 Mt NMVOC, 0.65 Mt of NMHC, 1.21 Mt of PM, where CO_2 is 91.57% of the total emissions. Remaining 8.43% consisted of 66% CO, 2.2% NO, 5% NMHC and 11% NMVOC.

Lower erosion risk

Stubble provides ground cover, which protects soil from wind and water erosion by slowing wind speed at the soil surface and reducing runoff. To protect soil the stubble needs to be at least partially anchored. At least 70 per cent ground cover minimizes water erosion risk and at least 50 per cent ground cover minimizes wind erosion risk. Stubble height should be at least one-third of the width of crop rows. In general, the shelter provided by a barrier is approximately three times its height; 10 cm tall stubble will protect the adjacent 30 cm of topsoil.

Improve water use efficiency

Retaining crop stubble can improve soil moisture content by reducing evaporation and increasing rainfall infiltration rates. Saving more surface soil moisture after autumn rains helps farmers to sow crops on time. This maximises grain yield potential and water use efficiency.

Other benefits

Promotes nutrient recycling. It can contribute to a very gradual improvement in soil organic carbon and the soils' microbial biomass. Significantly lower fuel costs and less labour as a consequential benefit.

Stubble management

Effective management of heavy stubble can begin with cutting the stubble at harvest as short as possible, ideally to no more than the row width. Inter-row sowing allows stubble to be retained when crop rows are more than 22 centimeters wide. This helps to retain soil moisture and accelerate decomposition.

- **Baling of Straw after harvest.** In some years, this is profitable, especially when feed is in short supply
- **Composting**
- **Biochar production** (thermo-chemical conversion called the pyrolysis): It is a mix of carbon (C), hydrogen (H), oxygen (O), nitrogen (N), sulphur (S) and ash in different proportions. When amended to soil, highly porous nature of the biochar helps in improved water retention and increased soil surface area. It mainly interacts with the soil matrix, soil microbes, and plant roots. Biochar also helps in nutrient retention and sets off a wide range of biogeochemical processes. Many researchers have reported an increase in pH, increase in earthworm population and decreased fertilizer usage due application of biochar.

As soil cover (Mulching)

Mulches are generally organic in nature and used to cover the soil for many purposes. Maintains a more even soil temperature. It reflects the sun and keeps the soil cooler and helps prevent evaporation. Prevent the germination and growth of weeds. It prevents soil erosion. Increases the infiltration. Also improve the condition of the soil – physical, chemical and biological

There are two types of mulches. 1. Live mulches and 2. Dead mulches. Live mulches include the intercrops such as cowpea, horse gram etc., Dead mulches are any dried organic or inorganic materials used as soil cover for the benefits of soil and moisture conservation, weed suppression and soil quality improvement. Over a period of time the decomposition process will take place on the soil as recommended in natural farming practices and add humus to the soil.

Challenges in crop residue management

Stubble retention has many benefits but requires an integrated 'systems' approach to manage challenges including weed, pest and disease pressures. All aspects of the farming system need to be considered, including agronomy, grazing management and set-up of machinery and guidance systems. With very heavy stubble loads, the challenges become greater, including difficulty in sowing due to stubble physically impeding the operation or causing seeder blockages, mouse populations build up, snails, slugs and insect pests such as mandalotus weevil and European earwigs and management of stubble-borne diseases.

Weed management

Weeds have emerged as a prominent issue in global agriculture due to their adeptness at outcompeting crops for essential resources. This competitive edge has led to a significant impact on crop yield and quality, necessitating effective weed management strategies.

Concurrently, proper management of crop residues is imperative for maintaining soil health and fertility.

Within the realm of natural farming, effective weed management is an integral aspect of successful crop production. Weeds can hinder crop growth by competing for critical resources, including light, water, nutrients, and space. The unfortunate result is a decrease in both crop yield and quality. Notably, in India, the impact of weeds on agricultural output is substantial, contributing to approximately 33% of total yield losses attributed to pests. In contrast, insects and diseases account for 26% and 20%, respectively. This underscores the urgency of timely and strategic weed management to achieve optimal crop yield.

Weed management in natural farming

Physical methods: Weed control is achieved through physical means such as hand weeding, hoeing, and mulching.

Cultural approaches: Crop rotation, intercropping, and cover cropping are integral to weed management in natural farming.

Mulching techniques: Mulching," stands out as a highly favoured method for managing weed-related challenges in Natural Farming. This approach contributes to the reduction of weed issues by either completely preventing the germination of weed seeds or obstructing the growth of emerging seedlings. Additionally, mulching supports the sustainable management of water resources and promotes biodiversity. Mulching comes in various forms, encompassing both natural options like straw, sawdust, weeds, paper, and plant residues, as well as synthetic alternatives like plastic. For instance, materials such as black polyethylene have found use in weed control across diverse agricultural production systems. However, it's important to note that in the context of natural farming, only natural mulches are permissible.

The effectiveness of mulching is generally more pronounced in countering annual weeds compared to perennial weeds, which include species such as *Cyperus* spp., *Cynodon dactylon* (L.), and *Sorghum halepense* (L.) Pers. Innovative mulching approaches that involve natural materials like straw, leaves, and cover crops play a crucial role in preventing the germination of weed seeds, serving as potent weed control strategies while concurrently bolstering soil health and preserving soil moisture.

Living mulches (Cover crops): Living mulches encompass cover crops that are either sown prior to or concurrently with the primary crop and are maintained as an active ground cover throughout the growth season. If the living mulch is of a perennial nature, it may obviate the need for annual reseeding. The utilization of living mulches offers a range of benefits, including the reduction of nutrient leaching particularly nitrates alongside the absorption of carbon and nitrogen. Moreover, living mulches effectively combat soil erosion, contribute to the accumulation of organic matter for enhanced soil structure, and provide a habitat for beneficial insects. For optimal effectiveness of living mulches, specific conditions are vital, such as fertile soil conditions, ample water supply, and the absence of perennial weed species.

It was concluded by Rashid Iqbal *et al.* (2020) from the literature that mulches are a cheap source to reduce weed populations and to conserve the soil moisture contents to a substantial level. Therefore, the properly managed mulching strategies could compensate the water requirement of Table 2 Selection of Mulches according to Ecological Conditions Sr. No. Ecological Situation Mulches 1 Rainy season Perforated mulch 2 Orchard and plantation Thicker mulch 3 Soil solarisation Thin transparent film 4 Weed control through solarisation Transparent film 5 Weed control in cropped land Black film 6 Sandy soil Black film 7 Saline water use Black film 8 Summer cropped land White film 9 Insect repellent Silver colour film 10 Early germination Thinner film Iqbal et al. Bulletin of the National Research Centre (2020) 44:75 Page 12 of 16 crops in water deficit/drought conditions. Moreover, integrating the mulching system (wheat straw, cotton sticks, black plastic, maize straw) with partial root zone drying (PRD) could serve an efficient technique to enhance overall crop growth, development, and yield

Effect of mulches in management:

Wilen *et al.* (1999) found that there was 92% reduction of weed population as compared to non-mulched treatment. When mulch is spread on the soil surface, they act as barriers in the passing of light resulting in reduced germination of small-seeded weed species. Some organic mulch also acts as the allelopathic and releases some toxic chemicals which are helpful for the reduction of weeds. Besides this, the environment that is created through the mulch is very helpful for beneficial microbes which feed on the weed species or weed seeds (Chalker-Scott 2007).

Crop Rotation and Polycultures:

Planting diverse combinations of crops can help reduce weed pressure by creating a more competitive environment for weeds. Recent research focuses on identifying beneficial companion plant combinations that work effectively together. Rotating crops or planting multiple crops together can disrupt weed growth cycles and prevent the dominance of specific weed species. Diverse plantings can create more competition for resources.

Intercropping:

Inter cropping entails the strategic planting of specific crops to facilitate weed suppression and enhance soil quality. Recent progress involves the identification of suitable companion inter crop species and varieties that excel in weed management, nutrient cycling, and the improvement of soil structure. By planting inter crops that can outcompete weeds for essential resources such as nutrients and sunlight, a natural mechanism for weed suppression is established. Moreover, these inter crops contribute to overall soil health and fertility.

The critical selection of suitable cover crop species is essential, and the choice of appropriate termination methods significantly influences their weed suppression capacity. Mechanical methods such as rolling-crimping and flail-mowing have proven effective for cover crop termination. Flail-mowing results in smaller, faster-decomposing fragments, which are less persistent as mulch. On the other hand, rolling creates a flattened cover that gradually decomposes into a mulch layer, offering more comprehensive ground coverage compared to flailing and leading to more gradual decomposition.

No-Till and Reduced Tillage Systems:

By adopting these systems, soil disturbance is minimized, which in turn preserves the integrity of soil structure and curtails the emergence of weeds. In the domain of natural farming, practitioners have been continuously honing their methods to curtail the necessity for extensive tilling, all the while fostering vigorous crop growth and effectively quelling weed proliferation. Through the deliberate act of minimizing soil disturbance, not only is soil structure conserved, but the appearance of weeds is also diminished. This approach stands as a safeguard for both soil health and robust crop development. The adoption of practices that advocate reduced tillage further fortifies this endeavor by curtailing soil disturbance, a pivotal factor in curbing weed emergence. This holistic methodology contributes to the safeguarding of soil structure and the creation of an environment conducive to thriving crop growth.

Allelopathy Exploration:

Researchers are actively investigating the allelopathic effects of specific plants, wherein biochemical compounds are released to hinder the growth of competing plants. These interactions hold the potential to reshape weed control strategies, minimizing reliance on synthetic herbicides. Notably, certain crops naturally discharge chemicals that restrain weed growth. By understanding and harnessing these allelopathic relationships, a promising avenue for effective weed management emerges.

Bioherbicides/Biological Control:

Natural farming methods incorporate bioherbicides crafted from naturally existing organisms, such as fungi and bacteria, to selectively combat and regulate specific weed species. Progress in this realm involves identifying potent strains and refining application techniques. Additionally, introducing beneficial insects or microbes that naturally prey on or compete with weed species offers a sustainable approach to managing weed populations.

Stale seedbed preparation:

In this method before final ploughing, after irrigation/rainfall allow the weed seeds to grow up to 1-2 leaf stage and mix it in the soil either cultivator or rotavator at final ploughing.

Flame weeding:

Killing of weeds with intense heat produced by a fuel-burning device, either hand-held or tractor-mounted. Usually relies on propane gas burners to produce a carefully controlled and directed flame that briefly passes over the weeds. The goal is to damage the cell structure of their foliage. Brief exposure to intense heat causes the cell sap to expand and that in turn disrupts cell walls.

Multi varietal crop sowing:

Seed differing root and shoot growth are mixed together and sowing densely to create competition to the weeds both above and below ground. At peak flowering stage it will be incorporated into the soil to add organic matter to the soil.

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RECYCLING OF CROP RESIDUES UNDER NATURAL FARMING SYSTEM

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Introduction

In the world of modern agriculture, the ever growing challenge of feeding an expanding global population often leads to practices that strain the environment, deplete natural resources, and disrupt the delicate balance of ecosystems. Traditional methods of agricultural production, reliant on synthetic inputs and high intensity cultivation, are increasingly recognized as unsustainable and detrimental to the planet's well-being.

As a response to these concerns, a paradigm shift towards sustainable farming practices has emerged, with natural farming leading the way. Natural farming embodies the wisdom of time-honoured agricultural traditions and the innovative spirit of modern ecological science. At its core, it emphasizes harmony with nature, minimal intervention, and the creative recycling of resources.

Within the realm of natural farming, the recycling of crop residues stands as a testament to the possibilities of creating a more sustainable and regenerative agricultural system. This chapter embarks on a journey to explore the intricacies of recycling crop residues under the umbrella of natural farming. We delve into the profound implications, ecological merits, and practical strategies that underline the integration of crop residue recycling as a cornerstone of this innovative approach to agriculture.

The recycling of crop residues under natural farming not only addresses the pressing issue of waste management but also offers a myriad of ecological, economic, and social benefits. It transforms what was once seen as a liability into a valuable resource that enriches the soil, fosters biodiversity, conserves water, mitigates climate change, and reduces the dependency on external inputs.

This chapterunearth the principles and methods that demonstrate the transformative power of integrating crop residue recycling into natural farming systems. From the conceptual underpinnings to the practical applications, readers will be equipped with a comprehensive understanding of this sustainable approach and its potential to shape the future of agriculture.

Crop residues or agricultural wastes are those which are generated as a result of different agricultural operations and processes. Although most of these wastes are derived from natural sources and are not toxic to the environment, they can accumulate in large quantities and subsequently cause advert effect to humans, animals and even plants. Agricultural waste can be mainly categorized into four main categories including crop residue, livestock waste, agro-industrial waste and aqua-cultural waste. Crop residue and agro-industrial waste are the largest available types of waste that are produced in large quantities on a daily and sustainable basis. However, the lack of proper management practices of these wastes, following the lack of or limited adequate information, has continuously become a great challenge, which is too great to be downplayed.

1.1. Crop Residues

Crop residues are the most common types of agricultural waste all over the world, with millions of tonnes produced every year, in which most of them are either burned or thrown into landfill. Crop residues include the straws of rice, oat, barley and wheat, corn stoves and the leaves of many fruit plants in addition to seed pods and shells. The global production of these wastes is projected to exceed 2802 million tonnes per year (Zabed*et al*., 2016: Bhardwaj *et al*., 2022).Corn stalks are the top produced crop waste with over 750 million tonnes produced per year, followed by wheat and rice with 600 and 360 million tonnes produced per year, respectively (Jin *et al*.,2020)Only a small portion of rice, corn and wheat crop residues are effectively utilized in some applications such as animal fodder and/or bioenergy production, while the rest is discarded into landfill or openly burned(Zhang *et al*., 2016). From a chemical aspect, crop residues contain from 40 to 45% carbon, 0.6 to 1% nitrogen and 14 to 23% potassium in addition to phosphorus and microelements that are necessary for crop growth (Wang et al.,2021).

1.2. Livestock Waste

Livestock waste consists of wastewater, solid manure from different farm animals and liquid manure. Animal manure is a renewable resource as it basically comes from cellulosic feed and undigested residue, which is excreted by livestock animal species. Traditionally, animal manure is used as a fertilizer without any proper treatment, which can cause significant environmental problems including greenhouse gas emissions, public hazards (asphyxia poisoning and infectious pathogens), air quality deterioration and water pollution. As a sustainable and eco-friendly solution, Tsai et al. (2019) successfully utilized cow manure as a precursor material for activated carbon production and reported its great properties and a surface area of more than 950 m^2/g. Owing to its organic source and its high carbon content, animal manure can be thermally converted (or further modified) into various forms of carbon materials and energy sources. However, the low energy yield and air pollution resulting from manure processing for energy production has added additional value to it as a suitable and sustainable adsorbent for several environmental applications.

2. On-Farm Waste Recycling Technologies

In the realm of natural farming, sustainable agricultural practices, ecological balance and the complete reduction of synthetic inputs take center stage. Within this framework, efficient management and recycling of farm waste play a pivotal role. Farm waste recycling is vital for maintaining soil fertility, minimizing environmental pollution and closing the nutrient loop within the organic production system. This chapter aims to explore the importance of farm waste recycling in natural farming systems, discuss various farm waste management techniques, and highlight the benefits of incorporating recycling practices into natural farming.

2.1. Importance of Farm Waste Recycling in Natural Farming

2.1.1. Soil Fertility

Natural farming relies on the health and fertility of the soil. Farm waste, such as crop residues, and animal manure are rich in organic matter and essential nutrients. Recycling these waste materials helps improve soil structure, enhance nutrient availability, and promote beneficial microbial activity. As organic matter decomposes, it releases nutrients slowly, providing a continuous supply of essential elements for plant growth. This nutrient-rich soil fosters healthy crops, reduces the need for synthetic fertilizers, and ensures sustainable agricultural practices.

2.1.2. Nutrient Cycling

Farm waste recycling facilitates the efficient cycling of nutrients within the organic production system. Instead of relying solely on external inputs, such as synthetic fertilizers, recycling farm waste allows the nutrients to be returned to the soil and reused. This closed-loop system minimizes nutrient losses and reduces dependency on non-renewable resources. By cycling nutrients through organic matter decomposition and subsequent incorporation into the soil, farm waste recycling contributes to the long-term sustainability of natural farming.

2.1.3. Organic Matter Addition

Organic matter is a critical component of fertile soils. It improves soil structure, enhances water holding capacity, and promotes beneficial microbial communities. Farm waste when recycled, contributes to the organic matter content of the soil. This, in turn, enhances soil fertility, promotes root development, and improves overall soil health. Organic matter also increases the soil's ability to sequester carbon, mitigating climate change impacts and contributing to carbon sequestration efforts.

2.1.4. Environmental Protection

Recycling farm waste in natural farming systems helps to protect the environment by reducing pollution risks. Inappropriate disposal or mismanagement of farm waste can lead to the release of pollutants, including excess nutrients, pathogens, and pesticides, into the surrounding ecosystems. By properly managing and recycling organic waste, farmers can prevent nutrient runoff into water bodies, minimize soil erosion, and reduce the contamination of air and water resources. Additionally, recycling farm waste contributes to the conservation of natural resources, such as water and energy, and supports biodiversity by creating habitats for beneficial organisms.

2.1.5. Circular Economy

Farm waste recycling aligns with the principles of the circular economy. Instead of treating farm waste as a burden or a waste product, recycling transforms it into a valuable resource. By converting waste materials into compost, vermicompost, or other organic fertilizers, farmers close the loop by reintroducing those nutrients back into the farming system. This reduces reliance on external inputs, minimizes waste generation, and promotes a sustainable and regenerative approach to agriculture.

2.1.6. Economic Benefits

Farm waste recycling can also yield economic benefits for organic farmers. By utilizing recycled organic fertilizers, farmers can reduce their expenditure on synthetic fertilizers. Moreover, on-farm composting or vermicomposting systems allow farmers to produce their own organic amendments, reducing the need for purchasing external inputs. These cost savings contribute to the economic viability of natural farming operations.

3. Farm Waste Management Techniques

Farm waste management techniques encompass various approaches to efficiently handle and recycle agricultural by-products and organic waste. These techniques are crucial in organic farming systems to promote sustainability, reduce waste accumulation, and enhance resource efficiency. Here are some farm waste management techniques commonly employed under natural farming system to get more benefits.

1) Composting
2) Compost tea
3) Vermicomposting
4) Vermiwash
5) Anaerobic digestion (Fermented Organic Manure)
6) Mulching
7) Mushroom production
8) Smoke water
9) Biochar
10) Hydrochar

3.1. Composting

Composting is a widely used technique that involves the decomposition of organic materials to produce compost which is nutrient-rich soil amendment. It utilizes the natural process of microbial breakdown and transformation of organic matter into stable humus. Composting requires a suitable mix of carbon-rich (e.g., crop residues, straw) and nitrogen-rich (e.g., animal manure, food scraps) materials, along with appropriate moisture and aeration. The organic waste is piled or placed in compost bins, where it undergoes microbial decomposition. Regular turning and monitoring of the compost pile ensure proper aeration and temperature control. Composting can be implemented on a small scale, such as backyard composting, or in larger-scale systems on farms.

Composting farm wastes is an effective and sustainable practice that can help reduce waste, improve soil health, and promote organic farming. It involves the decomposition of various organic materials, such as crop residues, animal manure, straw, hay, and other farm by-products, through the action of microorganisms. The end result is a nutrient-rich compost that can be used as a natural fertilizer and soil amendment. Here is a detailed breakdown of the composting process for farm wastes:

3.1.1. Selecting the materials

The first step in composting farm wastes is to gather the appropriate materials. These can include crop residues like paddy straw, corn stalks, wheat straw, or sugarcane bagasse, as well as animal manure from livestock such as cows, pigs, or chickens. It's important to have a balanced mix of carbon-rich (brown) and nitrogen-rich (green) materials to facilitate the decomposition process. Carbon-rich materials include straw, dried leaves, and wood chips, while nitrogen-rich materials include fresh grass clippings, animal manure, and vegetable scraps. The optimum C:N ratio of the material for effective degradation is 30-35 :1

3.1.2. Preparing the compost pile

Once the materials are collected, they are piled together to create a compost heap or bin. The size of the pile can vary depending on the available space and the amount of waste generated. However, a pile with a minimum size of 3 feet (1 meter) in height, width, and length is recommended to ensure proper heat generation and decomposition.

3.1.3. Layering the materials

Layering the materials is crucial to promote proper airflow and decomposition. Start by creating a base layer of coarse materials like twigs or straw to allow for drainage and aeration. Then, alternate between layers of carbon-rich and nitrogen-rich materials. The carbon-rich layer helps prevent the pile from becoming too compact, while the nitrogen-rich layer provides the necessary nutrients for the microorganisms. Repeat this layering process until the pile is built.

3.1.4. Managing moisture

Moisture is essential for the composting process, as it helps the microorganisms break down the organic matter. The pile should be kept moist but not waterlogged. If the pile is too dry, decomposition will slow down, while excessive moisture can lead to unpleasant odors and anaerobic conditions. Hence, an optimum moisture of 60% should be maintained throughout the composting period.

3.1.5. Turning the pile

Regularly turning or mixing the compost pile helps aerate it and accelerates the decomposition process. This allows oxygen to reach the microorganisms, preventing the formation of foul-smelling anaerobic conditions. Turning the pile every 15 days with a fork or shovel helps ensure that all parts of the compost are exposed to oxygen.

3.1.6. Monitoring temperature

As the organic materials decompose, the compost pile generates heat. Monitoring the temperature is important because it indicates the activity of the microorganisms. Ideally, the compost pile should reach temperatures between 130°F and 160°F (55°C and 70°C). These high temperatures help kill weed seeds, pathogens, and undesirable insects. If the temperature drops significantly, turning the pile can reignite the decomposition process.

3.1.7. Allowing for maturation

The composting process can take several days tomonths, depending on various factors such as the size of the pile, the materials used, and the environmental conditions. During this time, the compost pile gradually breaks down, and the organic materials transform into a dark, crumbly, and earthy-smelling substance. This mature compost is rich in nutrients and can be used to enrich soil.

3.1.8. Using the compost

Once the compost has matured, it is ready for use. It is recommended as basal fertilizer @5 t /ha for all the crops. It can be spread on fields or used in garden beds as a natural fertilizer and soil conditioner. The nutrients released from the compost improve soil structure, water-holding capacity, and nutrient content, promoting healthy plant growth. Compost can also help suppress plant diseases and enhance overall soil biodiversity.

It's important to note that composting farm wastes should be done responsibly to avoid potential issues. Here are a few considerations:

(i) **Avoiding contaminants:** Care should be taken about introduction of contaminants into the compost pile. Avoid adding materials that may contain pesticides, herbicides, or chemicals that could potentially harm plants or animals.

(ii) **Managing odour and pests**: Properly managing the compost pile can help minimize odours and deter pests. Avoid adding meat, dairy products, or oily substances, as they can attract unwanted animals. Covering the compost pile with a tarp or using a compost bin with a lid can help contain odors and prevent animals from accessing the pile.

(iii) **Composting large-scale farm waste:** Large-scale farm waste composting requires additional considerations, such as mechanical turning equipment, proper space allocation, and monitoring systems.

3.2. Compost tea

Compost tea is a liquid organic fertilizer and soil conditioner made by steeping compost in water, along with other additives, to extract the beneficial microorganisms and nutrients from the compost. This nutrient-rich liquid can be applied to plants and soil to improve plant health, stimulate growth, and enhance soil quality. Compost tea is a valuable addition to organic gardening and farming practices.

Dilute the compost tea with clean water (usually a 1:10 ratio of compost tea to water) and apply it to plants or soil. Watering can, sprayer, or irrigation system can be used. It's best to apply compost tea within a few hours of straining to ensure the microbial activity is still high. Compost tea is a valuable natural fertilizer and soil conditioner that enhances the soil's biological activity and improves plant health. Regular applications can lead to healthier, more productive gardens and crops.

3.3.Vermicomposting

Vermicomposting is a specialized form of composting that utilizes earthworms to decompose organic waste materials. Earthworms consume and break down the organic matter, producing nutrient-rich castings or vermicompost. Vermicomposting is ideal for managing food scraps, kitchen waste, crop residues, animal dung, and other organic materials. It can be done in small-scale systems, such as vermiculture bins or beds, which provide a suitable environment for the worms to thrive. Vermicompost is highly valued for its nutrient content, microbial activity, and ability to improve soil structure.

Vermicomposting is a process that utilizes earthworms to decompose organic wastes and convert them into nutrient-rich compost. It is an effective and sustainable method of recycling organic materials while producing high-quality fertilizer for plants. The worms used in vermicomposting are *Eudrilus eugeniae*, *Eisenia fetida* or *Lumbricus rubellus*, it consume the organic matter and excrete nutrient-rich castings, which are also known as worm castings or vermicompost.

The details of vermicomposting process are listed below.

3.3.1. Selecting a vermicomposting system

There are various vermicomposting systems available, ranging from simple home setups to larger-scale commercial systems. The selection of a system depends on the amount of organic waste generated and the available space. Common systems include stacked bins, flow-through systems, or even outdoor windrows for larger operations.

3.3.2. Choosing the bedding material

The bedding material provides a favourable environment for the worms and helps retain moisture. Suitable bedding materials include shredded newspaper, cardboard, coconut coir, straw, or a combination of these. The bedding should be moistened before adding the worms and organic waste.

3.3.3. Introducing the worms

Once the bedding material is prepared, the worms can be introduced. Red worms are most commonly used in vermicomposting due to their high consumption rate and ability to thrive in organic waste environments. The number of worms required depends on the size of the vermicomposting system and the amount of organic waste produced. A general guideline is to start with 0.5 kgof worms for every square foot (0.09 square meters) of surface area.

3.3.4. Adding organic waste

The pre-digested organic waste should be added in the vermicompost bed. Suitable materials for vermicomposting include animal dung, fruit and vegetable scraps, coffee grounds, tea leaves, crushed eggshells, shredded plant trimmings, and other non-animal food waste. It's important to avoid adding meat, dairy, oily substances, and large quantities of citrus or acidic materials, as they can be detrimental to the worms' health.

3.3.5. Maintaining the vermicomposting system

Regular maintenance is necessary to ensure optimal conditions for the worms and the decomposition process. Here are some key considerations:

- **Moisture:** The vermicomposting system should be kept moist. Around 60% of the moisture should be maintained. Dry conditions can harm the worms, while overly wet conditions can lead to anaerobic conditions and unpleasant odours.
- **Temperature:** Worms thrive in temperatures between 55°F and 77°F (13°C and 25°C). It's important to provide a suitable environment by keeping the vermicomposting system within this temperature range. Insulating the system in colder climates or shading it in hotter climates can help regulate the temperature.
- **Airflow:** Adequate airflow is crucial for the worms' health and the decomposition process. Avoid compacting the bedding material and periodically fluff it to maintain proper aeration. Some vermicomposting systems have built-in ventilation or can be manually aerated using a pitchfork or similar tool.

3.3.6. Harvesting the vermicompost

Over time, the worms will convert the organic waste into nutrient-rich castings. Harvesting the vermicompost involves separating the worms from the finished compost. There are several methods to do this:

- **Migration method:** Create a new section in the vermicomposting system with fresh bedding/cow dung and food. Place it next to the section with mature compost. The worms will migrate to the new section in search of food, allowing you to collect the worm-free vermicompost.

- **Hand sorting method:** Spread a tarp or plastic sheet on a flat surface and dump the contents of the vermicomposting system onto it. Create small piles and expose them to light. Since worms dislike light, they will burrow deeper into the pile, allowing you to remove the top layer of worm-free vermicompost.
- **Screen method:** Use a screen or sieve with holes large enough for the worm castings to pass through but small enough to retain the worms. Sift the vermicompost, collecting the fine castings and returning any worms caught in the screen back to the vermicomposting system.

3.3.7. Using the vermicompost

The harvested vermicompost is a nutrient-rich organic fertilizer and soil amendment. It is recommended @ 5t/ha for all the crops as basal dose. It can be used in various ways:

- **Garden soil amendment:** Mix the vermicompost into garden soil to improve its structure, water-holding capacity, and nutrient content. Apply it as a top dressing or incorporate it during soil preparation.
- **Potting mix component:** Use vermicompost as a component in homemade or commercial potting mixes to enhance plant growth and health.

3.4.Vermiwash

Vermiwash is the liquid that is collected after water passes through vermicompost made by earthworms. It is rich in plant growth hormones, micro-nutrients, and major nutrients like nitrogen, phosphorous and potassium.

Vermiwash unit

The vermiwash unit is prepared in a drum, tank or bucket of about 200 liters capacity of clay, iron or plastic. The upper part of the drum should be open for making vermiwash. By making a hole in the bottom of the tank, put a vertical "T" shaped tube, whose half inch should be submerged inside the tank. One side of the hose is attached with a tape and the other side is tightened with a dummy nut. The entire set is kept in a shady place above a proper post. Useful items for preparing vermiwash is Dung, soil, coarse sand, earthworm, straw or dry leaves, earthen pot, water, bucket, drum, small pieces of brick or ballast etc.

Application: Vermiwash can be applied in various ways, including foliar spraying @ 3%, root drenching, or as a soil amendment. It's important to dilute vermiwash with water before application to prevent over-fertilization and to ensure even distribution.

3.5. Anaerobic Digestion:

Anaerobic digestion (AD) is a natural biological process that breaks down organic materials in the absence of oxygen, resulting in the production of biogas and nutrient-rich digestate. This process has gained significant attention as a sustainable waste management solution that simultaneously addresses energy generation and nutrient recycling needs.

3.5.1. Anaerobic Digestion Process: Anaerobic digestion occurs in several stages, each facilitated by specific groups of microorganisms. The process can be divided into four main stages:

a) **Hydrolysis:** Complex organic materials such as proteins, carbohydrates, and fats are broken down into simpler compounds by hydrolytic bacteria. This stage prepares the waste for further degradation.
b) **Acidogenesis:** Acid-forming bacteria convert the simpler compounds from hydrolysis into volatile fatty acids, alcohols, and other organic acids.
c) **Acetogenesis:** Acetic acid-forming bacteria convert the organic acids produced in the previous stage into acetic acid, hydrogen, and carbon dioxide.
d) **Methanogenesis:** Methane-forming archaea convert acetic acid, hydrogen, and carbon dioxide into methane (CH_4) gas, which constitutes the primary component of biogas.

3.5.2. Products of Anaerobic Digestion:

a) **Biogas:** The methane-rich biogas produced during anaerobic digestion can be used as a renewable energy source. It has various applications, including electricity generation, heating, and fueling vehicles.
b) **Digestate:** The residual material remaining after anaerobic digestion is known as digestate. It is nutrient-rich and can be used as a valuable organic fertilizer, helping to close nutrient loops in agriculture.

3.5.3. Benefits of Anaerobic Digestion:

a) **Renewable Energy Generation:** Biogas produced during anaerobic digestion contains methane, a potent greenhouse gas. By capturing and utilizing biogas, AD reduces methane emissions while generating clean and renewable energy.

b) **Waste Management:** AD reduces the volume of organic waste and minimizes its environmental impact. It provides a sustainable alternative to landfilling or incineration.
c) **Nutrient Recycling:** The nutrient-rich digestate can replace synthetic fertilizers, reducing the reliance on non-renewable resources. This enhances soil fertility, improves crop yields, and supports sustainable agriculture.
d) **Greenhouse Gas Reduction:** AD reduces greenhouse gas emissions by preventing the release of methane, which is more harmful to the environment than carbon dioxide.
e) **Waste Valorization:** AD transforms organic waste into valuable resources—energy and nutrients—contributing to a circular economy.

3.6. Mulching

Mulching is a common agricultural practice that involves covering the soil surface with a layer of organic or inorganic material. This layer serves multiple purposes and can have various benefits for plant growth, soil health, and overall crop management. Mulching is used extensively in both small-scale and large-scale agriculture, as well as in gardening and landscaping. Here's an overview of mulching and its utilization in agriculture:

3.6.1. Types of Mulch:

a) **Organic Mulch:** This type of mulch includes materials that decompose over time, adding organic matter to the soil. Examples of organic mulch include straw, leaves, grass clippings, wood chips, compost, and bark.
b) **Inorganic Mulch:** Inorganic mulch consists of non-organic materials that do not break down quickly. Common examples include landscape fabric, and gravel.

3.6.2. Utilization in Agriculture: Mulching is widely used in various agricultural settings:

a) **Crop Production:** Mulching is commonly used in row cropping, fruit orchards, and vegetable gardens. Different crops benefit from different types of mulch, and it can be applied around plants or between rows.
b) **No-Till Farming:** Mulch can be part of no-till or conservation tillage practices, where it helps protect the soil and maintain its structure without disturbing it through conventional ploughing.

c) **Organic Farming:** Organic mulches align with the principles of organic farming by enhancing soil health and reducing the need for synthetic herbicides and fertilizers.

d) **Landscaping:** Mulching is used in landscaping to enhance the aesthetic appeal of gardens, parks, and public spaces. It helps create a tidy appearance and suppresses weed growth.

e) **Nurseries:** Mulching is often used in nursery operations to protect young plants from temperature extremes and to conserve moisture.

3.6.3. Benefits of Mulching in Agriculture:

a) **Weed Suppression:** Mulch acts as a physical barrier that prevents sunlight from reaching weed seeds, thus inhibiting weed growth. This reduces the competition for resources between crops and weeds.

b) **Moisture Conservation:** Mulch helps to reduce water evaporation from the soil surface, maintaining soil moisture levels and reducing the need for frequent irrigation. This is particularly important in arid or drought-prone regions.

c) **Soil Erosion Control:** Mulch prevents soil erosion by protecting the soil from the impact of raindrops and the movement of water. It also provides stability to sloped areas.

d) **Temperature Regulation:** Mulch helps to moderate soil temperatures by insulating the soil from extreme heat in summer and cold in winter. This can create a more favourable environment for plant growth.

e) **Nutrient Retention:** Organic mulches break down over time and contribute to the soil's organic matter content, enriching the soil with nutrients. Some mulches, like compost, release nutrients as they decompose.

f) **Disease Prevention:** Mulch can create a barrier between the soil and plant foliage, reducing the splashing of soil-borne diseases onto plants. Additionally, some organic mulches, like certain types of straw, have natural fungicidal properties.

g) **Improved Soil Structure:** Organic mulch improves soil structure by promoting the activity of soil organisms. As the mulch breaks down, it enhances soil aeration, drainage, and overall soil health.

Mulching is a versatile agricultural practice that offers numerous benefits for soil health, water conservation, weed management, and crop growth. The choice of mulch type depends on the specific needs of the crop, climate, and management goals.

3.7. Mushroom production

Mushroom production using on-farm wastes in the context of natural farming is a sustainable and environmentally friendly approach to growing edible fungi. Natural farming emphasizes minimal intervention and seeks to harness the natural processes and resources available on the farm. Here is a detail on how to produce mushrooms using on-farm waste materials under the principles of natural farming:

3.7.1. Selecting suitable mushroom species: Different mushroom species have specific requirements, and some are better suited for natural farming than others. Common choices include oyster mushrooms (*Pleurotus* spp.), shiitake (*Lentinula edodes*), and wine cap mushrooms (*Stropharia rugoso-annulata*). Choose a species that matches the available on-farm waste materials and local climate conditions.

3.7.2.Collecting On-Farm Waste Materials: Natural farming emphasizes recycling and reusing resources available on the farm. On-farm waste materials that can be used for mushroom cultivation include:

- Agricultural crop residues (e.g., straw, corn cobs, sugarcane bagasse)
- Fallen leaves, wood chips, and sawdust
- Animal manure (preferably aged and composted)
- Rice bran, coffee husks, or other agricultural by-products

3.7.3. Preparing Substrate: Substrate preparation is crucial for successful mushroom cultivation. The specific method may vary depending on the mushroom species, but generally includes:

- Mixing the waste materials to create a balanced substrate.
- Pasteurization or sterilization to kill potential competitors (bacteria, molds, etc.) and pests.
- Adjusting moisture levels to reach the optimal water content for the chosen mushroom species.

3.7.4. Inoculating with Mushroom Spores or Mycelium: Once the substrate is prepared, it's time to introduce mushroom spores or mycelium (the fungal network). This can be done by:

- Spore injection or grain spawn inoculation.

- Using mushroom culture purchased from a reputable supplier or isolating it from wild mushrooms.

3.7.5. Incubation: The inoculated substrate needs a controlled environment with stable temperature and humidity for the mycelium to colonize. This is usually done in a dark room or chamber.

3.7.6. Fruiting Stage: When the mycelium has fully colonized the substrate, initiate the fruiting stage by exposing the substrate to fresh air, light, and controlled conditions specific to the chosen mushroom species. For natural farming, try to mimic the local environmental conditions.

3.7.7. Harvesting: Mushrooms will begin to grow from the substrate. Harvest them when they reach the desired size and before they start to drop spores.

3.7.9. Post-Harvest Management: After harvesting, recycle mushroom waste (spent substrate and harvested stalks) into compost, which can then be used to enrich the soil in your farming operations.

3.7.11. Benefits of Mushroom Production in Natural Farming

a) Recycling On-Farm Waste: Mushroom cultivation can effectively recycle agricultural by-products and convert them into a valuable food source.

b) Natural Pest Control: The mycelium of certain mushroom species can help control pests and diseases in the farm ecosystem.

c) Soil Improvement: Using spent substrate as compost can enhance soil fertility, contributing to natural farming principles.

d) Local Food Production: Growing mushrooms on-farm can provide a local source of nutritious food while reducing the need for external inputs.

e) Sustainability: The integration of mushroom production with natural farming practices aligns with the principles of minimal intervention, reduced waste, and increased self-sufficiency.

Mushroom production using on-farm waste materials under natural farming principles is a holistic approach to sustainable agriculture that not only benefits the farm but also the environment. It promotes resource efficiency, biodiversity, and a closed-loop farming system.

3.8. Smoke water

In the realm of natural farming, sustainability is paramount, and every resource, no matter how seemingly insignificant, is harnessed to its fullest potential. Smoke water production and utilization is a prime example of this resourceful approach to on-farm waste management.

3.8.1. Smoke Water Production

The smoke generated during burning of crop residues contains valuable organic compounds and volatile substances. Smoke water is created by condensing and collecting the smoke as it passes through a cooling chamber or pipe. The condensation process traps the valuable constituents in the smoke.

3.8.2. Composition of Smoke Water

Smoke water is a complex mixture containing various organic compounds, including acetic acid, formic acid, and phenolic compounds. It may also contain beneficial microbes. The specific composition can vary depending on the feedstock used and the pyrolysis conditions.

In the realm of natural farming, using smoke water for seed treatment is a valuable practice that aligns with the principles of sustainability and minimal intervention. Below is a detailed exploration of the usage of smoke water for seed treatment in natural farming:

3.8.3. Seed Treatment with Smoke Water

a. Preparation of Smoke Water

Smoke water is obtained by condensing and collecting the smoke generated during the burning the crop residues. This smoke contains various organic compounds, some of which can be beneficial for seed treatment.

b. Dilution and Application

Smoke water is usually diluted with water to achieve an appropriate concentration, as using it undiluted may be too concentrated for seed treatment. The diluted solution (2%) is then used to treat seeds before sowing. Immerse the seeds in the diluted smoke water solution for a specified period, which can range from a few minutes to a few hours, depending on the seed type and concentration. After treatment, spread the seeds on a clean surface to dry. Ensure that they are completely dry before sowing.

3.8.4. Benefits of Smoke Water for Seed Treatment

a. Pathogen Suppression

Smoke water has been found to contain compounds with antimicrobial properties, such as acetic acid and phenolic compounds. Treating seeds with smoke water can help suppress seed-borne pathogens and soil-borne diseases, reducing the risk of crop infections.

b. Enhanced Germination

Studies have suggested that smoke water may enhance seed germination and seedling vigour. The compounds present in smoke water can potentially stimulate germination processes and promote quicker and more robust seedling growth.

c. Improved Seedling Health

The antimicrobial properties of smoke water can contribute to healthier seedlings by reducing the risk of damping-off and other seedling diseases. This, in turn, can lead to more vigorous and productive plants.

3.9. Biochar Production

Biochar, a stable form of carbon-rich material, is produced through a process called pyrolysis, which involves heating organic biomass in a low-oxygen environment. This process transforms waste into a valuable resource that has multiple applications, particularly in agriculture.

3.9.1. Biochar Production Process: Biochar production involves subjecting biomass (such as crop residues, wood chips, and organic waste) to controlled pyrolysis. The process can be divided into several stages:

a) **Drying:** Moisture is removed from the biomass to reduce energy consumption during pyrolysis.

b) **Pyrolysis:** Biomass is heated in a low-oxygen environment to temperatures ranging from 350°C to 800°C. This causes the release of volatile compounds (gases and oils) and leaves behind biochar.

c) **Cooling:** The biochar is cooled rapidly to prevent further combustion.

d) **Collection and Storage:** The resulting biochar is collected and stored for later use.

3.9.2. Benefits of Biochar in Agriculture

a) **Carbon Sequestration:** Biochar is a stable form of carbon that can remain in the soil for hundreds to thousands of years. This makes it an effective means of sequestering carbon dioxide from the atmosphere, helping mitigate climate change by reducing greenhouse gas emissions.

b) **Soil Fertility:** Biochar can improve soil fertility by enhancing nutrient retention, cation exchange capacity (the soil's ability to hold onto and exchange nutrients), and microbial activity. It can provide a habitat for beneficial soil microorganisms, promoting plant growth and health.

c) **Water Retention:** Biochar has the ability to retain water due to its porous structure. This can help alleviate drought stress for plants and reduce the need for frequent irrigation.

d) **pH Regulation:** Depending on its source material and production conditions, biochar can have a neutral to slightly alkaline pH. This can aid in regulating soil pH, especially in acidic soils.

e) **Reduced Nutrient Leaching:** By enhancing nutrient retention, biochar can reduce the leaching of nutrients (such as nitrogen and phosphorus) into groundwater and nearby water bodies. This is beneficial for both soil health and water quality.

f) **Contaminant Remediation:** Biochar have the ability to adsorb and immobilize heavy metals and organic pollutants, making them potentially useful for soil remediation in contaminated sites.

g) **Crop Yield Improvement:** The improved soil structure, nutrient availability, and water-holding capacity associated with biochar application can lead to increased crop yields and improved plant resilience.

3.9.3. Considerations and Best Practices

a) **Feedstock Selection:** Different feed stocks produce biochars with varying properties. Selection should consider availability, cost, and end-use goals.

b) **Application Rates:** The amount of biochar applied should be carefully determined based on soil type, crop, and intended benefits. Blanket recommendation is 5 t /ha.

c) **Incorporation:** Mixing biochar with soil during tillage or other soil preparation activities ensures even distribution.

d) **Long-Term Effects:** While biochar can improve soil properties over time, its effects may take several years to fully manifest.

3.10. Hydrochar

Hydrochar, similar to biochar, is a carbon-rich material produced through the hydrothermal carbonization (HTC) process, which involves subjecting biomass to high temperature and pressure in the presence of water, but without oxygen. This process results in the transformation of biomass into a solid, carbon-rich material known as hydrochar, along with the release of water and gases.

Hydrochar shares some similarities with biochar, but there are also differences in their production methods and properties.

3.10.1. Production of Hydrochar:

a) **Feedstock Selection:** Just like with biochar, the feedstock used for hydrochar production can vary widely. Agricultural residues, organic waste and other organic materials can be used as feedstock.

b) **Hydrothermal Carbonization:** The feedstock is mixed with water and then heated under high pressure at temperatures typically ranging from 180 to 250°C (356 to 482°F). The absence of oxygen prevents the complete combustion of the biomass, leading to the formation of hydrochar.

c) **Properties of Hydrochar:** Hydrochar is porous and carbon-rich, similar to biochar, but it may contain slightly higher moisture content due to the hydrothermal process. Its properties, such as porosity and surface area, depend on factors like temperature, pressure, and residence time during the hydrothermal process.

3.10.2. Utilization of Hydrochar in Agriculture: Hydrochar has the potential to be utilized in agriculture in various ways:

a) **Soil Amendment:** Hydrochar, when incorporated into soil, can improve soil structure, water-holding capacity, and nutrient retention, similar to biochar. It can enhance soil fertility and provide a habitat for beneficial microorganisms, promoting plant growth.

b) **Carbon Sequestration:** Like biochar, hydrochar can contribute to carbon sequestration by storing carbon in the soil for an extended period. This helps mitigate greenhouse gas emissions and combat climate change.

c) **Nutrient Management:** Hydrochar can adsorb nutrients like nitrogen and phosphorus, reducing their leaching into water bodies and promoting their availability to plants over time.

d) **Waste Valorization:** Hydrochar production offers a way to utilize organic waste streams, such as agricultural residues and food waste, that might otherwise be discarded. This can help in waste management and reduce the environmental impact of waste disposal.

e) **Alternative to Peat:** Hydrochar can be used as an alternative to peat in horticultural substrates and growing media. This can help conserve peatlands, which are valuable ecosystems.

f) **Contaminant Remediation:** Hydrochar can potentially adsorb heavy metals and organic pollutants from soil, contributing to soil remediation efforts.

It's important to note that research into hydrochar and its agricultural applications is ongoing, and its benefits and best practices are still being studied. As with any soil amendment, factors such as hydrochar type, application rate, and specific soil conditions need to be carefully considered to maximize its positive impactson soil health and crop growth.

7. Conclusion

Farm waste recycling is an integral part of organic farming systems. By adopting appropriate recycling techniques, farmers can improve soil fertility, reduce waste accumulation, and contribute to environmental sustainability. Recycling farm waste not only enhances soil health and nutrient cycling but also minimizes pollution risks and supports the circular economy. Implementing effective farm waste recycling practices is a crucial step towards achieving a more sustainable and resilient agricultural system.

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Preparation and application of Beejamrit, Jeevamrit, Ghanjeevamrit and Saptdhanya ankur ark for natural farming

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Introduction

Agricultural production has tripled since green revolution technologies. In the post green revolution indiscriminate use of toxic herbicides, insecticides, fertilizers has negatively influenced soil biochemical properties (Al-Daikh *et al.,* 2016; Ghosal and Hati, 2019). Zero Budget Natural Farming (ZBNF) is derived from one of the traditional methods and it is a type of organic farming agriculture, which gained momentum in recent times in India. It was practiced first in Karnataka state, India by the founder Subhash Palekar and gained momentum among the marginal and small land holding farmers (Khadse *et al.,* 2018; Khadse and Rosset, 2019)

In ZBNF nothing has to be purchased from outside. The principal methods of ZBNF include crop rotation, green manures and compost, biological pest control, and mechanical cultivation. The most popular and main pillars of ZBNF include biostimulant formulations like Bijamirth, Jeevamirth, Gnanajeevamirth, Acchadana (Mulching), Whapasa (Moisture) and *Astras* (Botanical extracts for pests)

Bijamirth is used as a treatment option of seed/seedling/planting material to reduce mortality rate and ensure vigorous crop growth and by suppressing various seed and soil borne diseases of younger seedlings. Jeevamirth is basically a kind of bio-fertilizer which adds nutrients to the soil for plant uptake. Gnanajeevamirth is a dry form of Jeevamirth and is used in situations of labour and water crisis. Inputs like Bijamirth, Jeevamirth, Gnanajeevamirth are advocated for soil and plant nutrition. Acchadana means covering or mulching the soil with plant materials for protecting soil from erosion. Besides, it improves soil aeration and conserves soil moisture by checking evaporation loss and weed emergence to some extent is checked through mulching. Further, organic types of mulches such as dried plants additionally produce humus on decomposition, which supplies nutrients to the crop. Mulching techniques are for weed management. *Whapasa* means moisture retention which focuses on improving water use efficiency by reducing the quantity and frequency of irrigation water applied as only a limited amount of water is needed for the crop growth. Astras such as Agniastra, Brahmastra and Neemastra are natural and purely organic plant protection biopesticides that needs scientific scrutiny for large scale recommendation. Most of these inputs required for the growth of the plant are available around the root zone of the plants which reduces the dependency on external resources. Only 1.5 to 2.0 percent is being taken up by the plant while the remaining 98 to 98.5 percent nutrients are taken from air, water and solar energy. Every green leaf of any plant produces 4.5 g of carbohydrates per square feet area, from which we get 1.5 g of grains or 2.25 g of fruits. For preparing this output, the plants take necessary elements like air, water and solar energy from the nature as reported by Padmashree. Mr. Subhash Palekar, the discoverer of theories, principles and methods of ZBNF that induces the indigenous soil microflora to participate in the plant growth activities. The methodical application of organic amendments helps in building up a suitable environment for these organisms to withstand the changes (Megir and Paulus, 2011). Panchgavya is a product derived from cattle waste and by-products, that improves soil fertility by increasing organic matter, macro and micronutrient levels, and the uptake of nutrients in plants, promoting the growth and reproduction of micro-organisms and maintaining good soil health (Komal *et al*., 2022).

Preparation methods and use of natural farming bio-inputs

Liquid organic manures are the extracts obtained during the process of decomposition / fermentation of organic matter or during the process of partial or complete composting or vermicomposting or excreta of animals such as urine, or extracts obtained during the decomposition / fermentation of concentrated organic manures or plants. Among indigenous technologies used by farmers, Panchagavya, Jeevamrutha and Beejamrutha are eco-friendly organic preparations made from cow products. Using of organic liquid products such as Beejamrutha, Jeevamrutha and Panchagavya results in higher growth, yield and quality of crops.

1. Bijamirth
2. Jeevamirth
3. Gnanajeevamirth
4. Saptdhanya ankur ark

1. Bijamirth

It is basically made up of water (20l), cow dung (5kg), urine (5l), lime (50gm) and just a handful of soil.

1.1 Preparation

- ✓ Take 5 kg of cow dung in a cloth and bound it by small rope as a small bundle and hang it for a night (12hr.) in 20 l of water
- ✓ In another container dissolve 50 g of lime in 1 l of water and keep it for a night
- ✓ Next day morning squeeze the cow dung in water add handful of soil and stir well
- ✓ To the solutions add 5 l of Desi cow urine and lime water and stir well

1.2 Usage

a. Add beejamruth to the seeds of any crop, coat them, mixing by hand, dry them well in shade and use for sowing. For leguminous seeds, just dip the seeds quickly (5 minutes) and dry them well in shade and use for sowing

b. While transplanting, the roots of the seedlings/setts/cuttings may be dipped in beejamrutha solution for five minutes and then planted/ transplanted.

After treating the seeds in beejamruth, will be kept for drying in shade and can be used for sowing. It protects the crops from harmful fungus, bacteria and other pathogens of soil borne diseases. It has hormones, alkaloids, which enhance the germination and gives protection to seeds and seedlings (Palekar, 2005).

2. Jeevamrutha

2.1. Preparation method

Jeevamrutha is a miracle microbial culture and is not a fertilizer. The useful soil microorganisms, earthworms are activated when jeevamrutha given with irrigation water. Desi cow dung is the main base of jeevamrutha.

2.2. Ingredients for* jeevamrutha*:

- Water 200 liters
- Jaggery 2 kg
- Cow dung 10 kg
- Pulse flour 2 kg
- Cow urine 10 l
- Handful of soil from farm/forest/bund

Take a container/ plastic drum of 50 litres to which add 10 kg cow dung, 10 liters of cow urine and 10 liters of water and mix it thoroughly. To this add 2 kg pulse flour, 2 kg organic jaggery and handful of garden soil and add 10 litres of water and stir it clock wise to form homogenous solution. Transfer this solution to 200 litres plastic barrel and makeup the volume to 200 liters. Keep the drum in shade or in room and cover it with wet jute bag. Stir the solution daily in clockwise direction at morning, afternoon and evening. Incubate the solution for 4 to 7 days and use (Palekar, 2006 and Devakumar *et al*, 2008).

3. Gnanajeevamirtha

3.1. Ingredients

- Cow dung - 50 kg
- Cow urine - 10 l
- Jaggery – 2 kg

- Green Gram powder – 2 kg
- Soil

3.2. Preparation methods

It is composed of the cow-dung, cow urine, jaggery and dicot flour and 1 hand full of soil. These ingredients are mixed together and make a ball like structure. While preparing the lumps should not be formed. Shade dry it and store for 6 months.

3.3. Usage: 100 kg / acre

4.0 Saptdhanyankur ark : Tonic for plants made from seven sprouted grains

Saptdhanyankur ark is a tonic for the plants. Using this during the fruiting (production) period increases the quality of fruits, vegetables & flowers. The solution can be prepared in-house by the farmers.

4.1 Ingredients

- Water (typically prepare using 200 litres of water).
- Cow urine 10% of the water i.e. 100 ml per litre of water.
- Black Sesame (*Sesamum indicum* - til) whole seeds 0.05% of the water
- Green gram (*Vigna radiata* - moong) whole seeds 0.05% of the water Blackgram (*Vigna mungo* - Urad) whole seeds 0.05% of the water
- Cowpea (*Vigna unguiculata* - chawli) whole seeds 0.05% of the water
- Moth beans (*Vigna aconitifolia* - matki / nari payaru) whole seeds 0.05% of the water
- Chickpea (*Cicer arietinum*- harbara) whole seeds 0.05% of the water
- Wheat (*Triticum aestivum* - gehu) whole seeds 0.05% of the water

4.2. Procedure (as suggested by Shri Subhash Palekar):

Step 1: Soak black sesame seeds in water in a bowl. Keep it aside for 1 day. After 24 hours proceed to next step.

Step 2: Soak the seeds of black gram, green gram, cow pea, moth bean, chick pea and wheat in water in a separate bowl. Soak it for 24 hours. After 24 hours proceed to next step.

Step 3: Next day take all the 7 types of seeds out from water. Tie the seeds in a cloth and hang it in shade. Keep the drained out water separately. The seeds are hanged till the seeds are sprouted with at least 1 cm root.

Step 4: After the seeds are sprouted crush them using wooden mantle. Do not use mixer grinder.

Step 5: Take water & pour cow urine in it. Pour the water that was used to soak the seed and mix it. Put the seed pulp in the solution and mix it properly. Use wooden stick for stirring the solution. Cover the tank with gunny bag. Keep the solution for 2 hours.

Step 6: After 2 hours filter the solution and use it within next 24 hours.

Preparation Time: 4-5 days.

Shelf life: 24 hours.

4.3. Usage:

The solution should be sprayed on the plants as a foliar spray. Do not mix water in the solution use the solution as is.

- Spray on the vegetable crops (kharif or rabi) when the vegetables are in milking stage.
- Spray on fruit trees when the fruits are small, medium or before they mature.
- When the fruit pods are small.
- In flower crops when the flowers are in budding stage.

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Natural Farming practices for Horticultural Crops

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Introduction

According to FAO, by 2050 the world needs to increase overall food production by 70 percent to keep up with the growing global population and the changes in consumption driven by expanding the middle class. At the same time, India is expected to be the most populous country in the world by 2030, with 1.51 billion people. Under such conditions, ensuring food security for the populace would be one of the biggest concerns for the country. Therefore, adopting of any farming practices or production technologies at large scale which are not scientifically proven and/or might have a negative effect on crop yield may pose serious concerns on the national goal of ensuring food and nutritional security.

For decades, Indian horticulture has primarily focused on boosting production, and various fertilizers and pesticides have been utilised to attain this goal. Horticulture sector is one of several industries that was shaped by technical advances in 20th century and with time, their negative impact on plant nutritional and medicinal quality, as well as the environmental changes including greater weather variability, soil degradation, water scarcity, and water bodies have been polluted, is becoming more apparent. Climate change, in particular, might reduce farmer incomes by 20-25 percent in the medium term in India, an issue that would be exacerbated by the current problem of water scarcity and food spoilage. Natural farming strive to maximize nature's potential to deliver ecosystem services that help to address food production. Natural farming, often known as traditional farming, is a chemical-free practice. It is a diversified farming system based on agroecology that mixes crops, trees, and livestock with functional biodiversity(Shankaraswamy,2023). Natural farming is similar to fertility farming, organic farming (but not necessary with organic certification), sustainable agriculture, agro-ecology, agro-forestry, eco-agriculture, and permaculture, but it differs from biodynamic farming. Natural farming is a novel approach to improving both traditional and modern agricultural techniques with the goal of protecting the environment, public health, and communities.

Natural Farming as Global Perspective

On a worldwide scale, there is widespread agreement that modern farming practices must be gradually transformed into more sustainable farming practices. People are also looking for 'organic' labelling in food because of the negative consequences of indiscriminate pesticide use. As a result, it is imperative to reorient and implement a variety of tactics in order to progress toward sustainable agriculture, which is aided by organic farming, natural farming, and other methods. India has long been regarded as a treasure trove of biological resources, intellectual understanding, and spiritual insight.

The main challenge now is how to restore damaged natural resources and minimize the burden of contemporary agricultural technologies through a comprehensive approach that addresses all aspects of the system for better agricultural sustainability.

Subhash Palekar's Approach of ZBNF

Sh. Subhash Palekar's ZBNF (Zero Budget Natural Farming) aims to improve soil health by improving the soil biological activity by adding microbe inoculants and organic matter. The practices of Natural Farming include the addition of microbial cultures to enhance decomposition and nutrient recycling; use of local seeds; integration of crops, trees and livestock (mainly cows of native breeds); effective spacing of crops, contouring and bunds to conserve water; intensive mulching; extensive intercropping and crop rotations. Moreover, mulching has huge positive effect on SOC content due to enhanced soil and water conservation, lower average and maximum soil temperatures under mulch than in unmulched soil surface, return of biomass to the soil, increase in soil biodiversity, and strengthening of the nutrient cycling mechanisms (Lal and Kimble, 2000).

Low Budget Natural-Way Farming (LBNF)/Vrikshayurvedic Farming in India

A typical system of using herbal preparations from trees and plants for crop production known as Vrikshayurveda, a Sanskrit word that literally means (Indian plant science), has been practiced in India for centuries, dating back to 400 BCE, with Vriksha meaning trees and Ayurveda meaning the traditional Indian system of medicine (incorporated in Atharvaveda, the last of the four Vedas), is based on the idea of balance in living Vrikshayurveda, which means "Ayurveda for plants," refers to the study of plant life components in order to improve agricultural sustainability. According to Prof. C. Swaminathan, an architect and father of this concept defines Vrikshayurvedic farming as a scientific reorientation of eco-friendly system of Indian agriculture by utilizing traditional and natural means of food production and implementing those indigenous practices for crop cultivation by using trees, plants, and animal products, with the goal of improving output quality (Shankaraswamy,2023). Scientific testing of a comprehensive method of utilizing diverse trees, their parts, and products for agricultural production is required.

Kyusei Nature Farming Perspective in Japan

Farming without synthetic chemicals is known as Kyusei Nature Farming. It is founded on the ideas and concepts of nature farming espoused by Mokichi Okada (1882-1955), the founder of Sekai Kyusei Kyo and a Japanese naturalist and philosopher. Kyusei Nature Farming is a broad interpretation of the Japanese word "Kyusei" which meaning 'preserving'.

Okada was inspired to pursue his ultimate objective of "creating paradise on earth by abolishing disease, poverty, and violence" in 1931. Okada purchased land in Tokyo in 1936 and began experimenting with vegetable, flower, and grape production; in 1942, he began experimenting with rice agriculture. This was the beginning of Mokichi Okada's natural farming approach. After nearly six decades, Kyusei Nature Farming is gaining international recognition as a sustainable farming practice that conserves natural resources, protects the environment, and produces healthy and nutritious food. The Japanese word "Kyusei" means "saving," thus Kyusei Nature Farming implies that the world can be saved by using Kyusei Nature Farming practises.

Korean Natural Farming (KNF) perspective in Hawaii

Korean Natural Farming (KNF) involves collecting and culturing indigenous microorganisms (IMO) and reintroducing them into an agro ecosystem, which has been managed by people. Nutrients from various composts are applied to a plant using a foliar spray to minimize the use of off-farm inputs (Park and DuPonte, 2008). This farming approach has been extensively promoted by Han-Kyu Cho and his followers (Cho and Cho, 2010; Drake, 2012). This farming approach maximizes the use of on-farm resources, recycles farm waste, and minimizes external inputs while fostering soil health and is gaining popularity among farmers in Hawai'i that are interested in sustainable agriculture.

Korean Natural Farming recycles nutrients from various herbs or farm waste, and combines them into a foliar spray for fertilization based on growth stages of the crop. A recent article in Critical Review of Plant Science stated that foliar fertilization is an agricultural method of increasing importance in practical terms (Fernández and Eichert, 2009). The application of nutrient sprays may indeed be environmentally friendly since the nutrients are directly delivered to the plant in limited amounts. Additional advantages of using foliar KNF inputs include benefits to young seedlings with smaller root systems, reductions in the amount of N application, better nutrient uptake during reproductive stage due to a decrease in root activity, and the ability to modify the nutrient inputs accordingly. However, the effect of foliar nutrient application could vary based on the plant's growth conditions.

Scope of Natural Farming in India

Today Agriculture covers 38 percent of the land surface on the cultivated planet in which modern societies live. Humans rely heavily on soil capacity to sustain agricultural and livestock output, which accounts for more than 95 percent of world food production. Agricultural systems are key causes of soil and environmental degradation as well as a significant source of massive biogenic greenhouse gas emissions. Ploughing, improper farming techniques, deforestation, and overgrazing are all contributing factors. In India, fertiliser use has increased, and pesticide use in agriculture is evident for the protection of crop damaging pests, fungi, and weeds, among other things. Pests, weeds, and diseases cause about 15-25 percent of potential agricultural production to be lost. Overuse of agrochemicals will deplete the environment and ecology over time. Natural farming, on the other hand, has the potential to improve the environment and ecology for current and future generations.

Principles of Natural Farming

In Natural farming there are three principles involves with the use of the tree, its parts, and its products.

a. Biomass transfer technique (BMT): Leguminous tree leaves are commonly utilised as manures and mixed into soil prior to sowing/planting to provide nutrients for crop growth. These plants leaves are utilised for green manure, enhanced fallows, and even improved animal manure production. Green leaf manure is made from leguminous tree species, ideally N-fixing trees with high nitrogen content and a fast decomposition rate.

b. Tree leaf extracts: Tree leaf extracts / tonics can be used as foliar nutrition during various phases of crop growth as well as seed treatment to ensure early germination and growth. Secondary metabolites found in tree leaf extracts are capable of boosting growth in plants through physiological and biochemical changes. Secondary metabolites found in tree leaf extracts are capable of boosting growth in plants through physiological and biochemical changes.

c. Tree leaf extracts for crop protection: Botanicals and other derivatives such as oil, extracts, and powder prepared from tree leaves and other parts such as seed, kernel, and bark will be widely used for pest and disease control, as well as weed control, due to the growing demand for environmentally friendly, safe, and selective bio formulations for total health care in crop production. Secondary metabolites with antibacterial, fungicidal, and alkaloid properties will be used in leaf extracts of tree species with bio-pesticide capabilities to control pests and illnesses of the farmed crop. India is home to a diverse range of plants that could be used as botanical insecticides. Botanical pesticides make use of secondary metabolites, which has become increasingly significant in modern agriculture. They have proven to be an effective weapon against crop pests by inhibiting phytophagous insects' detrimental effects on behaviour, physiology, growth, reproduction, and other functions. Plant products have been used in India for over a century to reduce pest-related losses.

In natural farming, crop protection with diverse leaf extracts of tree species such as neem, Pongamia, *Aegle marmelos*, *Vitex negundo*, *Albizia amara*, *Anthocephalus cadamba*, *Adina cordifolia*, *Morinda tinctoria*, and dry fruits of 'kadukkai' is noticeable with greater efficacy. The pest and disease threat is also reduced by leaf extracts with higher peroxidase, polyphenol oxidase, and phenyl alanine activity.

According to ZBNF-adopter farmers, when chemical fertilizers are applied to the crops, the vegetative growth of the crop is very good and lush green. This attracts the insects/ pests to the crops. While in case of Jeevamritha, the leaves colour is not that much green, and therefore, menace of pests is limited. However, when infestation occurs, the farmers prepare different types of formulations (Kashayam) made up of locally available plant materials to control the pests (Ranjit Kumar *et al* 2020). Some of these are:

Neemastra is the most commonly used pest controlling solution which is prepared by the farmers. Cow dung, cow urine, neem leaves, and water are used for preparing the neemastra. The neem leaves are grinded into paste and added with water. The solution is directly applied to plants without any further dilution. For this, 5 kg of neem paste is added with around 2-3kg of dung, 10-20 litres of cow urine, handful of soil. The solution is fermented for about 48 hours. It was found that the farmers are making the solution ranging from 100-200 litres depending upon their usage and crops grown.

Brahmastra is prepared from five types of bitter leaves. Neem leaves are used along with the other bitter-tasting leaves, like custard apple, chillies, etc. Around 20-30 litres of cow urine is used and is boiled for about 2-3 hours. The solution is cooled for about 12 hours and is filtered using fine cloths. The solution is further diluted with about 15 litres of water for every 1 litre of Brahmastra. The farmers are using 10-20 litres of cow urine and 5kg of neem leaves in preparing Brahmastra.

Agniastra is prepared by adding 5 kg of neem paste with around 1 kg of tobacco leaves, 0.5 kg of chillies and 0.5 kilo of garlic paste. These are added in about 25-30 litres of cow urine and is cooled down for about 24 hours. The solution is then filtered and used. The solution is diluted before applying in the field for every half litre of Agniastra about 15 litres of water is added. Agniastra is considered to be effective against insects like Leaf Roller, Stem Borer, Fruit borer, Pod borer.

Tutikada rasam is prepared from datura leaves and cow urine. The leaves are boiled in cow urine for 2-3 hours and is cooled then it is filtered using a cloth.

Dashparini Kashyam It is prepared from ten types of plant leaves. The leaves of Neem, *Agele marmelos*, Calotropis, *Senna auriculata*, Papaya, Custard apple, Gauva, *Vitex negundo*, castor, Pomegranate, Nerium, Ocimum, Aloe vera, Tobacco, Datura, *Lantana camara* and *Pongamia pinnata* are used in preparing the solution. Green chilli and garlic are also crushed and added and mixed with 20 litres of cow urine. It is kept up to 45 days for fermentation.

The solution is filtered and sprayed after dilution. In about 8-10 litres of solution 100 litres of water is added for dilution.

Systematized Natural farming practices:

i. Whapasa-moisture (Soil aeration): Whapasa describes the situation in which the soil contains both air and water molecules and building up of humus. Thus, irrigating merely at noon in alternate furrows may be sufficient to meet the crops' moisture requirements, resulting in a considerable reduction in irrigation requirements in natural farming. Farmers, on the other hand, rarely adopt this technique. It reduces the overreliance on irrigation and improve aeration and soil moisture profile.

ii. Acchadana (Mulching): Under natural farming, three methods of mulching have been suggested, which avoids tillage, improve the soil condition of top soil, add organic matter and fertility with increased activity of soil biota.

- **Soil Mulch**: This protects topsoil from being destroyed by tilling during farming. It improves soil aeration and water retention. Deep ploughing should therefore be avoided.
- **Straw Mulch**: Straw mulch is made up of dried biomass waste from earlier crops. Through the activity of the soil biota, which is stimulated by microbial cultures, any type of dry organic material will breakdown and generate humus.
- **Live Mulch**: It is essential to develop multiple cropping patterns of monocotyledons and dicotyledons grown in the same field, to supply all essential elements to the soil and crops. Dicot group such as pulses are nitrogen-fixing plants. Monocots such as rice and wheat supply other elements like potash, phosphate and sulphur.

iii. Beejamritham (Seed treatment): Seeds, seedlings, and other planting materials are treated with beejamritham. Beejamritha protects new roots from fungus, as well as soil borne and seed-borne illnesses that typically plague plants following the monsoon season. It protects from seed and soil borne diseases, increase soil organic carbon, activate nutrients.

Preparation: Mix local cow dung, which is considered a natural fungicide, with cow urine (an anti-bacterial liquid), lime, and soil to make beejamritha. The excrement is wrapped in a cloth and submerged in urine for 12 hours. Cow pee is separated from the dung, the dung is pressed, and the urine is mixed with 50g of lime.

iv. Jeevamritha (Liquid inoculant): is a microbial culture that has been fermented. It not only offers nutrients, but it also functions as a catalytic agent, promoting the activity of soil microbes and increasing the population of native earthworms.

Preparation: Fill a barrel with 200 litres of water and add 10 kg fresh local cow dung, add 5 to 10 litres old cow urine, add 2 kg jaggery (a local variety of brown sugar), add 2 kg pulses flour finally, add a pinch of soil from the farm's bund. Stir the mixture thoroughly before allowing it to ferment in the shade for 48 hours. Jeevamritha is ready to be used. One acre of ground may be covered with 200 litres of Jeevamritha. The aerobic and anaerobic bacteria found in cow dung and urine proliferate during the 48-hour fermentation process as they consume organic components (like pulse flour and jaggery). A small amount of undisturbed soil functions as an inoculant for natural microorganisms and creatures. Jeevamritha also aids in the prevention of bacterial and fungal plant diseases.

- **Application of Jeevamritha:** Jeevamritha is sprayed twice a month in irrigation water or as a 10% foliar spray to the crops. The preparation can be stored for up to 15 days and then sprayed or mixed with irrigation water in the field. Jeevamritha is used for horticulture crops. The majority of the farmers use the drip irrigation method to apply Jeevamritha.

v. Ghanajeevamritha: Farmers in places with limited water supply create Ghanajeevamritha, a solid form of Jeevmaritha. During the off-season, farmers produce Ghanajeevamritha and store it for up to six months to use in the following crop season. Cow dung and urine are combined with pulse flour and jaggery, which is formed into balls and dried in the shade. Before being applied in the field, the dry product is stored in gunny bags and finely pulverised. Farmers use the Ghanajeevmritha broadcasting method to apply it before sowing the crop.

vi. Pre-monsoon dry sowing (PMDS): Beejamritha-treated seeds are dispersed in the field before the beginning of monsoon in rainfed and unirrigated areas. Beejamritha protects seeds from being eaten by birds and helps to battle unpredicted and less rain for the Kharif crop. The seeds germinate immediately the first rain falls, so the farmer does not have to wait. It aids in the avoidance of repeated sowing due to monsoon failure or delay.

vii. Poly-cropping: poly-cropping is a five-layer cropping system in which trees, fruits, vegetables, pulses, and cereals are planted in layers. These have various levels of canopy and maturation periods, so they are harvested at various times. Some of these crops can be used as a border crop, while others can be used as a trap crop, such as pulses, vegetables, and cereals. It so aids in the timely delivery of one or more crops to the farmer.

viii. Navadhanya: Navadhanya is the process of combining nine millets/crops and broadcasting them as green manure before the Kharif season. Farmers use the mature plants as manure for their Kharif crop.

ix. Panchamula: Panchamula is a powdered combination made up of the dried roots of fiveplants.

x. Kunapajala: The fermented product contained basic constituents such as amino acids, sugars, fatty acids, keratins, macro- and (almost all) micronutrients in available form. It was natural that plants responded very well to the nourishment provided by kunapajala and flourished with excellent growth, flowering, and fruiting. Every two weeks, make up a new batch of kunapajala. Three applications of kunapajala to seasonal vegetables will be needed: one in nursery, one during growth stage, and one prior to flowering. For fruit plants, four soil drenches in one year or 6 spray applications in a year would be appropriate. Changes in timetables, however, must be made.

• **Preparation method:** Cook animal flesh, crushed bones, rice husk, black gram and transfer to a 200L container and add items Honey, cattle urine, ghee, milk and water to make up the volume to 100L. stir the mixture twice a day for 1-3 months. 12 hours before straining stir the mixture so that supernatant can easily removed. The strained liquid should be filtered further and make the final volume 200L.

xi. Effective Microorganisms (EM) Technology: Effective Microorganisms (EM) are a type of beneficial microorganism microbiological material. Beneficial microorganisms are a vast category of microorganisms that benefit the human body and are used as beverages or food starters, such as Lactobacillus in yoghurt and yeast in bread, in animals as feed supplements, and in soils as Rhizobium, Actinomycetes, and mycorrhiza. Nitrogen fixation, nutrient mineralization, humus production and decomposition, and disease suppression are all examples of the beneficial bacteria' effects. In the natural farming system, EM technology is just one tool. The microbes used in this approach have been shown to improve soil microflora, promote crop root development, and help to recover contaminated environments.

Natural farming practices for Horticultural crops

• **Seed treatments**: Seeds dipped in milk, covered with mustard and seasame ash, and Brihati rubbed with cow dung sprout without dormancy.

• Vidanga seeds soaked with milk, rubbed with cow dung, dried, then liberally spread with honey will sprout. Trees developed from such seeds produce an endless supply of high quality blooms and fruits.

• **Smoking/smudging for flowering**: Trees which are smoked heavily by a mixture of ghee, Vidanga, milk water and honey become full of flowers and fruits in a short time.

• **Fruit sapling growth:** A cold mixture of fish, flesh and sesame should be given every 7 days.

• **Mango tree nourishment:** The mango trees are nourished well and are loaded with sweeter and bigger fruits if treated with water mixed with ripe fruit of ankota, ghee, honey and marrow of a boar. Mango is specially benefitted by cold fish.

• **Coconut:** The coconut trees become loaded with weight of huge fruits and also become free from diseases if smeared at night with extracts of fermented washings. liquor, seasame, black gram and wine mixed with honey, salt and vidang. Coconut trees always produce fruits as big as pots if they are treated with soup of black gram, saltwater, powder of barley in abundant quantity.

- **Pomegranate**: When saturated with fish water and earthworms treated with milk the pomegranate tree produces sweet and big fruits.
- **Jackfruit**: Watered with plenty of triphala decoction and immediately with husk the jack fruit tree bears many fruits which are very sweet and without seed. When badar, lakuch, dhatri, jambu trees are amply watered and sprinkled with urine everyday, they bear fruits of big size with nector like taste.
- **For Banana**: Kadali (Musa paradisiaca; banana) plant produces excellent fruits when watered with decoction of kankola (piper cubeba) and blood and fat of hog.
- **For juicy fruits**: The bilva and kapitha trees when sprinkled with mixture of jaggery, ghee, milk and honey bear plenty of juicy fruits.
- **For sweet fruits**: A tree which normally produce tasteless fruits starts producing sweet fruits if thickly smeared at the root with the paste of mixture made out of Vidang, Yashtimadhu, Yava, milk and jaggery.
- **To remove insects**: To remove insects both from roots and branches of the trees one should water the trees with cold water 7 days. The insects on the leaves can be destroyed by sprinkling the powder of ashes and brick dust.
- **For mutagen**: Seeds of Vartaka (Solanum melongena) be smeared with honey and ghee should inserted carefully inside a fresh kushmanda (Benincasa hispida) fruit and extracted after a fortnight. When it is sown it produces a creeper with leaves of kushmanda but the fruits it bears are those of Vartaka. It is indeed a wonder.

1. Eco-Friendly Bee Pollination

More than 75% of 115 leading crop species world-wide are dependent on or at the benefits from bee pollination, whereas, wind and self-pollination are sufficient for 28 crop species. Thereby, pollination improves the yield of horticultural crop species and contributes to one-third of global crop production, and pollination is underestimated by international policies, which is particularly alarming in times of horticultural intensification and diminishing pollination services. In horticultural crops such as in Kiwi, melons, pumpkins, watermelons, cocoa beans and quince yield reduction reported greater than 90% without pollinators (Marcelo Aizen *et al.*, 2019). Bee pollinated fruits are heavier and less malformed and reach high higher commercial grade. Increase red colour, sugar to acid ratio, firmness of fruits and vegetables, shelf-life, fruit size and growth rate. Bee pollination results in higher number of fruits, berries or seeds with better quality. Value of bee pollination is 30-50 times the value of honey and wax harvests (Shankaraswamy,2023).

2. Fruit Bagging

Bagging During maturity, many fruits should be bagged. By this bagging technique we can reduce the risks of physical damage and improves fruit colour at harvest time (Muchui *et al.*, 2010). It is a major fruit conservation technique that not only protects the fruit from insect-pests and diseases, but also influences the quality of fruit by changing the microenvironment during fruit production (Hamedi *et al.*, 2019). Fruit bagging is one of the most significant methods for producing the quality of fruit and has long been used in production of fruits (Zhai *et al.*, 2006). All fruit fly species are quarantine threats (Abbasi *et al.*, 2009). The treatment combination of 50 percent fruit thinning (Qin *et al.*, 2012) and bagging with white polythene of guava may be considered depending on no. of fruits per plant, diameter of fruit, length of fruit, weight of fruit, thickness of mesocarp and yield per plant as well as guava fruit quality (Rahman *et al.*, 2020). Bagging is an important physical protection method to pomegranate (*Punica granatum*).

3. Crop covers/grow covers are new initiatives to produce quality crop by giving protection from direct sunlight, prevent black spot on fruit, give uniform size and colour of fruits, it protects from outer atmosphere effect on fruit, reduce pesticide usage, protect from bird and animal and increase shining on fruits.

4. Bioformulations/ biologicals for production & protection

The role of microbes in sustainable horticulture has provided new insights to horticultural economy, and one of the direct benefits is the lesser reliance on chemical fertilizers and pesticides as continuous application of these chemicals not only showed detrimental effect on ecosystem but also resulted in health risks to human and animals, moreover, use of synthetic fertilizers and pesticides are intensive and costly and its application increases the production cost and the continuous use of fertilizers is responsible for the decline of soil quality and productivity. Recently in a study, Liang *et al.* (2013) also showed that excessive application of nitrogen and phosphorus fertilizers induces soil acidification and phosphorus enrichment during vegetable production.

Microbe-based formulations also known as bioformulations are more robust than synthetic chemicals as the formulation product of a single microbe may involve direct interactions with pathogens, and numerous mechanisms take part in disease suppression and plant growth promotion (Rodrigo, 2011).

However regarding bioformulation we see that there is no uniform definition available and various authors define it in their own way. Burges and Jones (1998) stated bioformulation comprises aids to preserve organisms, to deliver them to their targets, and once there to improve their activities, whereas Arora *et al.* (2010) define the term bioformulation to preparations of microorganism(s) that may be partial or complete substitute for chemical fertilization/pesticides.

Natural Farming Components	Benefits Expected
Jeevamritha: A fermented microbial culture derived from cow dung and urine, jaggery, pulse flour, and soil	Stimulate microbial activity to synthesize/ to make bio-available plant nutrients *in situ*; protect against pathogens; and promote earthworm activity
Beejamritha: a microbial coating for seeds, based on cow dung, urine, and lime	Protects young roots from fungus and seed borne or soil borne diseases
Acchadana mulching: Covering the topsoil with cover crops and crop residues	Protects soil from direct exposure from sunlight, produces humus, conserves top-soil, increases water retention, encourages soil fauna, prevents weeds
Whapasa: Soil aeration, a result of jeevamritha and acchadana- represents water management through improved soil structure and humus content	Increase water availability, water use efficiency, increased activity of earthworm, increase resilience to drought
Inter-cropping/Mixed cropping: Cultivation of combination of different types of crops with different canopy and maturity time simultaneously	Reduces demand of particular types of plant nutrients and increases availability of different types of crop produce on regular basis to augment farmers income

Conclusion

Horticultural crops are high value crops generating higher profits than staple food crops per unit land and the income thus generated can be used for different purposes in terms of eradicating hunger through meeting the food requirements and other necessities to access the food. Reduction of post-harvest losses of fruits and vegetables is a complementary means for increasing production. Horticulture crops are easily adaptable

Natural Farming may not be looked at as yield-enhancing farming practices, but as one of the alternative practices particularly for those regions which are rainfed and have less intensive farming practices (Kumar *et al*, 2023). It also helps in increasing the farmers' income through cost reduction by saving market-based farm inputs. The NF produce may be recognized as niche produce free from chemicals and with a better quality and taste. It will help the farmers in realizing higher price for the produce. The practice seems to be good for human health as well as environmental health. However, systematic research is required to validate the long-term sustainability of the production system to examine the nutrient availability in the soil and to the crops. Hence, there is a requirement for generating scientific evidence before scaling out in different agro-climatic regions with different crop combinations in order to prove this hypothesis and theory of change.

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PHYSIOLOGICAL DISORDERS AND THEIR CORRECTIVE MEASURES

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Introduction

Physiological disorder may be defined as the abnormal growth pattern caused by adverse environmental conditions high temperature, high light, low/high moisture, and nutrients excess/deficit. The symptoms of physiological disorders may appear disease-like, they can usually be prevented by altering environmental conditions. Physiological or abiotic disorders are distinguished from other disorders in that they are not caused by living organisms viz. viruses, bacteria, fungi and insects etc. but are caused by non-living, abiotic situations and cause a deviation from normal growth. Some non-infectious disorders are easy to identify, but others are difficult or even impossible. Most of them are not reversible once they have occurred. Physiological disorders are often caused by the lack or excess of something that supports life or by the presence of something that interferes with life. Physiological disorders can affect plants in all stages of their lives cannot be transmitted. Physiological disorders are serious in themselves but often affected by pathogens.

Various atmospheric and edaphic factors affect physiological functioning of plant in different manners and resulted in specific type of symptoms. However, symptoms developed by a particular factor in various crops follow almost similar pattern and can be distinguished from the symptoms developed by another factor. Different types of physiological disorders caused by variable atmospheric/ edaphic factors are listed below. Disorders resulting from the reactions to temperatures outside the optimum range during crop growth. Various disorders of this nature are freezing injury, chilling injury, and heat injury etc.

Nutrients

Imbalance supply of essential nutrients to the plant may also results in various types of physiological disorders. For example, calcium and boron play very critical role in fruit development and harvest quality and deficiency of these nutrients lead to the physiological malfunctioning and deterioration of yield and quality in many fruits. Bitter pit in apple, hen and chicks in grapes etc are important physiological disorders caused by nutrient imbalances.

Specific roles of essential nutrients and disorders

1. Nitrogen

Nitrogen is important constituent of proteins, amino acids, nucleic acids, chlorophyll, cytochromes, alkaloids, vitamins and coenzymes. It plays very important role in protein synthesis, photosynthesis, respiration, growth and reproduction.

- Stunted plant growth
- Complete chlorosis - older leaves are affected first because of high mobility
- Senescence of older leaves
- Slender and woody stem
- Anthocyanin production – purple colouration in leaf, stem and petiole – Tomato and maize
- Purple colouration is associated with chlorosis
- Complete Yellowing – Tan leaves
- General Starvation

2. Phosphorus

It is important constituent of nucleic acids, phospholipids (cell membrane), coenzyme NADP and energy currency ATP. It plays important role in protein synthesis through nucleic acids and ATP. Through part of coenzymes, it plays important role in energy transfer reactions of photosynthesis, respiration and other metabolism in plants.

- Stunted plant growth
- Dark green to blue green leaves (purple) – synthesis of anthocyanin pigments
- Purple coloration is not associated with chlorosis
- Older leaves are affected first because of high mobility
- Slender stem not woody
- Sickle leaf disease
- Pseudostem splitting in Banana

3. Potassium

Plant absorbs potassium in the form of K^+ cation. It is not a constituent of any organic compound in the cell. It is major contributor to osmotic potential of cell and regulates water balance. It serves as an activator of many enzymes – DNA polymerase. It regulates stomatal movement. It has vital role in phloem translocation.

- Mottled or marginal chlorosis of older leaves
- Necrotic areas develop at the tip and margins of the leaf – marginal scorching

- Plants growth remains stunted with shortening of internodes
- Stem may slender and weak
- Plant easily susceptible to pest and diseases – easily bend and lodging
- Marginal scorching and Tip drying of older leaves
- Uneven fruit ripening

4. Calcium

It is important constituent of cell wall found as calcium pectate in middle lamella. It maintains the structure and permeability of cell membranes. It acts as secondary messenger in the cell. It serves as activator of several enzymes - ATPase. Plays important role in cell division and cell enlargement. Calcium binds to a protein (calmodulin) to form calmodulin-calcium complex and regulate the metabolism

- Necrosis of growing meristematic regions of root, stem and leaves
- Downward hooking of young leaves - Deformation
- Short and highly branched root – Brown in colour
- Serrated leaf margins of young leaves
- Growing point die
- Tip Hooking
- Blossom End Rot in tomato

5. Magnesium

Plants use magnesium in the form of Mg^{++} cation. It plays significant role in chlorophyll synthesis and it occupies central position in chlorophyll. It acts as activator of several enzymes – Phosphorylase. It stimulates binding of ribosomal units during protein synthesis.

- Interveinal chlorosis mostly first at older leaves because of high mobility
- Inverted 'V' shape green colour at base of the leaf is the characteristic symptom of magnesium deficiency called as "sand drawn"
- Severe deficiency, leaf become white
- Reddening in cotton

6. Sulphur

It is constituent of amino acids - Cystine, Cysteine and Methionine. Sulphur is involved in protein synthesis. It is also important constituent of vitamins like biotin, thiamine and coenzyme A and ferredoxin. It is responsible for characteristic odour of onion and garlic as by sulphur glycosides

- Deficiency symptoms similar to N, but in younger leaves because of immobility
- Stunting of growth, complete chlorosis and anthocyanin production
- Tips and margins of the leaf roll in ward
- Stem becomes hard due to the development of sclerenchyma.
- Downward rolling of leaf
- Tea yellow

7. Iron

It is a structural component of cytochrome and ferredoxin which plays important role in light reaction in photosynthesis. It is cofactor nutrient of several enzymes - catalase and peroxidase. It is essential for chlorophyll synthesis

- Interveinal chlorosis mostly first at younger leaves because of immobility
- Interveinal chlorosis – In between the veins of leaf showing chlorosis and veins remain green in colour
- Extreme deficiency, leaf become white
- Lime induced chlorosis

8. Zinc

Plants absorb zinc in the form of Zn^{++} mainly from surface of soil. It is essential for synthesis of amino acid tryptophan which is precursor for auxin synthesis (IAA). It is activator of many enzymes - Carbonic anhydrase and alcohol dehydrogenase.

- Shortened internodes - Rosette habit of growth – circular cluster radiating leaves
- The size of the leaves is very much reduced - 'Little leaf disease'
- Small and distorted leaf – puckered appearance of leaf margins
- Long interveinal chlorotic streaks from base of the leaf to tip in the older leaves of maize and sorghum
- White Bud of Maize & Khira in paddy

9. Manganese

It is necessary for photolysis of water and O_2 evolution in photosynthesis. It is an activator of many respiratory enzymes – malic dehydrogenase and oxalo succinic dehydrogenase. It acts as cofactor nutrient of the enzyme nitrite reductase.

- Intervenous chlorosis associated with necrotic spots
- Chlorosis may occur on younger or older leaves depending on plant species
- Scattering of necrotic spots
- Pahla Blight in Sugarcane

- Grey spec & Speckled yellow

10. Copper

It is an important constituent of plastocyanin - protein involved in light reaction. It is also a constituent of several oxidizing enzymes - Ascorbic acid oxidase, cytochrome oxidase and poly phenol oxidase. It acts as cofactor nutrient for reductase enzymes like nitrite and hydroxylamine. It is also used for preparation of fungicide like Bordeaux mixture

- Production of dark green leaves with necrotic spots
- Necrosis at tip of the young leaves and then extend to base along the margins
- Twisted or malformed leaves.
- Chlorosis and Gummosis
- Die back & Exanthema in citrus
- Stone fruit in Guava
- Reclamation disease in Cereals

11. Boron

Plays role in cell elongation, nucleic acid synthesis, hormone and membrane response. Boron facilitates the translocation of sugars by forming sugar borate complex. It involves in cell differentiation and development. It is also involving in fertilization – pollen germination and pollen tube growth

- Black necrosis at the base of young leaves and terminal buds - death of shoot tip
- Loss of apical dominance and plant become highly branched
- Flower formation is suppressed
- Cracking and splitting of fruits
- Abnormal growth & Malformation
- Irregular seed setting
- Hen & Chicks in grapes
- Yellow Top in Lucerne
- Heart Rot in Sugar Beet
- Hollow heart in groundnut

12. Molybdenum

It acts as cofactor nutrient of the enzymes nitrate reductase and nitrogenase. Hence, it plays essential role in nitrogen metabolism and nodule formation

- Molybdenum deficiency causes interveinal chlorosis of older leaves
- Necrosis in the older leaves

- Flower formation is inhibited and premature flower drop
- Twisted leaf in cauliflower and broccoli
- Whip – Tail of Cauliflower

Nutrient management under natural farming

Nutrient management on natural farms should economically meet crop nutrient needs and avoid soil nutrient depletion, while maintaining or improving soil productivity without excessive nutrient losses. Soil nutrient availability is dependent on diverse soil chemical, physical, and biological properties, their interactions, and their interaction with the cropping system. While measurements can be made for many soil properties, crop performance is the best indicator of soil productivity. Farmers typically manage to minimize soil physical and chemical constraints to sustainable productivity through practices such as:

1. Applying organic materials such as manure, compost, and biofertilizers to supply nutrients and maintain soil organic matter
2. Growing cover crops to cycle soil nutrients and biologically fix atmospheric nitrogen
3. Diversifying crop rotations for more efficient recovery

Manure

Manure application is often valuable to organic production. However, applying manure to meet all of the crop nitrogen demand can lead to excessive soil phosphorus because crops remove more nitrogen than phosphorus. The excessive soil phosphorus is not likely to be harmful to crops but contributes to phosphorus loss in runoff and erosion and contamination of water bodies. Therefore, manure nitrogen needs to be complemented by biological nitrogen fixation or other nitrogen sources in organic systems.

Compost

Composting processes organic waste into material of higher nutrient concentration, and reduces the bulk of organic materials through carbohydrate and water loss during decomposition. Compost is often easier to handle than the bulk organic material, and the composting process kills some pathogens and weed seeds. Compost has less odour and fewer microbial pathogens, with less risk of microbial contamination of fresh produce than with raw manure.

For organic production of agronomic crops, manure, compost, and nitrogen fixation are the main sources of added nutrients. However, other organic products are used to enhance nutrient availability for high-value crops with varying nutrient composition and mineralization rates. As with manure and compost, the nutrient mineralization rates of such products are largely driven by the C:N.

Use of these products for lower value commodities is limited due to high purchase and shipping costs. Given the low nutritional content of compost, manure, and organic products on a mass basis (relative to fertilizer), economic feasibility of application decreases as distance from the source increases. Biofertilizer nitrogen-fixers, phosphorus-solubilizers, phosphorus absorbers, and humic acid. Nitrogen-fixers such as Rhizobium (in symbiosis with legumes),

Azospirillum, and Azotobacter convert atmospheric nitrogen into ammonia. Bacillus and Pseudomonas are examples of microbes found in phosphorus-solubilizing biofertilizers that lower the soil pH to dissolve soil-bound phosphate for plant availability and may be most effective for calcareous soils. Arbuscular mycorrhizal fungi take up soil phosphorus, zinc, and copper and transfer these to plant roots, but these are typically abundant in Nebraska agricultural soils. Humic acid is important to plant growth but is already abundant in most soils. A soil with 3 percent organic matter may have as much as 10–15 tons of humic acid in the surface soil layer; thus, adding a few more ounces per acre is unlikely to enhance crop growth and yield

Biofertilizers are products designed to provide enhanced nutrient availability and uptake, stimulation of crop growth, biological nitrogen fixation, and protection against insect pests and disease. Depending on the purpose, biofertilizer products can be applied to soil, seeds, or foliar tissue. Evidence to support product claims is often limited or mixed. Recent research suggests biofertilizers may be most beneficial in soils of low to moderate soil organic matter and nutrient availability or with foliar application. In contrast, biofertilizer applications to soils of >3 percent organic matter rarely results in measurable crop or soil benefits. Introduced microorganisms often fail to compete and survive with already wellestablished and resilient microbial communities

Cover crops

Cover crops can improve soil physical properties, nutrient cycling, and soil microbial activity. In addition, cover crops can scavenge residual nitrogen mineralized from soil and organic amendments before it is lost to volatilization, runoff, or leaching. However, like other sources of organic nitrogen, nitrogen contained in cover crop biomass is not entirely available to the next crop. It is important to consider the C:N of the cover crop residue. Species with high C:N (>20:1; e.g., grasses) result in net immobilization of soil nitrogen in the short term, whereas nitrogen will be more readily available following decomposition of species with low C:N.

Cover crops can improve soil physical properties, and soil microbial activity. Well-grown cover and catch crops can retain nitrogen that might otherwise be lost by volatilization, runoff, or leaching and also provide a source of fresh organic matter. Like other sources of organic nitrogen, nitrogen contained in cover crop biomass is not entirely available to the next crop. The legume crops should be selected as cover crop because nitrogen fixation by a legume can be especially useful for increasing soil nitrogen and balancing the abundant phosphorus and potassium supplied through manure or compost application.

Crop rotation

It can contribute to improved soil physical properties, nutrient availability, pest management, crop yield and nutrient use efficiency. Develop crop rotations that include legumes as a source of nitrogen. Crop rotation sequencing should try to match N release and timing to crop uptake demands. Legume crops in the rotation can result in a nitrogen credit for subsequent crops due to fixation of atmospheric nitrogen and less immobilization of nitrogen in comparison with a non-legume. Root architecture is critical for long-term crop rotation. Deep-rooted crops such as alfalfa can scavenge immobile nutrients like phosphate and leached nutrients like nitrate-nitrogen from deep soil layers, which can then be released near the soil surface with crop residue decomposition, making them available to succeeding crops in the rotation.

Green Manuring

Green manuring is growing in the field plants usually belonging to leguminous family and incorporating into the soil after sufficient growth. The plants that are grown for green manure known as green manure crops. The most important green manure crops are sunnhemp, dhaincha, pillipesara, cluster beans and Sesbania rostrata. In addition to source of nutrients green manuring improves soil structure, increases water holding capacity, decreases soil loss by erosion, reduces off season weed proliferation. Green manuring helps in reclamation of alkaline soils.

Fishmeal

Traditionally used as livestock feed supplement contains high quality of animal protein with essential amino acids like lysine, methionine and cysteine. Good source of B group vitamins like cyanocobalamine, choline, niacin, pantathonic acid and riboflavin. Rich in minerals like calcium, phosphorous, copper and iron and is also the source of some trace elements referred as unknown growth factors.

Feather meal

It comes from the poultry industry, primarily chickens and turkeys and occasionally from ducks. Feathers have a lot of keratins in them which is a natural fibre. They are naturally very high in nitrogen and one of the richest nitrogen sources found in nature. The nutritional content of the meal varies between 10-1-0 to 13-0-0 (N-P-K).

Molasses

It is a primary by-product in the fermentation industry and can be used in the sugar production. However, these processes generate large amounts of wastewater. The liquid waste of molasses is acidic, with a pH of 3.5 to 4.5, and has a high concentration of organic materials and soluble, as well as high biological oxygen demand and chemical oxygen demand. Molasses wastewater is rich in mineral elements including nitrogen, phosphorus, potassium, calcium, sulfur, micronutrients and organic matter. Therefore, it is a challenge worldwide to use molasses wastewater legitimately, as it cannot be directly disposed of in water bodies for the potential of being detrimental to the environment.

Seaweed

It is a bio-stimulant, has immense benefits for plant growth. Liquid seaweed fertiliser is the most popular choice among gardeners as solid fertilisers take time to become soluble in the soil. Seaweed fertilisers contain complex carbohydrates and various other essential minerals that plants need to grow healthily. To avoid using chemical fertilisers and reap the benefits of organic gardening, using seaweed as it is completely natural and sustainable.

Greensand

It is a type of sand that naturally occurring iron potassium silicate, which is harvested from ocean floors to use as a soil conditioner because the moisture is better than the regular sand. It is made with phosphoric acid, iron oxide, marine potash, lime, magnesia, silica, and other trace elements. Its green colour is due to its high amount of mineral content. It is considered as a valuable soil conditioner than as a fertilizer. Micro-pore spaces within glauconite can enable greensand amended soils to have improved water holding capacity and increased ability to store and retain nutrients.

Guano

Guano is a natural fertilizer is exceptionally rich in some plant nutrients and is highly sought after by organic farmers today. Guano is made up of droppings of sea birds such as booby birds, cormorants and gulls. Since they eat sea food, they are essential in bringing nutrients from the sea to the land.

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INSECT PEST MANAGEMENT IN NATURAL FARMING

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Introduction

Use of chemicals in crop production is on the rise with many new molecules being imported. Excess and indiscriminate use of inorganic chemicals has disrupted the ecosystem and balance of nature. Chemical pesticides destroy natural enemies, bees and non-target organisms. Resurgence of target pests and outbreak of secondary pests are other side effects. Moreover, the residues of pesticides in food products and environment have caused serious health problems. Decline in quality of produce due to pesticide contamination is also frequently reported. Hence, the non-chemical organic / natural farming, which avoids the use of inorganic and synthetic chemicals for crop cultivation can be the best available solution for sustainable agriculture.

Natural farming is an ecological production management system that promotes and enhances biodiversity, biological cycles and soil biological activity. The principal guidelines for organic / natural farming are to use materials and practices that enhance the ecological balance of natural systems which integrate the parts of the farming system into the ecosystem as whole. The primary goal of natural farming is to optimize the health and productivity of interdependent communities of soil life, plants, animals and people called 'one health concept'. Natural farming is a system where the laws of nature are applied to agricultural practices. This method works along with the natural biodiversity of each farmed area, encouraging the complexity of living organisms, both plants, and animals that shape each particular ecosystem to thrive along with food plants.

Insects are highly mobile and well adapted to farm production systems and pest control tactics. In the organic/natural farms, where the focus is on managing insects rather than eliminating them, success depends on learning the biological, ecological and behavioral information of the insects. Biological information means what the insect needs to survive can be used to determine if insect pests can be deprived of some vital resource. Ecological information is how the insect interacts with the environment and other species can be used to shape a pest resistant environment. Behavioural information is about both pest and beneficial insects and how the insect goes about collecting the necessities of life can be manipulated to protect the crops. According to the natural farming system, insect pest problems may be managed through cultural, mechanical or physical methods; development of habitat for natural enemies of pests and non-synthetic control such as traps, lures and repellents.

Components of pest management under natural farming

The following components may be included in pest management under natural farming system

1. Ecology based pest management and habitat diversification
2. Use of resistant varieties
3. Physical methods of pest management
4. Mechanical methods of pest management
5. Use of plant products / botanicals like astras
6. Use of insect pheromones
7. Biological control of pests
8. Indigenous technical knowledge

Ecology based pest management

Various eco-friendly tactics of pest management have to be integrated so as to avoid the use of chemical pesticides. The knowledge of interaction among plant, pest, natural enemies and environment is essential for effective pest management. When the balance of nature is disturbed by man-made interventions, nature strikes back in the form of pest outbreaks. Moreover, the pest status changes over years due to interaction of various biotic and abiotic factors. One has to thoroughly understand the reasons for outbreak of pests and their changing status and plan the management practices accordingly so as to prevent further outbreaks.

Habitat diversification

Habitat diversification makes the agricultural environment unfavourable for growth, multiplication and establishment of insect pest populations. The following are some approaches by which the pest population can be brought down.

1. Intercropping system

Intercropping system has been found favourable in reducing the population and damage caused by many insect pests due to one or more of the following reasons.

- Pest outbreak less in mixed stands due to crop diversity than in sole stands
- Availability of alternate prey
- Decreased colonization and reproduction in pests
- Chemical repellency, masking, feeding inhibition by odours from non-host plants.
- Act as physical barrier to plants.

The following table gives a few examples of intercropping system where reduction in damage level was noticed

Table 1. Effect of intercropping system on pest levels

No.	Crop		Pest reduced	Reference
	Main crop	**Intercrop**		
1.	Sorghum	Red gram	Earhead bug	Raheja (1973)
2.	Sorghum	Cowpea	*Chilo partellus*	Balasubramainian (2000)
3.	Pigeon pea	Sorghum	*Empoasca kerri*	Sekhar *et al* (1997)
4.	Green gram	Sorghum	*E. kerri*	Sekhar *et al* (1997)
5.	Ground nut	Sorghum	*E. kerri*	Sekhar *et al* (1997)
6.	Pigeon pea	Sorghum	*H. armigera*	Mohammed and Rao (1998)
7.	Chickpea	Wheat/ mustard/ Safflower	*H. armigera*	Das (1998)
8.	Sugarcane	Greengram / Blackgram	Early shoot borer	Rajendran *et al.* (1998)

Inter-planting maize in cotton fields increased the population of Araneae, Coccinellidae and Chrysopidae by 62.8-115.7% compared with control fields. Maize also acted as a trap crop for *H. armigera* reducing the second generation eggs and damage to cotton (Wu *et al.,* 1991). Intercropping pulses in cotton reduced the population of leafhopper on cotton (Rabindra, 1985) and Lablab bean in sorghum reduced the sorghum stem borer incidence. Hence it is highly important that appropriate intercropping systems have to be evolved where reduction in pest level occurs.

2. Trap cropping

Crops that are grown to attract insects or other organisms like nematodes to protect target crops from pest attack. This is achieved by

- Either preventing the pests from reaching the crop or Concentrating them in a certain part of the field where they can be economically destroyed

Table 2. List of successful examples of trap crop

No.	Main Crop	Trap crop	Pest
1.	Tobacco / cotton/ groundnut	Castor	*Spodoptera litura*
2.	Maize	Sorghum	Shoot fly, Stem borer
3.	Cotton	Onion / Garlic	*Thrips tabaci*

Growing of 2 rows of mustard as trap crop per 25 rows of cabbage is recommended for the management of diamond back moth. First mustard crop is sown 15 days prior to cabbage planting or 20 days old mustard seedlings are planted. Growing castor along the border of cotton field and in the irrigation channels act as indicator or trap crop for *Spodoptera litura.* Planting of 40 days old African tall marigold and 25 days old tomato seedlings (1:16 rows) simultaneously reduces *Helicoverpa* damage.

Growing trap crops like marigold which attract pests like American bollworm to lay eggs, barrier crops like maize/jowar to prevent migration of sucking pests like aphids and guard crops like castor which attracts *Spodoptera litura* in cotton fields was reported by Murthy and Venkateshwarulu (1998).

3. Fertilizer management

Plant growth is dependent on the nutritional status of the soil which in turn has indirect effect on pests. High levels of N fertilizer always favour insects and makes plants more susceptible to insect infestation (Rathore and Lal, 1994). On the other hand lower potassium supply favours the development of insects, while optimum and high K has depressant effects (Dale, 1988). The following table (Table 3) shows the role of nutrient management on pest levels. Application of jeevamrit enhances the level of potash in the plants and soil.

Table 3 Effects of host plant nutrition on insect pests

S. No.	Host plant	Insect	Response	Reference
1.	Rice	Thrips, GLH, Whorl maggot, Leaf folder	High K application reduced pest incidence	Subramanian and Balasubramanian (1976)
2.		Leaf folder, gall midge, BPH, Yellow stem borer, WBPH	High N levels increased pest population and damage	Upadhyay *et al.*(1981) Narayanan *et al.* (1973) Saroja and Raju (1981)
3.	Wheat	Cutworm *(Mythimna separata)*	High N increased incidence	Deol *et al.* 1987
4.	Sorghum	Shoot fly	High P reduced incidence	Bangar, 1985
5.	Cotton	Pink boll worm, leafhopper	High N increased incidence	Simwat *et al.* 1987, Purohit and Deshpande, 1992
6.	Chickpea	*Helicoverpa armigera*	N increased infestation, while, P and K reduced	Yadav, 1987

4. Planting dates and crop duration

Planting dates should be so adjusted that the susceptible stage of crop synchronizes with the most inactive period or lowest pest population. The plantings should be also based on information on pest monitoring, as the data varies with location. Crop maturity also plays an important role in pest avoidance. The following table (Table 4) shows the importance of planting dates on pest population and damage

Table 4. Role of planting dates on pest population and damage

No.	Host plant	Insect	Response	Reference
1.	Rice	Leaf folder	Early planted rice (up to 3rd week of June) suppressed population	Dhaliwal *et al.* (1988)
2.		BPH	Planting during end of July in Kharif and early in Rabi escapes attack in Andhra Pradesh	Krishnaiah *et al.* (1986)
3.		Gall midge	Lowest incidence if planted in August or October	Uthamasamy and Karuppuchamy (1986)
4.	Sorghum	Shoot fly	Advancing sowing date (September to October) decreased incidence	Kotikal and Panchbavi (1991)
5.	Cotton	Leafhopper	Higher incidence in late sown crop	Dhawan *et al.* (1990)
6.	Chickpea	Pod borer	For every 10 days delay in sowing 4.02% increase in pod damage	Devendra Prasad *et al.* (1989)
7.	Tomato	Whitefly	Incidence is less if planted within July to November	Saikia abd Muniappa (1989)
8.	Chillies	Thrips	Late planted crop severely affected by thrips and leaf curl virus	Bagle (1992)

5. Planting density

Plant nutrient status, interplant spacing, canopy structure, etc., affect insect behaviour in searching food, shelter and oviposition site. It also affects natural enemy population. The effect of plant density on pest population is shown in Table 5.

Table 5. Effect of plant density on pest population

S. No.	Crop	Spacing/ density	Insect	Response	Reference
1.	Rice	Dense planting	Leaf folder, BPH	High incidence	Kushwaha and Sharma (1981); Kalode and Krishnaiah (1991)
2.	Chickpea	Dense plant population	*H. armigera*	High incidence	Yadav (1987)
3.		Less plant population	*Aphis craccivora*	High incidence	Lal *et al* (1989)

4.	Sugarcane	Dense seed rate	Top shoot borer	Low incidence	Singla and Duhra, 1990
5.			Early shoot borer	High incidence	

6. Destruction of alternate host plants

Many insects use a wide range of cultivated plants especially weeds as alternate hosts for off season carry-over of population. Matteson et al. (1984) reported that weeds around the crop can alter the proportion of harmful and beneficial insects that are present and increase or decrease crop damage.

Table 6. Effect of alternate hosts on pest damage

S. No.	Crop	Pest	Alternate host to be removed	Reference
1.	Groundnut	Thrips	*Achyranthus aspera*	Mohan Daniel *et al.* (1984)
2.	Rice	Gallmidge	Wild rice *(O.nivara*)	Kalode and Krishnaiah (1991)
3.		GLH	*Leersia hexandra*	
4.			*Echinochloa colonum*	
5.			*E.crusgalli*	
6.			*Cynodan dactylon*	
7.		WBPH	*Chleres barbata*	
8.	Sorghum	Earhead midge	Grassy weeds	Prem Kishore (1987)

Destruction of off types and volunteer plants, thinning and topping, pruning and defoliation and summer ploughing are other cultural methods which can reduce pest load in field.

7. Water management

Availability of water in requisite amount at the appropriate time is crucial for proper growth of crop. Hence, water affects the associated insects by many ways such as nutritional quality and quantity, partitioning of nutrients between vegetative growth and reproduction etc. The following table shows the effect of irrigation on pest population / damage.

Table 7. Effect of irrigation on pest population / damage

No.	Crop	Insect	Response	Reference
1.	Rice	Mealy bug	Continuous stagnation of 5 cm water reduced incidence	Gopalan *et al.* (1987)
2.	Rice	Caseworm and BPH	Draining of water to field capacity reduces incidence	Thomas (1986)

3.	Fruit tree nursery	Termite	Copious irrigation reduces incidence	Butani (1987)
4.	Groundnut	Aphids	Copious irrigation increased incidence	Rao *et al.* (1991)

8. Crop rotation

Sustainable systems of agricultural production are seen in areas where proper mixtures of crops and varieties are adopted in a given agro-ecosystem. Monocultures and overlapping crop seasons are more prone to severe outbreak of pests and diseases. For example growing rice after groundnut in garden land in puddled condition eliminates white grub.

Use of resistant varieties

Host plant resistance forms an important component of non-chemical method of pest management. Several resistant varieties of crops have been evolved against major pests, through intensive breeding programmes. Development of varieties with multiple resistance to several pests / diseases is essential.

Physical methods

The following are some examples of the use of physical methods of insect control

- Use of red earth or vegetable oil at one per cent has been found to effectively control damage by *Callosobruchus chinensis* in stored pulses.
- Sun drying of sorghum seeds kills rice weevil and red flour beetle without affecting germination of seeds.
- Biogas fumigation for 5 days period caused mortality of eggs, grubs, adults of pulse beetle *C. chinensis* (Mohan *et al.,* 1987; 1989)
- Drying seeds (below 10% moisture level) prevents insect development.
- Hot water treatment of rice seeds at 52 to 54 °C for 15 minutes will kill white tip nematode infesting rice.
- Cold storage of fruits and vegetables to kill fruit flies (1-2° C for 12-20 days)

Mechanical methods

1. Mechanical destruction

- Hand picking of caterpillars
- Hooking of rhinoceros beetle adult with iron hook
- Sieving and winnowing for stored product insect control
- Shaking plants to dislodge caseworm in rice and to dislodge June beetles from neem trees

2. Mechanical exclusion

- Wrapping of fruits against pomegranate fruit borer

- Banding with grease against mango mealy bug
- Trenching against larvae of red hairy caterpillar
- Tin barrier around coconut tree trunk to prevent rat damage
- Rat proof structure in storage go downs

3. Appliances based on mechanical control method

- Light trap
- Yellow sticky traps for attracting aphids and jassids
- Bait trap - fish meal trap for sorghum shoot fly
- Methyl eugenol trap for fruit flies
- Probe trap for stored product insects
- Pheromone trap for various adult insects
- TNAU automatic insect removal bin for stored product insects

Use of botanicals in pest management

Grainge and Ahmed (1988) listed about 2400 plant species with pesticidal properties (insecticide, acaricide, nematicide, fungicide etc. which are distributed in 189 plant families). Neem oil 3% and neem seed kernel extract (NSKE) 5% with liquid soap 0.05% was proven to be effective against major pests of rice, sucking pests of cotton and vegetable. Neem cake applied at 250 kg/ha at last ploughing before sowing has been found effective against cotton stem weevil, soil insects, soil pathogens and nematodes of many crops.

Neem seeds contain more than 100 compounds among which azadirachtin has been found to be biologically most active. The biological effects of neem products are insect growth regulation, feeding deterrent and oviposition deterrent effect.

In addition to neem which belongs to Meliaceae, plants belonging to Annonaceae, Asteraceae, Fabaceae, Labiatae, Rutaceae and many other families have been found to possess insecticidal activity. Research in this field will provide valuable information that will help in managing insect pests with plant products.

Herbal extracts in pest management

Five leaves extract

Collect the leaves of *Azadirachta indica*, *Vitex negundo*, *Calotropis gigantea* and *Datura metel* and *Aloe vera* each weighing 1 kg. Cut the leaves into small pieces, grind with cow urine at 2 litres per kg of fresh leaves and allowed for fermentation for 15 days with frequent stirring. Filter the contents and apply as foliar spray @ 10 per cent for the management of insect pests in organic or natural farming.

The herbal plants for preparation of five leaf herbal extract can be selected based on the properties *viz.,* availability in the local areas, pesticidal nature of the herbal plants and extraction properties. The studies conducted at Tamil Nadu Agricultural University revealed that foliar application of five leaves herbal extract @ 10 % effectively managed the sucking pests like whiteflies, aphids, thrips and red spider mites in cotton and bhendi.

3G extract

3 G extract consists of 1 kg of ginger, 1 kg of garlic and 1 kg of green chillies. Grind ginger, garlic and green chillies with cow urine at 2 litres / kg, mix together, keep it for fermentation up to 15 days with regular stirring twice a day. Filter the contents and apply as foliar spray @ 5 per cent for the management of sucking pests and leaf feeding insects.

Studies conducted at Tamil Nadu Agricultural University revealed that foliar application of 3 G extract @ 5 % effectively managed the sucking pests like whiteflies, aphids, thrips and red spider mites in cotton and bhendi.

Astras in pest management

1. Agniastra

This is also popular among the farmers practicing natural farming in India. It consists of 20 litres of cow urine, 5 kg of neem leaves, 2 kg of green chillies, 1 kg of garlic and 1 kg of tobacco leaves. All the 5 ingredients are to be mixed in a mud pot and boiled. The extract will be kept as such as for 48 hours.

Usage

To the filtrate, 100 litres of water and 3 litres of cow urine should be added. This is sufficient for spraying an area of one acre to repel all types of insect pests.

2. Brahmastra

- Cow's urine - 10 litres
- Neem leaves - 3 kg
- Custard apple leaf - 2 kg
- Papaya leaf - 2 kg
- Pomegranate leaf - 2 kg
- Guava leaf - 2 kg

Mix all the above contents and boil 5 times at some interval and allow the contents to cool. Keep for 48 hours then filter the extract.

Dosage

Dilute 2 litres of extract in 100 litres of water and spray for an area of one acre. It is effective against sucking pests and pod/fruit borers.

3. Neemastra

- Neem leaves - 5 kg
- Cow's urine - 5 litres

- Cow dung - 5 kg
- Water - 100 litres

Mix all the above contents and ferment for 48 hours with intermittent stirring. Filter the contents and the extract is ready for use.

Dosage

The extract prepared in 100 litres of water has to be sprayed as such without diluting further to cover an area of one acre. Effective against sucking pests infesting most of the crops.

Pheromones in Pest Management

Pheromones are chemical substances released by insects which attract other individuals of the same species. Sex pheromones have been used in pest management in the following ways

a. Monitoring

b. Mating disruption

c. Mass trapping

These methods can be successfully included in organic method of pest management. Sex pheromones of the following insects are commercially available in market.

Table 9. Commercially available sex pheromones for insects

No.	Common Name	Scientific name
1.	American bollworm	*Helicoverpa armigera*
2.	Pink bollworm	*Pectinophora gossypiella*
3.	Spotted bollworm	*Earias vitella*
4.	Spiny bollworm	*Earias insulana*
5.	Tobacco cutworm	*Spodoptera litura*
6.	Early shoot borer of sugarcane	*Chilo infuscatellus*
7.	Yellow stem borer of rice	*Scirpophaga incertulas*
8.	Diamond back moth	*Plutella xylostella*
9.	Mango fruit fly	*Bactrocera dorsalis*
10.	Melon fruit fly	*Bactrocera cucurbitae*

Aggregation pheromones of red palm weevil and Rhinoceros beetle of coconut are also available in market. Different types of pheromone traps such as sleeve type trap, delta and sticky traps are also manufactured and sold by different firms. In addition to the above many new pheromones of field and storage pests are being manufactured by commercial firms and will be available to farmers soon.

Biological control

Management of pests and disease causing agents utilizing, parasitoids, predators and microbial agents like viruses, bacteria and fungi is termed as biological control. It is an important component of IPM. Conservation is a method of manipulating the environment to protect the bio-control agents. ICAR and State Agricultural Universities play an important role in identifying potential bio-control agents. The commercial bio-control laboratories mass produce the agents and distribute among the farmers. There are at least 20 bio-pesticides production laboratories in Tamil Nadu managed by co-operative and private sectors. The following are the bio-control agents mass produced in Tamil Nadu.

Table 10. Commercially available bio-control agents

No.	Biocontrol agents	Pests managed
I.	**Parasitoids**	
	Egg parasitoids	
1.	*Trichogramma sp.*	Borers, bollworms
2.	*Telenomus remus*	*Spodoptera litura*
	Egg larval parasitoid	
3.	*Chelonus blackburni*	Cotton bollworms
	Larval parasitoids	
4.	*Bracon brevicornis*	Coconut black headed caterpillar
5.	*Goniozus nephantidis*	Coconut black headed caterpillar
6.	*Elamus nephantidis*	Coconut black headed caterpillar
7.	*Bracon kirkpatrici*	Cotton bollworms
8.	*B. hebetor*	Cotton bollworms
	Pupal parasitoids	
9.	*Brachymeria spp.*	Coconut black headed caterpillar
10	*Tetrastychus Israeli*	Coconut black headed caterpillar
11.	*Trichospilus pupivora*	Coconut black headed caterpillar
II.	**Predators**	
12.	*Chrysoperla carnea* (Green lacewing)	Soft bodied homopteran insects
13.	*Cryptolaemus montrouzieri* (Australian lady bird beetle)	Mealy bugs
	III Insect Pathogens	
14.	NPV of *Helicoverpa armigera* (Virus)	*Helicoverpa armigera*
15.	NPV of *Spodoptera litura* (Virus)	*Spodoptera litura*

16.	*Bacillus thuringiensis* (Bacteria)	Lepidopteran insects
17.	*Beauveria bassiana* (Fungus)	Many insect pests

Even though many commercial bio-control laboratories are involved in production of these agents, they are hardly sufficient to cover less than one percent of the total cultivated area. Hence, there is a vast scope for improvement.

Indigenous Technical Knowledge in natural farming

The knowledge of traditional agriculture with millions of farmers should be utilized and modern technology in agriculture should be blended with traditional wisdom. The following are certain practices of farmers which they have been following time immemorial

- Diluted cow dung slurry sprinkled to hasten paddy germination.
- Coconut fronds cut into small bits erected as perches in field to attract nocturnal birds which preys upon rats.
- Chilli mash and garlic juice sprayed to control rice earhead bug.
- Application of common salt at 1 - 1.5 kg/ palm of coconut gives insect resistance and prevents button shedding.
- Use of scarecrows to ward off bird pests in day time, which also serve as perches to nocturnal predatory birds.
- Use of Kavankal where stones are released from slings to scare away birds
- Ploughing of field during summer months (April-May) (Agninakshatra) when temperature is around 40 - 45 °C brings about killing of soil insects, pathogens, nematodes and pupae of lepidopteran pests.
- Treating stored pulses with red earth to prevent insect damage.
- Use of Tanjore bow trap, a common traditional gadget to kill rats in rice fields of Cauvery delta.
- 'Vrikshayurveda", a science of plant health, similar to 'Ayurveda" which is science of human life deals with maintenance of plant health and provides literature on control measures for control of pests and diseases.

There are many such practices based on traditional wisdom of farmers in different regions of the country. Scientific bases behind such practices if established based on research would help in including them in management measures.

Conclusion

Natural farmers' primary strategy in controlling pests and diseases is prevention. They build soil organic matter through the use of cover crops, compost and biologically based soil amendments such as jeevamrit. This produces healthy plants which are better able to resist insect feeding. Farmers also rely on diverse population of soil organisms, insects, birds and other organisms to keep pest problems in check. As a last resort, astras are sprayed when the pest population increases.

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BIO-INPUTS FOR PLANT PROTECTION IN NATURAL FARMING

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Introduction

Pests are one of the serious problems faced by farmers practicing organic farming. Synthetic pesticides that have been commercialized are halogenated hydrocarbons or organophosphates which have long environmental half lives and are suspected to possess toxicological properties than most of natural compounds. Considering above and several other factors there is a growing need for alternative, environmentally benign, toxicologically safe, more selective and efficacious pesticides. Botanicals being plant secondary metabolites, thus offer an attractive and favourable alternative for pest management. Documented scientific literature also support the fact that plant secondary metabolites are involved in the interaction of plant with other species, primarily in the defence response of plants against pests. Thus, the secondary compounds called botanicals represent a large reservoir of chemical structures with pesticidal activity. This resource is largely untapped for use as pesticides. There are several advantages of botanical pesticides like fast degradation by sun light and moisture or by detoxifying enzymes, target specific and less phytotoxicity which provokes researcher to use botanicals in pest management. Higher plants produce diverse array of secondary metabolites which include phenolics, terpenes, alkaloids, lignans and their glycosides. These play significant role in plant defence system and offer an array of structural prototypes for development of lead molecules which can serve as new pest control agents.

The knowledge of pest to which particular plant is resistant may provide useful information for predicting what pests may be controlled by secondary metabolites derived from a particular plant species. The discovery process for botanical pesticides is more cumbersome as compared to synthetic counterparts but less environmental load caused by botanical pesticides makes them an attractive alternate. The number of options that must be considered in discovery and development of a natural product as pesticide is larger than for a synthetic pesticide. Further, more complexity, limited environmental stability and low activity of many biocides from plants, compared to synthetic pesticides are discouraging. However, advances in chemistry and biotechnology are increasing the speed and ease with which man can discover and develop secondary compounds of plants as pesticides. All these advances combined with increasing need and environmental pressures are greatly increasing the interest for the production of botanical pesticides.

Phytochemicals are classified as either primary or secondary plant metabolites. Of the estimated 3,08,800 plant species, very few have been surveyed and most remained unexploited and unutilized for pesticidally active principles. Till date, about 2,400 plant species have been reported to possess pesticidal properties belonging to 189 families among which about 22 families contain more than 10 plant species in each family with anti insect properties. Approximately, more than 350 insecticidal compounds, more than 800 insect feeding deterrents and quite a good number of insect growth inhibitors and growth regulators have been isolated from various plant species but, apparently only few have achieved the commercial status.

Among the currently marketed botanical pesticides in the world, major ones include pyrethrins, rotenone, nicotine, ryanodine, sabadilla, neem based products and toosendanin. During last few years, plant essential oils comprising mono and sesquiterpenoids are being developed as green pesticides. Some of these oils are well known insect toxins, repellents and deterrents. Rosemary oil as hexacide has been released and is effective against aphids, whiteflies, thrips and mites on a variety of crops like cotton, strawberry, grapes, squash and many ornamentals.

Mode of action of botanicals

Over 100 insects belonging to 10 different orders *viz.,* Orthoptera, Dictyoptera, Lepidoptera, Homoptera, Heteroptera, Diptera, Coleoptera, Hymenoptera, Isoptera and Thysanoptera) and another 100 non-insect pests can be controlled successfully using plant products. Although plant products are basically stomach poisons, contact and systemic actions have been reported in some instances. They act as pest repellants, disruptors of mating and sexual communication, sterilants, growth retardant, oviposition deterrents, antifeedants and lethal toxins. Plant products also act as inhibitors of spore germination and growth retardants of bacteria and fungi, and prevent penetration of root nematodes.

Repellents

The chemical that causes insect to orient their movement away from the source is called as insect repellent. For example, neem repells the lepidopteran caterpillars, BPH and basil, *Ocimum basilicum*, lemon and eucalyptus repells *Corymbia citriodora*.

Antifeedants

Quassionoids isolated from volatile oil from *Vitex negundo* exhibited antifeedant activity against *Plutella xylostella*. Extracts of *Pogamia glabra* and *Tephrosia purpurea* showed antifeedant activity against fourth instar larvae of *Spodoptera litura* infesting varieties of crops. Extracts from calyxes of *Hibiscus sabdariffa*, fruit pericarps of *Thespesia populnea* and leaf of *Sida acuta* exhibited antifeedant activity against *Earias vitella*.

Compounds from *Azadirachta indica* and *Acorus calamus*, aqueous suspension of leaf tissues of *Ocimum basilicum* and a limonoid from the root bark of *Turraea nilotica* exhibited significant antifeedant activity against the larvae of *Leptiontarsa decemlineata*. Organic extracts of *Austroeupatorium inulaefolium* was found to be a feeding deterrent against *Sitophpilus oryzae*. Sesquiterpenoids of lactarane, isolactarane, marasmane and 13 normarasmane 8 keletons from *Lactarius* spp. inhibited feeding by *S.granarius*.

Insecticidal action

Sesquiterpenoids from *Celadtrus rosthorniianu,* C*. angulatus* and *C.paniculatus* were found to possess insecticidal activities against *Spodoptera litura*. Seeds of *Tephrosia candida*, stem bark of *Mundulea suberosa* and seeds of *Anona squamosa* were found to possess a fairy high degree of insecticidal potency against *S. litura*. Methanolic extracts of seeds of *Thevetia neriifolia* and *Pongamia glabra* and roots of *Nerium oleander* at 1% petroleum ether extract of *Curcuma longa*, an wilforine and alkaloid obtained from *Tripteriygium wilfordii* were found to be toxic to *P. xylostella*. Extracts of *Aesculus indica* flowers caused 70 per cent mortality of *Scirpophaga incertulus* 48 h after treatment. Aqueous extracts of *Parthenium hysterophorus* caused 52.8 per cent mortality of *Paplio demoleus*.

Piperine and its dihydrosaturated derivative (amide alkaloids) from *Piper guineense* exhibited the most potent activity against *Chilo partellus*. Aqueous extracts of the outer pulp of *Melia azedarach* and *Allium sativum* at 10 g/litre caused 91.7 and 85 per cent mortality of *Pthorimaea opercullella* larvae. A sesquiterpene polyol ester angulatin A isolated from the root bark of *Celastrus angulatus* and cold alcohol extracts of *P. hysterophorus* exhibited insecticidal effects against *Aphis gossypii*. Sesquiterpene poligodial from *Polygonum hydropiper*, extracts from *Tagetes patula*, garlic, passion fruit, avocado and guava and chamomile oil were found to be effective against *Myzus persicae*.

Extracts of flowering spikes of the *Phalaris minor* and *Arundo donax* at 100 ppm caused mortality of *Rhopalosiphum maidis* and gramine was the indole alkaloid found in the extracts. The ripe fruit of *Morinda citrifolia* was found to be toxic to *Drosophila melanogaster*, *D. simulans* and *D.mauritiana*. Orange, *Citrus chinensis* and grape fruits *Citrus paradise* peels, clove oil, citronella oil and lemon oil, groundnut oil, *Urtica dioica*, leaves of *Ricinus communis* and oil of *Diplolophium africanum* were found toxic to *Callosobruchus maculates.* Flowers of Jasminum, Pyrethrum, Bougainvilla, Callistephus, Caeasalpinia, Cassia, Tridax, Pongamia, Barelaria, Lantana, rhizomes of *A. calamus*, guava and eucalyptus leaves and *Pachyrhizus erosus* were found to be toxic to *Sitophilus oryzae*. Turmeric powder, *A.calamus* rhizomes, leaves of *Calotropis procera*, essential oil of *Pimpinella anisum* and *Mentha piperita*, methanol extract of *Datura metal* and cassia oil 0.2% were found to possess insecticidal activity against *Tribolium castaneum.*

Petroleum ether and ether extracts of sweet flag, allitin based on the active principle of garlic containing a mixture of diallyl di and trisulfides and a combination of citronella and *V. negundo* oils (1:1) were found to be toxic to *Sitotroga cerealella*. Turmeric, black pepper and cardamom as such dissolved in absolute ethyl alcohol at 0.1 ml/10 g and calamus oil at 30 g / insect caused cent per cent mortality of *Lasioderma sericorne* adults.

Growth retardants

Crude extracts and chloroform extract of *Ajuga nipponensis* exhibited strong growth regulatory activities against fourth instar larvae of *P.xylostella*. The methanol extract of *Persea indica* containing diterpene, produced larval mortality and reduced the growth rate of *H. armigera*. Steroidal saccharide esters from *Physalis peruviana* inhibited the larval growth of *H zea*. Flavone glycoside rutin from *Solanum incanum* and *Essenbeckia punila* and ergoline alkaloids from *Ipomoea parasitica* exhibited the growth retardant activity against *H.virescens*. Crude extracts of wood and bark of *Melia azedarach, A. indica, Eucalyptus maundina, Lantana camara* and *Cassia fistula* and ether extracts of *Tribulus terrestris* and *P. hysterophorous* exhibited growth retardant activity against *Dysdercus* spp. Rotenone isolated in 1895 by Geoffrey from dried roots of *Derris elliptica, D. malaccensis* (4-5%), *Lonchocarpus utilis, L. urucu* (8-10%) and *Tephrosia* sp. acts as respiration inhibitor.

Use of botanicals in pest management

Grainge and Ahmed (1988) listed about 2400 plant species with pesticidal properties (insecticide, acaricide, nematicide, fungicide etc. which are distributed in 189 plant families). Neem oil 3% and neem seed kernel extract (NSKE) 5% with liquid soap 0.05% was proven to be effective against major pests of rice, sucking pests of cotton and vegetable. Neem cake applied at 250 kg/ha at last ploughing before sowing was found effective against cotton stem weevil, soil insects, soil pathogens and nematodes of many crops.

Neem seeds contain more than 100 compounds among which azadirachtin has been found to be biologically most active. The biological effects of neem products are insect growth regulation, feeding deterrent and oviposition deterrent effect. In addition to neem which belongs to Meliaceae, plants belonging to Annonaceae, Asteraceae, Fabaceae, Labiatae, Rutaceae and many other families have been found to possess insecticidal activity. Research in this field will provide valuable information that will help in managing insect pests with plant products.

Preparation and application of astras for pest management

1. Agniastra

This is also popular among the farmers practicing natural farming in India. It consists of 20 litres of cow urine, 5 kg of neem leaves, 2 kg of green chillies, 1 kg of garlic and 1 kg of tobacco leaves. All the 5 ingredients are to be mixed in a mud pot and boiled. The extract will be kept as such as for 48 hours.

Usage

To the filtrate, 100 litres of water and 3 litres of cow urine should be added. This is sufficient for spraying an area of one acre to repel all types of insect pests.

2. Brahmastra

- Cow's urine - 10 litres
- Neem leaves - 3 kg
- Custard apple leaf - 2 kg
- Papaya leaf - 2 kg
- Pomegranate leaf - 2 kg
- Guava leaf - 2 kg

Mix all the above contents and boil 5 times at some interval and allow the contents to cool. Keep for 48 hours then filter the extract.

Dosage

Dilute 2 litres of extract in 100 litres of water and spray for an area of one acre. It is effective against sucking pests and pod/fruit borers.

3. Neemastra

- Neem leaves - 5 kg
- Cow's urine - 5 litres
- Cow dung - 5 kg
- Water - 100 litres

Mix all the above contents and ferment for 48 hours with intermittent stirring. Filter the contents and the extract is ready for use.

Dosage

The extract prepared in 100 litres of water has to be sprayed as such without diluting further to cover an area of one acre. Effective against sucking pests infesting most of the crops.

Preparation and application of herbal extracts for pest management

1. Five leaves extract

Collect the leaves of *Azadirachta indica*, *Vitex negundo*, *Calotropis gigantea* and *Datura metel* and *Aloe vera* each weighing 1 kg. Cut the leaves into small pieces, grind with cow urine at 2 litres per kg of fresh leaves and allowed for fermentation for 15 days with frequent stirring. Filter the contents and apply as foliar spray @ 10 per cent for the management of insect pests in organic or natural farming.

The herbal plants for preparation of five leaf herbal extract can be selected based on the properties *viz.,* availability in the local areas, pesticidal nature of the herbal plants and extraction properties. The studies conducted at Tamil Nadu Agricultural University revealed that foliar application of five leaves herbal extract @ 10 % effectively managed the sucking pests like whiteflies, aphids, thrips and red spider mites in cotton and bhendi.

2. 3G extract

3 G extract consists of 1 kg of ginger, 1 kg of garlic and 1 kg of green chillies. Grind ginger, garlic and green chillies with cow urine at 2 litres / kg, mix together, keep it for fermentation up to 15 days with regular stirring twice a day. Filter the contents and apply as foliar spray @ 5 per cent for the management of sucking pests and leaf feeding insects.

Studies conducted at Tamil Nadu Agricultural University revealed that foliar application of 3 G extract @ 5 % effectively managed the sucking pests like whiteflies, aphids, thrips and red spider mites in cotton and bhendi.

3. Dashparni Ark

Materials required	Quantity in kg or litres
Neem (*Azadirachta indica*) leaves	5 kg
Lantana (*Lantana camara*) leaves	2 kg
Pungam (*Pongamia pinnata*) leaves	2 kg
Nerium (*Nerium oleander*) leaves	2 kg
Jatropha (*Jatropha curcas)* or Castor (*Ricinus communis)* leaves	2 kg
Guduchi (*Tinospora cordifolia*) leaves	2 kg
Custard apple (*Annona squamosa*) leaves	2 kg
Calotropis (*Calotropis gigantea*) leaves	2 kg
Papaya (*Carica papaya*) leaves	2 kg
Vitex (*Vitex negundo*) leaves	2 kg
Cow urine	5 litres

Cow dung	2 kg
Water	170 litres

Method of Preparation

Take a 200 litre plastic drum. Pour 170 litres of water. Soak all 10 different leaves given above in the water. Pour 5 litres of cow urine and 2 kg of cow dung on top of the submerged leaves. Mix them well and leave it for 5 days. On sixth day, add 5-7 litres of water and again thoroughly mix all the contents. Leave the contents as it is for 30 days. The container should be kept in the shade and covered with a wire mesh or mosquito net to prevent houseflies from laying eggs and the formation of maggots in the solution. After 30 days, the contents can be filtered and ready for field application.

Foliar application of dasparni ark will be effective in the management of all kinds of insects as a prophylactic measure.

Botanicals used in pest management

Traditionally, plant parts (root, bark, leaves, seeds, kernels) or seed cakes are soaked overnight in water, filtered and soap water is added to this extract which is then sprayed on crops with knapsack sprayer at 250–500 l/ha depending upon crop type, plant canopy, crop stage and height.

Neem

Almost all parts of neem tree, *like* leaf, drupes, bark and seed contain a pool of biologically active constituents. It consists of a large number of bitter principles *viz.,* azadirachtin, azadiradione, fraxinellone, nimbin, salannin, salannol, vepinin and vilasinin in considerable quantities. Azadirachtin has proven effectiveness as a pesticide against about 300 insect species and is reported as non-toxic to humans. Neem based pestidcides are marketed in India in different trade names containing 300, 1500, 3000, 5000, 10000 and 50000 ppm of azadirachtin in it. These compounds give protection against borers in maize, plant hoppers in rice, rootknot and reniform nematodes and citrus red mite. Modes of pest control by neem include antifeedant, growth regulatory, repellent, hormonal or pesticidal action in larva and / or adult stages of these pests. Azadiractin act through stomach and contact can be control the sucking pests, fruit borers and leaf folders.

Chrysanthemum

Chrysanthemum cinerariaefolium contains the pyrethrin which has many advantages like rapid degradation, wide range of effect, less toxic to beneficial insects than other insecticides. Also it kills the target insects at low concentration and doesn't accumulate in the food or water. Recently, pyrethrin is used in many ways like using in organic farms. Two formulations of pyrethrum namely the pyrethrum 0.2% dust and pyrethrum 1% EC are registered for use against insect pests in vegetables. Pyrethrum dusts are used against the pests of vegetables and food crops.

Notchi

Leaf extracts of of *Vitex negundo* (5 and 10%) are reported to be effective against 2nd and 3rd instar larvae of *Spodoptera litura*. The leaf and branch extract caused repellency against paddy pests.

Sweet flag

Powdered rhizome of *Acorus calamus* is used for the destruction of fleas, moths, lice *etc*. Rhizome yields oil (1.5-3.5% on dry weight basis), containing asarone up to 82 per cent and its beta isomer is believed to be insecticidal.

Melia

The plant *Melia azadirach* is a close relative of neem. The active principle is tetraterpenoid (limonoids). Plant extracts have behavioural, physiological and toxic effects which have been tested on *E. varivestis, N. lugens, M. separata* and *P. xylostella*.

Pungam

The oil extracts of *Pongamia glabra* have been reported to be repellent for brown plant hopper and white backed plant hopper in rice, Epilachna beetle in brinjal, borers in maize and citrus butterfly.

Custard apple

This contain sesquiterpenes like á-pinene, â-pinene etc. These act as feeding deterrent against *Amsacta moorei*, *Nilaparvatha lugens, Helicoverpa armigera, Nephotetix nigropictus, Spodoptera litura* and *Epilachna vigintioctopunctata*. Root, stem, leaves, and seeds possess insecticidal properties than other species. Root bark contains alkaloids anonaine, liriodenine, norushinsunine and reticuline. Leaves and stem contain an alkaloid that yields sapogenins.

Ginger

The anti-feedant, insecticidal activities of garlic (*Allium sativum*) and ginger rhizomes (*Zingiber officinale*) against *S. littoralis* in cotton was studied. The results showed that the essential oils of ginger and garlic at LC_{50} concentration decreased the egg hatchability and prolonged the larval and pupal duration when compared to the control.

Ailanthus

Ailanthus altissima is a plant in the family Simaroubaceae, grows aggressively in harsh environments where it invades abandoned fields or cracked city sidewalks. The secondary compounds of *A. altissima* have been used to control insects such as *Pieris rape, Platyedra gussypiella*, and aphids in agricultural ecosystems. The bio-active products present in *A. altissima* include quassinoids (degraded triterpenes), ailanthone, amarolide, acetyl amarolide, and 2- dihydroxyailanthone. The secondary compounds of *Ailanthus altissima* have been used to control insects such as *Pieris rape, Platyedra gussypiella,* and aphids. The quassinoids (degraded triterpenes), ailanthone, amarolide, acetyl amarolide, and 2-dihydroxyailanthone, are some of the bioactive products present in *A. altissima*.

Garlic

Allicin present in the garlic was a transient compound, act as natural insecticide and the garlic extract alone and in combination with other plant extracts *viz.,* chilli, ginger, neem, tobacco with cow urine was found effective against sucking pests like aphids, whiteflies, thrips and mites up to 13 days of application. The efficacy of garlic kerosene extracts against the leafhopper (*Amrasca biguttula biguttula*) on okra and found that garlic kerosene extract recorded the lowest number of leafhoppers. The garlic bulb extract alone or in combination with kerosene, neem oil, chilli and other extracts effectively managed sucking pests like aphids, whiteflies, thrips and tetranychid mites infesting several crops. The garlic bulb extract alone or in combination with other plant extracts were effective in managing the several lepidopteran insects pests *viz.*, *Earias vitella, Chilo partellus*, *Helicoverpa armigera and Spodoptera litura.* The allicin present in garlic and found that the extract was very effective against the sucking insects like *Amarasca devastan*, *Thrips tabaci*, and *Bemisia tabaci* in cotton under field condition.

Green chilli

The fruits of *capsicum annum* contain hot flavour, due to the presence of group of seven closely related compounds called capsaicinoids and dihydro capsaicin are responsible for 90% of the pungency. The extract prepaared by using green chilli and garlic which was mixed with water in the proportion of 1:2 and sprayed over many crops infested by aphid and other sucking pests and found that the extracts were highly effective in controlling those pests under field condition. Literature has revealed that capsaicin has significant lethal and anti-feedant effects on various herbivores. Capsaicin has been proven as an oleoresin used against many pests in cotton. The chilli + garlic solution and NSKE spray were the common practices used by local farmers for pest management.

The indigenous materials like nimbecidine (5ml/l), GCK (garlic chilli kerosene extract) 0.5%, nimbecidine (2.5 ml/l), GCK alone (0.5 and 1.0%), turmeric +cow urine (25%) and cow urine (17%) for the management of pests in chilli crop and found that among the different treatments the GCK (5%) + nimbecidine (2.5 ml/l) recorded less percentage of fruit damage due to fruit borer, *H. armigera* with highest fruit yield of 11.3 q/ha.

Lantana

Lantana camara (Verbenaceae) grows widely throughout the tropical, sub tropical and temperate parts of World. Earlier work has shown that leaves of *Lantana. camara* is a source of insecticidal activity (Ogendo *et al.,* 2004) and preliminary studies indicated that the leaves of *L. camara* possess a rich source of bioactive molecules (Sharma *et. al.,* 1988). The leaf of *L. camara* seems to be a promising source for the development of new biopesticide. *Lantana camara* is a widespread plant species mostly native to subtropical and tropical regions of the world. In this study, insecticidal and repellent activities of *L. camara* essential oil were evaluated against *Callosobruchus maculate.* Analysis of chemical composition by gas chromatography/mass spectrometry (GC/MS) showed high amounts of sesquiterpenes, mainly α-humelene (23.3%) and *cis*-caryophyllene (16.2%) were responsible fot the insecticidal activity of lantana. The results showed that the essential oil of *L. camara* has strong repellent activity against adults of *C. maculatus* at all tested concentrations (Sohani Nooshin *et al*., 2012).

Advantages of botanicals

- Plants with pesticidal properties are known by the farmes because most of the time they grow theses plants in their farm itself.
- Often these plants also have other uses like household insect repellents or possess medicinal value.
- Rapid degradation of the active product may be convenient as it reduces the risk of residues on food.
- Some of these products may be used shortly before harvesting also.
- Many of these products act very quickly inhibiting insect feeding.
- Since most of these products have stomach action and are rapidly decomposed they may be more selective to insect pests and less aggressive to natural enemies.
- Most of these compounds are not phytotoxic.
- Resistance to these compounds is not developed as quickly as that of synthetic insecticides.

Limitations of botanicals

- The number of neem trees in India is estimated to be around 18 million with the potential of 540,000 tonnes seeds/year. But only 25 per cent of the seeds are collected.
- Regenerative resources of plant origin are available in villages and preparations are easy and economical. But lot of raw materials (neem seed kernel, leaves of lantana and vitex, stem of parthenium *etc.*) go as waste.

- Farmers lack knowledge on correct methods of harvesting/collection, storage of plant materials and preparation of crude extract.
- The content and stability of the active ingredients in plants vary considerably in different agroclimatic zones. Neem ecotypes with higher content of biologically active constituents have been identified in India which should be recommended to farmers for planting around their fields, road sides and in fallow lands.
- Presently, Indian market for plant products is only 0.5-1 per cent. However, good quality neem products can boost export potential and fetch higher prices in Indian and international markets.
- Water-based sprays are easily washed off from plants due to heavy rains. Plant products are also degraded in the field due to high temperature.Frequent applications are therefore needed which increases the application cost.
- Storage of raw material for a longer period with poor ventilation may lead to poor quality of spray liquid. Proper storage facility is needed for storing depulped dried fruits, kernels, oil cakes *etc*. containing 9-10% moisture up to 8-10 months.
- Toxicity to beneficial fauna (honey bees, other pollinators, predators, parasitoids, entomopathogens) and health risk to humans need to be verified because there are reports demonstrating toxic effects of plant products *viz.,* azadirachtin at 3000 ppm, 5 per cent aqueous extract of neem, *Acorus calamus*, NSKE 5% etc.
- Plant products possess poor contact toxicity and must be ingested by pests. Also, degradation of plant products in soil is triggered by soil microorganisms and residual systemic action is reduced.
- Rules for registration are stringent and procedure is time consuming. The technical formalities prescribed for chemical pesticides are prescribed for plant products also.
- In India, patents on plant products are limited because there is no awareness on importance and advantages of patents related to the geographical indications. Several plant species are indigenous to only certain region(s). They form a part of biodiversity and are valuable assets for the local people.
- Many plants possessing pesticidal properties are found abundantly in different climatic zones in India but remain unexploited not only for traditional preparations but also for commercial formulations, probably because the process of isolation, synthesis and formulation of phytochemicals is lengthy and expensive.
- Also, non-homogenous, active and inert natural products present in extracts pose problems for preparing stable formulations.

- Precautions are however necessary as some of the plant species are protected by forest rules and regulations against exploitation.

Conclusion

Botanicals are extracts of plants with insecticidal properties and used as excellent alternative to synthetic or chemical pesticides for crop protection in organic amd natural farming to avoid negative or side effects of synthetic insecticides. Botanical pesticides *viz.,* essential oils, flavonoids, alkaloids, glycosides, esters and fatty acids have various properties and modes of action *viz.*, repellents, feeding deterrents / antifeedants, toxicants, growth retardants, chemosterilants and attractants. In general, the botanicals are recognized as safe pesticides by the farmers practicing organic / natural farming in the country.

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MANAGEMENT OF DISEASES AND NEMATODES UNDER NATURAL FARMING

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Introduction

Natural farming can be defined as an ecological and economical way of farming. It plays a major role in conserving biodiversity, promoting animal and plant health and contributing to sustainable development. Organic farming has increased significantly worldwide over the last several years and is expected to grow further. Nutrients are supplied through the decomposition of cover crops of nitrogen-fixing legumes or animal manures or products. Pest management relies on an integrated approach of promoting plant health, vegetation management and biological control. The success of natural farming relies primarily on effective disease and nematode management. To manage plant parasitic nematodes associated with natural farming systems, farmers employ diverse practices such as crop rotation, use of cover crops, resistant crop cultivars, soil amendments as well as other beneficial practices to promote diverse and active soil microorganisms. These nematodes react differently to changes in diverse practices and are therefore good indicators for evaluating farming systems.

I. Management of diseases in natural farming

1. Cultural control

a. Crop rotation

Crop rotation will help to manage the weeds, pest and diseases. However, crop rotation can be ineffective if the pathogen is long-lived in the soil with a wide host range. A number of soil-borne pathogens like *Fusarium* spp., *Verticillium* spp. and *Ralstonia* spp causing wilts can effectively be managed by crop rotation. When rice - solanaceous crop rotation is followed, the severity of bacterial wilt is reduced. Sorghum + pigeon pea mixed cropping helps to reduce *Fusarium* wilt because of toxic root exudates of sorghum.

b. Planting time

Adjustment of sowing time is considered as an effective strategy in disease management. Early sown crop escapes blast in rice and blight in maize. The incidence of chick pea wilt and root rot of pea can be reduced by late planting.

c. Plant density

Proper spacing helps to reduce the incidence of sheath blight of rice caused by *Rhizoctonia solani*. High density planting in banana favours sigatoka leaf spot incidence.

Damping-off disease in nurseries of tomato, chillies, brinjal, papaya are favoured by poor drainage and excess seed rate. Proper drainage, optimum seed rate with good light source is required for reduction of damping off disease. The crop debris and weed hosts serve as reservoir for pathogen multiplication. Tilling and clearing the plant residue at the end of the season allows break down of the organic matter, leaving potential pathogens without the host.

d. Host plant nutrition

Antifungal activity among various organic composts has been reported against soil borne and foliar pathogens. Aqueous extracts of vermicompost and organic compost inhibited the mycelial growth of *Botrytis cinerea, Sclerotinia sclerotiorum, Sclerotium rolfsii, Rhizoctonia solani* and *Fusarium oxysporum* f. sp. *lycopersici* (Nakasone *et al*, 1999). Deficiency of certain elements can increase susceptibility of host plants, for example leaf spot of groundnut due to Mg deficiency, wilt of tomato due to Ca deficiency and downy mildew of maize due to Zn deficiency (Singh, 1998). Application of potash in the form of ash increases the disease resistance in crop plants.

e. Water management

Irrigation has both direct and indirect effects on pathogens. Plants under abiotic stress due to drought can be more susceptible to infection by pathogens. Maintaining soil moisture near field capacity during tuber formation protects potato from scab disease (Weinbold and Bowman, 1968). Charcoal rot fungus, *Macrophomina* and *Fusarium* spp. cause wilt diseases to those crops which are grown under moisture stress conditions.

f. Field sanitation

Sanitation involves destruction of crop debris, weeds, diseased plant parts which eventually reduce the inoculum load of pathogens. Removal of infected plant parts reduces the disease severity and further spread in case of leaf blotch of turmeric and sigatoka leaf spot of banana.

g. Organic amendments

Application of composts and organic amendments tends to increase quantity and diversity of soil microbial diversity and consecutive disease suppressiveness. Suppression of white pumpkin *Rhizoctonia* damping off was achieved by application of vermicompost (Rivera *et al.,* 2004).

2. Botanicals

Neem oil 3%, neem seed kernel extract 5%, neem cake @ 250 kg per ha are highly effective botanicals in the management of plant diseases. Oil cakes of neem (*Azadirachta indica*), castor (*Ricinus communis*), mustard (*Brassica compestris*) and duan (*Eruca sativa*) on management of pathogenic fungi like *Fusarium oxysporum* f.sp. *ciceri, Macrophomina phaseolina* and *Rhizoctonia solani* has been demonstrated under field conditions (Tiyagi *et al*., 2001). Neem based extract formulations have also been found to be effective against pests and other foliar pathogens like fungi, bacteria and viruses. Efficacy of neem based extracts and other products for management of root rots of *Elettaria cardamomum* caused by *Rhizoctonia solani* and *Phytophthora meadii* (Thomas 2000).

Plant based antiviral principles

Certain plant leaf extracts *viz.*, sorghum, coconut, *Bougainvillea*, *Prosopis juliflora* and *Vitex negundo* contain proteinaceous compounds that inhibit the multiplication of plant viruses.

Preparation of anti-viral principles

Twenty kg of dried coconut or sorghum leaves were powdered. This leaf powder was mixed with 50 liters of water and boiled for 1 hour at 60 ^{0}C. It was filtered and the volume was made up to 200 liters. The extract @ 10% concentration was effective in the management of peanut bud necrosis virus in groundnut. Fresh leaf extracts of *Prosopis juliflora, Bougainvillea* and *Vitex negundo* @ 10% concentration effectively suppressed the viral disease incidence in different crop plants. The root extract of *Mirabilis jalapa* is being exploited for the management of viral diseases in different crop plants.

3. Milk as virus inhibitor

Reduction of viral diseases by milk spray has been reported in Solanaceae, Piperaceae and Malvaceae families. Fermented buttermilk @ 500 ml in 10 litres of water was effective in suppressing the viral diseases

4. Sonthastra (Dry ginger extract)

Mix 200 g of dry ginger powder in 2 litres of water and boil until the volume of water is reduced to 1 litre and allow for cooling. Boil 5 litres of cow's milk separately and allow for cooling. Mix both the materials in 200 litres of water and can be sprayed in an acre area to protect the crop from fungal diseases.

5. Biological control

Biological control is an effective and sustainable alternative in natural farming for fungal and bacterial plant disease management. Most of the beneficial microbes such as *Pseudomonas fluorescens, Bacillus subtilis*, *Bacillus amyloliquefaciens*, *Trichoderma viride* secrete one or more compound with antibiotic activity to suppress the plant pathogens.

6. Indigenous traditional knowledge

- Mixture 2 to 3 kg of ash in 1 liter of castor oil was spread on a seed bed of a size of about 100 m^2. The application was repeated 2 to 3 times at an interval of 7 - 10 days to protect against soil borne diseases in tobacco nurseries.

- Mixture of 2 kg turmeric powder and 8 kg wood ash was used as dust over leaves for treatment against powdery mildew.
- Ginger powder at 20 g/ liter of water and sprayed thrice at interval of 15 days can be used for powdery mildew and other fungal diseases.

II. Management of nematode in natural farming

1. Cultural control

a. Tillage

Tillage inverts and mixes soil and exposes deeper soil layers to the sun. This practice is meant to kill nematodes by desiccation, since nematodes depend on moisture for survival. This practice kills some of the nematodes that are in the upper soil layers, however, it will not reach nematodes that have retreated into moderate or deeper soil layers. Nematodes can retreat to depths greater than 30 cm and can migrate upward once a susceptible host is planted. Once a field has been fallowed nematodes will move into deeper soil layers to avoid drying and may enter an inactive stage that enables them to survive periods without food and in addition protects them from desiccation.

b. Summer ploughing

During the onset of summer, the infested field should be ploughed with disc plough and exposed to hot sun, which in turn enhances the soil temperature and kills the nematodes. For raising nursery beds for vegetable crops like tomato and brinjal, seed beds can be prepared during summer and covered with polythene sheets of 25 microns thickness which enhances the soil temperature by 5 to 10°C and kills the nematodes in the seed bed. This method is very effective to raise nematode free seedlings using soil solarization with polythene sheets.

c. Green manure crops

Green manure crops are grown between main crops which are valuable tool for managing nematodes. Leguminous crops are effective in reducing populations of certain plant parasitic nematodes by breaking their life cycles (Potter *et al.*, 1998). Crotalaria is a poor host to many plant-parasitic nematodes including *Meloidogyne* spp., *Rotylenchulus reniformis*, *Radopholus similis*, *Belonolaimus longicaudatus* and *Heterodera glycines*. Green manuring with rapeseed, *Brassica napus* has given good results in suppression of nematodes under field conditions (Shanthi, 2022).

d. Selection of planting materials

Plants propagated by vegetative means can eliminate nematodes by selecting the planting material from healthy plants. Golden nematode of potato, burrowing, spiral and lesion nematodes of banana can be eliminated by selecting nematode-free plant materials. Wheat seed gall nematode and rice white tip nematode can be controlled by using nematode free seeds.

e. Crop rotation and cover crops

Crop rotation utilizes crops that are non-host to the nematodes. Cover crops such as sorghum, grains such as oat and rye, marigold, cowpea and some tropical legumes such as sunnhemp and velvet bean are useful to reduce root-knot nematode population densities. Sorghum is the most recommended cover crop to decrease population levels of root-knot nematodes.

f. Time of planting

Nematode life cycle depends on the climatic factors. The time of planting can be adjusted in order to avoid infestation of nematodes in crops like potato. Early potatoes and sugar beets grow in soil during cold season escape cyst nematode damage since the nematodes are inactive to cause damage during that season (Shanthi, 2022).

g. Organic amendments

Linford *et al.*, (1938) demonstrated significant reduction in the population of root knot nematode during decomposition of organic matter in soil. Organic amendments are materials that are added to soil to improve its quality and provide nutrients to crops. Here are some examples of organic amendments that manage nematodes

Compost: Compost is a rich source of organic matter that improves soil quality and promotes beneficial microorganisms that suppress nematodes.

Manures: Manure is another source of organic matter that improves soil quality and reduces nematode populations. Organic amendments such as composted animal manure release nematicidal compounds such as ammonia that is directly lethal to nematodes. Poultry manure reduced the numbers of cyst and citrus nematodes and resulted in increased yields of potato and citrus.

Green manure: Green manure refers to plants that are grown specifically to be incorporated into soil as an organic amendment. Plants such as clover and rye improve soil quality, increase soil organic matter and reduce nematode population.

Nematode suppressive plants: Many species of marigold resistant to a number of nematode species can effectively control nematodes on agricultural crops when they are grown in rotation, inter-cropped or used as soil amendments (Akhtar and Alam, 1992; Akhtar, 1998). French marigold variety Nemagold, Petite Blanc, Queen Sophia and Tangerine are the most effective in suppressing the nematode population.

2. Host plant resistance

Choice of a suitable crop cultivar can be a critical decision. Host plant resistance achieved by traditional breeding programs can be a valuable protection against some nematodes. Two terms those are often used when talking about host plant resistance to nematodes are 'tolerance' and 'resistance. Tolerance means the plant can withstand some damage caused by nematodes without experiencing significant yield reduction. Resistance means nematode reproduction is very low or non-existent on the plant. Both provide protection to the crop plant, but the next crop following a tolerant plant could be damaged by the nematodes that survived on the tolerant plant. Different plant species or even cultivars of the same plant species can exhibit varying degrees of resistance or tolerance. Vegetable crops resistant to root-knot nematode include broccoli, Brussels sprout, mustard, garlic, leek, ground cherry and rutabaga. Sweet com, horseradish, lima bean and onion are considered to be tolerant.

3. Soil solarization

Soil solarization is a promising technique that uses heat to decrease not only nematode densities but also other harmful organisms and weed seeds. Solarization involves covering the soil with clear plastic. Transparent plastic sheets allow short-wave radiation from the sun to penetrate the plastic. Once the light passes through the plastic and is reflected from the soil, the wavelength becomes longer and cannot escape through the plastic. The trapped light facilitates heating of the soil to temperatures detrimental to most living organisms. There are different types of plastic sheets available, mainly differing in their thickness and ability to let light through. Black, opaque or translucent plastics are not suitable for solarization. Thin transparent plastic sheets appear to achieve the best results. Plastic sheets are to be sealed at the ends to prevent air movement underneath the plastic, which would prevent temperatures from rising sufficiently. The disadvantage of solarization is its negative impact on beneficial soil organisms, since they will meet the same fate as their harmful counterparts. But recovery is usually attained quickly through rapid recolonization. However, beneficial microbes such as *Bacillus*, *Pseudomonas* and *Trichoderma* are able to survive at the temperatures generated by solarization process.

4. Biofumigation

Biofumigation is a process of using specific plants to release compounds that are toxic to nematodes and other soil-borne pathogens. Biofumigation can be an effective method for managing nematode populations in natural farming. The steps involved in biofumigation are:

Selection of crops: First step in biofumigation is to select right crops. Brassica crops such as mustard are effective in releasing compounds that are toxic to nematodes. Other crops, such as marigold and sunflower can also be effective.

***In-situ* incorporation:** Once the crop reaches right age, it should be incorporated into the soil. by ploughing or tilling at a depth of 4-6 inches to ensure that the compounds are released into the soil.

Decomposition: After *in-situ* incorporation, the crops should be allowed to decompose. During the process of decomposition, the plant materials release compounds such as isothiocyanates and glucosinolates that are toxic to nematodes.

Nematode resistant crop: After biofumigation, it is important to plant nematode resistant crop to help prevent nematode populations from rebounding.

5. Botanicals

Neem, *Azadirachta indica* is the best known example that acts by releasing nematicidal constituents into soil. Neem products, including leaf, seed kernel, seed powder, seed extracts, oil, and particularly oil cake have been reported as effective in the management of several nematode species (Akhtar and Alam, 1992). Raising green manure crops and addition of more amounts of farm yard manure, oil cakes of neem and castor, press mud and poultry manure enrich the soil and further encourages the development of predacious nematodes like *Mononchus* spp. and also other nematode antagonistic microbes in the soil which check the plant parasitic nematodes in the field.

6. Biological control

Management of plant-parasitic nematodes by living organisms such as bacteria, fungi, predatory nematodes or other invertebrates is known as biological control. Weibelzahl Fulton *et al*. (1996) reported that *M. incognita* and *M. javanica* were suppressed exclusively by *Pasteuria penetrans*. Large number of fungi are known to trap or prey on nematodes but the most important genera include *Verticillium*, *Hirsutella, Nematophthora, Arthrobotrys, Drechmeria, Fusarium* and *Monacrosporium*. Nematode-trapping fungi are also potential candidates for biological management (Wang and McSorley 2003). Fungi, *Purpureocillium lilacinum* and *Pochonia clamydosporia*a successfully controlled the nematode *M. incognita* on potato (Jatala *et al*., 1980) and on tomato (Villanueva and Davide, 1984; Hano and Khan, 2016).

Conclusions

Indiscriminate application of chemicals has degraded the quality of soil and lead to residue accumulation in plant products and environmental pollution along with toxicity to living organisms including human beings. Nematodes remain unrecognized as a major factor causing yield losses since nematode problems are often overlooked, misidentified or ignored, thus allowing for a steady increase in nematode populations. Therefore, awareness about nematodes problem in natural farming is the main concern at present in addition to focus on various ecologically sound techniques to keep the nematode population below pathogenic level. Development of resistant varieties and innovation of other sustainable practices is the requirement for safe environment. To achieve promising results in management of disease causing pathogens and plant-parasitic nematodes under natural farming various sustainable techniques should be incorporated together and used as integrated management approach.

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INTEGRATED FARMING SYSTEM APPROACH UNDER NATURAL FARMING

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1. Introduction

Agriculture is their major source of income for around 58% of India's population.The country achieved its remarkable agricultural growth in the 1960s, after the emergence of the Green Revolution. India marked a new era in Indian agricultural history. The Green Revolution technology aimed to increase agricultural production mainly by substituting typically hardy plant varieties with high-response varieties and hybrids, the use of fertilizers and plant protection chemicals, irrigating more cultivated land by investing heavily on large irrigation systems, and consolidation of agricultural holdings (Sebby, 2010). India has gained its outstanding position in food production, but it is also facing a poor ranking in the hunger index (Menon *et al.,* 2008). The Green Revolution left its harmful footprints on Indian agriculture. The monocropping system, increased and frequent use of fertilizers and pesticides caused considerable damage to the soil's biological operation, crop diversity, increased cost of cultivation, deterioration of groundwater, loss of flora-fauna, increased human diseases, malnutrition, and decreased soil fertility, which have almost left it barren in large areas. As a consequence, farmers with small farms invest in these costly inputs, which are exposed to high monetary risks and push them in the debt cycle (Eliazer *et al.,* 2019). The possible health implications of pesticide residue have terrified many of us into choosing pesticide-free items. Even though rules exist to assure legal maximum residual levels that have been considered scientifically acceptable for food, the campaign to eliminate pesticides has gained traction. Restoring soil health by reverting to non-chemical agriculture has assumed great importance in achieving sustainability in production.

In India, a chemical-free and climate-resilient method of farming given by a scientist Subhash Palekar, during 2006 in Maharashtra to end the problems arising after the Green Revolution by introducing natural farming. His methods popularized when farmers started adopting his methods. After that, many researchers and scientists claimed that natural farming is a good alternative to chemical farming that directly or indirectly impacts sustainable development positively (Tripathi and Tauseef, 2018). The aim of natural farming is to reduce the cost of production to almost zero and to come back to the "pre-Green Revolution" style of agriculture.

2. Natural farming

Natural farming, popularly known as zero budget natural farming, is an innovative farming approach. It is low input based, climate resilient, and low-cost farming system because all the inputs (insect repellents, fungicides, and pesticides) are made up of natural herbs and locally available inputs, thereby reducing the use of artificial fertilizers and industrial pesticides (Laishram *et al.,* 2022). The word zero budgets mean no credit or no expenses, without any credit and without spending any money on purchased agricultural inputs. Another term natural farming is a method of chemical-free agriculture drawing from traditional Indian practices. In other sense, natural farming shows the importance of the synergistic effect of both plant and animal products on crop establishment, to build soil fertility and microorganisms (Smith *et al.,* 2020). Natural farming is working with nature produced good food, and keeping healthy over selves, it is also known as do nothing farming because the farmer is considered as a facilitator and the real work can be done by nature. No-tillage, no chemical fertilizer, no pesticides in this farming.

First time in Japan, M Fukuoka started work on natural farming, and his results showed that yields from natural farming are similar to chemical farming but without soil erosion also maintains soil fertility for a longer time (Devarinti, 2016). There are no external inputs to his experiments and he used locally available on farm products are used. That's why he got zero or negligible cost of cultivation. His results compiled in a book one straw revolution. Natural farming minimizes the external inputs to farmland which degenerate the soil nature, increases microbial population better soil aeration and good water retention capacity (Fukuoka, 1978; Andow & Hidaka, 1998; Neera *et al.,* 1992).

In the last couple of years, the government of India has promoted natural farming in big way to promote chemical-free farming. Schemes such as-National Mission on Natural Farming, Paramparagat Krishi Vikas Yojana (Conventional Agriculture Development Scheme) under the sub-mission of Bharatiya Prakritik Krishi Paddhati (BPKP), Andhra Pradesh Community Natural Farming (APCNF), Mission Organic Value Chain Development for North Eastern Regions (MOVCDNER), etc., are popularizing the adoption of natural farming among the farmers in different parts of the country. The Indian Council of Agricultural Research (ICAR), the apex research body, has initiated a study on the evaluation of NF on certain crops. The popularity of NF has drawn the attention of many sections in society. It is estimated that more than 500,000 hectares of land in India across different states are currently being cultivated under natural farming (Economic Survey, 2022) and it is expected that this may expand to bring 14 million hectares of land under natural farming by 2025 under the PKVY scheme (Jain, 2022).

3. IFS

Integrated farming system is a resource management strategy to achieve economic and sustainable agricultural production to meet diverse requirement of the farm household while preserving the resource base and maintain high environment quality.

Table 1. Components of IFS for different ecosystems

Wetland	Irrigated upland	Dry land
Cropping	Cropping	Cropping
Fishery	Milch cows	Goat
Poultry	Buffalo	Agroforestry
Forestry	Biogas	Horticulture
Pigeon	Spawn production	Tree
Goat	Mushroom	Pigeon
Duck	Homestead garden	Rabbit
Pig	Silviculture	Farm pond
Mushroom	Sericulture	Fish
Fodder		

4. Components integration in integrated farming systems under Natural Farming

4.1. Bio-intensive complementary cropping system for IFS

Identification of bio-intensive complimentary cropping systems by inclusion of cereals, vegetables, oilseeds and pulse crops which are ecologically sustainable and more viable is pertinent. Hence, selection of component crops needs to be suitably planned to make use of the synergy among them for efficient utilization of resource base and to increase overall productivity. By using bio-intensive agriculture in its modern, scientifically proven form, at intermediate-level yields, with a reasonable build-up of soil quality and farmer skill, on approximately 4000 square feet (317.6 m^2) per person it is possible to raise a complete vegan diet plus all the carbonaceous and nitrogenous compost materials necessary to maintain fertile soil and a modest income. A healthy bio-intensive farm has the capacity to use 67–88% less water, 50–100% less fertilizer, and 99% less energy than conventional agriculture practices. Furthermore, bio-intensive farming has been known to replenish soil nutrients 60 times faster than nature does on its own (Jeavons, 2006).Shanmugam (2015) conducted field experiments at Tamil Nadu Agricultural University, Coimbatore to identify the appropriate bio-intensive complementary cropping systems for irrigated uplands of Tamil Nadu. Among the different cropping systems tested, onion-cotton-maize cropping system produced significantly higher cotton equivalent yield (5407 kg/ha) higher production efficiency (16.38 kg/ha/day) and economic efficiency (561 Rs./ha/day).The higher B: C ratio (3.18), sustainability yield index (SYI) (0.98) and water use efficiency (WUE) (3.28 kg/ha/mm)were also registered in onion-cotton-maize cropping system. Green manuring of sunnhemp (*Crotalaria juncea*) improved organic carbon, available N, P and K level of the respective cropping sequence over the others. Similar experiment was also conducted to enhance productivity of sodic soil thorough bio intensive complementary cropping systems with organic amendments was conducted at ADAC, Tiruchirappalli. From this study it can be concluded that complementary cropping of maize + cowpea + daincha with application of 75% recommended NPK through fertilizers + 25% N through poultry manure is recommended for sodic soils for soil health improvement and obtained maximum economic benefits (Shanmugam, 2021)

4.2. Dairy production

Integrated organic farming systems comprising of crop and livestock would pave way for the organic dairy production. In this system animals are raised on agricultural waste and voids are used as manure for crop production. Based on the recent research evidence it can be revealed that in integrated farming the yield would be inherently more sustainable because the waste of one enterprise becomes the input of another leaving almost no waste to pollute the environment. Integrated farming system involving dairy cattle is more prevalent under existing ecological and socio-economic conditions in India and would provide an increased quantity of manure for cropping. Many research evidences showed that, livestock keeping along with crop production would provide manure and nutrient necessary for crop production. Crop - livestock integration would be a viable option for organic based farming systems because through effective recycling it helps in reducing the demand for external input.

The productivity of livestock mainly depends on the availability of quality feed and fodders in requisite quantity. The residues of different agricultural crops constitute the major source of fodder for livestock. A sizeable portion of crop residues i.e., about two third is fed to animals in India and only remaining one - third is available for incorporation into the soils. A greater proportion of nutrients in the residues fed to animals are recycled to soils through dung.

Recycling of animal voids through biogas unit

At present the voids are being utilized for fuel and as FYM/Compost. When recycled through biogas unit, there is good possibility to improve the organic source of nutrients apart from generation of fuel energy when recycled through biogas unit, there is good possibility to improve the organic source of nutrients apart from generation of fuel energy. Apart from the major nutrient there is a good amount of enhancement in the availability of secondary and trace elements (Table. 2).

Table 2. Manurial potential of animal excreta (Mt/annum)

Animals	N	P	K
Cattle	2.07	0.79	1.33
Buffalo	0.75	0.28	0.49
Goat and sheep	0.21	0.06	0.02
Pig	0.04	0.03	0.03
Poultry	0.03	0.02	0.01
Other livestock	0.08	0.02	0.07
Total	3.18	1.20	1.95

For effective recycling of farm and animal waste, a biogas unit of 2 m^3 can be installed for the production of enriched manure along with methane gas used as fuel for cooking and lighting. By this recycling, biogas could be obtained along with bio-digested slurry with enhanced nutrient value. The digested slurry is a superior organic manure as it has narrow C:N ratio. Some of the weed seeds present in the raw cow dung also get killed during the digestion process, thus improving the quality of the slurry over raw cow dung. Trace elements like Fe, Mn, Zn and Cu are also present in an enhanced level over FYM.

Biogas gives a good proportion of methane gas, a fuel supplement, apart from its enhanced manurial value of the slurry that comes out of the biogas chamber. This biogas can be used for cooking, lighting and as a substitute for diesel. The quality improvement by way of recycling the cow dung through biogas chamber was studied by analyzing the NPK content of slurry and FYM prepared utilizing the cow dung from the system. The total quantity secured from the unit over the period of 365 days has been taken on equal weight basis. Recycling of cow dung also led to the production of 730 m^3 of biogas with the possibility of enhancing the nutrient value of NPK to the tune of 44.5 kg, 65.9 kg and 28 kg respectively in a year. Trace elements like Fe, Mn, Zn and Cu were found to be present in an enhanced level over FYM (Table. 3).

Table 3. Nutrient content in biogas slurry and FYM

Particulars	Nutrient content						
	Major element (%)			Trace element (ppm)			
	N	P	K	Fe	Mn	Zn	Cu
Biogas slurry	1.43	1.21	1.01	4200	550	150	52
FYM	0.94	0.56	0.72	4000	490	100	45

4.3. Poultry production

Integration of poultry in the organic farms will not only help to increase the production but also the consumption of organically produced eggs with the lowest production costs through effective recycling advantages. Poultry unit in any farm has many advantages. Poultry dropping if collected properly can be used as organic manure and it increases the yield of the crops. Reports are available indicating low and sparse weed population in the fields supplied with poultry manure. When allowed for foraging in cropped fields, the birds would reduce the insect population by eating the larvae, destroying egg masses there by pest damage can be reduced. Poultry dropping becomes useful feeding material for fish grown in fish ponds.

4.4. Integration of poultry and fish culture

Poultry farming is integrated with fish farming by erecting poultry sheds on the fish ponds. According to Ray and David (1969), most of the important soluble inorganic salts for fish are present in the poultry droppings. A fish yield of 670 kg/ha in 90 days was recorded using poultry manure with no supplemental feed (Banerjee *et al.*, 1979). In one acre farm 90 cents can be assigned for crop activity and the remaining 10 cents allotted to fish pond (Jayanthi, 2002). Twenty fowls sheltered above the fish pond in the cage arrangement. In poultry + fish + cropping integration, application of recycled poultry manure from fish pond sustained the productivity of soil through the addition of bio-resource residue with better NPK nutrient supply potential (Table. 4).

Table 4. Nutrient value of recycled poultry in IFS

Nutrient	Raw poultry dropping		Pond manure		Additional nutrient gained by recycling (kg)
	%	Kg / 700 kg	%	Kg / 4500 kg	
N	3.22	22.5	1.96	88.2	65.7
P_2O_5	2.50	17.5	1.02	45.9	28.4
K_2O	1.05	7.4	0.72	32.4	25.0

4.5. Integration of sheep and goat

The integration of goat as a component with crop activity in farming systems has tremendous potentials for on-farm input generation. The organic manures like litter from the goat unit can readily be used for soil application, and thus will help in enriching the soil. Goat droppings are found to be a good source, which can also be linked with biogas unit before it is utilized as manure. This will generate good volume of gas (22 kg of goat dropping will generate one cubic meter of gas against 30 kg of cattle dung as well as enhance nutrient availability. This quantum is sufficient to enrich the soil fertility under rainfed situation as farmers hardly apply inorganic fertilizers. Thus, through recycling of organic in the farming systems approach, the potential of each produce can be exploited to a greater extent.

The droppings of sheep and goats contain higher than FYM and compost. On an average, the manure contains 3% N, 1% P_2O_5 and 2% K_2O. The sweeping of sheep or goat sheds can be placed in pits for decomposition and applied later to the field. The nutrients present in this method are wasted.

Sheep penning is another method, wherein sheep and goats are kept overnight in the field and urine and faecal matter added to the soil is incorporated to a shallow depth by working blade harrow or cultivator. The feasibility of integrating fish culture with goat rearing was studied under lowland conditions by Jayanthi (2001) and it was found that goat droppings can be used as fish feed, which resulted in fish yield of 825 kg/0.04 ha of ponded water (Table. 5). At the end of the year after the fish harvest, about 4500 kg of settled silt from the pond were collected, which was utilized as organic source to supply sufficient quantity of nutrients to crops. The nutrient contents of raw animal manures and settled silt collected from different fish ponds are furnished.

Table 5. Nutrient recycling in crop + goat + fish IFS model

Nutrient	Raw goat dropping		Pond manure		Additional nutrient gained by recycling (kg)
	%	Kg/700 kg	%	Kg/4500 kg	
N	1.40	11.3	0.70	31.5	20.2
P_2O_5	0.85	6.9	0.62	27.9	21.0
K_2O	0.70	5.7	0.48	21.6	15.9

4.6. Integration of mushroom

Mushroom cultivation could also be a better proposition for the organic based integrated farming systems. Crop residues can be reutilized through inclusion of mushroom in the farming system. Agricultural wastes including paddy straw, wheat straw, hulled maize cobs, bajra and sorghum stalks can be used as substrate for mushroom cultivation (Table. 6).

Inclusion of mushroom with the production capacity of 2 kg/day as one of the components in IFS utilizes about 1800 kg of paddy straw and could yield about 2340 kg of mushroom spent after the harvest of edible mushroom at the end of one year. The enhancement in weight of the mushroom spent is due to unharvested mycelial growth. The nutrient value as well as the total nutrient content of utilized straw and the mushroom spent are furnished.

Table 6. Residue recycling of paddy straw through mushroom cultivation

Particulars	Content (%)			Nutrient added (kg)		
	N	P	K	N	P	K
Paddy straw	0.62	0.24	1.72	11.2	4.3	31.0
Mushroom spent	0.71	0.29	1.74	16.6	6.8	34.6
Additional benefit through recycling	-	-	-	5.4	2.5	3.6

4.7. Border planting of trees in IFS

Growing of perennial fodder trees in the borders and watercourses is a recommended practice in IFS. This practice not only helps in supplementing legume fodder but also enriches soil nutrient by fixing the atmospheric nitrogen. These practices would certainly relieve the crisis of non-availability of quality fodder to the animal component linked. *Gliricidiasepium* and *Sesbania grandiflora* area fewleguminous trees, which can be grown on field bunds of lowlands without apparent negative effect on crops. They are a potential source of nitrogen for crops and a fodder for cattle. Large quantity of biomass was harvested from *Gliricidia* that resulted in 100 to 200 kg N ha^{-1} when applied to a field. Many such leguminous trees can be raised which have potential both as leguminous fodder for the animal component and as green leaf manure for the crop component. Neem trees can be raised along the borders, which would serve the requirements as organic manure and bio-pesticides for the organic farm. Annual moringa can also be raised along the field boundary at the rate of 326 numbers per ha of farm land as a viable vegetable component.

4.8. Integration of apiculture in farming systems

Honeybees are popularly known as 'angels of agriculture' since they are instrumental in increasing the productivity of number of agricultural crops through cross-pollination. This integration also leads to increased production of high-quality organic honey. The apiculture unit within the farm is highly useful especially for the cross-pollinated crops whose yield potential can be achieved only when pollination requirement of the crop is fulfilled. Therefore, in integrated farming system 5-6 honey bee box/ha is recommended.

5. Integrated Farming System (IFS)

It is a biological system which integrates the natural resources and regulation mechanisms into farming activities to achieve maximum replacement of off-farm inputs, secures sustainable production of high-quality food and other products through ecologically preferable technologies, sustains farm income, eliminates or reduces sources of present environment pollution generated by agriculture and sustains the multiple function of agriculture. Thus, an IOFS represents multiple crops (e.g., cereals, legumes, horticultural crops, agroforestry) and multiple enterprises (e.g., livestock, poultry, fishery) on a single farm in an integrated manner (Behera and France, 2016). It is the set of resource development and utilization practices, which leads to a substantial and sustained increase in agricultural production.

5. 1. Productivity enhancement through IFS

5.1.1. Lowland ecosystem

Integrated farming systems experiment was conducted in one hectare area includes crop (0.805 ha) +fish (0.172 ha) +poultry birds component above the fish pond (0.172 ha) + vegetable garden (0.023 ha). The result revealed that Integration of leaf banana + fish (catla + common carp) + *desi*chicken + vegetable garden recorded highest rice grain equivalent yield of 38437 kg/ha during 2019-20 and 43774 kg/ha during 2020-21.The highest employment generation of 254.4 man days was generated during 2020-21 in Leaf Banana + Fish (Catla + Common carp) + *desi*chicken + Vegetable garden system with major share from leaf banana accounting to136.9 man days, 63 man days from *desi* chicken, 43.1 man days from vegetable garden and 11.5 man days from fishery. Additional employment of 189.6-man days/ha/year were generated from integrated organic farming system accounting to74.5 per cent of total employment generation when compared with cropping system alone. For enhancing the productivity, economic returns, employment generation with effective recycling of waste, leaf banana + fish (catla + common carp) + *desi* chicken + vegetable garden was found beneficial for the small and marginal farmers of Tamil Nadu (Latha*et al.,* 2022).

An integrated farming system (IFS) model (0. 43 ha) was assessed during 2005- 2017 at ICAR Research Complex for NEH Region, Umiam, Meghalaya with diversified farming components like field crops, horticultural crops, livestock (one cow + calf) along with perennial fodder crops, central water harvesting pond for composite fish culture and as a source for irrigation during lean season and provision for nutrient recycling. The productivity and income from the on-farm IFS model was compared with the ruling farmers practice-I (Monocropping, i.e.,rice-fallow system) and farmers practice-II (cultivating about 30% farm area for second crop like vegetables after rice). The average results indicated that the rice equivalent yield (REY) from the IOFS model was 19. 8 t/ha as against 4 t/ha and 6.72 t/ha from the farmers practice-I and II, respectively. On economics total net return of Rs.71442 per annum was achieved under the IFS model which is much higher than the farmer common practices of rice monocropping or improved practice of rice-vegetables cropping system (Table 7). The highest contribution towards the total net return was given by crop component of the model (66.5%) followed by dairy (24%) and fishery components (15.2%). The fish production was approximately 136 kg from the model. Thus, IFS could be a viable option for organic food production and sustainable agricultural development in the hill ecosystem of north east India (Das *et al.,* 2019).

Table 7. Production, productivity and economics of the IFS

Component	Area (ha)	Rice equivalent production (tonnes)	Annual cost of production/(Rs.)	Net return/year (Rs.)	Employment (man days)
Crops	0.373	4.93	26429 (46.6%)	47487 (66.5%)	98
Dairy	0.004	2.56	21365 (37.8%)	17065 (24%)	121
Fishery	0.05	1.05	4910 (8.6%)	10840 (15.2%)	8
Nutrient cycling	0.01	-	3950 (7%)	-3950	28
Total	0.43	8.54	56,654	71442	255
Farmers' practice-I (Rice-Fallow)		1.72	10100	15700	87
Farmers' practice-II (Rice vegetables in small scale)		2.90	18975	24518	125

IFS experiment was conducted at Thanjavur, TNAU with integration of crop + Horticulture + Dairy + Goat + Poultry + Kitchen Garden+ Boundary planting + Vermicompost + Value addition in 0.85 ha area to improve the productivity and profitability of farm house holds of Cavery delta zone of Tamil Nadu. In the cropping component, three cropping systems were included in a total area of 6100 m^2. Considering the annual green fodder requirement of the dairy unit, an area of 0.04 ha was allotted for the Cumbunapier grass (Co CN 4) to get year-round green fodder supply. To effectively utilize the border and boundaries of the cropping area, plants like Black gram, coconut (15 nos.) and curry leaf (50 nos.) were planted. In horticultural component 0.10 ha area was allotted for planting of Banana (Monthan, Poovan, Nendran & Karpooravalli) + Blackgram+ Marigold. The livestock unit consists of dairy Bovine and Holstein Friesian cross breed cow & calf were maintained in 20 m^2 area. Thepoultry unit was constructed in an area of 10 $m^2$and 150 nos. of *desi* birds (Aseel) were reared per year. The fishery unit being maintained to a level of 1 m depth in an area of 800 m^2 (composite fish culture namely Cutla, Rohu, Mirgal& Grass carp were released 1 no./sq.m). The result revealed that integrated Farming system in 0.8 ha area recorded total net return of Rs.267311/year. The maximum net return of Rs.92474was obtained from the Dairy unit. This was followed by cropping component with a net return of Rs. 82657 and fishery unit with a net return of Rs.30665. A major share of 34.6% was contributed by dairy unit to the net income followed by cropping system unit (30.9%) and fishery unit (11.4%). Further 401 Man days was generated from the IFS model (AICRP – IFS Annual report – TNAU - 2021).

5.1.2. Irrigated upland ecosystem

Integrated farming system model involving components *viz.,*Cropping system (0.85 ha) includesCowpea - Ragi - Green manure, Maize - Sunflower - Green manure, Panivaragu - Chillies - Green manure, Cumbu - Cotton - Green manure, Perennial fodder (Cumbu Napier grass and *Desmanthus),* Silvipasture(*Cenchrus sp.* and fodder tree) + Horticulture (0.10 ha- Sapota, Guava, Aonla, Pomegranate, Acid lime)+ Dairy (50 m^2-Gir and Kankrej along with calf)+ Goat (50 m^2-Salem black) + AseelPoultry (50 m^2- 50 numbers per batch; 3 batches per year) + Kitchen garden (200 m^2 Vegetables and Greens) + Boundary planting (Annual moringa, Curry leaf, Agathi, *Gliricidia*) + Vermicompost (50 m^2) + Value addition in an area of 1.0 ha was recorded an overall cost of cultivation ofRs. 2,80,299/- and net return of Rs. 4,54,674/- with a B:C ratio of 3.71. In economics goat rearing contributed 35.3% to total net returns followed by cropping system 21.1 % and the rest by dairy and other components. On productivity total MEY of this system was 22.52 t. Further energy use efficiency was calculated based on standard formula suggested by Devasenapathy*et al.* (2009) and higher Energy Use Efficiency was recorded in cropping components followed by dairy. Inputs generated from the IFS model recycled was Rs. 1,37,927/- (without family labour). Employment generation from the IFS model was 394-man days(AICRP – IFS Annual report – TNAU - 2021).

One-acre integrated farming system (IFS) model for irrigated upland ecosystem of Tamil Nadu was developed in at the Tamil Nadu Agricultural University (TNAU), Coimbatore, to cater the needs of marginal farmers of Tamil Nadu and was evaluated continuously for 6 years from 2013–2019. The system consists of crops, livestock, fodder, agroforestry, pest-repellent cafeteria, composting and bee keeping. The system productivity on expand was 3,034 kg/ha/year. *Kharif* crops shares 45% of the net returns compared to the winter season (*rabi*) crops. Total 34 tonnes crop residues were recycled through which revenue of 11,762 was realized. About 29 tonnes of green fodder was produced per annum, which met the fodder requirement of the livestock for 342 days. Annually 1,742 litres of milk was produced to assure an annual income of 37,426. Net income of 5,544 was realized through boundary plantations. From the IFS model, a total mean annual net income realized was Rs. 72,095. Through recycling of residues and manures 12% of the total cost of the model was saved. The relative share of different components in the order of merit was livestock (43%), crops (29%), fodder (20%), boundary horticultural crops (6%) and compost (2%). The benefit: cost ratio of the IFS model was 2.24, with an annual employment generation of 571 man-days (Somasundaram *et al.,* 2021). This integrated farming system of irrigated upland ecosystem improved soil fertility with effective recycling of crop residues and animal waste.

5.2. Nutrient addition through residue recycling

The experimental evidences indicated below, clearly show that the recycled organic residues/wastes of crop and allied activities could supplement the chemical fertilizers. Moreover, this will also provide opportunity to reduce the environmental pollution produced from the process of manufacturing chemicals. The soil health problems caused due to excessive use of inorganic substances can also be minimized to a greater extent by proper utilization of organics. Through this method thebyproduct of one enterprise should become the input for another enterprise. This not only reduces the wastage of resources but also minimizes the costs.

IFS experiment was conducted by Latha*et al.* (2022) revealed that integration of horticultural crop (leaf banana) with fish (Catla + Common carp), *desi* poultry bird and kitchen garden produced 47311 kg/ha ofresidue and a quantity of 44187 kg/ha residues were recycled in the system (Table 8.)

Table 8. Residue recycling in lowland IFS

	Residue generated (kg)				Residue recycled (kg)		
	Crops	Fish pond	Poultry birds	Total	Crops	Fish pond	Total
Green manure – Rice – Fallow	22694	-	-	22694	15725	-	15725
Green manure – Rice – Blackgram + Fish + Japanese quail	24747	12453	2105	39305	16018	12453	28471
Bhendi – Green manure – Pumpkin + Fish + Duck	22664	12386	3510	38560	22664	12386	35050
Leaf Banana + Fish + *Desi* chicken	31875	12312	3124	47311	31875	12312	44187

Das *et al.* (2019) reported that integration with horticultural crops, livestock and fishery in an area of 0. 43 ha produced 59.7, 18.9 and 51.9 N, $P_2O_5$and K_2O, respectively within the system itself. Hence, 92% of the total N, 82% of the total $P_2O_5$and 96% of the total K_2O requirement could be met through the model itself and only 8, 18 and 4% of N, $P_2O_5$and K_2O requirement is to be needed from the external sources to sustain the model, respectively (Table 9.) The nutrient requirement of the model from external source would be reduced substantially with the efficient recycling of pond silt, intercropping with legume, use of biofertilizers such as *Azotobacter*, *Rhizobium*, phosphorus solubilizing microorganism etc.

Table 9. On-farm nutrient supply balance sheet under lowland IFS

Component	Nutrient requirement (kg)			On-farm nutrient recycled (kg)			Nutrient balance (kg)		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
Cereals (rice, maize)	21.1	7.5	17.5	6.6	2.3	12.2	-14.5	-5.3	-5.3
Horticultural crops (vegetables, fruits)	31.4	11.2	26.2	11.8	2.6	9.0	-19.6	-8.6	-17.2
Dairy component	0.0	0.0	0.0	13.1	4.9	6.6	13.1	4.9	6.6
Others (oilseeds, pulses, green manuring crop, fodder)	12.2	4.4	10.1	28.2	9.1	24.1	16.0	4.8	14.0
Total	64.7	23.1	53.8	59.7	18.9	51.9	-4.9	-4.2	-1.9

Integrated farming system model for lowland ecosystem of Tamil Nadu was developed in at the ARS, Thanjavur. The components comprise of Cropping system + Horticulture + Fishery + Dairy + Poultry + Boundary plantation + Vermicomposting. From the findings it can be evident that 30.5 % of inputs generated from the IFS model was recycled within the system. Further, nutrient addition from the model was 263 kg/ha, 105 kg/ha and 251kg/ha (Table.10) (AICRP – IFS Annual report – TNAU - 2021).

Table 10. Total residue production and nutrient addition in lowland IFS

Waste/ Residue	Quantity (kg)	Nutrient content (%)			Nutrients added (kg)		
		N	P	K	N	P	K
Rice straw	3580	0.69	0.16	1.31	24.7	5.7	46.9
Maize stover	2900	0.59	0.21	1.22	17.1	6.1	35.4
Pulses residue	597	0.92	0.18	1.02	5.5	1.1	6.1
Gingelly residue	187	1.21	0.32	1.22	2.3	0.6	2.3
Sunnhemp biomass	3920	2.58	0.20	1.66	101.1	7.8	65.1
Azolla	435	3.16	0.25	2.50	13.7	1.1	10.9

Vermicompost	3950	2.50	2.09	2.15	98.8	82.6	84.9
Total nutrients (N, P & K)					263	105	251

Integrated Farming System model involving components *viz.,* Cropping system+ Horticulture + Dairy + Goat + Aseel Poultry birds + Kitchen Garden + Boundary planting + Vermicompost + Value addition in an area of 1.0 ha produced 6210 kg of dairy dung and shed waste, 11749 kg of crop residue, 3978 kg of weeds and horticultural litter fall,9456 kg of vermicompost produced,8609 kg goat manure and shed waste and 556 kg poultry litter (Table 11). Further by residue recycling the total quantity of nutrient addition obtained was 182 kg N, 43 kg P and 71 kg K (AICRP – IFS Annual report – TNAU - 2021).

Table 11. Nutrient content and nutrient addition in irrigated upland IFS

Manures	Nutrient content (%)			Nutrient addition (kg)		
	N	P	K	N	P	K
Dhaincha	1.60	0.50	1.00	57.0	17.8	35.7
Vermicompost	1.20	0.20	0.30	113.0	18.9	28.4
Poultry manure	2.00	1.00	1.20	11.5	5.74	6.9
		Total		182	43	71

A field experiment was conducted at Department of Agronomy, TNAU, Coimbatore to evaluate the suitable IFS for irrigated upland ecosystem. The experimental system consists of crops, livestock, fodder, agroforestry, pest-repellent cafeteria, composting and bee keeping. The result revealed that annually 11.8 tonnes of cow dung and 9,217 litres of cow urine were obtained with the nutritional value of Rs. 5,586. Similarly on an average, 2004 kg compost was produced through which Rs. 3,007 was realized (Somasundaram *et al.,* 2021).

7. Conclusion

Nature farming has a bright future in our modern society. Indiscriminate use of chemical fertilizers and pesticides posed a threat to the soil and environment. Many investigations have shown their adverse effects of change in soil nature, soil contamination, ground water pollution and decrease in soil micro flora etc. Studies have shown that natural farming, with the minimum external inputs and by application of supplements like Jeevamruth, improves the soil fertility by increasing the soil micro flora and available nutrients. This method encourages Integrated Farming System, multi cropping and biodiversity of micro and macro flora. Natural farming is eminently suited to the farmers particularly small and marginal farmers because of its simplicity, adoptability and drastic cut in cost of cultivation of crops. Therefore, it is concluded that nature farming has a good future although there are many problems yet to be overcome by practitioners and by adopting integrated farming every individual of the country will be able to get chemical free food with improved nutritional security.

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ONE HEALTH: AN EMERGING CONCEPT

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One health is a concept which connects the health of human beings with the health of animals and their surroundings. It is a collaborative, multisectoral, and transdisciplinary approachworking at the local to global levels through regional and nationallevels with the goal of achieving optimal health outcomes recognizing the interconnection between people, animals, plants, and their shared environment.

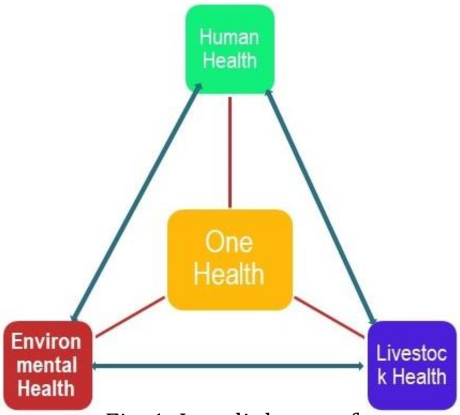

Fig. 1: Interlinkages of environmental, livestock and human health in One health concept

Origin of one health concept

During 1970s, a surveys of pet ownership was carried out by Robert Schneider and his colleagues for developing a One Health solution to human cancer by studying the cancer incidence in relatively short-lived companion animals as a possible means of understanding and predicting human cancer risk. As a outcome of this study, a book "Cattle Priests and Medicine" authored by Calvin Schwabe was published in 1978 which described many linkages between animal and human health. Therefore, understanding of animal health is essential for human health which brought the concept of "One medicine". In 2007, the American Medical Association approved a "one health" resolution promoting the importance of a partnership between human and veterinary medicine. Nevertheless, it took another ten-plus year and a global pandemic before the World Health Organization added 'One Health' to its main website's list of health topics. One Health describes a holistic approach to medicine in which the interactions "between humans, plants, animals and their environment are all examined to improve our health outcomes" (Rowan, 2023).So, environmental health, livestock health and human health are the three corners of a triangle in which one health concept lies at the center.

Environmental health

Everything that makes up our surroundings and affects our ability to live on the earth is called the environment. The environment is really the whole planet on which we live. Everything (winds, trees, animals, insects, people etc.) forms part of the living system of earth.Environment or land ecosystemcan be studied by dividing it intotwo major components such as terrestrial and aquatic environment. The terrestrial environment covers the soil and soil-air boundary and the associated biological communities. Most living things are directly linked to the interface between the soil and the compartment above it, either by being in contact with both compartments at the same time or in other ways. Compared to freshwater or marine habitats, the terrestrial environment is more hostile.With rapid urbanization and industrialization, human activities affect the structure and function of terrestrial ecosystems to a certain extent, which leads to severe ecosystem degradation and threat to the sustainable development of the social economy. Terrestrial health has become a focus issue, especially where there are ecological problems such as land desertification and soil erosion. There are various tools to measure terrestrial health and the scale of measurement may vary with the objective of the study such as most of the existing research is focused on countries, provinces, cities, rivers, wetlands and forests. The terrestrial ecosystem is a large and complex system, and the level of it is mostly evaluated by establishing frameworks for ecosystem health assessment. At the same time, existing frameworks do not comprehensively quantify the level of terrestrial health. For example, the relationship between the environment and human activity was disregarded while utilizing the vigor-organization-resilience and the vigor-organization-resilience-function to assess the state of an environment. The vigor–organization–resilience model (VOR), proposed by Constanza, is a widely used model to assess ecosystem health (EH). In the VOR model, EH is measured through three aspects: vigor indicates ecosystem metabolism and primary productivity; organization represents ecosystem diversity, connectivity, and interactions; and resilience measures the capability to rebound from perturbations, and resilience of maintaining ecosystem structure and function when there is interference.The frameworks of pressure-state-response and driving force-pressure-state-impact-responsehighlight the causal relationship between human activities and changes in the terrestrial ecosystem. In the process of assessment of any terrestrial ecosystem health, determining the weight of the indicators is particularly important, and it substantially affects the result of its assessment. There are many approaches (subjective, objective and combination of them) for determining the weight of indicators, such as the entropy method, analytic hierarchy process, and coefficient of variation method (Yang*et al.*, 2020).

Environmental health is a big issue, and it is getting worse every second of the day.Over time, this can have a very bad effect on people and animals. Weather patterns have changed, there are more droughts and more floods, the temperature is rising and most important, the ozone layer that protects us from the dangerous rays of the sun has been damaged and does not work as effectively as it did before. These are some examples of what is happening to the earth because it has been exploited and not protected.So, it is important to protect the environment from being exploited and it is one of the important reasons why people now talk about the term one health concept. In the recent past specially after Rio 1992, Two issues: Climate change and Biodiversity have been hotly debated among scientists, resource managers, policy makers and public. Biodiversity acts as a buffer against climate change. It is an important factor in regulating how ecosystems will respond to increasing earth temperature and atmospheric carbon dioxide. The diverse plant ecosystems are better able to absorb carbon dioxide and nitrogen, both of which are on the rise due to human activities and industrial processes. The more species, the better job they do at absorbing the greenhouse gases. Many scientific findings suggest that protecting biodiversity worldwide will contribute to safeguarding the capacity of ecosystems to capture a larger fraction of additional carbon and nitrogen entering our environment.Changing climate makes other threats such as Globalization and climate change encourage the spread of invasive species. Increases in human mobility and expansion of global trade encourage the spread of alien invasive species. Global climate change creates conditions suitable for new invasives. For example, increased temperatures potentially enable disease-carrying mosquitoes to expand their ranges. Invasive diseases are a growing problem in birds e.g., Bird flu. With unmitigated emissions, substantial die back of tropical forests and tropical grasslands is predicted to occur by the 2080s, especially in northern South America and central southern Africa. Under emissions scenarios leading to stabilization of CO_2 at 750 ppm, the die back of tropical forests is delayed by about 100 years, but under stabilization at 550 ppm this loss is substantially reduced, even by the 2230s (Nigel *et al*., 2002).Shifts in distribution of plants and animals may be observed due to global warming whichmay lead to large-scale shifts in vegetation boundaries into high latitudes and elevations. Biome boundaries will be either shifted or overlap more. Vegetation zones may move towards higher latitudes or higher altitudes. More movements at higher latitudes where temperatures are expected to rise more than near the equator. Within the 45 to 60º mid-latitude region, current temperature zones may move 150–550 km. reduced capacity of forests to absorb carbon from the atmosphere, leading to a reduction in their potential to slow down global warming. As a result, throughout the summer months, lower soil moisture levels will exacerbate drought-related stress and enhance wildfire intensity.Wetlands are important habitats and regulators of water regimes and have unique biodiversity. They provide refuge and breeding grounds for many species. In lakes and streams, warming would have positive biological effects at high latitudes where biological productivity would increase and lead to the expansion of ranges of species and impact. In low latitude boundaries of cold and cool-water species ranges, the extinction is the greatest. Warmer climate will contribute to the decline in the wetlands through higher evaporation.

Another significant factor contributing to one health concept under climate change is biodiversity erosion. Climate change poses a particular threat to the biodiversity of certain coastal habitats, including saltwater marshes, mangroves, wetlands, coral reefs, coral atolls, and river deltas. Significant negative consequences on freshwater supplies, fisheries, biodiversity, and tourism would result from changes in these ecosystems. One of the main obstacles to species or ecosystem migration will be a lack of corridors, fragmented patches, and limited possibilities for adaptation in a fast-changing environment. This is one area where good land use management, planting, creating corridors, etc., will be beneficial. As per the study on alteration of ecosystem,urbanization will lead to an increase in global urban land cover in biodiversity hotspots by over 200% and 1.6 to 3.3 million hectares of prime farmland could be lost by 2030 (UNCCD). The share of the global population is expected to live in cities by around 2.5 billion by 2050s and due to it the habitats of 139 amphibian species, 41 mammalian species, and 25 bird species could either be encroached on or devastated.

Due to deforestation and intensive farming, India's deforestation rose from 384,000 hectares between 1990 and 2000 to 668,400 hectares between 2015 and 2020 (Down to Earth, 2023) which brought India to the second highest for the rate of deforestation (Longley, 2023). Disruptions in environmental conditions and habitats can provide new opportunities for diseases to pass to animals to human (through international travel and trade).

Livestock health

The health of animals can be described as normal physiological functioning of all the systems of the body of animals to achieve the highest production or the lack of disease. Whenever an animal gets ill, economic issues arise. Livestock diseases result in loss of production, treatment cost, prevention cost, and a barrier to trade (Ducrot et al, 2011).Over $1.4 trillion worth of assets are related to livestock worldwide. In developed as well as emerging nations, the livestock industry is significant. The livestock industry employs around 1.3 billion people, either directly or indirectly. Meat and milk from animals are valuable sources of nutrition. 33% of the world's total protein intake comes from livestock products. Due to the rising demand for livestock products, one of the main agricultural subsectors that is expanding quickly is livestock. Global meat production is expected to rise from 229 million tons in 1999 to 465 million tons by 2050. Similarly, it is anticipated that the amount of milk produced will rise from 580 million tons in 1999 to 1043 million tons in 2050 (Abubakar et al., 2020). The cattle industries in industrialized and emerging nations differ greatly from one another. Because of rising demand, there is a greater likelihood that the value of livestock will increase in developing nations compared to developed nations where demand is stagnant. The livestock industry has a lot of effects on the environment. After the electricity enterprise,the livestock sector is the one that produces the most pollution worldwide. Various greenhouse gases like ammonia (NH_3), carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) are released by animals and acid rain and global warming are caused by these gases.

Any epidemic of cattle disease in a developed nation would have an impact on the farm's and the nation's economy. However, additional concerns including food scarcity, loss of draught power, and social security are also stressed in underdeveloped nations in case of any outbreak of livestock disease (Rich and Perry, 2011). Because many animal diseases are zoonotic, public health is also impacted by them. According to Tomley and Shirley (2009), these illnesses can spread through direct contact (tuberculosis, brucellosis) or by vectors (Lyme disease, West Nile disease, Rift Valley fever). Around 60% of existing human infectious diseases are zoonotic in nature. About 75% of emerging infectious diseases of humans including Ebola, HIV and influenza have an animal origin. About 80% of the agents with potential bioterrorist use are zoonotic pathogens and 5 new human diseases appear every year out of them three are animal in origin.Another tip of the iceberg that we are currently dealing with is the spread of antibiotic resistance brought on by the overuse and misuse of antibiotics in the cattle industry (Ayukekbong *et al.,* 2017). Changing climate, deforestation and other land use land cover changes, illegal and poorly regulated wildlife trade, antimicrobial resistance and intensified agriculture and livestock production are the major factors for zoonosis emergence.Intensive animal farming, industrial livestock production, and macro-farmsalso known by opponents as factory farming, is a type of intensive agriculture, specifically an approach to animal husbandry designed to maximize production, while minimizing costs. To achievethis, agribusinesses keep livestock such as cattle, poultry, and fish at high stocking densities, at large scale, and using modern machinery, biotechnology, and global trade. The main products of this industry are meat, milk and eggs for human consumption.https://en.wikipedia.org/wiki/Intensive_animal_farming - cite_note-9 There are issues regarding whether intensive animal farming is sustainable in the social long-run given its costs in resources.There is a continuing debate over the benefits, risks, and ethics of intensive animal farming(Anonymous, 2023). Due to intensive animal farming, outbreaks of zoonotic diseases, such as avian influenza, Salmonella, Campylobacter, and many more diseaseshave become more widespread which require more use of antibiotics. There are innumerous consequences of antimicrobial resistance (AMR). At present, about 7.0 lakhs deaths each year are from AMR of which 90% occur in low- and middle-income countries (LMIC). As per one prediction, about 67% antimicrobial use will be increased mainly in LMIC by 2030s and due to which about 10% livestock production fall per year may be registered during the prediction period. The amount of USD 3.4 trillion per year would be involved in this

67% additional AM use which may be the equivalent of 40% of global expenditure on health today ultimately lead 24 million more people forced into extreme poverty and by 2050s, 10 million deaths each year from AMR is predicted. Therefore, animal health components haveanequal role in one health concept for sustainable development of a region or a nation.

Human health

The balance between a person and the environment, the unity of soul and body, and the natural origin of disease, was the backbone of the perception of human health in ancient Greece. Similar concepts existed in ancient Indian and Chinese medicine. In the 5th century BC, Pindar conceptualized health as "harmonious functioning of the organs", accentuating the physical dimension of health, the physical body, and the overall functionality, accompanied by the feeling of comfort and absence of pain. Even today, his concept bears importance as a prerequisite for overall health and wellness. In his "Dialogues," Plato (429–347 BC) made the statement that harmony between the interests of the individual and the community could lead to a perfect human society. He also suggested that people could achieve the ancient Greek philosophical ideal of "**a healthy mind in a healthy body**" by establishing both internal harmony and harmony with the external environment. The teachings of Aristotle hold that because humans are social creatures by nature, they have an obligation to uphold moral principles and ethical norms in the societies in which they reside. Aristotle highlighted that for a society to work harmoniously and for its members' health to be preserved, social ties must be controlled. Democritus wondered why people prayed to God for health and made the connection between behavior and health. Democritus connected health with behavior, wandering why people prayed to God for health, which was essentially under their own control.Hippocrates was the creator of the concept of "positive health", which depended on the primary human constitution (we consider it today as genetics), diet, and exercise.He believed that a healthy diet and regular exercise were vital to good health and that the changing of the seasons had a significant impact on the body and mind, leading to distinct disorders that predominate in the summer (digestive tract diseases) and winter (respiratory tract diseases). Many things could be said about the long-standing philosophical debate concerning body and soul, as well as the relationship between body and mind in contemporary society, either as an integrated whole (typically referencing Aristotle) or as an active dichotomy (Plato and Hellenism) that is crucial to understand in the context of today's online society (Svalastog*et al.,* 2017).

Interlinkages among environmental, livestock and human health

The connections between the health of humans, animals, and the environment are becoming increasingly clear considering the world's expanding human and animal populations as well as the drastically changing environment. For identifying and addressing new public health risks, it is important to broaden the scope of public health beyond a single species, given the shared health risks that animals and humans face from shifting environments. To mitigate the effects of new diseases, toxicant releases, climate change, and changes in the built environment, global public health capabilities and resources must be altered across many species. Besides these, to execute necessary health plans, specialists in the fields of human and animal health must surmount obstacles to interprofessional collaboration (Rabinowitz and Conti, 2013). It is also noticed that timely improvement is essentialin our relationship with animals and nature to tackle the global health, climate and biodiversity crises that put humanity and future generations at risk. Human activities, including the destruction and fragmentation of natural habitats, our unsustainable production and consumption patterns, and the direct exploitation of wildlife, are among the major drivers of biodiversity loss, disease outbreaks and climate change.The results of incorporating animal health and welfare concerns into policies intended to lower health risks to human beings, promote social justice and well-being, enhance food security and safety, and preserve biodiversity and the benefits it provides to people should therefore be investigated.

Therefore, it can be said that a proactive policy analysis based on prevention through coordinated action on human well-being, animal welfare, and environmental health is possible with the "One Health" approach. It offers a thorough strategy in support of worldwide sustainable development by considering how these connections affect livelihoods, food security, disaster resilience, public health, and other important socioeconomic, psychological, and environmental issues. In order to 1) eliminate wildlife exploitation and lower the risk of zoonotic diseases, 2) create inclusive and sustainable food systems, and 3) use group engagement to mainstream animal health and welfare into important industries, policies, and investment, certain revolutionary steps must be initiated by the policy makers and supported by the people.

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CERTIFICATION PROCESS AND STANDARDS FOR NATURAL FARMING

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Natural Farming (Bhartiya Prakratik Krishi Paddhati) is a way of chemical free farming based on livestock and locally available resources, with no chemical fertilizers and pesticides and rooted in Indian tradition. It is aimed at promoting traditional indigenous practices which gives freedom to farmers from externally purchased inputs (seeds to some extent, fertilizers, herbicides, insecticides, fungicides *etc*) and is largely based on on-farm biomass recycling with major stress on biomass mulching, use of on-farm livestock dung-urine formulations (concoctions); time to time working for soil aeration and exclusion of all synthetic chemical inputs directly or indirectly. Natural Farming systems process requires to be certified based on certain standards to get the trust of consumers. Government of India has proposed to develop certification process and standards for the Natural Farming through the committee constituted under the chairmanship of Dr S. Bhaskar, Former ADG (Agronomy, Agroforestry and Climate Change). The committee has proposed some norms and regulations for certifying the natural farming area and commodities which is under active consideration for approval by Ministry of Agriculture and Farmers Welfare and Bureau of Indian Standards (BIS). The Bureau of Indian Standards has already formulated two standards for Organic production systems covering crop and animal bases through IS 16550 (Part 1): 2016 and IS 16550 (Part 2): 2021. Now, started working on the standardization of the natural farming production system and are working closely with the Ministry of Agriculture and Farmers Welfare, Indian Council of Agricultural Research (ICAR), National Centre for Organic and Natural Farming (NCONF), Ghaziabad, and a diversified stakeholder group to formulate the right standard for the right people and at the right time. The salient features of the standards and processes proposed by the committee constituted to develop standards for natural farming certification are given below.

All agricultural, horticultural, medicinal / herbal and agroforestry crops, livestock / fisheries/Beekeeping systems and their products are being covered under proposed National Standards for certification of Natural Farming Products. Processing under Natural Farming Certification System (NFCS) is expected to be limited to on-farm processing at individual or at group of producers. Multi-ingredients processing, where raw material from different sources and from different certification systems are derived is expected to be not part of natural farming standards and NFCS. Various definitions pertaining to natural farming are given. Selected are described below.

Appetizers: Small portion of food before a meal to stimulate the appetite.

Antibiotics: Antibiotics are medicines that fight bacterial infections in people and animals. They work by killing the bacteria or by making it hard for the bacteria to grow and multiply.

Buffer zone: A clearly defined and identifiable boundary area bordering natural farming production site that is established to limit application of, or contact with, prohibited substances from an adjacent area.

Certification: Certification is a formal authentication whether individuals are knowledgeable enough in a given area to be labeled "competent to practice" in that area

Concoctions: Concoctions are prepared by combining different ingredients of cow based dung, urine mixed with natural on-farm resources.

Conversion: Conversion is the process of changing an agricultural farm from conventional to natural farm. This is also called transition.

Conversion period: The transition from conventional to natural farming within a given period of time, during which the provisions concerning natural production have been applied.

Grower Groups: Grower groups are Local groups (LGs), Individual farmers (IFs), Large area certification (LAC) farmers who intend to practice natural farming/engage in natural processes in accordance with the requirements of this standard.

ITKs: Indigenous Technical Knowledge (ITK) is specifically concerned with actual application of the thinking of the local people in various operations of agriculture and allied areas.

Mulching: Mulching is the practice of adding live or dead matter to help with weed suppression, soil fertility, water retention etc

The committee defined the Natural farming as an agricultural production system which mainly emphasis on use of locally available on farm/traditional inputs integrated system with good agronomic practices which encourages coexistence, soil health, ecology, natural cycles, natural micro flora and fauna, diversity, production density and good production management system.

Crop and Livestock production system under natural farming certification process mainly involves habitat care, agro-biodiversity, landscape, seeds and planting material, diversity in crop production and management plan, soil fertility management, insect, pest and weed management, contamination control (separate storage, buffer zones, cleaning etc), transition / conversion period and requirements for transition, soil and water conservation and non-cultivated material of plant origin /forest produce, Therapeutic use of veterinary drugs are permitted under prescription and supervision of a registered veterinarian, provided that the double the mandatory withdrawal periods as prescribed for that drug is followed. In drugs where withdrawal period is not prescribed, a minimum of 48 hours of withdrawal period shall be observed.

According to standards proposed, in natural farming practices, the widely practiced methodology in India is native breed of Cow based or Go Aadharith Vyavasay. This Cow based or Go aadharith Vyavasay is based on use of bio-formulations like Jeevamrit, Beejamrit, Ghanjeevamrit, Neemastra and cultural practices such as Acchadana and Whapasa. These are formulas, methods and treatments which help the crops grow with natural constituents. The combination of these concoctions and practices makes it possible to achieve a more sustainable farming. It is also proposed that natural farming system shall avoid use of purchased inputs (chemical or otherwise). Therefore, all inputs shall be prepared on-farm or sourced locally on exchange basis from fellow natural farmers within the 10 KM radius and maximum upto Taluk/Tehsil Level. Authorised Gaushalas upto District level can also be considered for purchase of NF inputs.

The inputs are classified under 3 categories namely permitted, restricted and not permitted as in organic farming certification. Permitted inputs can be used directly while restricted inputs are allowed based on certain requirements and conditions of the farm by the proposed local executive committees.

Major Steps proposed in Natural Farming Authorization for local Groups / Individuals/ LAC includes online registration of farmers (upload farmer's identification and land details), uploading time to time self-peer inspection practices as per Natural Farming Standards, submission of details of self-peer inspection and declaration, generation of self-certificate with QR code with UID Numbers, automatic integration to *Jaivikkheti* web portal and online sale of product and generate Transaction certificate. Similarly, the steps proposed for processors include online registration of processors (upload production unit details), submission of unit details and annual products production plan/details, physical inspection of unit by QCAs, authorization of processors by QCAs and approval of annual products production plan/details besides purchasing of products by processors from authorized operators with Transaction certificate.Under Natural farming certification systems, gaushalas (cow shelters) are expected to be certified for natural farming inputs supply to local farmers.

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https://naturalfarming.dac.gov.in/Schemes/Nfstandardscertification

AGRO ECOSYSTEM SERVICES UNDER NATURAL FARMING

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1. Introduction

Ecosystem services are defined as the goods and services provided to humans. These services offered by diverse types of ecosystems differ in nature and consequence. Such ecosystems include agro ecosystem, forest ecosystem, grassland ecosystem and aquatic ecosystems. These ecosystems functioning in healthy relationships, offer such things as natural pollination of crops, clean air, extreme weather mitigation and human mental and physical well-being. Some services directly affect the livelihood of neighbouring human populations (such as fresh water, food or aesthetic value) while other services affect general environmental conditions by which humans are indirectly concerned (such as climate change, erosion regulation or natural hazard mitigation, etc.). Collectively these benefits are becoming known as ecosystem services and are often integral to the provision of food, clean drinking water, decomposition of wastes and resilience and productivity of food ecosystems (Alexander *et al*., 2016; Maes *et al*., 2016).

2. Agricultural ecosystems

Agricultural ecosystems provide food and basic necessary services to human for nourishment of life besides providing as fiber, fuel, and other non-marketed services to the environment. As indicated by FAO (2023), organic agriculture is a holistic production management system which promotes and enhances agro-ecosystem health, biodiversity, biological cycles and soil biological activity. It emphasizes the use of biological inputs to avoid using synthetic materials. Similarly Natural farming system works along with natural biodiversity of each farmed area, encouraging the complexity of living organisms including both plant and animal that shape each particular ecosystem to thrive along with food crops. Natural farming is a closed system that mimics nature and demands no human supplied inputs (Asokan *et al*, 2020; Panda *et al*., 2022).

3. Categorization of Ecosystem services

Ecosystem services from agricultural activity are grouped broadly into two categories viz., marketing and non marketing services and specifically into four categories are:

(i). Provisioning services

(ii). Regulating services

(iii). Supporting services and

(iv). Cultural services

An ecosystem does not necessarily offer all four types of services simultaneously but given the intricate nature of any ecosystem, is mostly assumed that humans benefit from a combination of these services.

(i). Provisioning services

Provisioning services also called as ecosystem goods include: food crops, wild foods and spices, raw materials (lumber, skins, fuel wood, fodder, organic matter), genetic resources including crop improvement genes and health care, biogenic minerals, medicine resources (pharmaceuticals), energy (hydropower, biomass fuels) and ornamental resources (including fashion, handicrafts, furs, feathers, ivory, orchids, butterflies, aquarium, fish, shells etc.)

(ii). Regulating services

Regulating services includes purification of water and air, carbon sequestration and climate regulation, waste decomposition and detoxification, regulation of predation and prey population, biological control of pest and disease control, pollination, flood protection etc.

(iii). Supporting services

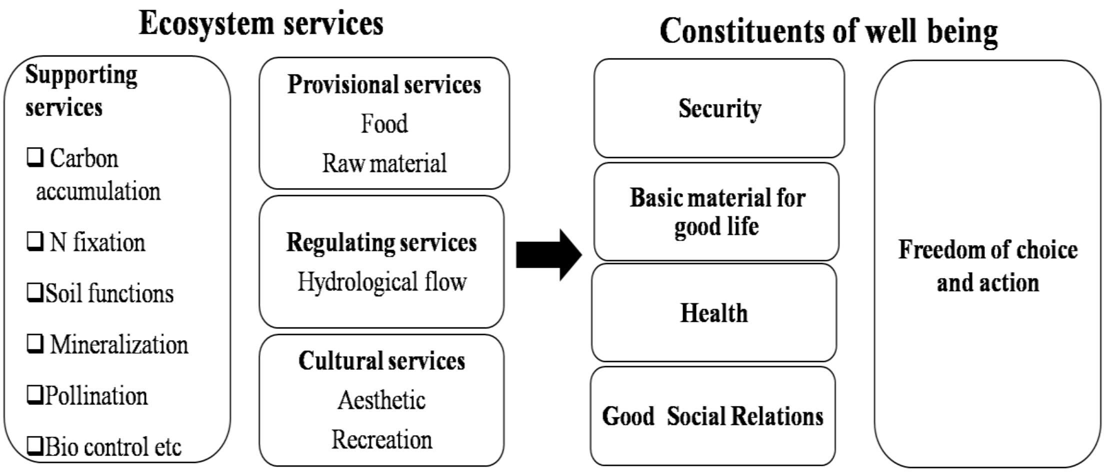
Supporting services may be redundant with regulating services in some categorizations, but include services such as nutrient cycling, primary production, soil formation, habitat provision. These services make it possible for the ecosystem to continue providing services such as food supply, food regulation and water purification.

(iv). Cultural services

Cultural services include cultural (including use of nature as motif in books, film, painting, folklore, national symbols, advertising etc.), spiritual and historical (including use of nature for religious or heritage value or natural), recreational experiences (including ecotourism, outdoor sports and recreation), science and education (including use natural systems for school excursions and scientific discovery), therapeutic (including eco-therapy, social forestry and animal assisted therapy).

4. Need for ecosystem services evaluation

Decline of natural resources worldwide due to over exploitation resulted in the loss of ecosystem services necessitating that ecosystem services being accounted for through proper valuations. This process helps to promote the ES concept within governmental policy agendas. Many researchers have suggested that in order to increase the income of farmers, some minimum compensatory mechanism/allowance may be adopted / provided on the basis of a valuation of the ES that they generate. It has been reported that providing a monetary value for ES is an important step to raise awareness as well as convey the importance of ES to policy makers (Nayak *et al.* 2019; Meli *et al.,* 2023; Morizet-Davis *et al.*, 2023; Bruno *et al.*, 2023). In this context, valuation of Ecosystem services (ES) under natural farming is vital for the sustainable supply of safe food and fibre including other non-marketed services, but their economic value has rarely been evaluated in agricultural crops at field level. The connections between ecosystem services and human well being are presented in the figure below.



Ecosystem services and their connections to human well-being

5. Methodology for the evaluation of agro-ecosystem services

Ecosystem Services associated with the any agricultural production systems can be assessed by conducting field survey and field experiments using 'bottom-up' assessment methods i.e., by conducting field experiments to assess each service. Total economic value of ES will be calculated by summing the total of all the individual ES values measured.

$$ES_{Total} = \sum ES_n = \sum ES_{Market} + \sum ES_{Non\text{-}market}$$

Where,

ES_{Total} = Total Ecosystem Services

ES_n = Number of Ecosystem Services

ES_{Market} = Market value of ES included the economic value of products and raw materials produced

$ES_{Non\text{-}market}$ = Non market ES generated in the farm

These market and nonmarket values are the two components of total economic value of ES.

ES market = ES1 + ES2

ES non-market = ∑ ES1-2 - ∑ ES3-8

Change in the value of ES for both the systems will be calculated by using the value of organic and conventional farms

$\Delta ES = \sum ES\ organic - \sum ES\ conventional$

5.1. Evaluation of Biological control of pests

Under natural farming, pests managed by predators and parasitoids will be assessed by using real pests and prey surrogates used to define 'predation rate' (Sandhu *et al.*, 2010). Predation rate can be arrived by counting the population of biocontrol agents present (Bonato *et al.*, 2023). Under conventional farming the pesticides are recommended to be applied when pest population crosses the economic threshold level / ETL. The corresponding predation rate is used to calculate the number of pests removed. Thus, the value of biological control is calculated by multiplying the number of pests removed by the cost involved in spraying.

5.2. Evaluation of Soil formation

Soil formation is an important ecosystem service provided by the soil biota (Bock & Markovchick, 2023). It will be assessed on the basis of earthworm population as they are the indicators of soil structure and fertility. Earthworm populations in each of the selected fields will be assessed to estimate the quantity of soil formed $ha^{-1}\ yr^{-1}$ (Sandhu *et al.*, 2005; Camila *et al.*, 2023). The economic value of earthworms in soil formation was calculated based on the assumptions that the mean biomass of an earthworm is 0.2g (Dume *et al.*, 2023) and that one tonne of earthworm's forms 1000 kg of soil $ha^{-1}\ yr^{-1}$ (Toshov *et al.*, 2023).

5.3. Evaluation of Mineralization of plant nutrients

The economic value of mineralization of plant nutrients will be calculated using data on mineralization of soil nitrogen obtained from soil samples using colorimetric determination. The total amount of nitrogen mineralized is valued at equivalent price per kg of fertilizer N (US$ 0.0824 /kg) as reported by Shahid *et al.* (2017).

5.4. Evaluation of Carbon sequestration

The amount of crop and root residue will be estimated and then amount of carbon accumulated by tissue in the soil will be calculated based on soil carbon analysis by using the Walkley-Black chromic acid wet oxidation method (Nelson and Sommers, 1996; Fan et *al.*, 2022). Normally it is assumed that the crop residue is 1.5 times the crop grain yield and 40% of this is carbon (Metzger and Benford, 2001; Johnson *et al.*, 2006). This is used to calculate the economic value of carbon accumulation in each field.

5.5. Evaluation of Nitrogen fixation

The economic value of nitrogen fixed by different crops was estimated by the amount of nitrogen fixed per hectare which was then valued at the unit price of urea.

5.6. Evaluation of Soil fertility

Soil fertility service will be estimated by assessing the available forms of nitrogen, phosphorus, potassium, sulphur and other micronutrients in representative soils and valued at the unit price of respective local fertilizers.

6. Case studies on ecosystem services evaluation

Several studies were undertaken regarding the valuation of ecosystem services in different sectors. Constanza *et al*. (1997) assessed that the viability of the Earth's life-support system depends on the services provided by ecological systems and the natural capital stocks that generate those services. They make both direct and indirect contributions to human welfare, making up a portion of the planet's overall economic worth. Value transfer technique was used to estimate the value of the goods and services provided by the global ecosystem. According to the estimates, the annual economic value of 17 ecosystem services in 16 biomes ranges from US $16 to US $54 trillion, with a typical worth of US $33 trillion. According to Pimentel *et al*. (1997), all ecosystems and human societies depend on a stable, productive environment that is inhabited by a diverse range of plant and animal species. An estimated 10 million different species of plants, animals, and microorganisms make up the earth's biota. They calculated the financial and environmental benefits of all biota. The benefits were assessed to be worth $2928 billion annually, or 11% of the $26 trillion global economy.

Adhikari (2009) compared the economics of organic and inorganic carrot production in Nepal. Benefit Cost ratio approach was used for this study. The results revealed that among the cost components, per unit cost on female labor and organic fertilizer were found to be higher in organic production system where as per unit cost on seed, tillage operation and male labor were found to be higher in inorganic production system. Overall the cost and revenue was higher under inorganic production system whereas higher benefit cost ratio was found in organic production system and revealed that organic carrot production system was economically profitable than inorganic production system.

Biswas and Charyalu (2010) compared the economics and efficiency of organic and conventional farming in India. Four states namely Gujarat, Maharashtra, Punjab and U.P were selected and four major crops i.e., cotton, sugarcane, paddy and wheat were chosen for comparison. A model based nonparametric Data Envelopment Analysis (DEA) was used for analyzing the efficiency of the farming systems. It is concluded that the unit cost of production is lower in organic farming in case of cotton and sugarcane crops whereas the same is lower in conventional farming for paddy and wheat crops. The DEA efficiency analysis conducted on different crops indicated that the efficiency levels are lower in organic farming when compared to conventional farming, relative to their production frontiers.

Binta and Barbier (2015) compared the economic and environmental performances of organic and conventional horticultural farming systems in the Niayes region, Senegal. While carbon emissions are considered environmental indicators, the gross margin is considered as an economic indicator. As both farming systems have the same sale price, the results show that conventional farming is still more desirable than organic farming.

Fan *et al*. (2016) studied the economic valuation of ES given by organic cereal crop production systems with different management strategies (low, medium and high) by adding the market and non-market ES. Their results showed that organic matter inputs had a significant impact on the overall ES value on organic cereal crop production systems. The highest gross total ES value was found in the system with a high input of organic matter ($1991 ha/ year), followed by the system with a low input of organic matter ($1688 ha/ year), and the lowest ES value was found in the system with a medium input of organic matter ($1492 ha/ year).

Mahlouji Rad *et al.* (2016) compared the value of ecosystem services in conventional wheat and potato organic farms in Nariman city. The agro-ecosystem services studied included primary and secondary production as market services and pest control, soil production, carbon sequestration, supply of nutrients from the soil and soil fertility as non-market services. The findings indicated that organic wheat farms had better market and non-market values than conventional farms, with a total value of ecosystem services in organic farms equivalent to 9.75 million Rs. ha^{-1} $year^{-1}$ and a gain of roughly 7.84 million Rs. ha^{-1} $year^{-1}$.

Sivashankar (2017) calculated the welfare values related to three important ecosystem services: water control, soil retention, bio diversity related to organic farming fields, and the willingness of Valikamam residents to pay for improvements on those ecosystem services at Jaffna, Sri Lanka. Choice modelling technique and Logit model was performed to analyze the welfare values related to ecosystem services. The results showed that the average annual welfare value of enhancements to all three ecosystem services was calculated to be roughly Rs. 150 per household and the reduction in nitrate leaching, soil quality improvement and enhancement of biodiversity per household per year was cost around Rs. 61, Rs 56, and Rs 25, respectively.

Sugandh and Joshi (2018) reflected on the significance of wetlands as highly productive ecosystems with diverse ecological benefits crucial for human well-being. Keoladeo National Park (KNP) in Rajasthan, India, a prominent man-made wetland, was highlighted for its avian biodiversity. Land use changes due to irregular water supply and invasive species disrupted ecosystem services. The research estimated KNP's annual provision of Carbon sequestration, avian habitat, and recreation, valuing them at $1.33 million through geospatial tools. Insights aided habitat identification and conservation priorities. The study underscored trade-offs between ecosystem services, emphasizing balanced supply.

Nayak *et al.* (2019) calculated the value of ecosystem services produced by rice farms in various agro climatic zones (ACZs) in Eastern India and they evaluated the disparity between farm revenue and the value of marketed and non -marketed ES produced by rice farms. They found that the rice fields in eastern India had an overall economic value per unit area ES that ranged from US$ 1238 to 1688 per hectare per year.

Environmental degradation may be caused by excessive chemical use in agriculture by the way of synthetic fertilizers and pesticides which may have negative effects on ecosystems, soil fertility, biodiversity, and human health. Benefit Cost Ratio (BCR) approach was used to analyze the benefits of organic and conventional horticultural farming in Gatesan, Indonesia. It showed that the ratio of the cost of benefits from organic horticulture farming was higher (4.93) compared to the benefits of conventional agricultural cultivation (2.73) with a significant difference (Asfawi *et al.*, 2020).

Balasubramanian (2020), assessed the ecosystem values in Karnataka's Western Ghats, focusing on Biligiri Rangaswamy Wildlife Sanctuary, Nagarahole National Park, and Bannerghatta National Park. Combining primary and secondary data, quantified services via surveys (148 soliga tribal households for non-timber forest products), and interviews (425 tourists for recreation services). Carbon sequestration and soil prevention were also valued. Outcomes indicated an economic value of approximately Rs138.4 million across the three areas, with recreation services holding the highest worth, followed by carbon sequestration, soil prevention, and provisioning. The research offered valuable insights for local-level policy decisions and integration of ecosystem services into broader goals.

Sachin *et al.* (2020), assessed the monetary value of mangrove ecosystem services in Uttara Kannada, India, and findings revealed limited awareness of certain services. Nonetheless, local communities heavily relied on mangrove resources, yielding financial benefits. Inland fishers exhibited stronger interest in preserving mangroves than marine fishermen and Gazni farmers, influenced by socio-economic factors. The research highlighted mangroves' pivotal role in community well-being, suggesting that enhancing their development and management could amplify ecosystem services, fostering socio-economic progress.

Rasal *et al*. (2021) extensively explored Kailadevi Wildlife Sanctuary's transformation post the loss and recovery of its Tiger population. Using a VALUE+ approach, the study methodically assessed ecosystem services, revealing substantial societal values generated. Despite exploitation challenges, the sanctuary provided significant benefits, valued at around INR 84.47 billion annually. Comparative analysis with Ranthambhore National Park highlighted differing service provision, showcasing potential gains like ecotourism and wildlife resurgence, while also revealing challenges for resource extractors.

7. Conclusion

There is a growing interest among the farmers, consumers and policy makers towards organic and natural way of producing goods and services. Organic agriculture has potential to provide residue free food for protecting the human health along with fiber and fuel and also to support the ecosystem by providing number of non-marketed services such as enhancing the soil fertility, soil formation, carbon sequestration, biological control of pest, mineralization of plant nutrients, Nitrogen fixation, etc. The value of non-marketed services is important to assess the contribution of each service in the human and environment wellbeing. However the valuation of ecosystem services on natural farming has been little documented across the world and in India. Moreover, the comparing the gap in average income realized by the farmers and the total value of ecosystem services generated under the natural production system will provide insight to the policy makers so as to trigger the organic and natural way of production.

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BUSINESS APPROACHES FOR NATURAL FARMING AND NATURAL FOODS

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Introduction

Natural Farming is the method of chemical and toxic free farming based on desi cow and locally available resources, with no chemical fertilizers and pesticides. It promotes traditional indigenous practices which give freedom to farmers from externally purchased inputs. It is largely based on the biomass recycling, biomass mulching, use of desi cow dung-urine formulation, managing pests through diversity and exclusion of all synthetic chemical inputs directly or indirectly. The major emphasis is given on improving natural nutrient cycling and increase in organic content in the soil. It can help with climate change resilience and carbon sequestration in soils. National Standard of Organic Production (NSOP) has defined organic agriculture as "system of farm design and management to create an ecosystem which can achieve sustainable productivity without use of artificial off farm input such aschemical fertilizer and pesticides". Organic farming is considered to be climate friendly farming practices promoting low external input usage, recycling, reuse and reduced use of synthetics in farming.

Organic/ natural food production sector should be linked to sustainable farm food production. It mainly uses the locally available and renewable resources as well as wastes and by-products of plants and animal origin. Natural/ Organic food ensures the quality of the food to the consumers and completely avoid toxic pesticides, synthetic fertilizer and free form genetically modified organisms (GMOs) in the food production. Moreover, it also ensures that strict cultivation standards with respect to impact on soil, water and air support in order to protect the environment. Sustainable food production is associated with following aspects like consumers health, animal welfare, food security and environmental advantage.

Apart from these, other advantages of natural and organic agricultural foods are free from harmful chemicals, reduction in production cost, usage of natural fertilizers and improvement in plant growth, healthy, natural and pure food, environmental Farming and natural Foods protection and helps saving energy, reduction in different types of pollution, higher food nutritional value and better taste and poison-free food

Global Scenario

According to the latest FiBL survey, 2021 on organic agriculture, the global market for organic food reached 106 billion euros. Major importers of natural/ organic agricultural products are United States of America (USA) (44.7 billion euros) followed by Germany (12.0 billion euros) and France (11.3 billion euros). About 3.1 million producers across the globe cultivated different crops through organic method of cultivation in the year 2019. India continues to be the country with the highest number of producers (13,66,000), followed by Uganda (2,10,000) and Ethiopia (2,04,000). Globally, 1.5 percent of farmland is under organic method of cultivation. Australia has the largest organic agricultural area (35.7 million hectares), followed by Argentina (3.7 million hectares) and Spain (2.4 million hectares). However, in case of India, the total land under organic agriculture is 1.3 percent of total agricultural land.

In order to motivate farmers to adopt chemical free farming and to enhance the reach of natural farming, the Government of India (GoI) had formulated National Mission on Natural Farming (NMNF) during 2023-24 by up-scaling the Bhartiya Prakriti Krishi Paddati (BPKP). The success of NMNF requires the behavioural change among farmers to shift from chemical based inputs to cow based locally produced inputs. Thus, it requires continuous awareness creation, handholding and capacity building of farmers in the initial years.

Indian Scenario

In India, total area under organic cultivation through certification process (registered under National Programme for Organic Production) is 10.17 mha (2022-23). This includes 53,91,792.97 ha of cultivable area and another 47,80,130.56 ha of wild harvest collection. Among all the states, Madhya Pradesh ranked number one position with respect to largest area under organic certification followed by Maharashtra, Gujarat, Rajasthan, Odisha, Karnataka, Uttarakhand, Sikkim, Chhattisgarh, Uttar Pradesh and Jharkhand. India produced around 2.9 Million MT (2022-23) of certified organic products which includes different varieties of food products namely Oil Seeds, fibre, Sugar cane, Cereals & Millets, Cotton, Pulses, Aromatic & Medicinal Plants, Tea, Coffee, Fruits, Spices, Dry Fruits, Vegetables, Processed foods etc. It produces organic cotton fibre, functional food products etc., Among different states in India, Madhya Pradesh is the largest producer followed by Maharashtra, Rajasthan, Karnataka, and Odisha. In case of agricultural commodities, Fibre crops are the single largest category followed by Oil Seeds, Sugar crops, Cereals and Millets, Medicinal/ Herbal and Aromatic plants, Spices & Condiments, Fresh Fruit Vegetable, Pulses, Tea and Coffee. The total volume of export during 2022-23 was 312800.51 MT. The organic food export realization was around INR 5525.18 crores (708.33 million USD). Organic products are exported to USA, European Union, Canada, Great Britain, Switzerland, Turkey, Australia, Ecuador, Korea Republic, Vietnam, Japan, etc. Detailed information regarding production and export of organic products from India is attached in Annexure I.Consumer behaviour towards natural/ organic food products

The natural/ organic food market in India is a niche market and it is in nascent stage. The market is expected to see wider penetration in the coming years. Also, the market for natural/ organic food is currently exhibiting strong growth in India. The increased awareness about harmful effects of chemicals, toxic food, shift in consumers' tastes and preferences have led to the rise in domestic as well as global demand for natural/ organic food products. The major factor driving for the demand of India's natural/ organic food market is the increasing levels of health awareness. Indian consumers have started giving consideration to the nutrient content and also the quality of the food they eat, thereby leading to a rising demand of naturally grown organic food. Moreover, research studies reported that factors such as strong economic growth, urbanization, rising income levels, consumer expenditure on health and wellness products have increased significantly to consume natural/ organic foods. New initiatives in marketing of naturally/ organic produce are emerging and there exists a huge gap in certification and identification of the prospective customers.

India is one of the potential and largest producers of a variety of organic/ naturally grown agricultural produce. The demand of organic food in India is being catalysed by the strong support of the government. The Indian government is promoting natural/ organic farming by providing financial Support to farmers who are adopting natural/ organic farming under various government schemes such as Mission for Integrated Development of Horticulture (MIDH), National Food Security Mission (NFSM), National Mission for Sustainable Agriculture (NMSA), Rashtriya Krishi Vikas Yojana (RKVY), Paramparagat Krishi Vikas Yojana *etc.,* In the same line, state governments like Andhra Pradesh, Meghalaya, Sikkim, Maharashtra and Karnataka are promoting in a bigger way.

Production management aspects of Natural and organic agricultural products

The major objective of production management is to produce goods and services of the right quality, right quantity, at the right time and at minimum cost. It is done by allocating time and effort into production planning, scheduling, controlling and maintenance. The production management involves different combinations of local seeds, on farm produced microbial formulation for seed treatment, on farm made microbial inoculants, cover crops and mulching, mixed cropping, integration of trees, management of pests through diversity and local on farm botanical concoctions, integration of livestocks and no external inputs. Based on the above aspects, the cost of production can be minimised and produce the natural and organic healthy food.

Marketing management aspects of Natural and organic agricultural products

Marketing of natural and organic produces requires a sound knowledge of the product, market, target audience and other stakeholders involved in the supply chain. In order to be successful in the business venture, natural and organic startups need to be correctly marketed to the relevant audience who are in demand. Marketing mix *viz.,* Product, Price, Place and Promotion needs to be taken care.

A) Product

In case of organic and natural agricultural product, there is a need to assess the demand of the product, quality of the product, cost minimisation and profile of the competitor's product.

B) Price

Price of the product is another important factor influences the marketability of the organic and natural agricultural products. Price is the amount that consumers provide the value for the utility of the product and willing to pay for a product. Different pricing mechanisms suitable for the organic and natural products are skimming price (High initial price), fixing premium price for the quality product, cost plus margin pricing and demand-based pricing.

C) Promotion

The major objective of the promotion is to communicate the consumers about the nature and other information about the product. Promotion encompasses advertising, public relations and publicity about the agricultural products.

D) Place

It refers to customer access and provides convenience for consumers about the natural and organic agricultural products. The information regarding location of the availability of natural and organic products.

Target consumers: The target consumers for natural/ organic agricultural products are high net worth individuals (HNIs), health-conscious consumers and patients suffering from chemical food allergies.

Farm Business Strategies for natural and organic agricultural products

Business strategies concentrates on the scope and direction of the business in terms of expansion, maintenance, contraction, etc. For instance, Farm business strategies are part of the strategic planning process. The business strategy should create and sustain a competitive advantage that enables to consistently earn above average returns and need to attain super normal profits status.

According to Don Hofstrand (2016), business strategies are classified into five types and are listed below

- Growth Strategies - expanding the size of the business
- Stability Strategies - maintaining the size of the business
- Restructuring Strategies - refocusing the business for improved performance
- Succession Strategies - transferring the business to the younger generation
- Exit Strategies - ending and leaving the farm business

Growth Strategies

Growth strategies for natural and organic agricultural products involve various ways of expanding the size of the farm business. Growth may take many forms and directions. Some of the common growth strategies are listed below.

- **Capacity Expansion** - With this strategy, the natural and organic farm cultivation enterprises may be expanded. It means more acres of crops or more head of livestock under natural and organic farming methods of cultivation. It is a horizontal form of expansion as opposed to a vertical expansion which moves up or down the supply chain. The economies of size will be achieved based on this strategy.
- **Replicate** - This is a form of capacity expansion where the existing operation (i.e) natural and organic methods of cultivation can be replicated at a different locations and place. This strategy is often used for livestock operation when further expansion at the current location is not feasible.

- **Intensify/ Modernize** - This is another form of capacity expansion where the real assets of the business are not expanded. Rather, they are modernized so more production can be pushed through a fixed asset base. This can occur in both crop and livestock production. High value crops through protected cultivation under natural farming methods of cultivation can be
- **Diversify** - This is another form of horizontal expansion. However, instead of expanding the existing enterprises, new enterprises are added. A diversification strategy may be designed to make use of economies of scope and other synergies between the enterprises to achieve low-cost status. It achieves the high benefit cost ratio for the natural and organic agricultural products.
- **Networking** - This involves working with others to gain advantages not available to individuals. Networking may leverage the activities and resources of your business operation. It may also increase the efficiency of the business operation. Networking can be used for either vertical or horizontal expansion. Networking can be accomplished through information arrangements, contracts or various types of joint ventures.

Stability Strategies

Stability strategies includes various ways of maintaining the size and organization of the business at its current level. Stability strategies sometimes occur after a long period of growth. Or they may occur from the beginning of the business. It often depends on the goals and ambitions of the owner/ operator.

- **Adequate Income** – Natural and organic method of cultivation is expanded until it generates adequate income levels for the owner/ operator and farm family. However, if adequate income levels are not maintained over time, the business may be expanded until it does.
- **Profit** - After a period of expansion of natural and organic method of cultivation, the owner/ operator can decide to sacrifice future growth by not reinvesting in the business.
- **Wait and See** – If market is not conducive for natural and organic agricultural products, the cultivator needs to wait until the future is more certain before expanding. However, if not managed correctly, the owner/operator may wait too long and miss the opportunity for expansion.

Restructuring Strategies

Restructuring strategies are used when the farm business is not performing as it should. Performance problems will range from inadequate income levels to the major threat of insolvency and bankruptcy. If the business cannot feasibly be restructured, it is liquidated.

- **Refocus** - This strategy is used to refocus the activities of the business. It usually involves changing the mix of enterprises including the primary enterprises on which the business is built. It is used for farm businesses that are solvent (adequate equity) but not profitable.
- **Retrenchment** - This strategy usually involves three sequential phases of contraction (liquidate part of business), consolidation (restructure business) and rebuilding. This strategy is used for farms that are neither profitable nor financially sound.
- **Liquidation** - If the business is neither profitable, nor financially sound and a retrenchment strategy is not deemed to be feasible, the decision is made to liquidate the business before the owner/operator loses all equity in the business.

Succession Strategies

These are strategies for transferring a farm business (not just the assets but the on-going business) from one generation to the next. The younger and older persons are often related but don't need to be. Succession strategies are often combined with estate planning by the parties.

- **Spin-off** - A younger person initially returns to the farm business but after a year or so starts his/her own farm business. The younger and older parties may work together and share machinery, equipment, etc. However, each party operates his/her own business. At the retirement of the older party, the younger person merges the two businesses together and operates them as one business in organic and natural farming business.

Exit Strategies

These are strategies for ending the farm business. This usually occurs at the retirement of the farm owner/operator but the strategy may start to be implemented several years before retirement.

Different methods of selling natural and organic products

Farmer's market: Farmer's market provides opportunities for farmers to sell their natural and organic products directly to the consumers. It is the larger target customer for natural and organic produces. These channels increase the producers share in consumers rupee for the welfare of farmers.

Restaurants and hotels: Many restaurants and hotels are in need of the natural and organic produce to meet their consumption habits and trends of their diet and health-conscious consumers and also to enlarge their menu options.

Retail grocery stores: The retail grocery stores are in direct contact with the consumers. These stores provide wide options for their customers to choose their natural and organic products. Health-conscious customers and High Networth Individuals (HNIs) prefer natural and organic products in order to meet the nutritious and diet needs.

Coffee house and cafes: These are massive market strategy to target the customers spend their time in coffee house and cafes. These customers requires the organically produced herbs like coffee, tea and other organic seeds like coffee to give their customers and also an organic experience.

Online grocery stores: Online grocery stores are another largest target consumers to meet the online shopping consumer's needs of organically produced fruits, vegetables, grains *etc.*

Online platforms

Government owned online e-commerce portals like ONDC, Uzhavan app and TNAU Agricart can be used to promote natural and organic agricultural products.

Identification of the market demand

It is mandatory to identify the demand for the natural and organic product in the market. Identification of the demand for these product needs to be done. If the demand for the particular is high and lucrative, one should move towards production and marketing of the particular product.

Create a unique website

Based on the market demand, separate website carrying the information about natural and organic products can be created. Creating a website is one of the first steps that natural and organic producers to initiate and start any online business. If the demand is high, then making a website is the best step to be taken to sell organic products online. It is one of the best ways to sell the natural and organic products through online method. Through this method, the products reach all over the globe and the cost of advertisement is also on the lower side.

Social Media

Promotion of social media account on social media platforms like Facebook and Instagram and WhatsApp is a good way to advertise and enhance the number of customers. It is one of the most important advertising methods in modern days for the most active part of the youth and the adults are on these social media platforms. It helps to create awareness and attraction resulting in more sales.

Provide Home Delivery

Creating comfort to customers in the form of door delivery enhances the selling process of natural/ organic products. If this need is fulfilled, then it coerces them to click on that buy option again. Providing home delivery services enhances the online business of natural and organic agricultural products.

Post Testimonials

Customers of natural and organic agricultural products feedback are very important. Posting the review and feedback for the usage of the natural and organic agricultural products increases the business's trust and enhances the sales.

Challenges in marketing of natural farm products

Identifying the market and prospective buyers is the biggest challenge for natural/ organic agricultural products in India. There exists a gap in identification of potential market for natural/organic market. Producers, traders, marketers and policy makers dealing with naturally grown farm products are facing lot of challenges. However, huge opportunities exist for the export of natural/ organic farm products. Researchers pointed out the following aspects regarding the natural and organic agricultural products *viz.,*

- Uniformity
- Trustworthiness of the quality of natural/ organic agricultural products
- Certification
- Willingness to pay the premium price
- Assurance of pest and disease-free nature of the product

In order to bridge the gaps and identify the solution to above challenges, some of the start-ups and private companies dealt natural and organic agricultural products and are listed below

- Organic India
- Naturel and organic

- Samrudhi organic farm
- Farm2kitchen
- Organic tatwa

These start-ups produced natural and organic agricultural products and selling their products to customers in a successful and innovative manner. Apart from these, farmers from Andhra Pradesh, Maharashtra, Gujarat, Rajasthan, Haryana, Sikkim, TamilNadu and Uttar Pradesh are successfully cultivating natural and organic agricultural products. According to NITI Aayog (2022), benefit cost ratio pertaining to agricultural crops cultivated under natural method of cultivation is higher when compared to conventional method of cultivation. Hence, It is understood that farmers cultivating agricultural crops under natural method of cultivation realised better price and higher profits than conventional method of cultivation of agricultural crops. Success stories of farmers cultivating agricultural crops under natural farming reported by NITI AAYOG (2022) in the compendium of success of natural farming are listed below

Success stories of farmers adopted natural farming in the state of Andhra Pradesh

SHRIACHIRTHINARAYANAMURTHY	**SMT. ANUGULAVENKATASUGUNAMMA**
Village : P KothaGudem Mandal: Nathavaram District: Visakhapatnam, Andhra Pradesh Contact No: 9963859901 Education : Intermediate	Village: Nagamangalam Mandal: Palamaner District: Chittoor, Andhra Pradesh Contact No: 9550166197 Education: Intermediate
Practices adopted • He adopted natural farming in an area of 0.5 acres and gradually brought the entire 2 acres of land under natural farming within two years. • Owns a pair of cow and buffaloes. • Practiced System of Rice Intensification (SRI) method of paddy and raised desi varieties in 0.4 acres for seed generation.	**Practices adopted** • Adopted natural farming in 2018, after attending a meeting at the Mandal level delivered by a community resource person explaining the practices and benefits of natural farming • Owns 18 acres of land consisting of 15 acres of mango orchard, 2 acres of groundnut and 1 acre of paddy. Cultivated Dhanista variety of paddy under natural farming.

- Adopted all natural farming techniques like beejamrit, ghanajivamrit, dravajivamrit, PMDS, usage of growth promoters (egg amino acid, sapthdanyakurakashaya and botanical extracts), and kashayas for pest management.
- Master farmers or best practising farmers called Community Resource Persons (CRPs) take the technology to each farmer, and provide continuous support to the farmers through regular field visits, farmer field schools, and training videos.
- Farmers' experiences are discussed regularly in the women' SHG meetings.
- The farmer can contact the village level CRP whenever they have a problem. If the village level CRP is not able to solve the problem, it is escalated to a Senior CRP who is responsible for 5 villages.
- The harvesting along with crop cutting experiment is done in the presence of APCNF field staff, farmers, and officials of the agriculture department.

Comparison between Natural and Conventional Farming

Parameters:	**NF (1 ha)**	**CF (1 ha)**
Crop: Paddy (MTU1121)		
Cost of cultivation (Rs)	42550	55650
Production (q)	68.32	52.27

- Followed all the natural farming practices like beejamrit, ghanajivamrit, dravajivamrit, kashayams *etc*.
- Applied 400 kg of ghanajivamrit per acre to the soil, followed by 3 tons of farm yard manure. Dravajivamrit was sprayed in every 15 days. Seed treatment was done with beejamrit.
- Navadhanya was sown in 9 acres of land and later this was incorporated into the soil.
- Demonstratednaturalfarmingpracticestoot herfarmersinthevillage.Afteroneseason, many farmers were inspired by her and started practicing natural farming.

Comparison between Natural Farming and Conventional Farming

Parameters	**Natural Farming (0.4 ha)**	**Conventional Farming (0.4 ha)**
Crop	Paddy (Dhanista)	Paddy (RNR-15048)
Cost of cultivation (Rs)	25950	32450
Production (q)	27.4	24
Gross return (Rs)	68500	45600
Net return (Rs)	42550	13150
BC ratio	**1.6**	**0.4**

Benefits and achievements

- Decreasedcostofcultivation.
- Resulted in chemical-free food.

Gross return (Rs)	125470	108050
Net return (Rs)	82920	52400
B C ratio	**1.94**	**0.94**

Benefits and achievements

- Increased number of earthworms in the field.
- Soil became spongy with increased water holding capacity.
- Motivated farmers in the neighbourhood to reduce the usage of chemicals.
- Improved health of family members.
- Became a champion farmer in the village.

- Reduced incidence of pests and diseases.
- Increased soil fertility by increase in the number of earthworms.
- Resulted in soil conservation and rejuvenation.
- Paddy crop withstood the lodging effect during cyclone. During Nivar cyclone, crops were resilient to floods, however, on the other hand, there was a lot of damage observed in the fields following chemical farming.
- Earned higher profit than farmers following chemical farming, by selling paddy after processing into rice.

Source: *Andhra Pradesh Community Managed Natural Farming and Niti Aayog (2022)*

SMT. BELLANA SRIDEVI

Village: Chipurupalli

District: Vizianagaram, Andhra Pradesh

Contact No:9912693789

Education: Degree

Practices adopted

- Cultivated 9 varieties of desi paddy in rabi season.
- Used navadhanya as a green manure before paddy cultivation.
- Adopted farm mechanization for weed management.
- Prepared natural inputs like dravajivamrit, ghanaivamrit & kashayas.
- Imparted training to input dealers through a Diploma in Agricultural Extension Services for Input Dealers (DAESI) programme to promote usage of natural inputs.
- Participated in Farmer Field School (FFS) Trainings of the Agriculture department.

SHRI R. BHASKAR REDDY

Village:N. Gundlapalli

Mandal: Beluguppa

District: Anantapur, Andhra Pradesh

Education:Intermediate

Contact No:9346000811

Practices adopted

- Started natural farming in 2018.
- In the total farm of 15.00 acres, 5 acres of land was cultivated under natural farming. Of this, 3.50 acres were planted with groundnut as intercrop of red gram, field bean, cowpea and castor. On 0.50 acres, groundnut was the main crop, while onion, sorghum, lentils, field bean and castor were intercropped. Tomatoes and vegetables are grown on 0.50 acres, while fodder crops such as peas and lentils are grown on 0.50 acres under Pre-Monsoon Dry Sowing (PMDS).
- Adopted methods like ghanajivamrit, dravajivamrit, various botanical extracts (neem extract, sour buttermilk, agniastra,

- Imparted training on Andhra Pradesh Community Managed Natural Farming (APCNF).

Parameters	NF (1 ha)	CF (1 ha)
Crop Paddy (RGL-2537)		
Cost of cultivation (Rs)	32500	34000
Production (q)	67.12	66.56
Gross return (Rs)	140952	139776
Net return (Rs)	108452	105776
BC ratio	3.3	3.1

Benefits and achievements:

- Reduced cost of cultivation.
- Managed incidence of pests and diseases.
- Motivated farmers to come forward and practice integrated Pre-Monsoon Dry Sowing (PMDS) along with APCNF Methods.
- Resulted in chemical-free healthy food.
- Awarded the Uthama Mahila Raithu by Agricultural Research Station (ARS)

kashaya), mulching, sowing and multi-cropping.

- Used ghanajivamrit 400 kgs per acre and sprayed jivamrit every 15 days till the completion of the harvest.
- Used crop residues as fodder for livestock which increased milk production and the percentage of butter in milk.
- Educated fellow farmers about inputs used in natural farming with the help of SHGs and motivated them by sharing success stories in Rythu Bharosa Kendras
- Comparison between Natural Farming and Conventional Farming

Parameters	Natural Farming (2 ha)	Conventional Farming (2 ha)
Crop	Groundnut, Red Gram, Field Bean, Castor, Cowpea, Onion, Green Gram, Black Gram, Vegetables	Groundnut, Red Gram
Cost of cultivation (Rs)	96500	125000
Gross return (Rs)	221000	145000
Net return (Rs)	124500	20000
BC ratio	1.29	0.16

Benefits and achievements

- Increased income through agriculture along with allied activities.
- Reduced the incidence of pests and diseases by spraying dravajivamrit.
- Multi-cropping increased the number of beneficial insects and sparrows in the field.
- Increased soil fertility and number of earthworms in the soil.

- Crop withstood drought conditions.
- Cattle grazing of crop residues increased milk production
- Reduced investment cost and obtained regular income with multi-cropping
- Improved family health

Source: *Andhra Pradesh Community Managed Natural Farming*

Natural Foods

The term 'natural foods' is banded around here there and everywhere in the foodie world – usually accompanied by images of luscious farmland and grazing animals. Natural foods are:

- Free from synthetic and artificial ingredients or additives
- Unprocessed
- Full of nutrients

For example, a carrot picked straight from the ground would be classed as natural but that carrot cake on the shelf in the supermarket – not so natural. Natural foods are free from artificial/synthetic ingredients, unprocessed and usually richer in nutrients, e.g. fresh fruit and vegetables

Natural food vs organic foods

Natural foods may have certain crossovers with organic foods, but they are two totally different things. 'Organic' is a protected term that is subject to legal regulation.In order for a drink or food to be labelled organic, at least 95% of the ingredients must come from organically produced animals or plants. These ingredients must be approved by an independent certification body, like the Soil Association Certification, who certify over 70% of organic food in the UK. The main aim of organic food production is to limit the environmental impact as much as possible.

The European Commission states that organic farming is required to encourage:

- Maintenance of biodiversity
- Responsible use of energy and natural resources
- Preservation of regional ecological balances

- Maintenance of water quality
- Enhancement of soil fertility

On the other hand, the term 'natural' is not subject to legal regulation. This is why you can't always trust food packaging has 'natural' plastered all over it.

Summary

- Organic food is a protected legal term for food that has less environmental impact, e.g., organic vegetable growers won't use chemical pesticides that harm the soil
- Natural foods also follow most of this logic, but it is more of a vague term to describe food that is un-altered and as nature intended it to be, e.g. a fresh potato from the ground rather than a portion of French fries

Annexure I

Organic Certification Data under NPOP 2022-23

Area of organic crops cultivated in India

Cultivated Area (Organic)	1764677.15 ha
Cultivated Area (In conversion)	3627115.82 ha
Wild Harvest Collection Area	4780130.56 ha

Production of organic crops in India

Farm Production (Organic)	2664679.54 MT
Farm Production (In conversion)	288146.75 MT
Wild Harvest Production	19468.21 MT

Export of Organic agricultural products from India

Total Export Quantity	312800.51 MT
Total Export value (INR)	Rs.5525.18 Crores
Total Export Value (US$)	708.33 Million USD

Source: www.APEDA.gov.in

Table 5 State-wise Area under Organic certification NPOP 2022-23

S. No	State Name	Cultivated Area		Total Area (In ha)
		Organic Area (In ha)	Conversion Area (In ha)	
1	Madhya Pradesh	686208.31	831168.8	15,17,377.11
2	Maharashtra	258638.55	1025675.6	12,84,314.15
3	Gujarat	84404.36	851526.64	9,35,931.00
4	Rajasthan	216440.36	364239.43	5,80,679.79
5	Odisha	77950.82	117128.66	1,95,079.48
6	Uttarakhand	32634.01	65,759.72	98,393.73
7	Telangana	7288.85	77,185.37	84,474.22
8	Karnataka	44342.45	37,673.11	82,015.56
9	Sikkim	75453.18	22.096	75,475.28
10	Uttar Pradesh	52422.44	15,584.61	68,007.05
11	Andhra Pradesh	26949.05	35,966.97	62,916.02
12	Tamil Nadu	18652.5	39,914.20	58,566.70
13	Jharkhand	1499.76	52,620.11	54,119.87
14	Kerala	32602.71	11,511.74	44,114.45
15	Bihar	17594.82	15,152.76	32,747.58
16	Jammu & Kashmir	25093.94	7,510.56	32,604.50
17	Meghalaya	21652.71	2,356.33	24,009.04
18	Assam	15593.93	7,473.49	23,067.42
19	Mizoram	4796.84	15,264.10	20,060.94
20	Tripura	2490.13	17,124.31	19,614.44
21	Chhattisgarh	13258.18	3,641.68	16,899.86
22	Arunachal Pradesh	3109	9,773.68	12,882.68
23	Nagaland	7550.61	5,002.56	12,553.17
24	Goa	11203.22	1,193.19	12,396.41
25	Himachal Pradesh	8507.25	2,557.85	11,065.10
26	Manipur	7682	3,003.50	10,685.50
27	Punjab	890.12	9,002.53	9,892.65
28	West Bengal	7479.66	1,314.58	8,794.24

29	Haryana	2265.54	629.22	2,894.76
30	LADAKH	0	121.42	121.42
31	Pondicherry	21.17	0.34	21.51
32	New Delhi	0.72	16.67	17.39
33	Andaman & Nicobar Islands	0	0	0.00
	Total	**1764677.15**	**3627115.82**	**53,91,792.97**

Source: www.APEDA.gov.in

Table 6 State wise organic Area under Wild collection for 2022-23

S. No	Name of the State	Organic area (in Ha)
1	Chhattisgarh	3,235,754.28
2	Madhya Pradesh	804,864.98
3	Rajasthan	356,895.48
4	Himachal Pradesh	202,215.76
5	Punjab	63,879.73
6	Uttar Pradesh	30,018.80
7	Kerala	19,718.20
8	West Bengal	14,700.00
9	Jammu & Kashmir	14,399.00
10	Tamil Nadu	9,816.11
11	Goa	8,006.78
12	Uttarakhand	6,321.41
13	LADAKH	5,000.00
14	Odisha	3,612.07
15	Karnataka	2,815.81
16	Andhra Pradesh	1,754.00
17	Andaman & Nicobar Islands	155.00
18	Maharashtra	107.15
19	Jharkhand	96.00
	Total	**4780130.56**

Source: www.APEDA.gov.in

Table 7 State wise Organic Farm Production for the year 2022-23

S. No.	State Name	Organic Production (MT)	Conversion Production (MT)	Total Production (MT)
1	Madhya Pradesh	738,201.84	87,424.57	825,626.41
2	Maharashtra	724,946.90	65,380.40	790,327.30
3	Rajasthan	311,170.77	11,802.18	322,972.95
4	Karnataka	237,090.18	1.25	237,091.43
5	Uttar Pradesh	215,506.50	2,013.01	217,519.51
6	Gujarat	89,978.28	49,750.40	139,728.68
7	Odisha	64,976.16	65,100.84	130,077.00
8	Jammu & Kashmir	50,230.38	0.00	50,230.38
9	Uttarakhand	43,954.51	0.00	43,954.51
10	Kerala	42,729.09	5.16	42,734.25
11	Tamil Nadu	24,964.04	109	25,073.04
12	Andhra Pradesh	24,190.25	0.00	24,190.25
13	Bihar	19,853.89	0.00	19,853.89
14	Chhattisgarh	17,703.47	0.00	17,703.47
15	West Bengal	15,409.18	0.00	15,409.18
16	Assam	14,497.86	0.00	14,497.86
17	Meghalaya	9,919.69	0.00	9,919.69
18	Himachal Pradesh	6,978.06	0.00	6,978.06
19	Punjab	482.98	5,940.72	6,423.70
20	Jharkhand	4,363.09	0.00	4,363.09
21	Haryana	2,679.58	0.00	2,679.58
22	Goa	2,488.52	70.14	2,558.66
23	Telangana	837.64	433.05	1,270.69
24	Arunachal Pradesh	793.00	0.00	793.00
25	Tripura	332.78	216.04	548.81
26	Mizoram	334.00	0.00	334.00
27	Sikkim	51.90	0.00	51.90
28	Manipur	11.00	0.00	11.00

29	Pondicherry	4.00	0.00	4.00
Total		**2664679.54**	**288246.75**	**2952926.29**

Source: www.APEDA.gov.in

Table 8 State wise organic Production from Wild area for 2022-23

S. No.	State Name	Organic Production (MT)
1	Goa	4,820.01
2	Andaman & Nicobar Islands	3,624.00
3	Rajasthan	2,767.19
4	Madhya Pradesh	2,336.21
5	Jammu & Kashmir	1,574.62
6	Punjab	1,309.48
7	Chhattisgarh	1,029.77
8	LADAKH	710.5
9	Karnataka	416.233
10	Odisha	316.92
11	Andhra Pradesh	214.109
12	Uttar Pradesh	154.859
13	Uttarakhand	106.024
14	Tamil Nadu	67.091
15	Maharashtra	21.2
Total:		**19468.21**

Source: www.APEDA.gov.in

References

www.apeda.gov.in

www.niti.gov.in

ICT APPLICATIONS AND AGROINFORMATICS

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Introduction

ICT stands for Information and Communication Technologies. It provides access to information through telecommunications Eg. Internet, wireless networks and smart phones. ICT incorporates both the internet-enabled sphere as well as the devices powered by wireless networks

Benefits of ICT

The following are the benefits of ICT:

- Data-Driven Decision-Making
- Resource Efficiency
- Enhanced Market Access
- Traceability and Food Safety
- Farm Management and Record-Keeping
- Increased Productivity

Components of ICT

The following chart (Fig. 1) explains the various components of ICT:

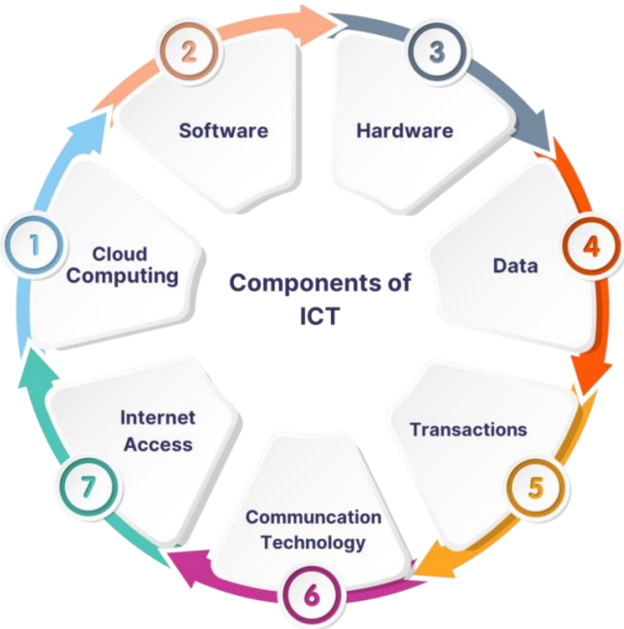


Fig. 1 Components of ICT

Cloud Computing

These are the data centres available to many users over the Internet. Large clouds have functions distributed over multiple locations from central servers. If the connection to the user is relatively close, it may be designated an edge server.

Software

Necessary software will be available as cloud service

Hardware

Hardware includes tangible physical elements, viz., monitor, hard drive, memory and the CPU

Data

Digital Data represents other forms of data usingspecific machine language systems, which simply stores complex audio, video or text information in a series of binary characters, traditionally onesand zeros, or on and off values.

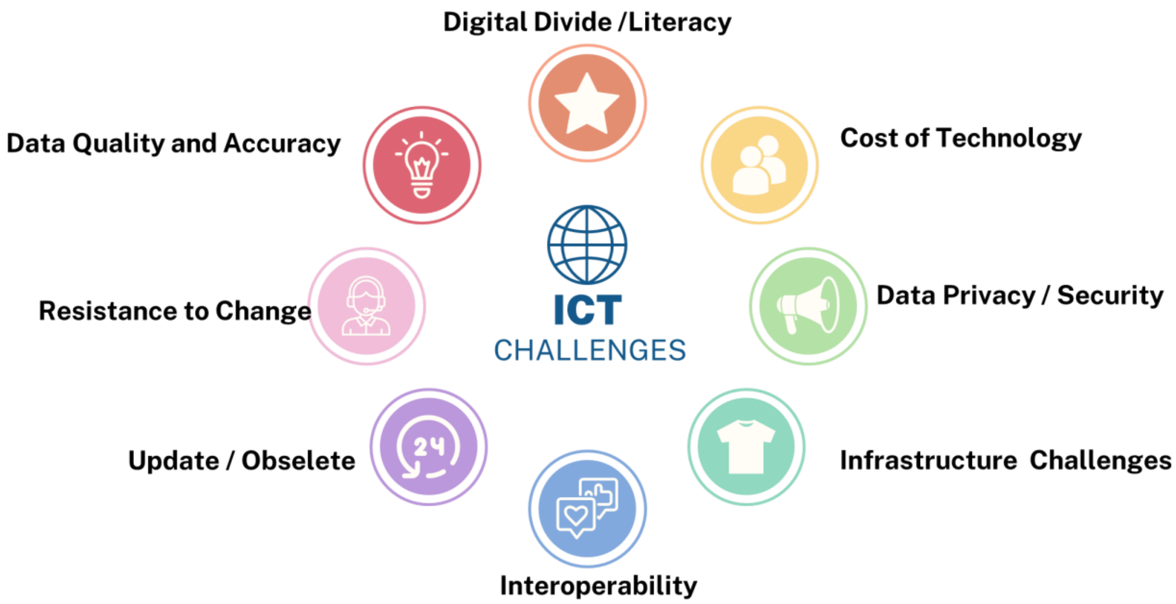
Transactions

Any attempt to use the server by the client or user leads to a transaction.

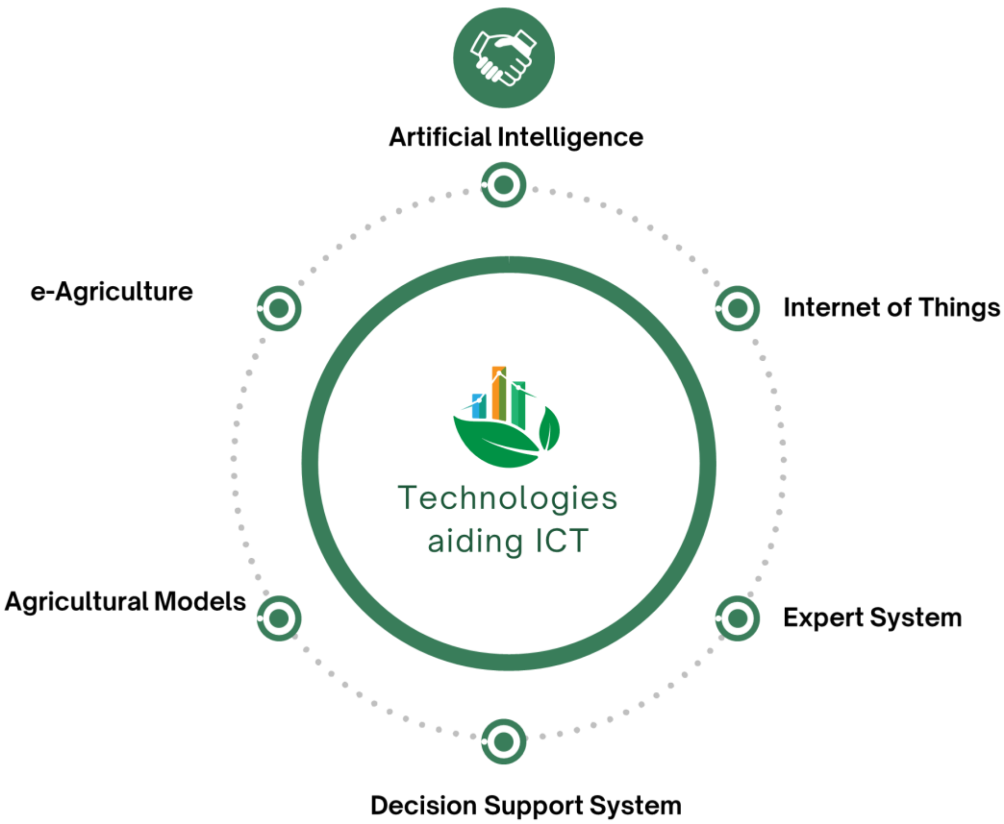
Communication Technology and Internet Access

Communication and Internet access may done in many different ways viz., Wireless connection, Mobile connection, Hotspots, Dial-up, Broadband, DSL or Satellite.

Challenges in ICT



Technologies aiding ICT



Internet of Things

IoT is a lively global network infrastructure with self configuring capabilities based on standard and interoperable communication protocols where physical and virtual things have identities, physical attributes and virtual personalities and use intelligent interfaces, and are flawlessly integrated into information network, often communicate data associated with users and their environments

IOT defined into three categories as follows:

- People to People
- People to machines or things
- Things or machines to things or machine

Characteristics of IoT

- Dynamic and self adapting - E.g. surveillance system is adapting itself based on context and changing conditions
- Self Configuring - Allow a large number of devices to work together to provide certain functionality

- Inter operable communication protocols - communicate with other devices and also with Infrastructure
- Unique identify - Each IoT device has a unique identity and a unique identifier such as IP address
- Integrated into information network - to communicate and exchange data with each other and systems.

Why IoT?

It is growing trend that will influence everything from businesses to out daily personal lives. Here the main focus is on agriculture as it plays a vital role in development of our country's economy

IoT has many applications in

- agriculture
- smart cities
- smart home
- Healthcare
- business sectors
- traffic monitoring
- transport and logistics etc.

Expert System

Expert System (ES) was coined by Edward Feigenbaum, "father of expert systems". Expert system was developed in LISP programming environment and Prolog.

Definitions of an expert system

A model and associated procedure that exhibits, within a specific domain, a degree of expertise in problem-solving that is comparable to that of a human expert **-Ignizio**

An expert system is a computer system which emulates the decision-making ability of a human expert ***- Giarratono***

Expert System is the division of Artificial Intelligence fraternity. The idea of an expert system is to develop a system with the help of human knowledge. Knowledge is used in the system whenever it is required. The knowledge can be used according to the need of the system. ES also solve the problems in a real-world situation. The interdisciplinary research can be developed with the systems.

Expert systems help to transfer the promotion in agriculture, traditional method problems are identified and helps overcome the problem. In the field of agriculture, the expert system is used to make the correct decision for farmers. Knowledge from various fields such as pathology, Nematology, weed, entomology, and nutrition disorder is used in crop and integrated pest management. In the last decades, the rapid growth of information has increased.

Characteristic of Expert System

Stimulation is done with human reasoning about the problem domain, rather than simulating by the domain itself.

- With human knowledge, reasoning is represented.
- Problems are solved by approximate methods.

Components of Expert System

1. User interface
2. Database
3. Knowledgebase and
4. Interface mechanism

The user interface represents query and information to the user and the response is directed to the interface engine. User interface validates all the response and ensures the correct data, the user enters an illegal response, informs the user that input was invalid and prompt a message to correct it. The knowledgebase is the collection of rules and other information derived from the human expert. The interface engine interacts with knowledge base through the reasoning capability. Knowledge base solves the problem within every domain. Interface engine compares the specific problem domain in general with what is known about specific problems and tries to provide logically a better solution towards the problem. Inference rules are followed by the inference engine to give a solution for diagnosis and prescription problems. The rules can be added, deleted without affecting other rules. The expert system does

1. Problem selection
2. Knowledge acquisition
3. Knowledge representation

Introduction to Decision Support Systems (DSS)

A decision support system is an information system that supports decision-making activities in all the fields. DSS are software-based systems that gather and analyze data from a variety of sources. In the agricultural sector, it helps farmers to solve complex issues related to crop production, management, and marketing. DSS is a tool for diagnosis, risk assessment and reasoning assistance. It is defined as

1. "A computer-based system that aids the decision-making process".
2. "An interactive, flexible, and adaptable computer-based information system especially developed for supporting the solution of a non-structured management problem for improved decision making".
3. "Computer-based support for management decision making".

Characteristics and Capabilities of DSS

- Decision Support System comprises of a vast set of characteristics and capabilities. The key characteristics and capabilities of DSS are:
- Ability to support semi-structured and unstructured problems, including human judgment and computerized information.
- Ability to support individuals and groups.
- Ability to select any desired subset of stored knowledge for presentation or derivation during problem-solving.
- Ability to support interdependent or sequential decisions.
- Ability to support intelligence, design, choice, and implementation.
- Ability to support modelling and analysis.
- Ability to support data access.

Components of DSS

A Decision Support Systems consists of three main components, namely database, software system and user interface.

DSS Database

It contains data from various sources, including internal data from the organization, the data generated by different applications and the external data mined from the Internet, etc. The decision support systems database can be a small database or a standalone system or a huge data warehouse supporting the information needs of an organization. To avoid the interference of a decision support system with the working of operational systems, the DSS database usually contains a copy of the production database.

DSS Software System

It consists of various mathematical and analytical models that are used toanalyze the complex data, thereby producing the required information. A model predicts the output in the basis of different inputs or different conditions or finds out the combination of conditions and input that is required to produce the desired output.

A decision support system may compromise different models where each model performs a specific function. The selection of models that must be included in a decision support system family depends on user requirements and the purposes of DSS.

DSS User Interface

It is an interactive graphical interface which makes the interaction easier between the DSS and its users. It displays the results (output) of the analysis in various forms, such as text, table, charts, or graphics. The user can select the appropriate option to view the output according to the requirement.

Computer-based agricultural models

Model

1. A model is a schematic representation of the conception of a system or an act of imitation or a set of equations, which represents the behaviour of a system.
2. Model is "A representation of an object, system or idea in some form other than that of the entity itself".
3. A model is, by definition "A simplified version of a part of reality, not a one to one copy".

Simulation

Simulation is the reproduction of an observed phenomenon (e.g., growth of biomass with time; water use by a growing crop etc.,) by developing a model and computer program written for a specific application. The program comprises of mathematical, statistical, physical, graphical, or empirical expressions given asinput information or data with its parameters

Mechanistic process models

A Mechanistic process model is a detailed and practically complete depiction of the mechanism involved in a processes photosynthesis, green or dry matter production, soil water uptake and transport by the root system etc., Models for crop growth are designed to simulate daily growth of a plant including all known processes in the soil-plant-water-environment system. They include water-fertilizer uptake and their transport, the effect of flood and water logging, the effect of pest-disease incidence etc., popularly known as the dynamic crop growth simulation models. With the relevant data input, they are designed to compute day-to-day expected crop growth as a result of several growth-related phenomena that ultimately influence the yield.

Operational models

Operational models which are for day-to-day field operations concerning the SPAW system can be developed to simulate crop growth using known relations such as statistical, empirical, mathematical or operational models which are for day-to-day field operations concerning the SPAW system can be developed to simulate crop growth using known relations such as statistical, empirical, mathematical or graphical models, based on data availability, regional and local crop-environmental conditions for growth, including or bypassing some of the mechanistic details involved in the system. Different models are developed for space and time variations. The area of operation (starting from the village), a time duration of individual crop growth phases and seasonal factors, characters of the crop are involved.

Operational models can be modified or integrated to extend from local (village) to the district or agro-climatic regional level. Several modifications are needed in this process. They are "user -targeted" to find a solution to day-to-day crop weather-related problems encountered in the field.

Statistical and Dynamic simulation models

Crop-weather modelling is of two types. They are

1. Statistical simulation model
2. Dynamic simulation model

Statistical simulation model

The statistical simulation modelling approach is used as research tools for yield forecasting rather than for field operations. Statistical models are developed using the long term (say 20-30 year series) average values over a long period between two or more parameters, say rainfall and crop yield. Statistical functions like linear, curvilinear, multiple regression, orthogonal polynomials etc., are used for modelling. Their variability and significance are tested using accurate procedures. These could assist in making along-term assessment of crop performance on an average over a couple of decades. As an example, insemi-arid regions, rainfall variability being high (>100%), the applicability of such regressions may fail in an individual season. So, in practice, it becomes unusable except to understand the extent of association between rainfall, temperature etc., and yield in a locality over a long period. This is a limitation of models in the tropical or sub-tropical region. Statistical models are a significant improvement over naive historical predictions but are not preferred for very fine-grained predictions.

Dynamic simulation model

Dynamic simulation model computes growth values on a day to day basis using the relations between crop growth parameters and weather parameters. It rebuilds the day to day crop growth in mathematical or mechanistic terms (simulation) depending on the magnitude of rainfall (or any other parameters) on a particular day and magnitude of a crop parameter (or other parameters like physiological, soil, biological parameters) representing crop growth till that day. *i.e.*, daily simulation is done depending on the parameter values obtaining on a 5 day and cumulated over the growth period. Such simulation is continued until harvest time. "Growing the crop on the computer" is a popular phrase. It is not essential to run a mechanistic model for all purposes. In the dynamic model, both dependent and independent variables have values which remain constant over a given period.

E-Agriculture

E-Agriculture is an emerging field in the intersection of

- agriculture and informatics
- agricultural development and entrepreneurship
- referring to agricultural services
- technology dissemination and information delivered or enhanced through the internet and related technologies.

It also involves the conceptualization, design development, evaluation and application of new ways to use existing or emerging information and ICT tools.

Agro-informatics

Agro-informatics is a specialized branch of informatics that specifically deals with the development and application of information technology and data science methods in agriculture. It focuses on the systematic collection, analysis, and utilization of agricultural data to support decision-making and enhance agricultural practices. Agro-informatics is more narrowly tailored to the specific needs of the agriculture sector.

Components of Agro-informatics