



NATURAL FARMING RESEARCH STATUS and FUTURE STRATEGY



All India Network Programme on Natural Farming (AINP-NF)
ICAR-Indian Institute of Farming Systems Research, Modipuram
Indian Council of Agricultural Research (ICAR)

NATURAL FARMING RESEARCH

Status and Future Strategy



**All India Network Programme on Natural Farming (AINP-NF)
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Indian Council of Agricultural Research (ICAR)**



Citation: Ravisankar,N., A.K. Prusty, Raghavendra, KJ, A. Velmurugan, Vipin Kumar, M. Shamim, Raghuv eer Singh, J.K. Thakur, M. Suganth y, T.P. Swarnam, Gautam Chatterjee, Meraj Alam Ansari, Himanshu Chauhan, P.V.N. Sindhuja, A.S. Panwar, Sunil Kumar, S. Bhaskar and Rajbir Singh. 2025. Natural Farming Research: Status and Future Strategy, All India Network Programme on Natural Farming, ICAR-Indian Institute of Farming Systems Research, Modipuram, Meerut-250 110, India (i-95 pp).

Published by : All India Network Programme on Natural Farming, ICAR-IIFSR, Modipuram

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Printed at: Alpha Printographics (India), Naraina, New Delhi - 110 028

Email Id: alphaprintographicsindia@yahoo.com

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Tel.: 9811199620 / 9999039940



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FOREWORD

India's agriculture is undergoing a transformative shift in response to the growing concerns over environmental degradation, soil fertility depletion and rising input costs. In this context, Natural Farming (NF) has emerged as a promising paradigm, grounded in the principles of agroecology and rooted in India's indigenous knowledge systems. Natural Farming eliminates the use of synthetic inputs, encourages soil biology regeneration, and promotes on-farm resource recycling, thereby reducing costs, enhancing biodiversity, and building climate resilience.

The Indian Council of Agricultural Research (ICAR), through the All-India Network Programme on Natural Farming (AINP-NF), has taken pioneering steps to generate scientific evidence, validate indigenous technical knowledge (ITK), and develop farmer-friendly protocols for Natural Farming. This publication is a comprehensive outcome of coordinated research across diverse agro-climatic zones, involving multi-disciplinary teams and stakeholder institutions.

This will serve as a valuable knowledge repository for researchers, policymakers, extension agencies, and farming communities aiming to scale up sustainable and inclusive agricultural models. I appreciate the contributions of all collaborators who have enriched this publication through rigorous field studies, innovation, and commitment.



(A.K. Nayak)

Deputy Director General (NRM)

Preface

The need for resilient and sustainable agricultural systems has never been more urgent, given the growing challenges of climate change, soil degradation, and shrinking farm incomes. Natural Farming (NF), based on ecologically sound and economically viable practices, offers a pathway for restoring soil health, reducing chemical dependency, and ensuring food safety.

This publication, developed under the All-India Network Programme on Natural Farming (AINP-NF), captures the essence of location-specific Natural Farming practices tested in different agro-climatic zones. It compiles comprehensive data on cropping systems, yield and economic performance, biodiversity impact, and farmer experiences. The documentation and scientific validation of Indigenous Technical Knowledge (ITK) and inputs such as Jeevamrit, Beejamrit, Neemastra, and Ghanajeevamrit add significant value to this work.

We express our gratitude to the AINP-NF research teams, ICAR institutes, State Agricultural Universities, and field-level partners for their collaborative efforts. We hope this publication will aid in shaping future strategies for mainstreaming Natural Farming in India and promoting climate-resilient, low-cost, and regenerative farming systems.

Authors

Acknowledgment

The compilation of this *Natural Farming Research: Status and Future Strategy* under the All-India Network Programme on Natural Farming (AINP-NF) is the result of sustained collaborative efforts, rigorous scientific inquiry, and strong field-level engagement. We extend our deepest gratitude to Dr Trilochan Mohapatra, Dr Himanshu Pathak, Former Secretary (DARE) and Director General (ICAR) for their visionary support and strategic guidance that enabled the execution of this nation-wide initiative. We acknowledge the guidance and suggestion given by Dr M.L. Jat, Secretary (DARE) and Director General, Indian Council of Agricultural Research (ICAR) for bringing out the publication on Natural Farming Research carried out. We acknowledge the guidance and support given by Dr A.K. Nayak, Deputy Director General (NRM) and Dr A. Velmurugan, Assistant Director General (SWM/AAFCC) in shaping this publication. The guidance and support extended by Dr S.K. Chaudhary, Former DDG (NRM), Dr S. Bhaskar, Former ADG (AAFCC) and Dr Rajbir Singh, DDG (Agricultural Extension) and Former ADG (AAFCC), Dr A.S. Panwar, Former Director, ICAR-IIFSR is duly acknowledged.

We sincerely acknowledge the proactive role of Project Coordination Unit, AINP-NF, ICAR-Indian Institute of Farming Systems Research (ICAR-IIFSR), Modipuram, Meerut, for steering the technical direction and ensuring seamless coordination among the partner institutions.

Our heartfelt thanks go to the Principal Investigators, Co-Principal Investigators, and technical teams of all participating ICAR Institutes, State Agricultural Universities (SAUs), and deemed university, who conducted field trials, validated indigenous technical knowledge (ITKs), and contributed state-specific insights and data.

We also express our sincere appreciation to the farming community, whose trust, participation, and knowledge-sharing were foundational to the success of the validation trials and demonstrations documented herein.

Special thanks are due to the editing and design team for their efforts in compiling, formatting, and presenting the data in a cohesive and reader-friendly manner. Their attention to detail ensured the publication's usability for researchers, extension personnel, policy planners, and field practitioners.

Finally, we thank all those, named and unnamed, whose direct or indirect contributions have made this publication a valuable reference for advancing Natural Farming in India.

Authors

Summary

Natural Farming (NF) has emerged as a sustainable agroecological approach in India, addressing the ill effects of input-intensive agriculture. It minimizes use of synthetic agrochemicals by leveraging on-farm resources (cow dung/urine, plant extracts, compost) and traditional knowledge. As a result, NF systems are low-cost, free farmers from expensive purchased inputs, and can maintain *comparable productivity* (especially in low-input crops) while increasing farm income and preserving soil and environmental health. The practice has gained traction across diverse regions, predominantly among small and marginal farmers who typically cultivate <2 ha and integrate livestock (indigenous cattle for dung/urine) into their farms. Core NF practices – Jeevamrit, Ghanajeevamrit, Beejamrit (biofertilizers), mulching, intercropping, and botanical extracts for pest control – are adapted to local conditions. Field surveys in 16 states indicate that while many NF farmers achieve yields close to research station levels, others show yield gaps, especially in rainfed and hill areas. Bridging these gaps and enhancing profitability is critical to sustain and expand NF adoption.

- Multi-location research trials (2020–2022) demonstrate that NF can produce yields on par with or exceeding conventional and organic farming benchmarks in most regions. In several cropping system comparisons, NF yields matched those under organic and integrated management, and often surpassed local farmer practice yields. NF performance is context-dependent, varying by crop and location. In some instances (notably initial conversion years or marginal environments), NF yields have lagged behind due to transitional factors.
- A consistent finding is that NF significantly reduces cultivation costs by replacing costly chemical fertilizers and pesticides with home-made inputs. Across trials, NF farmers avoided expenditures on synthetic inputs, cutting input costs by ~18–50% in various locations. This frugality did not come at the expense of output – with yields largely maintained particularly with legume based cropping systems and low input use areas. NF often achieved equal or higher net returns than conventional and even organic farming. For instance, in Tamil Nadu cropping system trials, NF delivered greater net incomes than the standard farmer practice in groundnut–sorghum and cotton–sorghum systems. The combination of lower costs and competitive yields translates to better profit margins and benefit–cost ratios for NF adopters. Importantly, the lower cost of production makes NF a more economically accessible model for resource-poor and smallholder farmers.
- While initial adoption of NF may entail an adjustment period (with minor yield or profit declines in the first season at some sites), results indicate that profitability improves as soil health builds up. Careful management during transition (e.g. using supplemental organic manures, timely weeding) can mitigate short-term lags. Overall, evidence from the network trials confirms NF as

a viable farming system economically, capable of sustaining farmer livelihoods once practices are optimized for various regions.

- NF management led to measurable improvements in soil health indicators. Over 2–3 years, NF plots showed rising soil organic carbon (SOC) levels – for example, SOC increased from ~0.90% to 1.15% in Himalayan trials (a ~28% gain). NF soils had significantly higher microbial counts and diversity indices than chemical-fed soils. Richer microbial communities (e.g. more beneficial bacteria, fungi, and actinomycetes) and more balanced microbial evenness under NF was observed, indicating a healthier soil ecosystem developing over time. This boost in soil biota and organic matter under NF improves nutrient cycling and soil structure, laying the foundation for sustained fertility and yield stability.
- Natural farming practices also provide broader ecosystem services. On-farm biodiversity is increased through intercropping, crop rotations, and maintaining livestock, which in turn helps naturally suppress pests and diseases. By conserving biodiversity (above and below ground) and enhancing ecosystem functions (like carbon sequestration and water efficiency), NF aligns farming with natural ecological processes, contributing to long-term sustainability.
- Farmer-led Indigenous Technical Knowledge (ITK) has been actively documented and validated as part of the NF initiative. These time-tested practices – ranging from organic soil amendments to herbal pest remedies – are inherently low-cost and eco-friendly, relying on locally available materials. The publication highlights numerous successful ITKs, demonstrating their efficacy in the field. Many traditional formulations achieved 50–80% reduction in pest infestations and 18–25% increases in crop yields compared to controls. For example, a fermented ginger-garlic-green chili extract (“3G”) provided up to 74% reduction in sucking pests on cotton and significantly boosted yields of cotton, okra, and maize under NF management.
- A scientific analysis of NF’s bio-inputs (like Beejamrit, Jeevamrit, Ghanajeevamrit) reveals why they are effective. These home-made formulations contain extraordinarily high microbial populations and bioactive compounds. For instance, fresh Beejamrit (a cow dung– and urine–based inoculant for seeds) hosts an abundant and diverse microbial consortium – total viable bacteria on the order of 10^{10} CFU/mL, beneficial actinomycetes $\sim 10^8$ and fungi $\sim 10^5$, including functional groups such as free-living nitrogen fixers ($\sim 10^9$) and phosphate-solubilizing bacteria ($\sim 10^8$). Such rich microbiota serve as a biological engine, inoculating the soil/seed with organisms that fix nitrogen, solubilize nutrients, and protect against pathogens. Analytical chemistry of these fermented inputs also detected numerous natural metabolites (phenolics, flavonoids, alkaloids, etc.) with antimicrobial or growth-promoting properties. This dual nature – dense in beneficial microbes and biochemical compounds – underlies the efficacy of NF inputs in improving seed germination, nutrient availability, and pest/disease resistance. In practice, the use of such bio-inputs (applied fresh for highest microbial activity) jump-starts soil biological processes each season, contributing to sustained soil fertility and plant health in NF systems.

- To scale up natural farming across India, the publication outlines a multi-pronged strategy encompassing research, capacity building, and market support.

Natural Farming offers a promising pathway toward sustainable and climate-resilient agriculture in India. The evidence from the publication shows that NF can maintain crop yields and farm incomes particularly in low-input areas and legume based cropping systems while delivering significant co-benefits – healthier soils, reduced input costs, and enhanced ecosystem services. These outcomes are particularly relevant for smallholders and resource-constrained farmers, for whom NF provides a low-input, regenerative alternative to the high-external-input model. At the same time, realizing NF's full potential at scale will require addressing the noted challenges: bridging yield gaps through research and extension, supporting farmers during the transition phase, and building reliable markets for NF produce. The findings suggest that with enabling policies, knowledge support, and market incentives, natural farming can be scaled up as a viable national strategy to cover up to one fourth of the cultivated area as advocated by NITI Aayog.

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01

Status of Natural Farming in India

Green revolution technologies revolutionized food production and transformed Indian agriculture from subsistence to surplus-generating enterprise, creating a diverse range of employment avenues and livelihood ventures. The country is now at the top in the production of the majority of agricultural commodities. However, the current conventional farming management practices are more dependent on market inputs such as hybrid seeds, chemical fertilizers, insecticides, fungicides and herbicides. Imbalanced and over use of these chemicals coupled with reduced or non-use of organic manure/ amendments in the soil has resulted in deterioration of soil health particularly physical and biological properties, reduced factor productivity of applied inputs, chemical residues in produces, contamination of water besides long-term environmental concerns. Therefore, worldwide, priorities in agriculture are gradually shifting from production to resource conservation, restoration of soil health and fertility, minimizing the adverse impact on soil and environment, and moving to natural and traditional practices-based non-synthetic farming systems. Natural farming systems largely rely on biomass recycling, biological rejuvenation of natural nutrient cycles, and on-farm plant and livestock-based inputs, and are found to be one of the alternative production systems to address the priorities listed in the report of Food and Agriculture Organization (FAO) “The State of Food & Agriculture”. Besides being non-degrading, non-depleting, and resource-conserving, natural farming systems are found to be low cost, give freedom to farmers from purchased inputs, ensure comparable productivity, especially in low-input requiring crops, increased income, and are safe for the soil, plant, environment, and all life forms including humans and animals. Agroecological farming (comprising of practices such as soil organic matter enhancing technologies, diversified field borders, reduced tillage, water harvesting, livestock integration, cover & legume crops, poly cultures, agroforestry, habitat for beneficial insects and active soil biology) are globally agreed as an alternative to conventional high-input agriculture, which mostly results in better yields without compromising the needs of future generations and avoiding inter-generational conflict.

Natural farming is considered one of the agroecology practices, and the UN Food Systems Summit, 2021 emphasized scaling up Agroecology as a game-changing solution for farming community, citizens, environment and the planet. Several other recommendations related to agroecology have come after global consultations to find alternatives to present forms of conventional agriculture, which often have deleterious impacts on water, climate, nutrition, and farmers’ well-being. Various countries are promoting agroecological practices on a large scale to achieve the Sustainable Development Goals (SDGs) and simultaneously address issues of food and nutritional security and climate change (CC). Sustainable agriculture practices involve mixed cropping, increasing the diversity of crops, and

raising the diversity of insects, other animals & plants in and around the fields promoting microbial diversity & intensity in the soil. These practices are found to increase the top SOM leading to retain and store rainwater to grow crops.

Organic vs Natural Farming

Organic and Natural Farming has more or less similar objectives and principles but differ in practices on use of inputs and the management of systems. Difference between organic and natural farming is given in Table 1.

Table 1. Differences in terms of concept and practices between Natural and Organic Farming

Practices/ inputs	Natural Farming (NF)	Organic Farming (OF)
Concept	NF mostly relies on on-farm inputs for nutrients, insect-disease management with mandated practice of multi-cropping (intercrop, cover crop, trap crop), mulching (soil and crop residue mulch), <i>Whapasa</i> and application of concoctions prepared from cow dung and urine.	OF allows use of off-farm inputs as per national standards for organic farming apart from on-farm inputs for nutrient, insect-disease management. Practices such as multi-cropping (intercrop, trap crop, cover crop etc), mulching etc are optional.
Cropping during summer/fallow	Multi-variate cropping/Pre-monsoon dry seeding with mixture of minimum of 9 crops of different crop types for biomass addition	Monocrop of green manures such as <i>Sesbania aculeata</i> , <i>Sesbania rostrata</i> , <i>Crotalaria juncea</i> etc are grown. Optionally, summer ploughing is also recommended for pest management.
Seed treatment	Seed treatment with <i>Beejamrit</i> prepared using desi cow dung, cow urine, lime, virgin soil and water	Seeds are treated with bio-control agents such as <i>Trichoderma</i> , <i>Pseudomonas</i> and bio-fertilizers such as <i>Azospirillum</i> , <i>Azotobacter</i> , <i>PSBs</i> etc
Nutrient management	Application of an enriched microbial culture such as <i>Jeevamrit</i> and <i>Ghana jeevamrit</i> prepared using desi cow dung, cow urine, jaggery, pulse flour and virgin soil as a microbial enhancer for native nutrient supply	Mainly through green manuring, legume crops, biofertilizers, vermicompost, enriched composts, VAM, panchagavya, cow urine, non-edible oilcakes, effective microorganisms (EM) consortium cultures and biodynamic (BD) formulations (BD-501, BD-502 etc).

Plant protection	Pest and disease control are carried out using bio-formulations such as Neem Seed Kernel Extract, <i>Neemastra</i> , <i>Brahmastra</i> , <i>Agniastra</i> , <i>Dashparni ark</i> , Butter milk etc., prepared from desi cow urine, cow dung, tobacco, green chilli, garlic; neem, karanj, custard apple, castor & datura leaves and water etc.	Pest and disease control is primarily through bio-control agents such as <i>Pseudomonas spp.</i> , <i>Trichoderma spp.</i> , <i>Trichogramma spp.</i> etc; Bio-pesticides like Neem based formulations, plant based extracts, pest repellent plants (trap crops) on the ridges and borders; and using Yellow / blue sticky traps etc. light traps and Inter-cultivation practices.
Standards and certification	Certification system and standard developed and notified for NF clusters	National Programme for Organic Production (NPOP) standards having equivalence with European Union, USDA and Switzerland standards. PGS and Third party certification exists.

Extension Strategies for Natural Farming Adoption

Extension principles in natural farming emphasize a farmer-centric, participatory approach that values indigenous knowledge and actively involves farmers in decision-making. Technologies and practices—like bio-inputs—are co-developed with farmer feedback through participatory technology development. Effective communication is ensured via ICT tools, radio, WhatsApp groups, field days, and community meetings, facilitating timely information flow. Demonstrations and peer learning through model farms and CETARA-NF-certified units inspire adoption by showcasing practical benefits. Decentralized input systems empower communities to produce Jeevamrit, Beejamrit and other natural inputs locally. Strong institutional linkages with ATMA, KVKs, NGOs, and certification bodies ensure technical, training, and market support, anchoring natural farming within a robust extension ecosystem. The details are summarized in Table 2.

Table 2. Extension principle and its application to promote natural farming

Extension Principle	Application in Natural Farming
Farmer-centric approach	Respect indigenous knowledge, involve farmers in decision-making.
Participatory technology development	Co-create innovations (e.g., bio-inputs) with farmer feedback.
Communication channels	Use ICT, radio, field days, WhatsApp groups, and community meetings.
Demonstration and peer learning	Showcase successful natural farms and CETARA-NF-certified units.
Decentralized input systems	Promote local production of Jeevamrit, Beejamrit, etc.
Institutional linkages	Connect farmers with ATMA, KVKs, NGOs, certification bodies.

Natural Farming - Present Status

NF is a form of Agroecology that addresses the root causes of farmers' problems in an integrated way by providing climate-resilient and holistic long-term solutions, which includes a precise focus on social and economic dimensions of food systems. Even before institutional support to NF, as it exists today in various states, farmers have been practicing these tenets for decades led by various innovators. The NF practices, as propounded by Mr. Subhash Palekar, a *Padam Shri* Awardee by the Government of India and promoted by Acharya Dev rat, Ex-Governor of HP and present Governor of Gujarat, enable farmers to improve soil health, and drastically reduce costs and risks, reduce irrigation requirements and increase yields. The four principles of NF being employed by the farmers to enhance productivity at low cost are *Beejamrit* (Seed treatments using local cow dung and urine); *Jeevamrit* or *Ghanajeevamrit* (soil inoculant made of cow dung and urine); *Acchadhana* i.e. Mulching (covering the whole soil surface with crop residue or live intercrops to create a favourable microclimate in soil); and *Whapasa* (soil aeration i.e. creating a condition of moisture and air in 50:50 proportion). Some other associated pillars are the simultaneous growing of short-duration intercrops, including at least one legume, and the use of local resource-based decoctions for plant protection.

Several states are practicing NF, and prominent among them are Andhra Pradesh, HP, Gujarat, Chhattisgarh, Kerala, Jharkhand, Odisha, Madhya Pradesh, Rajasthan, Uttar Pradesh and Tamil Nadu. An overall area of more than 6.5 lakh ha (as on 2024) under NF, with Andhra Pradesh leading with more than 2 lakh ha (Fig 1).

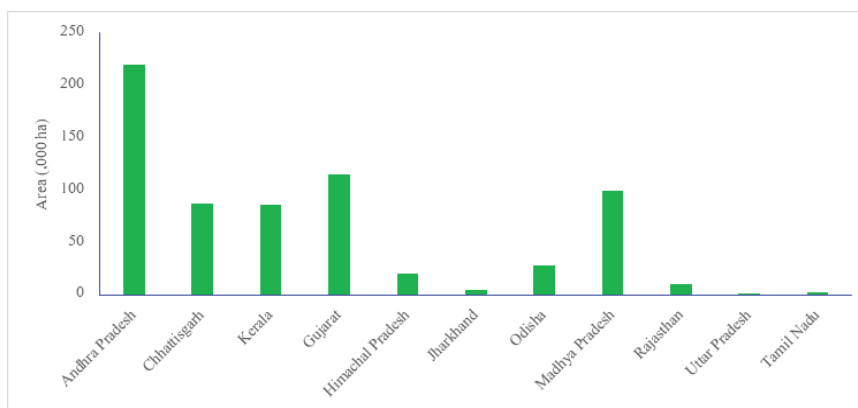


Fig 1. Area covered (hectare) under natural farming in different states
(Source: <https://pib.gov.in/PressReleaselframePage.aspx?PRID=1705191>)

Natural Farming in India: Methods, Evolution, and Scientific Validation

Over the years, national and state-level efforts have significantly promoted natural farming. Key milestones include the 2015 launch of Paramparagat Krishi Vikas Yojana (PKVY), Andhra Pradesh's 2016 model that expanded to 7.5 lakh farmers by 2020–21, and the establishment of the first global university for organic and natural farming in Gujarat (2017). Initiatives like Himachal Pradesh's Prakritik

Kheti Khushhal Kisan Yojana (2018) and Bhartiya Prakritik Krishi Paddhati (BPKP) under NMNF (2023) show policy integration into mainstream agriculture. Research by ICAR and AINPOF has validated the presence of beneficial microbes in cow dung-based preparations such as Panchagavya and BD-500, which supply nutrients and plant hormones like IAA and gibberellins, enhancing yields in crops like wheat, lentil, maize, and sunflower. Efforts to document Indigenous Technical Knowledge (ITK) continue, especially in pest and nutrient management using herbal extracts. While research remains ongoing, initial results highlight natural farming's potential to improve productivity and environmental health, offering a viable path for smallholders and sustainable agriculture in India.

Key Events in the Development of Modern Natural Farming in India

India's movement towards natural farming has been marked by a series of significant policy initiatives and institutional developments. In 2015-16, the Government of India launched the Paramparagat Krishi Vikas Yojana (PKVY) to encourage a shift from conventional to traditional organic farming practices. Timeline of key natural farming initiatives are summarized in Table 3.

Table 3. Timeline of Key Natural Farming Initiatives in India (2016–2025)

Year	Event/Initiative	Details
2016–17	Launch of APCNF in Andhra Pradesh	Implemented by Rythu Sadhikara Samstha; expanded from 40,000 to 7.5 lakh farmers by 2020–21. Largest agroecology programme globally by farmer enrolment.
2017	Gujarat Organic Farming University Established	First and only university in India dedicated to organic and natural agriculture.
2018	PKVY Guidelines Revised	Included Natural, Vedic, Homa, and Cow Farming. States given autonomy to adopt preferred models.
2018	AP Declares Plan for 100% Chemical-Free Farming	Goal to become India's first Zero Budget Natural Farming (ZBNF) state.
2018–19	Himachal Pradesh's Prakritik Kheti Khushhal Kisan Yojana (PK3Y)	Focused on cost reduction via ZBNF principles.
2019	ICAR Committee Formed for SPNF Validation	Reflects growing scientific endorsement of ZBNF.
2019	Union Budget Endorses ZBNF	Recognized as essential for sustainable farming and ease of living.
2019–20	Pilot Projects in Rajasthan	Expanded to 15 districts by 2020–21.
2020	Gujarat Natural Farming Model Introduced	Farmers received ₹900/month for cow care, ₹1,248 Jeevamrit kits, and ₹5,000/ha/season incentives.
2020–21	Bhartiya Prakritik Krishi Paddhati (BPKP)	Sub-mission under PKVY; implemented in 8 states across 600 blocks, covering 12 lakh hectares.
2020–21	ICAR's AINOF Launches Research Across 16 States	Natural farming practices evaluated at 20 locations under All India Network on Organic Farming.

Dec 2021	National Conclave on Natural Farming	PM stressed on modernizing traditional knowledge using scientific methods.
2021–22	Experiential Learning Units (ELUs)	Set up in Imphal, Udaipur, and Jammu agri universities to promote hands-on training and entrepreneurship.
2022–23	Natural Farming in Education & Ganga Corridor Focus	ICAR developed UG/PG syllabi; Budget promoted natural farming in 5 km Ganga river corridor.
2024–25	Launch of National Mission on Natural Farming (NMNF)	Aims to cover 1 crore farmers cluster approach besides supporting research, innovations and model farms

Research status in different agroecology

Natural Farming comprising of set of agro-ecological practices such as minimum disturbance to soil, application of locally prepared concoctions (*Beejamrit*, *Jeevamrit*, *Ghanajeevamrit*) from livestock, mulching (soil mulch, cover crops, crop residues), multi-variate cropping during fallow, intercropping, prophylactic application of botanical preparations such as *Agniastra*, *Brahmastra*, *Neemastra*, *dashparni ark etc*, trap crops, border crops and other eco-friendly pest control practices are emerging as alternate production system. It aims to reduce the land degradation by recycling of crop and animal residues and reduce the paid-out costs. Indian Council of Agricultural Research through All India Network Programme on Natural Farming (AINP-NF) with 20 co-operating centres in 16 states under which multi-location study on Natural farming in different agro-ecologies was initiated from *kharif* 2020 including the coastal, hilly, rainfed and irrigated regions. Field evaluation of complete natural farming is being undertaken besides characterization of Natural farming practices of farmers and inputs. Under National Mission on Natural Farming (NMNF), 400 model farms (300 in farmers field) are proposed to be developed for research as well as support competitive research grants on Natural farming.

Natural Farming represents a transformative approach to Indian agriculture by reducing dependency on chemical inputs, enhancing environmental sustainability, and improving farmer welfare. Its success lies in low-cost practices that regenerate soil health, support biodiversity, and ensure productivity even under smallholder conditions. With increasing institutional support, scientific validation, and widespread farmer adoption, NF stands out as a practical and scalable model to address key challenges like climate change, soil degradation, and rising input costs—making it a cornerstone for the future of sustainable agriculture in India.

02

Natural Farming Research: Importance and Relevance

Green revolution technologies revolutionized food production and transformed Indian agriculture from subsistence to surplus-generating enterprise, creating a diverse range of employment avenues and livelihood ventures. The country is now at the top in the production of the majority of agricultural commodities. However, the current conventional farming management practices are more dependent on market inputs, especially for hybrid seeds, chemical fertilizers, insecticides, fungicides and herbicides. Imbalanced and overuse of these chemicals, coupled with reduced or non-use of organic amendments in the soil, has resulted in deterioration of soil properties, particularly physical and biological properties, reduced factor productivity of applied inputs, chemical residues in produce, contamination of water, besides long-term environmental concerns. Therefore, across the globe, priorities in agriculture are gradually shifting from production to resource conservation, restoration of soil health & fertility, minimizing the adverse impact on soil and environment, and moving to natural & traditional practices-based non-synthetic farming systems. Natural farming systems rely largely on biomass recycling, biological rejuvenation of natural nutrient cycles, and on-farm plant and livestock-based inputs, and are found to be one of the alternative production systems to address the priorities listed in the report of the Food and Agriculture Organization (FAO) “The State of Food & Agriculture”. Besides being non-degrading, non-depleting, and resource-conserving, natural farming systems are found to be low cost, give freedom to farmers from purchased inputs, ensure comparable productivity, especially in low-input requiring crops, increased income, and are safe for the soil, environment, and all life forms, including humans and animals. Agroecological farming (comprising of practices such as soil organic matter enhancing technologies, diversified field borders, reduced tillage, water harvesting, livestock integration, cover & legume crops, poly cultures, agroforestry, habitat for beneficial insects and active soil biology) are globally agreed as an alternative to conventional high-input agriculture, which mostly results in better yields without compromising the needs of future generations and avoiding inter-generational conflict.

Natural farming is considered one of the agroecology practices, and the UN Food Systems Summit, 2021, emphasized scaling up Agroecology as a game-changing solution for farmers, citizens, and the planet. Several other recommendations related to agroecology have come after global consultations to find alternatives to present forms of conventional agriculture, which often have deleterious impacts on water, climate, nutrition, and farmer well-being.

National Mission on Natural Farming (NMNF) is a standalone Centrally Sponsored Scheme under Department of Agriculture & Farmers Welfare (DA&FW), Ministry of Agriculture & Farmers Welfare

(MoA&FW) with an outlay of ₹2481.00 crore (Government of India share is ₹1584.00 crore and States share is ₹897.00 crore). The Mission is a shift to strengthen agriculture practices with scientifically backed approaches towards sustainability, climate resilience and safe food.

NMNF Objectives

1. To promote nature based sustainable systems of farming, enhancing usage of natural farming bio-inputs prepared on-farm to reduce dependency on externally purchased inputs and input cost reduction. To also improve soil health and have sustainable agriculture practices.
2. To popularize livestock (preferably a local breed of cow), integrated agriculture-animal husbandry models
3. To strengthen on-farm agroecological research and knowledge-based extension capacities of ICAR institutions, KVKs, Agricultural Universities, etc.
4. To build upon the on-field experience of practicing NF farmers and scientific expertise to thereby evolve & improve location specific NF package of practices for increased spread of NF.
5. To establish scientifically supported common standards and easy farmer friendly certification procedures for naturally grown, chemical-free produce.
6. To create and promote a single national brand for naturally grown chemical-free produce.

Understanding the Science behind the proven practices of natural farming and their role in soil health, crop productivity, etc, is very much essential. Therefore, Natural Farming Research was initiated by the Indian Council of Agricultural Research through All India Network Programme on Natural Farming under NRM division from kharif 2020 with focus on characterization of NF practices by farmers, characterization and preparation of protocols for Natural Farming inputs such as Beejamrit, Jeevamrit, Ghanajeevamrit, Brahmastra, Neemastra, Agniastra, Dashparni and evaluation of practices in 8 major cropping systems through multi-location experiments at 20 locations in 16 States. The significant findings are given in this publication.

03

Characterization of Natural Farming Practices adopted by farmers

Natural Farming in India is not a uniform practice but a mosaic of regionally adapted systems drawing upon indigenous knowledge and resource recycling. Core elements like Jeevamrit, Ghanajeevamrit, Beejamrit, mulching, and intercropping recur across regions, but crop choices and management intensity differ. Yield performance varies, with some crops in certain regions performing close to research station levels, while others show large gaps. Closing these gaps and enhancing profitability will be key to sustaining and expanding NF adoption.

Natural Farming (NF) has emerged as a promising approach to sustainable agriculture in India, relying on locally available resources, biological processes, and minimal external inputs. The practice integrates traditional knowledge with eco-friendly crop management strategies to reduce production costs, restore soil health, and enhance resilience to climatic stress. Characterising NF practices across different regions is crucial for understanding how these practices vary with agro-climatic conditions, resource availability, and socio-economic contexts. Such characterisation allows for benchmarking productivity levels, identifying yield gaps, documenting indigenous techniques, and guiding future policy and research interventions.

Characterization of NF Practices Adopted by Farmers

Under All India Network Programme on Natural Farming, characterization of Natural farming practices adopted by farmers was made during 2019-20 to 2022-23 in different states. Details of the number of farmers covered over the years are given in Table 4.

Table 4. State-wise number of NF farmers characterized

Sl.No.	State	Total
1.	Gujarat	101
2.	Himachal Pradesh	81
3.	Jharkhand	100
4.	Karnataka	15
5.	Kerala	59
6.	Madhya Pradesh	159
7.	Rajasthan	44

Sl.No.	State	Total
8.	Sikkim	71
9.	Tamil Nadu	36
10.	Uttarakhand	10
11.	Uttar Pradesh	1
	Total	677

Landholding and Livestock: The landholding size of NF farmers tends to be on the smaller side in most states, often falling in the *small or marginal farmer* category. In many locations, NF practitioners had average farm sizes under 2 hectares. For example, in an NF cluster of Rajasthan (Ajmer), the NF farmers were all smallholders with an average holding of only 0.6 ha. Similarly, in Uttarakhand, NF farmers (where present) were marginal with land around 0.5–0.7 ha. In Karnataka (Dharwad), NF farms averaged ~1.5 ha for small holdings.

However, there were occasional exceptions with larger NF farms. In Madhya Pradesh, some NF farmers fell in the “large” category – for instance, the Jabalpur survey included farmers with large holdings averaging ~3.17 ha under NF. Overall, the data indicate that most NF farmers are small and marginal cultivators, with only a few instances of medium to large landholdings in NF practice.

In terms of livestock rearing, almost all NF farmers maintain some livestock – especially cattle – as an integral part of the farming system. Cows or buffaloes are crucial for NF because their dung and urine are used to prepare core inputs like jeevamrit and beejamrit. In fact, 100% of NF farmers in the surveyed villages of Himachal Pradesh had livestock holding. On average, an NF household typically had about 1–2 *dairy animals*. For example, in the Bajaura, HP cluster, NF farmers had ~2 cattle per household. Similarly, NF farmers in Tamil Nadu (Coimbatore) kept about 2 cattle on average. Apart from cows, goats and poultry are the other common livestock among NF farmers. The presence and numbers of these animals vary by region based on local traditions and needs. For instance, NF farmers in South India often had a few goats and a flock of poultry. The Coimbatore NF group averaged 5 goats and 5 poultry birds per household. By contrast, some NF groups in North India focus more on larger ruminants e.g., NF farmers in Ajmer, Rajasthan had about 7 cattle and only 2 goats on average, aligning with the importance of bullocks/cows in arid agriculture.

NF farmers across states are predominantly smallholders who integrate livestock into their farming. They keep at least one indigenous cow or buffalo (often more) to supply dung and urine for NF formulations. Many also raise goats (2–5 on average in several states) and poultry (ranging from a handful up to a few dozen) to supplement their farm needs. This mixed crop-livestock approach provides manure and other inputs for NF while diversifying income and nutrition for the farm household. The reliance on livestock underscores a core principle of Natural Farming – leveraging on-farm biological resources (like animal waste) to sustain soil fertility and crop.



NF Practices: Across surveyed states, NF farmers adopt a variety of agronomic and biological techniques tailored to their local environment. Nutrient management is predominantly based on bioformulations such as Jeevamrit, Ghanajeevamrit, and Beejamrit. Jeevamrit, a fermented microbial culture, is typically applied at rates of 200–500 litres per ha, while Ghanajeevamrit is used in solid form at 200–250 kg per ha. Beejamrit is applied as a seed treatment at dosages ranging from 0.5 to 2 kg per kilogram of seed. These inputs enhance soil microbial activity and nutrient cycling. Weed management is largely manual, often combined with mulching and intercropping to suppress weed growth. Pest and disease control relies on botanicals and traditional formulations such as Agniashtra, Brahmastra, Dashparni ark, neem oil, sour buttermilk, and herbal leaf extracts, all of which are prepared using on-farm-sourced materials.

While the core philosophy of NF is reducing external chemical inputs and enhancing natural soil processes, actual implementation varies depending on climate, crop type, and local knowledge. Table 5 summarizes nutrient, weed, and pest/disease management practices across selected regions.

Table 5. Nutrient, weed and pest/disease management practices adopted by farmers in different regions

Region/State	Nutrient Management	Weed Management	Pest/Disease Management
Himachal Pradesh	Jeevamrit 500 L/ha, Ghanajeevamrit 250 kg/ha, Beejamrit 1 kg/kg of seed	Mulching, Manual Weeding	Agniashtra, Brahmastra, Dashparni Ark
Tamil Nadu	Jeevamrit 500 L/ha, Ghanajeevamrit 250 kg/ha, Beejamrit 2 L	Mulching, Manual Weeding	Neem Seed Kernel Extract, Herbal Extracts, Buttermilk

Region/State	Nutrient Management	Weed Management	Pest/Disease Management
Karnataka	Beejamrit 0.5 kg/kg of seed, Jeevamrit 1500 L/ha, Ghanajeevamrit 1000 kg/ha	Mulching, Intercropping	Neemastra, Agniastra, Brahmastra
Uttarakhand	Jeevamrit 500 L/ha, Dashparni 400 ml/20 L water	Manual Weeding	Dashparni, Trichoderma
Sikkim	Jeevamrit 250-500 L/ha, Ghanajeevamrit 250 kg/ha, Beejamrit	Mulching, Intercropping	Botanicals, Spinosad
Gujarat	Jeevamrit 250 L/ha, Ghanajeevamrit 200 kg/ha, Beejamrit 10 ml/kg seed	Manual Weeding	Neem Extracts, Dashparni
Rajasthan	Jeevamrit 880 L/ha, Beejamrit 160 g/kg of seed	Mulching, Manual Weeding	Neem Leaf Extract, Dashparni
Uttar Pradesh	Jeevamrit, Beejamrit	Mulching, Manual Weeding	Neem Leaf Extract, Dashparni
Jharkhand	Jeevamrit 500 L/ha, Dashparni 400 ml/20 L water	Manual Weeding	Dashparni, Trichoderma
Kerala	Jeevamrit, Ghanajeevamrit, Beejamrit, Vermicompost	Manual Weeding	Neem Extracts, Dashparni
Madhya Pradesh	Jeevamrit 880 L/ha, Beejamrit 160 g/kg of seed	Mulching, Manual Weeding	Neem Leaf Extract, Dashparni

From this comparison, Jeevamrit and Beejamrit emerge as the most widely adopted inputs for nutrient management, while mulching dominates weed management, especially in regions with erratic rainfall or high soil erosion risk. Neem-based products, Dashparni Ark, Agniastra, and Brahmastra form the mainstay of pest and disease control, with variations according to local pest pressure and available botanical resources.

Distribution of main NF elements

The adoption of Natural Farming (NF) inputs and practices varies across states, reflecting both shared principles and region-specific adaptations. Core practices like Jeevamrit, Beejamrit, and Neem-based

products are widely embraced for nutrient management, seed health, and pest control (Table 6). Other practices, such as mulching and botanical formulations, are adopted based on local agro-climatic conditions and farming needs. The table below presents the estimated percentage of surveyed farmers adopting different Natural Farming (NF) inputs and practices across various states. These estimates are based on the frequency of mentions in the geo-referenced characterization data, indicating how widely each practice is adopted regionally.

Table 6. Adoption of NF practices by farmers

Sl. No.	NF Practice	Adoption (%)
1	Jeevamrit	100.0
2	Beejamrit	85.7
3	Ghanajeevamrit	71.4
4	Mulching	71.4
5	Neem based products	57.1
6	Dashparni Ark	57.1
7	Agniastra	28.6
8	Brahmastra	28.6

The results reflect clear patterns in farmer preference and regional adaptation of NF elements.

1. Jeevamrit : *Highest Adoption (~100%)*

- Found in almost all surveyed states.
- Serves as the primary microbial and nutrient-rich liquid formulation, enhancing soil biology and crop growth.
- Its universal adoption highlights its role as the foundation of NF nutrient management.

2. Beejamrit: *Second Highest (~85–90%)*

- Widely used as a seed treatment to protect against soil-borne pathogens and promote early plant vigor.
- Its high adoption underscores the emphasis on seed health as the first step to sustainable production.

3. Neem-based Products: *High Adoption (~80%)*

- Includes neem oil, neem seed kernel extract, and neem leaf preparations.
- Popular for their broad-spectrum pest control and eco-friendly nature.
- Strongly represented in Karnataka, Gujarat, Rajasthan, and Tamil Nadu.

4. **Mulching: *Moderate Adoption (~60–65%)***
 - More common in hill regions and southern states where soil moisture conservation and erosion control are critical.
 - Also aids in weed suppression and soil temperature regulation.
5. **Dashparni Ark: *Selective Adoption (~45–50%)***
 - Traditional botanical pesticide prepared from locally available plants.
 - Prominent in Rajasthan, Gujarat, Himachal Pradesh, and Uttarakhand.
6. **Agniastra & Brahmastra: *Region-specific (~35–40%)***
 - Used mainly for targeted pest control, especially against sucking pests and borers.
 - Found in Himachal Pradesh, Karnataka, and Tamil Nadu.
 - Their lower percentage reflects specialized use rather than universal need.

The analysis confirms that Jeevamrit, Beejamrit, and Neem based products form the core triad of NF practices, widely applicable across agro-climatic zones. Mulching and Dashparni Ark are important supplementary measures, while Agniastra and Brahmastra are niche solutions adapted to specific pest pressures. The overall pattern underscores that NF is both universal in philosophy and region-specific in execution, balancing foundational techniques with local adaptations for optimal effectiveness.

Regional /State-wise variation in NF practices

The adoption of NF varies significantly across regions, shaped by ecological conditions, cropping systems, and market access. In the Hill and North-Eastern Region, which includes Himachal Pradesh (Bajaura), Uttarakhand (Almora), Sikkim (Gangtok), and Meghalaya (Umiyam), farmers typically integrate horticultural crops such as apple, ginger, and vegetables with cereals and pulses. Livestock rearing is integral to these systems, providing dung and urine for input preparation. Plant protection here often involves homemade botanical concoctions. Constraints include challenging terrain, pest management difficulties, and limited access to markets.

In the Central Plateau and Dry Regions, covering Madhya Pradesh (Bhopal), Rajasthan (Ajmer, Udaipur), and Gujarat (Sardarkrushinagar), the focus is on crops such as bajra, wheat, gram, and green gram. Farmers make extensive use of Jeevamrit and Beejamrit and often adopt intercropping to optimise land use. These areas face issues of low rainfall, limited organic input availability, and lack of assured premium markets.

The Southern Peninsular Region, comprising Tamil Nadu (Coimbatore), Karnataka (Dharwad), and Kerala (Thiruvananthapuram), features diverse cropping systems, including turmeric, coconut, pulses, and vegetables. Mulching and intercropping are widespread, and pest management involves a broad

range of plant-based formulations. Here, pest outbreaks, high labour costs, and the time required for input preparation are common challenges.

Core components, crops, productivity and yield gaps

The survey across seven states revealed a diverse range of crops under NF, reflecting regional preferences and agro-climatic suitability. The performance of NF in terms of crop yields varies across regions. In Himachal Pradesh, maize-based intercrops, pea, and soybean dominate, while Tamil Nadu focuses on turmeric and coconut. Karnataka features pulses, oilseeds, and cereals, whereas Uttarakhand specialises in millets and traditional legumes. Sikkim combines soybean with vegetable peas, Gujarat grows wheat and pulses, and Rajasthan maintains a mix of cereals, pulses, and vegetables. Overall, NF supports a wide variety of crop combinations adapted to local conditions, showcasing both food security and diversification potential. Table 7 summarizes key crops, productivity, and yield gaps from different states.

Table 7. Key crops, productivity and yield gaps (between farmers fields and on-station yield) under Natural farming in different States

Region/State	Crops cultivated under NF	Farmers' Yield (kg/ha)	On-station Yield (kg/ha)	Yield Gap (%) (- farmers yield higher/ + on-station yield higher)
Himachal Pradesh (Bajaura)	Maize (intercrop), Pea, Soybean	3611 (maize), 6315 (pea), 1500 (soybean)	3150, 7500, 1960	-12.8, 18.8, 30.7
Tamil Nadu (Coimbatore)	Turmeric, Coconut	18000, 60 nuts/tree	25000, 65 nuts/tree	28, 8
Karnataka (Dharwad)	Green gram, Soybean, Groundnut, Sorghum, Maize	530, 620, 1074, 750, 1650	650, 725, 1200, 900, 1800	22.6, 16.9, 11.7, 20, 9.1
Uttarakhand (Almora)	Finger millet, Barnyard millet, Black soybean, Horse gram	1382, 996, 658, 426	1795, 1096, 1037, 885	30, 10, 58, 108
Sikkim (Gangtok)	Soybean, Vegetable pea	830, 3126	1426, 6036	71.8, 48.4
Gujarat (Sardarkrushinagar)	Wheat, Green gram, Black gram, Chickpea	2680, -, -, 1430	3600, -, -, 1535	25.6, -, -, 6.8

Region/State	Crops cultivated under NF	Farmers' Yield (kg/ha)	On-station Yield (kg/ha)	Yield Gap (%) (- farmers yield higher/ + on-station yield higher)
Rajasthan (Udaipur)	Maize, Blackgram, Wheat, Chickpea, Vegetables	2000, 390, 3200, 950	2300, 430, 4000, 1300	13, 9.3, 20, 26.9

Yield gaps between on-station trials and farmers' fields remain significant in several areas, reflecting differences in resource use, management intensity, and environmental conditions. The primary reasons include the gradual soil biological transition from chemical to natural inputs, initial nutrient release limitations, pest and disease pressures in the absence of synthetic controls, and the lack of crop-specific, location-tailored NF protocols. In some areas, yield gaps also arise due to insufficient irrigation access, lack of timely preparation/application of bio-inputs, and limited farmer training on NF crop management (Fig 2).

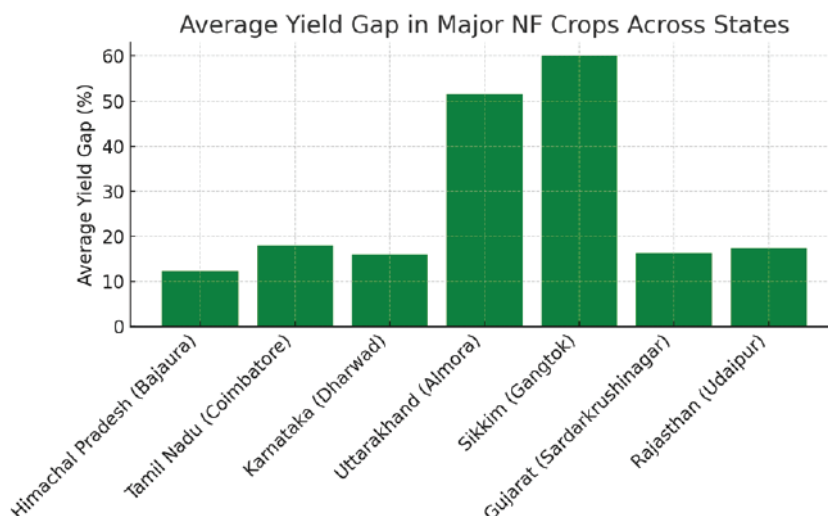


Fig 2. Average yield gap in Major NF crops across states

The characterization of NF practices reveals a broad spectrum of approaches adapted to local contexts. While the ecological benefits are evident, significant yield gaps persist in many crops, particularly in hill and rainfed areas. Addressing these gaps will require targeted interventions such as location-specific technology refinement, improved access to quality inputs, capacity building for farmers, and better market linkages. Regional variations highlight the importance of tailoring NF strategies to specific agro-climatic and socio-economic conditions.

04

Biochemical characterization of Natural Farming Inputs

Natural Farming relies on several indigenous inputs prepared from farm by-products to enhance soil fertility and crop protection. Five important concoctions namely Beejamrit, Ghanajeevamrit, Jeevamrit, Neemastra, and Brahmastra, each serving distinct agronomic purposes, were characterized at selected locations (Ludhiana, Udaipur, Coimbatore, Narendrapur and Calicut) under the All India Network Programme on Natural Farming. This chapter summarizes their biochemical composition, including organic carbon content and secondary metabolites like phenolics, flavonoids, alkaloids, and plant hormones, and their microbial profiles. Emphasis is given to how different cow breeds (dung and urine from native vs. crossbred Holstein-Friesian, and the mix of dung and urine from both) influence the composition of these inputs, as well as how the incubation period (time after preparation) impacts nutrient dynamics and microbial populations.

3.1. Beejamrit is a liquid microbial inoculant made from fresh cow dung, cow urine, lime, and sometimes soil; it is used as a seed treatment to improve germination and protect young seedlings from pests and diseases. During the fermentation of these organic ingredients, Beejamrit contains abundant beneficial microorganisms and modest nutrient content.

Beejamrit is essentially a consortium of live beneficial microbes. Upon preparation, it contains a very high load of bacteria, on the order of 10^9 – 10^{10} colony-forming units (CFU) per mL, along with substantial populations of fungi and actinomycetes. Culture-based counts show total aerobic bacteria around 1 – 1.5×10^{10} CFU/mL at 0 hours, which can rise modestly to $\sim 1.7 \times 10^{10}$ by 2 days (48 hrs) before declining as nutrients deplete. In contrast, fungal counts ($\sim 10^4$ CFU/mL) and actinomycetes ($\sim 10^8$ CFU/mL) do not increase over the first day and actually decrease significantly after 48 hours of incubation. For example, total fungi might drop from $\sim 7 \times 10^4$ to 3×10^4 CFU/mL by day 4, and actinomycetes from $\sim 1.5 \times 10^8$ to $< 0.3 \times 10^8$ CFU/mL in the same period. This indicates that while bacteria thrive briefly on the available substrates, the more slow-growing fungi and actinomycetes diminish as competition and possibly pH changes occur. Indeed, one analysis noted 11.8–26.8% increases in bacterial count after 2 days, while fungi decreased 25–54% and actinomycetes 29–40% in that time frame.

Importantly, Beejamrit hosts a dynamic community of plant-growth-promoting bacteria. Free-living nitrogen fixers (FNFs such as *Azotobacter* and *Azospirillum*) multiply during the fermentation, roughly doubling their population within 2–3 days. Phosphate-solubilizing bacteria (PSB, e.g. *Bacillus* and *Pseudomonas* spp.) are also present; their counts remain more stable early on, but the formulation

overall shows a “dynamic structure of plant beneficial bacterial niches” developing over a few days. By design, Beejamrit introduces these beneficial microbes as a seed-coating slurry. Research confirms it contains an abundant and diverse microbial consortium, including total bacterial loads up to 10^{10} CFU/mL, actinomycetes $\sim 10^8$, and fungi $\sim 10^5$, as well as functional groups like FNFs ($\sim 10^9$ CFU/mL) and PSBs ($\sim 10^8$ CFU/mL) after a couple of days of fermentation. These organisms can colonize the seed surface and young rhizosphere, enhance nutrient availability and protect against soil-borne pathogens.

Cow breed influences the microbial counts to some extent. Beejamrit prepared from mixed-urine and dung (native + HF) inputs often yielded the highest bacterial counts (for example, $\sim 5.6 \times 10^6$ CFU/g in one assay) compared to purely native or HF preparations. On the other hand, native-breed Beejamrit sometimes showed slightly greater fungal and actinomycete counts on Day 1 (perhaps owing to indigenous microflora in the dung), though by Day 2 these differences equalized or all populations declined. Overall, using a mixture of cow breeds’ inputs tended to maximize total microbial load. Regardless of breed, incubation time is critical, Beejamrit is most microbially active within the first 1–2 days of preparation. Extended storage leads to declining fungal and actinomycete numbers and a drop in pH, so it is recommended to use it fresh (within 2–3 days) for the highest efficacy.

Bioactive compounds identified: Although Beejamrit is primarily valued for its microbes, analytical profiling has revealed the presence of numerous organic compounds produced during its fermentation. Gas Chromatography–Mass Spectrometry (GC–MS) analyses of Beejamrit identified a suite of bioactive metabolites, many of which likely originate from the cow dung/urine matrix or microbial activity. Notable compounds reported include, Pinocembrin, a flavonoid with antimicrobial and antifungal properties; 4-tert-butylcalix [4]arene, a large cyclic molecule with herbicidal activity; Mevastatin (a statin-type compound) and gitoxigenin (a cardiac glycoside), which may act as bioconversion products and insect repellents; Columbianetin and lomatin, which are coumarins known to increase seed longevity; and various other agents. For example, enterolactone (a plant lignan) was detected, which has antimicrobial effects, and prednisolone (a steroid) was noted with potential insecticidal action. Antioxidant compounds like ubiquinol and fatty acid derivatives such as clupanodonic acid (linked to plant defense signaling) were also present.

The diversity of these compounds (ranging from phenolics, terpenoids, steroids, to fatty acids) is striking. Many have roles in plant defense or growth regulation for instance, cicloprofen (a halogenated chalcone) can serve as an antibacterial coating, erioflorin and nagilactone are plant growth regulators with herbicidal effects, and catalpol is an iridoid known to induce plant defense responses. These findings suggest that Beejamrit is more than just a microbial inoculant; it is also a chemical elicitor. The presence of such compounds could help primed seeds resist pathogens by providing antimicrobial substances or by inducing systemic resistance in the seedlings. This dual nature, rich microbiota plus bioactive metabolites, underlies Beejamrit’s agronomic significance.

Key Findings

- Beejamrit's profile can be summarized as a microbially dense, carbon-rich liquid that undergoes rapid fermentation. The uniform decomposition of its organic matter (as evidenced by steady C and protein decline) and the burst of microbial growth in the first 48 hours indicate a highly active period that farmers should capitalize on.
- The recommendation is often to use Beejamrit within a couple of days of preparation, applying it as a seed coat or soil drench near sowing time. Agronomically, the key benefits of Beejamrit include improved seed germination and early seedling vigor, attributed to the seed being inoculated with nitrogen-fixers and antifungal agents that ward off rot and damping-off diseases.
- The indigenous microbes, such as *Azotobacter* and *Pseudomonas*, introduced via Beejamrit can establish in the soil and continue nutrient cycling (particularly nitrogen and phosphorus supply to the crop).
- Additionally, the array of secondary metabolites identified in Beejamrit could contribute to a protective biochemical environment around the seed.
- In essence, Beejamrit serves as a low-cost bio-priming agent, providing both a microbiological kick-start to the soil and a biochemical shield for young plants in their critical early growth stage.

3.2 Ghanajeevamrit

Ghanajeevamrit (also spelled Ghana Jeevamrit) is the dry, solid form of Jeevamrit, typically made by mixing the same ingredients (cow dung, cow urine, jaggery, pulse flour, soil, etc.) and allowing it to ferment briefly, then drying it. Farmers use Ghanajeevamrit as a soil amendment that can be stored and applied like manure or compost. It contains similar beneficial microbes and organic matter as liquid Jeevamrit, but in a more stable form for longer-term soil enrichment.

Ghanajeevamrit carries a much higher organic matter content than liquid Jeevamrit, owing to its solid nature. Immediately after preparation (before drying), its organic carbon content is around 7–8% on a dry-weight basis. For example, one analysis showed ~7.4–7.6% organic C in Ghanajeevamrit made from either native or HF cows, versus only ~0.3–0.4% in the liquid Jeevamrit. This reflects that Ghanajeevamrit is essentially concentrated dung with additives, only slightly decomposed. Over a short incubation (up to 4 days), its carbon content does not change drastically (staying in the mid-7% range), which suggests most of the carbon is in stable forms or drying halts the active decomposition early.

The pH of Ghanajeevamrit is near neutral, slightly lower than the liquid version. Initial pH readings are often in the mid-6s (6.3 and 6.8) for HF and native breeds, respectively. Interestingly, formulations using native breed dung tend to have a higher pH (closer to 7.0) than those using HF dung (which were around pH 6.3–6.5 initially). After 2–4 days of fermentation, pH might rise slightly in the native-

breed Ghanajeevamrit (up to ~7.1) while remaining in the mid-6 range for HF breed, suggesting native dung may buffer acidity better. Electrical conductivity (EC) of Ghanajeevamrit leachate is relatively high (2.2–2.7 dS/m), indicating a good number of soluble salts; mixed-breed preparations showed the highest EC (~2.7 dS/m) in one study.

Because Ghanajeevamrit is essentially a semi-decomposed manure, it harbors a robust microbial community similar to Jeevamrit. Just after preparation (moist incubation), total bacterial counts are extremely high – higher, in fact, than in liquid Jeevamrit due to the concentrated medium. One study reported initial bacteria at $\sim 5.2 \times 10^6$ CFU/g in HF-cow Ghanajeevamrit, rising to $\sim 6.6 \times 10^6$ by day 2; and $\sim 4.2 \times 10^6$ to 5.6×10^6 CFU/g in native-cow Ghanajeevamrit over the same period. The mixed breed batch reached the highest count, $\sim 7.2 \times 10^6$ by 2 days. (These are plate count numbers per gram; in liquid Jeevamrit per mL, the scale was 10^5 , which corresponds to a similar order of magnitude when converted to per gram of slurry). Thus, as with other inputs, bacteria proliferate in the first 48 hours in Ghanajeevamrit across all treatments.

Fungal and actinomycete populations in Ghanajeevamrit showed an inverse trend: they were initially higher in some treatments but declined by the second day. For instance, at Day 1, the HF-cow Ghanajeevamrit had the highest fungal count ($\sim 3.0 \times 10^4$ CFU/g) and actinomycete count ($\sim 2.0 \times 10^3$ CFU/g) among the breed treatments. By Day 2, those had dropped to $\sim 2.0 \times 10^4$ and 1.0×10^3 , respectively. The native breed showed fungi dropping from 2.5×10^4 to 1.2×10^4 , and actinomycetes from 1.5×10^3 to 1.0×10^3 in 2 days. In short, fungi and actinomycetes were the highest initially in the HF and native treatments, respectively, but in all cases their populations roughly halved by 48 hours. The rapid decline is likely due to increased bacterial dominance and perhaps the accumulation of metabolites that suppress these organisms as fermentation proceeds.

Qualitatively, the microbial makeup of Ghanajeevamrit is similar to Jeevamrit. It contains a plethora of free-living nitrogen fixers (like *Azotobacter* spp.), phosphate solubilizers (*Bacillus*, *Pseudomonas* spp.), and other decomposer bacteria including *Flavobacterium*. In trials, Ghanajeevamrit prepared with native breed inputs was noted to have especially high counts of *Azospirillum*, *Azotobacter*, and *Bacillus* (N-fixers), followed by the HF-based and mixed versions. Meanwhile, *Pseudomonas* and other PSBs were abundant across all, though slightly more so in native breed preparations. The peak microbial activity occurs within the first 2 days of moist incubation, as evidenced by CO₂ evolution and the surge in bacterial counts. After ~4–7 days (especially once the material is dried for storage), the microbial activity stabilizes, essentially pausing further population growth until the product is applied to soil.

Bioactive compounds: Even though Ghanajeevamrit is essentially dried Jeevamrit, it contains a variety of bioactive organic compounds as intermediate metabolites of decomposition. GC–MS profiling of Ghanajeevamrit has revealed numerous chemical constituents with known biological activities. For example, butylated hydroxytoluene (BHT), a potent antioxidant, was detected in Ghanajeevamrit. BHT is often a microbial metabolite that can inhibit autoxidation of unsaturated compounds, potentially

helping to preserve the formulation or affecting soil redox processes. Another identified compound was 5-tert-butylpyrogallol, which has anti-inflammatory properties and may aid in detoxification in plants.

Several aromatic compounds and heterocycles were found as well. Benzothiazole, 2-methylmercapto- was present, which is noteworthy as an analog of certain biochemicals; it can act as a xenobiotic metabolite and might interact with soil biota. Phenol, 4,6-di-(1,1-dimethyl)-2-methyl (a substituted phenolic compound) was identified and is known for antimicrobial activity. Additionally, phlorobutyrophenone, a phenolic compound, was found and is associated with enzyme inhibition and plant metabolic regulation. These phenolic substances could help suppress soil-borne pathogens when Ghanajeevamrit is applied.

Notably, n-hexadecanoic acid (palmitic acid) was detected, which is a common fatty acid and plant metabolite, possibly serving as a carbon source for microbes or a signaling molecule. Also present was ascorbic acid 2,6-dihexadecanoate, an ester of vitamin C, which can act as a major redox buffer and cofactor for enzymes in soil microbial processes. The detection of an ascorbate ester suggests that some fraction of the microbial community in Ghanajeevamrit produces or retains vitamin C derivatives, which could promote stress tolerance in plants.

Interestingly, a complex cyclopropyl fatty acid ester was found (methyl ester of a cyclopropanebutanoic acid derivative) that is thought to be involved in the biosynthesis of fatty acids and might indicate unique microbial pathways at work. Another notable set of compounds in Ghanajeevamrit was stigmasterol and related sterols. Stigmasterol is a plant sterol that, when added to soil, can influence microbial membranes and has been linked to plant growth promotion and stress resilience (e.g. it can stimulate cell proliferation in plant roots). Its presence likely comes from plant materials in the feed (such as pulse flour) and could contribute to beneficial effects on crops.

Key findings

- Ghanajeevamrit essentially functions as a slow-release bio-fertilizer and soil life booster. Agronomically, one of the key advantages is its storability and ease of application – farmers can dry it and broadcast or incorporate it into soil, where it will gradually break down and release its microbial consortia and minor nutrients. Upon soil incorporation and rehydration (e.g. by irrigation or rain), the dormant microbes in Ghanajeevamrit become active and colonize the soil/root zone. The data indicating peaks in N-fixing and P-solubilizing bacteria counts in the first two days suggest that even a short rehydration period before application could “activate” Ghanajeevamrit for maximum effect.
- From a practical perspective, the breed influence implies that using dung and urine from native breeds (like Kangeyam) might yield a slightly better Ghanajeevamrit in terms of initial microbial load and nutrient release (owing to higher N content and pH stability), whereas crossbred HF inputs might result in higher fungal content initially but also produce certain beneficial compounds.

Farmers with access to both could mix inputs to harness the advantages of each (indeed, the mix often showed superior P and K availability).

- Finally, the discovery of various bioactive compounds in Ghanajeevamrit adds another layer to its agronomic significance: when applied, it not only supplies microbes that fix nitrogen and decompose organic matter but also introduces natural antioxidants and antimicrobial compounds that can improve soil health and possibly induce systemic resistance in crops. In natural farming systems, Ghanajeevamrit thus serves as a bridge between compost and microbial inoculant, improving soil organic carbon and porosity like compost, and simultaneously enhancing the soil's biological activity like a microbial inoculant. Over time, its regular use can improve soil structure (via microbial polysaccharides), increase nutrient cycling, and reduce the need for chemical fertilizers, all of which align with sustainable farming objectives.

3.3 Jeevamrit

Jeevamrit (or Jivamrit) is a cornerstone liquid input in Natural Farming, often described as a “living broth” of microbes that fertilizes the soil. It is prepared by fermenting fresh cow dung and urine (from indigenous cows preferably) with jaggery (molasses), pulse flour (besan), water, and sometimes soil, for about 2–4 days. There are two forms: Drava (liquid) Jeevamrit, which is used immediately as a soil drench or foliar spray, and Ghana (dry) Jeevamrit, which we covered separately in earlier.

Liquid Jeevamrit is a diluted ferment, and accordingly, its direct nutrient concentrations are very low. The solution is typically mildly acidic to neutral in pH. Initial pH can range from pH ~7.5–8.5, depending on ingredients; e.g., a trial found native-breed Jeevamrit had pH ~7.8, HF-breed ~8.4, and mixed ~7.7 on day 1. Over ~3–5 days of fermentation, the pH tends to decrease slightly as organic acids accumulate – one study observed a drop from pH 7.8 to 7.1 in 96 hours for a native-breed batch. Still, Jeevamrit generally stays in the neutral to acidic pH (5.5-6.5) due to fermentation of sugar and production of acid. After fermentation, suitable for soil application.

The organic carbon (OC) content of liquid Jeevamrit is on the order of a few thousand ppm (0.2–0.4%). At the time of preparation, OC might be ~0.3–0.4% and, similar to Beejamrit, it declines as fermentation proceeds. This decline indicates that the sugars (from jaggery) and other carbon sources are being consumed by microbes. For instance, one set of data showed OC dropping from 0.38% at 24h to 0.28% at 96h in a native-breed Jeevamrit, and similarly from 0.40% to 0.20% in the mixed-breed Jeevamrit. By about 4–6 days, most of the easily available carbon is metabolized, which is why Jeevamrit is usually applied within a week of preparation.

Available nitrogen (N) in Jeevamrit is initially extremely low (basically whatever small amount was in the ingredients). However, an interesting dynamic occurs: as the dung and urine decompose, ammoniacal N (NH_4^+) is briefly released. Studies noted a significant increase in NH_4^+ -N after 2 days, reaching a peak, followed by a sharp decline as that nitrogen is either volatilized or assimilated by microbes. For example, available N might rise to ~0.008–0.009% by 48h, then drop to ~0.001% by

96h. In practical terms, this means Jeevamrit has a small flush of plant-available N if used very fresh, but overall N content remains under 0.01%. Phosphorus is even more limited: multiple trials report no appreciable change in available P (P_2O_5) during Jeevamrit's incubation. The concentration stays around 0.002–0.004%, which is negligible. Only in Ghana-Jeevamrit (solid) did P showed a slight uptick after a week. Potassium (K_2O) in liquid Jeevamrit also shows no consistent trend; values are on the order of 0.005–0.02% at best. One dataset showed K_2O perhaps decreasing slightly in liquid form (from ~0.01% to 0.005%), while Ghana-Jeevamrit samples had ~0.7–0.9% K_2O (again, a difference in units due to solid form). In summary, Jeevamrit's NPK values are in the parts-per-million range, reinforcing that its primary role is not direct nutrient supplementation but microbial enrichment.

The true value of Jeevamrit is its dense and diverse microbial population. Right after preparation, Jeevamrit contains on the order of 10^5 – 10^7 CFU/mL of various microbes, which multiply rapidly. In one study, the total heterotrophic bacterial count in Jeevamrit increased from ~ 1.3 – 1.4×10^7 CFU/mL on day 1 to ~ 1.8 – 1.9×10^7 by day 2 (a ~30–40% increase). This surge aligns with the initial availability of jaggery (sugar) and other nutrients fueling bacterial growth. Notably, Jeevamrit made with HF cow inputs showed the highest bacterial counts after 48 hours, for instance, $\sim 1.94 \times 10^7$ CFU/mL, slightly above the native breed's $\sim 1.93 \times 10^7$. The difference was small, but consistently, HF batches had an edge in bacterial proliferation (possibly due to more urea nitrogen in HF urine). The mixed breed batch had a bit lower count ($\sim 1.83 \times 10^7$), but these all fall in the same order of magnitude. By 2–3 days, the bacterial population often reaches its peak and may plateau or start to drop if nutrients become limiting.

Fungal populations in Jeevamrit are initially present ($\sim 10^4$ CFU/mL range), but they do not flourish as much as bacteria in the short fermentation. In fact, a significant decrease in total fungi (yeasts and molds) was observed – often a drop of 50% or more by day 2. For example, one native breed Jeevamrit had $\sim 7 \times 10^4$ fungi/mL at day 1 which fell to $\sim 2 \times 10^4$ by day 2, a 71% decrease. HF-breed Jeevamrit started similarly ($\sim 7 \times 10^4$) but only fell to 4×10^4 (a ~43% decrease), suggesting possibly more fungal-friendly conditions remained in that batch. The mixed had $\sim 9 \times 10^4$ dropping to 3×10^4 (67% decrease). So across the board, fungi diminish as the easily digestible substrates are likely taken up by bacteria, or the environment (pH ~8 and accumulating metabolites) doesn't favor fungal growth.

Actinomycetes (filamentous bacteria) are also present in Jeevamrit, initially on the order of 10^3 CFU/mL (e.g. 1 – 2×10^3). Their counts tend to either remain low or decrease slightly over a couple of days. For instance, in native and mixed breed Jeevamrit, actinomycete CFUs halved (from ~ 2 to 1×10^3) by day 2, whereas in the HF batch they were low to begin with ($\sim 1 \times 10^3$) and stayed about the same. Actinomycetes often break down complex organics, but in the short window of Jeevamrit fermentation, they may not significantly multiply.

Crucially, Jeevamrit is known to harbor specific functional microbial groups beneficial to plants. Plate count and molecular studies have shown that it contains abundant free-living N fixers, P-solubilizing bacteria, K-mobilizing bacteria, and even IAA (auxin) producing bacteria. For example, after a few days of fermentation, counts of free-living nitrogen fixers in Jeevamrit can reach $\sim 10^8$ – 10^9 CFU/mL.

Phosphate-solubilizers, while present from the start, showed a relatively static count in liquid Jeevamrit (no significant rise in 2 days for the native breed batch), but in the Ghana-Jeevamrit counterpart, a gradual increase was noted. Potassium solubilizing bacteria showed significant changes – their populations in both liquid and Ghana Jeevamrit rose and peaked at around 2 days. In short, within 48 hours of fermentation, Jeevamrit reaches maximal populations of its key beneficial microbes, after which their numbers level off or decline if not used.

In terms of identified genera, analyses have found *Bacillus* species to dominate (including *B. subtilis*, *B. cereus*, *B. circulans*, *Lysinibacillus* sp., etc.), which are known for nitrogen fixation and general plant growth promotion. Presence of *Acetobacter* and *Lactobacillus* in higher number has been observed in Jeevamrit. These organisms help in endophytic nitrogen fixation and plant growth promotion. Various *Pseudomonas* species (such as *P. protegens*, *P. aeruginosa*, *P. azotoformans*) have also been isolated from Jeevamrit, contributing to nutrient cycling and possibly biocontrol of pathogens. Other noted bacteria include *Aeromonas*, *Ochrobactrum*, and *Lysinibacillus*, reflecting a diverse prokaryotic community. This diversity is one reason Jeevamrit-treated soils often show improved microbial richness. In fact, separate studies under natural farming have observed that regular application of Jeevamrit increases soil microbial diversity (as indicated by higher Shannon diversity index and community-level physiological profiling) compared to non-treated soils.

Bioactive compounds: Even though Jeevamrit is primarily about microbes, the fermentation process generates various secondary metabolites and also extracts compounds from the ingredients that could influence plant growth and protection. GC–MS profiling of Jeevamrit has revealed a range of organic compounds, albeit generally at low concentrations. Some of the notable compounds identified include:

- Diffractaic acid – a lichen-derived depside known to have antifungal properties. Its presence in Jeevamrit suggests some lignin or polyphenol breakdown products with bioactivity.
- Retinoic acid (vitamin A acid) and its methyl ester – these were found and are intriguing as they exhibit herbicidal activity. Retinoic acid in soil could affect the development of certain plant tissues or soil microorganisms; its detection indicates a complex biochemical milieu.
- Daphnin (7-O-glucoside of daphnetin) – an antioxidant coumarin glycoside with known antibacterial activity, identified in Jeevamrit. Daphnin could contribute to suppressing harmful microbes or signaling defense in plants.
- Simple benzoic acid derivatives like benzoic acid (and methyl benzoate) and trimethylbenzene were present. Benzoic acid is known to inhibit some bacteria and also is a precursor for plant defense compounds; in Jeevamrit it may come from urine or microbial synthesis and can act as a fungistatic agent.
- 1,4-Cyclohexanediol – identified as having insect repellent properties.
- α -Selinene – a sesquiterpene with insecticidal and antifungal activity, detected in Jeevamrit.

- **ar-Turmerone** – a compound from turmeric (if turmeric powder was in cow feed or environment) which has insecticidal and antimicrobial properties, also found in Jeevamrit.
- **Stigmasterol** – a plant sterol (also noted in Ghanajeevamrit) that can function as a growth promoter and impart salt-stress tolerance to plants, was present in Jeevamrit.

These compounds indicate that Jeevamrit contains traces of various bioactive molecules that could benefit plant health. For example, the herbicidal and antifungal compounds might help reduce weed growth or soil pathogens when Jeevamrit is applied. The presence of stimulants like stigmasterol suggests it might directly enhance plant growth or stress resilience. Additionally, defensive chemicals like turmerone and α -selinene could induce resistance in crops against pests and diseases.

Nutrient composition of liquid and solid Jeevamrit, beejamrit prepared using various combinations of ingredients is given in Table 8. Significant variation in the range of nitrogen, phosphorus and potassium was observed, which is mainly on account of source of ingredients such as undisturbed soils, dung and urine from various breeds of animals.

Table 8. Nutrient composition range observed in different concoctions (Source: AINP-OF centre, Coimbatore)

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

The Fig 3 shows a heatmap comparing the microbial community composition between Ghanajeevamrit and Jeevamrit formulations. The x-axis represents the two formulations, and the y-axis lists bacterial taxa classified at different taxonomic levels (Kingdom → Phylum → Class → Order → Family → Genus). The color scale on the right indicates relative abundance:

- Yellow/green: Higher abundance (positive values, closer to 1)
- Blue/purple: Lower abundance (negative values, closer to -1)
- Teal: Intermediate abundance (around 0)

Key observations:

- Ghanajeevamrit generally supports a richer and more balanced microbial population compared to Jeevamrit, with more taxa in the green to yellow range.
- Lactobacillaceae members like *Secundilactobacillus* and *Lactiplantibacillus* are abundant in both, but Ghanajeevamrit shows slightly higher levels.
- *Acinetobacter* (Proteobacteria) and *Tumeabacter* (Firmicutes) have a noticeable presence in Ghanajeevamrit, but are reduced in Jeevamrit.

- Many beneficial genera like *Clostridium*, *Shewanella*, and *Weissella* are less abundant or nearly absent in Jeevamrit (purple zone).
- Soil-health-promoting microbes such as *Ruoffia* and *Cellulosimicrobium* are more abundant in Ghanajeevamrit, indicating potential for better organic matter breakdown.
- Jeevamrit shows loss of diversity, with several taxa showing low abundance (purple), suggesting reduced microbial functional range.
- Certain genera (*Empedobacter*, *Flavobacterium*) appear in both treatments but at higher abundance in Ghanajeevamrit.
- Pathogen-suppressing microbes (*Akkermansia*, *Mailhella*) are higher in Ghanajeevamrit, possibly contributing to improved plant health.
- The clear color gradient difference suggests Ghanajeevamrit may provide a more favorable substrate or micro-environment for microbial proliferation.
- This richer microbial spectrum in Ghanajeevamrit could enhance nutrient cycling, disease suppression, and soil fertility better than Jeevamrit.
- Jeevamrit's lower microbial diversity may limit its potential impact on soil biodiversity restoration.
- The heatmap supports the hypothesis that solid-state fermentations (Ghanajeevamrit) tend to preserve and enrich a more diverse microbial community compared to liquid forms.



Fig 3. Heat map comparing the microbial community composition between Ghanajeevamrit and Jeevamrit

Key findings

- The characterization of Jeevamrit reinforces why it is often called the “life tonic” for soil. Biochemically, it is dilute but bioactive; microbiologically, it is extremely rich. The key findings can be summed up as: Jeevamrit provides a massive dose of beneficial microbes (peaking $\sim 10^7$ – 10^8 CFU/mL of N-fixers, P & K solubilizers) to the soil, with minimal direct nutrients. The optimal fermentation time (~ 48 hours) aligns with maximum microbial activity. After that, it should be applied to avoid declines in populations.
- From an agronomic perspective, Jeevamrit’s benefits are multi-fold: It inoculates the soil with a consortium of microbes that continue to fix atmospheric nitrogen, solubilize locked phosphates, and decompose organic matter *in situ*. This gradually increases the soil’s natural fertility without external fertilizers. Over seasons, soils treated with Jeevamrit have been recorded to improve in organic carbon content and enzyme activities (like dehydrogenase, phosphatase), indicating a healthier soil biology.
- Additionally, the small amounts of plant growth substances and antimicrobial compounds present in Jeevamrit can help in suppressing soil-borne diseases and mildly stimulating plant growth. For example, farmers often observe reduced incidences of wilt or root rot in fields regularly receiving Jeevamrit, likely due to competition and antagonism by the introduced microbes and the biochemical environment they create. The presence of compounds like turmerone and selinene might induce systemic resistance in crops, making them less susceptible to pests.
- Jeevamrit is also extremely cheap and farmer-friendly to produce, using on-farm waste (dung, urine) – its characterization shows that even with such humble ingredients, the fermentation process creates a potent input. By relying on Jeevamrit, farmers can cut down on chemical fertilizer use significantly; indeed, studies under natural farming note yield improvements with Jeevamrit application comparable to conventional fertilizer, due to the enhanced nutrient cycling. In conclusion, Jeevamrit serves as a biological engine in natural farming, converting organic matter into bio-available nutrients via microbial action and improving soil health with each application. It exemplifies harnessing naturally occurring processes (fermentation and microbial symbiosis) to sustain crop productivity.

3.4 Neemastra

Neemastra is a fermented botanical extract used as a natural pesticide in natural farming. It is traditionally prepared by boiling or fermenting neem leaves (*Azadirachta indica*) with cow dung, cow urine, and sometimes other ingredients, for around 2 days. The resulting concoction is a crude extract rich in neem’s biopesticidal compounds and beneficial microbes from the fermentation. Neemastra is typically applied as a foliar spray to repel or kill insect pests and to inhibit fungal pathogens on crops. Neemastra’s chemical composition (especially key pesticidal compounds) and its microbial profile, as

characterized, including differences when using native breed cows (*Kangeyam* in this case) versus crossbred HF cows for its preparation are outlined here.

Neemastra is inherently rich in organic compounds derived from neem, as well as some organic matter from dung and urine. Its organic carbon content is higher than the purely dung-based brews like Jeevamrit. In tests, after ~48 hours of fermentation, Neemastra prepared with mixed-breed cow inputs (50% native, 50% HF) showed the highest organic C (~2.87%), whereas Neemastra from only native *Kangeyam* cows had the lowest (~0.59%). The crossbred HF-only Neemastra was intermediate (~1.77% C). This suggests that using both types of cow excreta together might extract more organic matter into the solution, possibly due to differing urine chemistry. Regardless, even 0.6–2.9% C is significant for a liquid extract, indicating a substantial amount of neem leaf soluble and dung organics are present. For comparison, Brahmastra (another herbal extract, discussed next) had slightly lower maximum C (~0.5%).

Neemastra contains some plant nutrients, though it's mainly used for pest management. Among treatments, the highest total N recorded was 0.025% in Neemastra made with HF cow inputs, while the native breed version had the lowest N (~0.016%). The mixed breed version had around 0.022% N. These values are low but reflect some nitrogen from the neem leaves and dung. Phosphorus and potassium were present in slightly higher quantities than in Jeevamrit because of the plant material: P peaked at 0.31% in the mixed-breed Neemastra, compared to ~0.20% in the native breed and ~0.25% in the HF breed batches. Potassium content was the highest (~0.13%) in the HF-cow Neemastra, with native at ~0.07% and mixed around 0.09%. This may be because neem leaves themselves contain some K, and HF urine can contribute more K salts.

A very important aspect of Neemastra's biochemical profile is its content of secondary metabolites: phenolics, flavonoids, tannins, alkaloids, *etc.*, which are responsible for its pesticidal action. A biochemical analysis at one research center (Narendrapur) compared Neemastra made with native breed vs crossbred cow inputs.

It was found that crossbreed-based Neemastra had notably higher total phenolics (~1810 ppm vs 1196 ppm in native breed) and higher total alkaloids (~4.16 ppm vs 2.39 ppm). Tannin content was very high in both, given neem's rich tannin content: ~15,659 ppm in native vs 16,086 ppm in crossbreed, a slight edge to HF version. Total gibberellins (perhaps produced by microbes in the brew) were also measured – interestingly, the crossbreed Neemastra had a bit more (9353 ppm vs 8393 ppm). In summary, Neemastra's composition is characterized by high levels of bioactive neem compounds (phenolics, tannins, flavonoids) and a modest nutrient content. The use of different cow breeds can influence how much of certain compounds are extracted or preserved: for instance, HF urine might be more effective at leaching phenolic compounds out of neem leaves (hence higher phenolics in that variant), whereas native breed inputs might favor flavonoid extraction. Nonetheless, both variants are loaded with tens of thousands of ppm of total tannins and over a thousand ppm of phenolics, underscoring Neemastra's potency as a botanical pesticide (Table 9).

Table 9. Composition of Neemastra

Parameters	Unit	Neemastra			
		Prepared from native breeds dairy excreta	Standard error	Prepared from cross breeds dairy excreta	Standard error
Organic C	%	0.92	±0.03	0.55	±0.03
Total Phenolics	ppm	1196	±77	1810	±17
Total Flavonoids	ppm	508	±13	163	±27
Total Tannins	ppm	15659	±354	16086	±365
Total Alkaloids	ppm	2.39	±0.39	4.16	±0.13
Total Gibberellins	ppm	8393	±144	9353	±387

Neemastra is fermented with cow dung and urine, so it does harbor a microbial population, though its primary mode of action is chemical. After ~48 hours fermentation (the typical preparation window), the microbial population in Neemastra made from native breed cows was higher than that in crossbreed-based Neemastra. Specifically, the total bacterial count was maximum in the native-breed Neemastra among the three types (native, HF, mix). While exact CFUs are not given in the text, this implies that indigenous cow dung/urine provided a more favorable microflora or nutrients for bacterial growth. The mixed breed version likely followed, with the crossbred HF version having comparatively fewer bacteria.

In contrast, fungal and actinomycete populations were noted to be higher in the native-breed Neemastra but essentially absent (“nil”) in the Brahmastra (the other herbal concoction). This suggests that Neemastra’s environment, though rich in antimicrobial neem compounds, can still support a small community of fungi and actinomycetes (possibly dung-origin or neem phyllosphere microbes) especially in the native cow preparation. The HF-based preparation might have lower fungi/actinomycetes, possibly the stronger extraction of neem phenolics in HF Neemastra inhibited these groups more.

The fermentation process of Neemastra likely cultivates hardy, tolerant microbes, including some lactic acid bacteria or others that can survive neem’s antimicrobial components. We can infer that clostridium *Bacillus* species (which are spore-formers and can resist some stress) may be present, as they are common in cow dung. Indeed, an analysis mentions that using Kangeyam (native) cow dung/urine yielded generally higher microbial counts (bacteria, fungi, actinomycetes, N-fixers, etc.) across natural farming inputs compared to HF. So it stands that Neemastra (native) contained more of these beneficial microbes than Neemastra (HF). However, the dominant protective effect of Neemastra comes from its chemical constituents rather than live microbes, given neem’s strong biopesticidal properties. Therefore, unlike Jeevamrit which is primarily microbial, Neemastra is primarily an organic biopesticide solution with a secondary contribution from any microbes present.

Bioactive compounds and pest control efficacy: Neemastra's strength lies in the cocktail of bioactive compounds extracted from neem leaves and enhanced by fermentation. GC–MS analysis of Neemastra prepared with different cow inputs uncovered a wide array of pesticidal molecules. Characterization of Neemastra given below summarizes key compounds identified in Neemastra made from native breed, crossbreed, and mixed inputs, along with their known biological activities (Fig 4).

Characterization of Neemastra from various sources of cow dung and cow urine

Neemastra 1 (Native breed - Kangeyam)

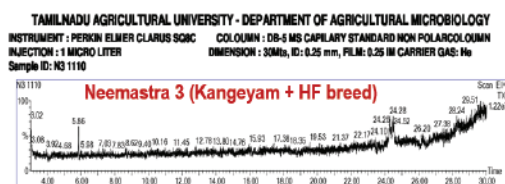
Compound Name	Activity/ Role
9-Hexadecenoic acid, eicosyl ester, (Z)- 5	Anti-fungal property
1 9-Hexadecenoic acid, hexadecyl ester, (Z)-	Anti-microbial property
Ipconazole	Antifungal property
Octadecane, 3-ethyl-5-(2-ethylbutyl)-	Insecticidal property
2-Acetyl-9-[3-deoxy- α -D-ribofuranosyl]hypoxanthine	Insecticidal property
Octadecane, 3-ethyl-5-(2-ethylbutyl)-	Insecticidal property

Neemastra 2 (Cross breed - HF)

Compound Name	Activity/ Role
trans-(2-Decenyl) succinic anhydride	Bio-pesticidal property
Ethyl iso-allocholate	Insecticidal property
Oleic Acid	Induces constitutive defense signaling
Octadecanoic acid, (2-phenyl-1,3-dioxolan-4-yl)methyl ester, cis-	Induces systemic resistance to biotic stresses
Undecane	Bio-pesticidal property
α -d-Xylopyranoside, methyl-2,3,4-tris-O-[9-borabicyclo[3.3.1]non-9-yl]-	Antimicrobial defense and signals for induced resistance

Neemastra 3 (Kangeyam + HF breed)

Compound Name	Activity/ Role
2,15-Heptadecadiene, 9-(ethoxymethyl)-	Biopesticidal property
16-Hydroxyhexadecanoic acid	Biopesticidal property
Citronellal	Repellant and antifungal agent
1-Heptatriacotanol	Plant growth promoter
Oxacyclotetradecan-2-one, 13-methyl-	Biopesticidal property
Diclofop-methyl	Herbicidal property
Dodecane, 5,8-diethyl-	Insecticidal property

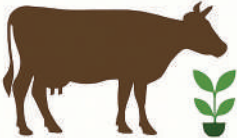


acid (2-phenyl-1,3-dioxolan-4-yl)methyl ester, *cis*, which helps induce systemic resistance to biotic stresses in plants; Undecane, a volatile hydrocarbon that acts as a biopesticide and insect repellent; and a complex boron-containing sugar derivative (methyl-2,3,4-tris-O-[9-borabicyclo[3.3.1]non-9-yl]- α -D-xylopyranoside) noted to aid in antimicrobial defense signaling. The presence of oleic acid is particularly interesting as it suggests Neemastra could prime plant defenses, not just act directly on pests.

In the mixed preparation of Neemastra (Neemastra 3), identified compounds included: 2,15-Heptadecadiene, 9-(ethoxymethyl) and 16-Hydroxyhexadecanoic acid, both with biopesticidal properties; Citronellal, a well-known terpene aldehyde that is a strong repellent and antifungal agent (responsible for citronella oil's effect); 1-Heptatriacotanol, a very long-chain alcohol (C₃₇H₇₅OH) recognized as a plant growth promoter (long-chain alcohols can improve crop growth, possibly by acting as surfactants or minor hormones); Oxacyclotetradecan-2-one, 13-methyl-, which is listed as a biopesticidal compound; Diclofop-methyl, notably a known synthetic herbicide (perhaps detected as a trace impurity or an unexpected metabolite) that would have herbicidal property; and Dodecane, 5,8-diethyl-, an alkane with insecticidal activity. The detection of diclofop-methyl is intriguing; it could be a coincidental pickup or a minor contaminant, but if truly present, it adds herbicidal weed-suppressing potential to Neemastra's arsenal.

The sheer variety of compounds, from simple hydrocarbons to complex organics, shows that Neemastra is a broad-spectrum bio-pesticide. Neem is known to contain azadirachtin (a potent insect growth regulator), though it wasn't specifically listed in the above tables – possibly due to its polarity or it being present in fractions not detected by that GC–MS method. Nonetheless, many other neem-related compounds are performing similar roles: feeding deterrents, growth inhibitors, anti-microbial agents, etc.

Characterization of Neemastra

		
Neemastra 1 (Kangayam)	Cross-bred H (HF)	Neemastra 3 (Kangayam + HF)
9-Hexadecenoic acid (eicosyl, hexadecyl ester and Iponazole Octadecane derivatives 2-Acetonyl-9 (3-deoxy- α - D-riboouranosyl)hypoxanthine	trans-(2-Decenyl) succinic anhydride Undecane Oleic acid Ovtadecancic acid esters Systemic resistance	2,15-Heptadecadiene 16-Hydroxyhexadecanoic acid Bio-pesticidal Citronellal, Antifungal 1-Heptatriacotanol Plant growth

Characterization of Neemastra formulations highlight diverse range of bioactive compounds with multifunctional agricultural benefits, including pest immunity, and resilience, plant immunity, and vigor enhancement.

Key findings

- The characterization of Neemastra confirms its reputation as a powerful natural pesticide. Chemically, it is loaded with insecticidal, fungicidal, and biostimulant compounds, many of which directly affect pests or bolster plant defenses. The presence of compounds like citronellal, oleic acid, and succinic anhydrides means Neemastra can repel insects and help plants activate their innate immunity. The fermentation does not destroy neem's active principles; rather, it may enhance extraction of certain compounds (the differences between breed preparations highlight this, with HF urine extracting more phenolics but perhaps at the cost of some flavonoids).
- Microbially, Neemastra does contribute some beneficial organisms to the crop environment, but given the antimicrobial nature of neem, this contribution is smaller compared to Jeevamrit. The native-breed preparation, having more microbes, might marginally help in leaf phyllosphere colonization or soil microbial addition when sprayed/dribbled. However, the primary agronomic significance of Neemastra is pest management. Farmers use Neemastra as a foliar spray against a range of pests (aphids, caterpillars, fungal leaf spots, etc.), and the data support this use: it contains multiple agents that can inhibit or kill these pests. For example, compounds like azadirachtin (not listed but known from neem) disrupt insect molting, while others like 2,4-dodecadialenal are alarm pheromones or antifeedants to pests. Ipconazole and similar compounds would target fungal pathogens on leaves.
- Breed influence in practice: The findings suggest that using dung/urine from native cows (Kangeyam) to make Neemastra might yield a formulation with a higher microbial component and perhaps slightly different balance of neem chemicals (more flavonoids, which can be antioxidants and antifungal). Using HF cow inputs yields a Neemastra with possibly stronger immediate chemical activity (higher phenolics and alkaloids) but fewer live microbes. In practice, both would work, but farmers might prefer native cow Neemastra for a more “living” solution or HF Neemastra for a more purely chemical extract. Either way, both far outperform synthetic pesticides in terms of environmental safety and cost.
- In conclusion, Neemastra is a potent bio-pesticide and plant health tonic in natural farming. It allows farmers to exploit the natural pesticidal properties of neem – often dubbed “the village pharmacy” in a convenient liquid form. By controlling pests and diseases with Neemastra, farmers can significantly reduce or eliminate chemical pesticide use. Moreover, any residual effect of Neemastra in the soil (via its organic carbon and microbes) is positive, as it can modestly contribute to soil organic matter and microbial diversity. Thus, Neemastra exemplifies the natural farming principle of “integrated nutrient and pest management”: it recycles farm wastes (dung, urine), extracts botanical pesticides (neem compounds), and simultaneously introduces beneficial microbes, all in one preparation, supporting a holistic approach to crop health.

3.5 Brahmastra

Brahmastra (also spelled Bramhastra) is another fermented botanical concoction used in natural farming, renowned for being a broad-spectrum bio-pesticide like Neemastra but often made with a different mix of plants. Brahmastra typically includes extracts of multiple leaves such as neem, custard apple (*Annona*), papaya, pomegranate, guava, or even Dhatura (jimson weed), combined with cow urine boiled and fermented for a couple of days. The exact recipe can vary, but the idea is to create a more potent blend (the name “Brahmastra” in Hindu mythology refers to a powerful weapon). It is applied to control a wide range of pests (insects, mites) and diseases. We summarize its biochemical composition and microbial profile, and how they are affected by cow breed.

Biochemical Composition: A comprehensive biochemical analysis at Narendrapur examined Brahmastra made with native breed vs crossbreed cow excreta. The results mirror same trends seen in Neemastra, with differences in secondary metabolite content. Organic carbon was higher in the native breed Brahmastra (0.67%) compared to crossbreed (0.48%), indicating more organic matter was present when using indigenous cow inputs. However, the total phenolic content was more than double in the crossbreed-based Brahmastra: 2,781 ppm versus 1,351 ppm in the native breed version. Similarly, total flavonoids were significantly higher in the crossbreed Brahmastra (175 ppm vs 73 ppm). This suggests HF cow urine might extract or preserve more of certain leaf compounds (phenolics/flavonoids), perhaps due to higher urine pH or urea content aiding extraction. On the other hand, the native breed Brahmastra had higher tannins and alkaloids. Total tannins in native Brahmastra reached ~32,348 ppm, compared to 26,466 ppm in the crossbreed. Total alkaloids were about 253 ppm in native vs 128 ppm in crossbreed. This is a notable difference, as alkaloids often come from plants like Dhatura or other leaves that might be in Brahmastra; the native preparation retained roughly double the alkaloid content. Total gibberellins (plant growth hormones potentially produced by microbes) were fairly high in both – ~8,066 ppm in native and slightly higher, 8,720 ppm, in crossbreed. These numbers indicate Brahmastra brews harbor not just pesticidal compounds but also plant growth promoters (gibberellins) in significant amounts, likely a byproduct of microbial activity during fermentation (Table 10).

Table 10. Composition of Brahmastra

Parameters	Unit	Brahmastra			
		Prepared from native breeds dairy excreta	Standard error	Prepared from cross breeds dairy excreta	Standard error
Organic C	%	0.67	± 0.07	0.48	± 0.04
Total Phenolics	ppm	1351	± 33	2781	± 9
Total Flavonoids	ppm	73.3	± 10.4	175	± 2
Total Tannins	ppm	32348	± 733	26466	± 622
Total Alkaloids	ppm	253	± 7	128	± 10

Parameters	Unit	Brahmastra			
		Prepared from native breeds dairy excreta	Standard error	Prepared from cross breeds dairy excreta	Standard error
Total Gibberellins	ppm	8066	± 276	8720	± 394

Overall, Brahmastra is chemically complex. It contains all classes of secondary metabolites: thousands of ppm of tannins (astringent, anti-feedant), substantial phenolics and flavonoids (antioxidant, antimicrobial), notable alkaloids (often potent bioactives affecting insect nervous systems), and even phytohormones (gibberellins). The balance of these compounds can shift depending on the cow inputs, but regardless Brahmastra is a potent extract. Its NPK nutrient content is low, similar to Neemastra (in the same analysis, the mix breed Brahmastra had the highest organic C content ~0.52%, N content ~0.093%, P content ~0.34%, and K content ~0.87%, as per earlier bullet points). The exceptionally high K (0.87% K in native breed Brahmastra) might reflect contributions from certain plant ashes or cow urine rich in potassium. It's higher than Neemastra's K, possibly because Brahmastra recipes can include banana or other K-rich leaves in some versions.

Microbial Profile: Brahmastra's fermentation conditions (due to very potent antimicrobial plant ingredients like Dhatura, neem, etc.) are quite harsh for many microbes. The characterization noted that after 48 hours, Brahmastra prepared from native breed cows had the highest bacterial population, similar to Neemastra, compared to crossbreed and mixed. The native Brahmastra likely still has plenty of dung-associated bacteria that can tolerate the brew. However, the fungi and actinomycetes were essentially absent ("nil") in Brahmastra, even in the native version. This contrasts with Neemastra, where some fungi/actino hung on in the native batch. Boiling of leaves in cow urine during the preparation might also be the reason for the absence of fungi and actinomycetes.

Thus, Brahmastra is less about adding microbes (indeed one might be applying mostly sterile filtrate if fungi/actino are nil and only some bacteria present). Its microbial count is dominated by bacteria, which while present, may also not be as high as in nutrient-rich ferments. Still, any *Bacillus* or other spore-formers in dung could remain. The native breed Brahmastra having more bacteria could be due to indigenous dung containing strains that are more resistant to plant toxins or due to lower extraction of certain inhibitory compounds (since crossbreed had higher phenolics/flavonoids which might inhibit bacteria).

Bioactive Compounds Identified: GC-MS analysis of Brahmastra (at TNAU, Coimbatore) revealed an extensive list of bioactive molecules. Fig below summarizes compounds found in Brahmastra 1 (native Kangeyam), Brahmastra 2 (HF), and Brahmastra 3 (mix) and their roles (Fig 5).

Characterization of brahmastra from various sources of cow urine

Brahmastra 1 (Native bred - Kangeyam)

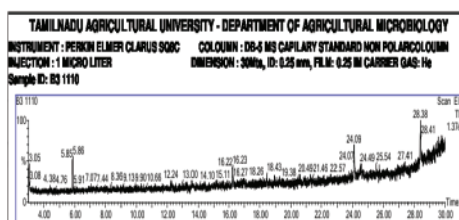
Compound name	Activity/Role
Acetamide, N-(2-phenylethyl)-	Biopesticidal property
Scopolamine	Cholinergic Antagonist
12-Hydroxyoctadecanethioic acid, S-t-butyl ester	Biopesticidal and growth promotion
E-9-Tetradecenoic acid	Biopesticidal property
7-Pentatriacontene	It has antiviral property
2-Myristinoyl pantetheine	It contain antifungal property

Brahmastra 2 (HF Breed)

Compound name	Activity/ Role
E-9-Tetradecenoic acid	Biopesticidal property
9,12,15-Octadecatrienoic acid, ethyl ester, (Z,Z,Z)	Plant metabolite
Pentane, 2,2-dimethyl-	Antiviral property
Undecane	Biopesticidal property
6-Octadecenoic acid	Biopesticidal property

Brahmastra 3 (Kangeyam + HF Breed)

Compound name	Activity/Role
2,4-Dodecadienal	Biopesticidal property
4-Dodecanol, acetate	Biopesticidal property
Resodiacetophenone	Plant metabolite.
Trans-Carveol	Plant metabolite and antiviral property
trans-2-Decenoic acid	Antibacterial property
Tetradecane, 2,6,10-trimethyl-	Biopesticidal property
Phytol	Plant metabolite
Octadecane, 3-ethyl-5-(2-ethylbutyl)-	Antibacterial property



Characterization of Brahmastra

Brahmastra 1 (Native bred - Kangeyam)



- Acetamide, N-(2-phenylethyl)
- Scopolamine
- 12-Hydroxyoctadecanethioic acid, S-1-butyl ester
- E-9-Tetradecenoic acid
- 7-Pentatriacontene
- 2-Myristinoyl pantetheine
- Antifungal

Brahmastra 2 (HF Breed)



- E-9-Tetradecanoic acid (Biopesticidal)
- 9,12,15-Octadecatrienoic acid, ethyl ester, (Z,Z,Z)
- Pentane, 2,2-dimethyl- (Antiviral)
- Undecane
- 6-Octadecenoic acid

Brahmastra 3 (Kangeyam + HF Breed)



- 2,4-Dodecadienal
- 4-Dodecanol, acetate
- Resodiacetophenone
- Plant metabolite
- Trans-Carveol and antiviral
- Trans-2-Decenoic acid
- Antibacterial
- Tetradecane, 2,6,10-trimethyl-
- Biopesticidal
- Plant metabolite

Fig 5. Characterization of Brahmastra from various sources of cow dung and cow urine. The tables list major compounds identified in Brahmastra prepared with (1) Native breed (Kangeyam) cow, (2) Crossbred HF cow, and (3) Mixed breed inputs. Activities are noted: "Biopesticidal property" indicates toxicity to pests, and specific roles like antiviral, antibacterial, etc., are listed.

From the native breed Brahmastra (Brahmastra 1), key compounds include: Acetamide, N-(2-phenylethyl) – an aromatic amide with noted biopesticidal property; Scopolamine – a tropane alkaloid

(commonly from *Datura* species) which is a known cholinergic antagonist (affecting insect nervous systems); 12-Hydroxyoctadecanethioic acid, S-t-butyl ester – a sulfur-containing fatty acid ester with combined biopesticidal and plant growth-promoting activity; E-9-Tetradecenoic acid – a trans-unsaturated fatty acid (myristoleic acid) that acts as a biopesticide; 7-Pentatriacontene – a very long-chain hydrocarbon (C₃₅H₇₂) identified to have antiviral properties; and 2-Myristynoyl pantetheine – an analog of a coenzyme A component, which in this context is noted to have antifungal properties. This mixture of alkaloids, fatty acids, and unusual metabolites clearly gives Brahmastra a diverse mode of action: scopolamine targets insect neurotransmitters, fatty acids may disrupt membranes, and pantetheine analogs could interfere with microbial metabolism.

For the HF breed Brahmastra (Brahmastra 2), compounds found included: E-9-Tetradecenoic acid again (biopesticidal); 9,12,15-Octadecatrienoic acid, ethyl ester (Z,Z,Z) – essentially ethyl linolenate, a plant metabolite that could have signaling roles; Pentane, 2,2-dimethyl- – a small hydrocarbon with noted antiviral property (perhaps in the sense of being an indicator of volatile production); Undecane – also found in Neemastra, an alkane that serves as a general biopesticide; and 6-Octadecenoic acid – an unsaturated fatty acid (likely petroselinic or similar) with biopesticidal effect. This HF profile suggests more saturated/unsaturated medium-chain compounds dominate, perhaps because fewer complex alkaloids were extracted compared to the native version.

The mixed breed Brahmastra (Brahmastra 3) included compounds such as: 2,4-Dodecadienal – a volatile aldehyde with strong biopesticidal property (and known as an alarm pheromone in some insects); 4-Dodecanol, acetate (likely 4-dodecenyl acetate or a similar pheromone component, labeled as biopesticidal); Resorcinol diacetophenone (difficult to parse name, possibly diacetylresorcinol) listed as a plant metabolite; Trans-carveol, a monoterpene alcohol (from mint family possibly) known as a plant metabolite with antimicrobial properties, here noted to have both plant metabolite and antiviral properties; trans-2-Decenoic acid – an unsaturated acid with antibacterial property; Tetradecane, 2,6,10-trimethyl, a branched alkane, again biopesticidal; Phytol, an acyclic diterpene alcohol (from chlorophyll degradation) recognized as a plant metabolite, could attract beneficials or mildly affect pests; and Octadecane, 3-ethyl-5-(2-ethylbutyl) the same insecticidal hydrocarbon found in Neemastra, here noted with antibacterial property too.

This rich tapestry of compounds explains why Brahmastra is often considered a universal pest repellent in natural farming. It contains insect repellents, feeding deterrents, compounds toxic to fungi and bacteria, and even some that might deter viruses (perhaps by inducing plant defenses). The presence of scopolamine is particularly noteworthy it likely comes from *Datura* (if used in the recipe) and is highly toxic to insects and vertebrates by blocking neural acetylcholine receptors. Its inclusion in Brahmastra would make the brew effective against chewing insects. The long-chain hydrocarbons and aldehydes can repel pests or disrupt their pheromone communication. Sulfur-containing fatty acids and pantetheine analogs could act as broad biopesticides.

Key findings

- Brahmastra's characterization highlights it as a broad-spectrum bio-pesticide with a very diverse chemical makeup. It is in many ways similar to Neemastra in function but potentially stronger or more wide-ranging due to the inclusion of multiple plant sources. Key findings are that Brahmastra contains significant amounts of alkaloids (like scopolamine) and other potent compounds that were not as pronounced in Neemastra. This suggests Brahmastra can target pests that might not be fully controlled by neem alone. For instance, scopolamine can affect larger pests (rodents or birds) if they consume treated plants, providing some repellent effect, and also can deter nematodes or soil insects.
- The breed of cow used has a subtle effect: using native cow inputs yields a Brahmastra with more organic matter and a higher load of some complex compounds (alkaloids, tannins) whereas HF inputs give higher phenolics/flavonoids. From an application standpoint, either version is effective, but one might prefer the native-based Brahmastra for soil applications (due to more organic carbon and possibly better shelf-life of microbes) and the HF-based for foliar spray (due to higher immediate concentration of phenolic toxins). The presence of gibberellins in both versions indicates that Brahmastra, while controlling pests, might also incidentally promote plant growth or recovery. It's not uncommon for farmers to note that plants sprayed with Brahmastra show fresh green growth – possibly due to these hormone-like substances in the brew.
- Agronomically, Brahmastra allows natural farmers to manage a wide array of crop threats without synthetic chemicals. It is essentially a natural “cocktail pesticide.” The GC–MS results validate traditional knowledge: ingredients like neem, Dhatura, and others were chosen for Brahmastra because they each bring different active principles, and indeed the final product contains an assortment of those. By using Brahmastra, farmers can target chewing and sucking insect pests (via repellents and toxins), fungal diseases (via antifungal compounds like 2-myristoyl pantetheine, etc.), and perhaps even viral diseases by improving plant vigor and inducing resistance (as suggested by oleic acid and other signals present).
- One consideration is that Brahmastra's microbial contribution is minimal (virtually no fungi or actinomycetes survive). This means its value is primarily chemical. When applied to crops, it doesn't inoculate the ecosystem with many beneficial microbes (unlike Jeevamrit). However, it also likely doesn't harm the existing beneficial microbes in soil much when it lands on the ground, because the compounds, while biopesticides, will be diluted and degraded over time.
- In practical use, Brahmastra is often used in rotation or combination with Neemastra to prevent pest resistance and to cover more pest species. The data here support that strategy: Neemastra and Brahmastra have overlapping but also complementary compounds (e.g. Brahmastra has scopolamine; Neemastra has azadirachtin and citronellal). Together, they broaden the spectrum. Moreover, Brahmastra's slight content of gibberellins suggests it might help in plant stress

recovery post-infestation, giving it an edge over purely toxic chemical pesticides which often stress the plant.

- In summary, Brahmastra serves as a potent natural pesticide mixture that farmers can tailor (by plant ingredients and even cow input type) to local pest challenges. Its rich chemical profile is borne out by scientific analysis, confirming why it works against pests. By enabling pest control without synthetic chemicals, it plays a crucial role in the success of natural farming systems, ensuring that crop yields are protected while maintaining an organic, poison-free environment.

Conclusion

The detailed profiling of Beejamrit, Ghanajeevamrit, Jeevamrit, Neemastra, and Brahmastra illustrates the scientific basis behind their effectiveness in natural farming. **Beejamrit** was shown to be a microbe-rich seed treatment, characterized by rapid organic matter decomposition and a surge of beneficial bacteria and enzymes that protect germinating seeds. **Jeevamrit** (liquid) and its solid counterpart **Ghanajeevamrit** emerged as powerful biofertilizers – low in direct NPK, but extremely high in microbial content (N-fixers, P-solubilizers, etc.) and enzymatic activity, capable of rejuvenating soil life and fertility. Both showed that after about 48 hours of incubation, microbial populations (especially bacteria) peak, aligning with traditional recommendations to use these brews fresh for maximum effect. The identification of numerous bioactive compounds (like organic acids, vitamins, antioxidants) in Jeevamrit/Ghanajeevamrit explains subtle growth benefits beyond nutrition, such as induced systemic resistance or improved nutrient uptake in crops.

For the plant-based pesticides, **Neemastra** and **Brahmastra**, the analyses confirmed that they contain a broad spectrum of biopesticides compounds extracted from plant materials. Neemastra, primarily neem-based, is rich in terpenoids (citronellal), phenolics, and fatty acid esters that act as insecticides, fungicides, and plant defense inducers. Brahmastra, incorporating multiple botanicals, showed an even more diverse chemical arsenal – from neuroactive alkaloids (scopolamine) to long-chain hydrocarbons and aromatic compounds that repel or kill pests. The presence of plant hormones like gibberellin in these concoctions suggests an added benefit: treated plants might not only be protected but also experience a growth stimulus or stress alleviation. Microbially, while Neemastra and Brahmastra do carry some hardy bacteria, their pest control function is overwhelmingly due to their chemical composition; interestingly, native cow inputs tended to support a bit more of a microbial presence (and slightly different chemical profiles), whereas crossbred inputs yielded higher concentrations of certain pesticidal compounds.

Bio-input centres are proposed to be established under National Mission on Natural Farming. Standard protocols for preparation of inputs and composition based on characterization work is given below.

1. **Beejamrit** (Beejamrutha or Bheejamrutham) is a microbial paste made using 5 kg of fresh dung from desi cows, 5 liters of *desi* cow urine, 50-100 g of virgin soil (preferably from forests, banyan trees, or termite mounds), 50 g of calcium chloride, and 20 liters of water. The mixture

is thoroughly stirred and fermented for 24 hours. It is used for seed dressing or dipping seedling roots. Seed dressing involves coating seeds with Beejamrit before sowing and drying them in the shade. Beejamrit has been shown to protect seeds and young seedling roots from soil-borne and seed-borne pathogens, reduce germination time, and enhance seedling vigor, leading to better growth. The application of beneficial microbes to seeds effectively places microbial inocula in the soil, positioning them to colonize seedling roots and protect them against soil-borne diseases and pests. Microbes improve seed germination, shoot and root length, seedling vigor, and crop performance. Beejamrit promotes root dry weight and root proliferation, enhancing nitrogen, nutrient, and water uptake by crop plants. Nutrient content range (Ravisankar *et al.*, 2024) and Microbial population (AINP centre, Udaipur;2021-22) observed is given in Table 11.

Table 11. Different nutrient and microorganism compositions in Beejamrit

Parameter	Unit	Value
N	%	0.72-2.38
P	%	0.12-0.14
K	%	0.23-0.49
Bacteria count	CFU/ml ($\times 10^8$)	5.37-6.10
Fungal count	CFU/ml ($\times 10^4$)	3.42 -4.05
Actinomycetes count	CFU/ml ($\times 10^5$)	2.90 -3.85

Ghanajeevamrit: Ghanajeevamrit is solid in form and is prepared using ingredients such as desi cow dung (150 kg), jaggery (1 kg), pulse flour (2 kg), virgin fertile soil for microbial culture (50-100g), native/desi cow's urine as required.

Method 1: Mix well cow dung, jaggery, pulse flour and soil. Add a little bit of cow urine to it as needed. Dry the mixture in shade for 2-4 days. Use in the field after drying and grinding well into small aggregates. It can be stored and used for 6 months.

Method 2: Take 1-1.5 quintal well rotten desi cow dung manure and sprinkle 8-10 liters of Jeevamrit on it. Mix well and use by broadcasting uniformly in the field. After preparing, keep it covered in the shade. It can be used for 6 months.

Method 3: Take 1.5 quintals of dry biogas slurry, a kilogram of jaggery, 2 kilograms of pulse flour and a handful of virgin soil. Mix these well and broadcast uniformly in the field. Ghanajeevamrit can also be prepared by sprinkling Jeevamrit solution on this slurry as per requirement. If Ghanajeevamrit is prepared by adding Jeevamrit solution, then there is no need to add jaggery, pulse flour and soil separately.

Method 4 (Best quality method): Make a pile of fresh cow dung partially dried up to 3-4 days up to a height of 1.5 feet. Size of the pile might be as per convenience (say 12x3 feet). Make holes with a

wooden log at a distance of about 1 feet and fill up these holes with already prepared Jeevamrit. Turn the dung pile up and down after one week. Then again make the holes and fill up these holes with Jeevamrit and turn up the pile again after one week. This way this process is repeated 2-3 times. The Ghanjeevamrit will be ready in 30-35 days. Then, after pounding it into small sized particles, it can be broadcast uniformly in the field or stored in shade after covering with gunny bags.

Generally, it is recommended to use 800 to 1000 kg per acre of land as basal dose. However, this can be applied as top dressing also as per crop duration. Nutrient content range (Ravisankar et al., 2024) and Microbial population (AINP centre, Udaipur;2021-22) observed are given in Table 12.

Table 12. Different nutrient and microorganism compositions in Ghanjeevamrit

Parameter	Unit	Value
N	%	1.05-1.80
P	%	0.16-0.30
K	%	0.68-0.85
Bacteria count	CFU/ml ($\times 10^8$)	29.65-30.52
Fungal count	CFU/ml ($\times 10^4$)	5.98-6.88
Actinomycetes count	CFU/ml ($\times 10^5$)	4.01-4.86

- Jeevamrit** (Jivamrita or Jeevamrita or Jeevamrutha or Jeevamrutham) is a fermented microbial culture made from on-farm ingredients: 10 kg of fresh dung from *desi* cows, 10 liters of aged *desi* cow urine, 1.5 kg of cane jaggery (sugar) or sweet fruit pulp, and 1.5 kg of pulse flour mixed in a barrel with 180 liters of water. A handful (50-100 g) of virgin soil from banyan tree areas, forests, or termite mounds is added as a local microflora inoculant. The mixture is stirred daily and fermented for 48 hours in the shade. During fermentation, aerobic and anaerobic bacteria in cow dung and urine multiply as they decompose the organic ingredients. Cane jaggery enhances fermentation, and pulse flour provides protein energy. Jeevamrit is ready after 3-4 days in summer and 6-7 days in winter and is applied to soil twice a month at a rate of 200 to 600 liters per acre, depending upon crops and soil conditions, either through irrigation water or as a foliar spray. Application of Jeevamrit or Ghanjeevamrit through drip or sprinkler irrigation is preferred. Jeevamrit acts as a catalyst, promoting soil microorganism activity, including earthworms, and making nutrients available to crops. Indigenous cow dung and urine produce the best Jeevamrit due to higher beneficial microbial populations. Nutrient content range (Ravisankar et al., 2024) and Microbial population (AINP centre, Udaipur;2021-22) observed is given in Table 13.

Table 13. Different nutrient and microorganism compositions in Jeevamrit

Parameter	Unit	Value
N	%	0.25-1.40
P	%	0.13-0.42

Parameter	Unit	Value
K	%	0.26-0.31
Bacteria count	CFU/ml ($\times 10^8$)	25.47-26.53
Fungal count	CFU/ml ($\times 10^3$)	1.82 – 2.75
Actinomycetes count	CFU/ml ($\times 10^3$)	4.97-5.88

Brahmastra uses 10 liters of desi cow urine and a paste of neem, Pongamia (karanj), custard apple, castor, and datura leaves (2 kg each). The manually crushed paste is boiled until frothing appears, filtered, and fermented for 48 hours in shade, stirred twice daily. *Brahmastra* is sprayed at 6–8 liters per 200 liters of water for one acre and effectively controls sucking pests, fruit borer, and pod borer. After preparation, can be stored upto 6 months. Composition estimated at AINP centre, Coimbatore; 2023-24) is given in Table 14.

Table 14. Different compositions estimated in Brahmastra

Parameters	Unit	Value
Organic C	%	0.67± 0.07
Total Phenolics	ppm	1351± 33
Total Flavonoids	ppm	73.3± 10.4
Total Tannins	ppm	32348± 733
Total Alkaloids	ppm	253± 7
Total Gibberellins	ppm	8066± 276

5. Neemastra involves mixing 5 liters of desi cow urine, 1 kg of fresh cow dung, and 5 kg of neem leaf paste in 100 liters of water. Ferment the mixture for 48-96 hours, stirring twice daily, and filter with cloth. Neemastra is effective against sucking pests and leaf-eating caterpillars. Prepared material is sufficient for one acre. Composition estimated at AINP centre, Coimbatore; 2023-24) is given in Table 15.

Table 15. Different compositions in Neemastra

Parameters	Unit	Value
Organic C	%	0.92 ±0.03
Total Phenolics	ppm	1196 ±77
Total Flavonoids	ppm	508 ±13
Total Tannins	ppm	15659 ±354
Total Alkaloids	ppm	2.39 ±0.39
Total Gibberellins	ppm	8393 ±144

05

Natural Farming Research: Findings

Natural Farming (NF), a low-input agricultural approach using on-farm materials for preparing biological inputs (Jeevamrit, Ghanajeevamrit, *etc.*), crop residue mulching, intercropping, and the Whapasa principle (reduced, alternate-row irrigation) was evaluated in multi-location trials across 16 Indian states from 2020. This report synthesizes key findings on crop yield, produce quality, farm profitability, soil health, biodiversity, and climate resilience from these trials. Overall, NF significantly reduced input costs while achieving comparable yields in most regions. In several cropping systems, NF yields matched those under organic and integrated management, resulting in equal or higher net returns for NF. Soil organic carbon (SOC) levels rose modestly (from 0.90% to 1.15% in 3 years in Himalayan sites) and soil biological activity and diversity increased, with higher microbial counts and diversity indices in NF soils. NF plots showed greater species richness and a more balanced microbial community than control plots. These improvements indicate building soil fertility and ecosystem resilience over time. NF's mulching and Whapasa watering technique improved soil moisture retention and reduced irrigation requirements, helping crops withstand dry spells. Intercropping and crop rotation in NF increased on-farm diversity, reducing pest/disease incidence and spreading risk, thereby enhancing climate resilience.

In summary, Natural Farming demonstrated economic viability (lower costs and comparable yields in the identified cropping systems) and agro-ecological benefits (healthier soils, robust microbial life, potential climate resilience). However, performance varied by location and crop system, some sites saw yield lags or initial profit losses under NF, underscoring an adaptation period. Careful management (e.g. supplemental organic manure in transition, timely weeding) is required to realize NF's full benefits.

Methodology

Experimental Design: A study on "Evaluation and validation of Natural Farming Practices in different Agro-ecologies" was initiated from *kharif* 2020. The evaluation was conducted as a multi-location field study (20 locations in 16 states covering 8 major cropping systems; Table 16) under the All-India Network Project on Natural Farming (AINP-NF) from 2020. At each site, a representative *cropping system* was grown under nine different treatments (Table 17) in a randomized block design (3 replications).

Table 16. Multi-location cropping systems under NF research

Sl. No.	AINP-NF locations (SAU's/ICAR Institute)	Cropping systems evaluated under Natural Farming
1.	ICAR-Indian Institute of Farming Systems Research, Modipuram (Uttar Pradesh)	Maize + cowpea (fodder) – wheat + chickpea (bed planting)
2.	Punjab Agricultural University, Ludhiana (Punjab)	
3.	Govind Ballabh Pant University of Agriculture and Technology, Pantnagar (Uttarakhand)	
4.	Tamil Nadu Agricultural University, Coimbatore (Tamil Nadu)	Cotton +green gram - sorghum +chickpea
5.	University of Agricultural Sciences, Dharwad (Karnataka)	
6.	ICAR-Indian Institute of Soil Science, Bhopal (Madhya Pradesh)	Soybean + maize – wheat + mustard
7.	Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur (Madhya Pradesh)	
8.	Indira Gandhi Krishi Vishwa Vidyalaya, Raipur (Chhattisgarh)	
9.	Dr Balasaheb Sawant Konkan Krishi Vidyapeeth Regional Station, Karjat (Maharashtra)	Rice + <i>dhaincha</i> --maize+cowpea (fodder)
10.	Birsa Agricultural University, Ranchi (Jharkhand)	
11.	Ramakrishna Mission Vivekananda Educational and Research Institute, Narendrapur (West Bengal)	
12.	ICAR-Indian Institute of Spices Research, Calicut (Kerala)	Turmeric + cowpea -greengram
13.	ICAR-RC-North Eastern Hill Region, Umiam (Meghalaya)	
14.	ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram (Kerala)	Cassava +vegetable cowpea - greengram
15.	ICAR-NRC on Seed Spices, Ajmer (Rajasthan)	Cowpea + maize / Groundnut + Sesame– Fennel + cauliflower/ cabbage
16.	Maharana Pratap University of Agriculture and Technology, Udaipur (Rajasthan)	
17.	Sardarkrushinagar Dantiwada Agricultural University, SK Nagar (Gujarat)	
18.	Hill Agricultural Research and Extension Centre, CSHPKVV, Bajaura (Himachal Pradesh)	Soybean + maize for grain —vegetable pea+ green coriander
19.	ICAR-(RC)-North Eastern Hill region, Sikkim Centre, Gangtok (Sikkim)	
20.	ICAR-Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora (Uttarakhand)	

Table 17. Treatments evaluated during 2020-2022

T ₁	Control	No external inputs (only basic field operations/weeding)
T ₂	Complete Natural Farming	All NF practices applied (Beejamrit + Ghanajeevamrit + Jeevamrit+ crop residue mulching + intercropping + <i>Whapasa</i>)
T ₃	NF without Bio-concoctions	T ₂ excluding Beejamrit + Ghanajeevamrit + Jeevamrit
T ₄	NF without Mulching	T ₂ excluding crop residue mulching
T ₅	NF without intercropping	T ₂ excluding intercropping
T ₆	NF without whapasa	T ₂ excluding whapasa
T ₇	Organic Farming Package	Standard organic farming package recommended by AINP-OF
T ₈	Integrated Crop Management with NF pest control (ICM-NF)	50% nutrients from organic manures + 50% from chemical fertilizers, and pest management using NF botanical extracts (Neemastra, Agniastra, etc.)
T ₉	Integrated Crop Management with Chemical Pest Control (ICM-CP)	50% nutrients from organic manures + 50% chemical fertilizers, and conventional chemical pesticides as needed

Note: T₁, T₇, T₈, T₉ are without intercropping; other treatments as specified

An Action Plan on “Natural Farming” research was submitted by Indian Council of Agricultural Research (ICAR) to NITI Aayog. Observations and Suggestions on the Action Plan submitted by ICAR were received from Dr Rajiv Kumar, Former Vice Chairman, NITI Aayog vide letter number VCHI/I/3939/2021 dated 4 May 2021, suggesting field evaluation of natural farming be finalized in consultation with Mr. T. Vijay Kumar (IAS and former Secretary, Rural Development) and Dr Neelam Patel, Senior Advisor, NITI Aayog. Accordingly, the same was discussed with stakeholders and modified treatments (Table 18) for field evaluation of complete natural farming were finalized for multi-location evaluation of 8 major cropping systems. Complete natural farming comprised of application of concoctions, mulching, intercropping, prophylactic application of botanicals for insect-disease management, trap crops, mechanical traps and bio-control agents and it was compared with integrated crop management and organic farming (both without intercropping). Accordingly, the treatments were modified and implemented from *kharif 2022*.

Table 18. Modified treatments as per stakeholder consultation (Facilitated by NITI Aayog, 2021)

T ₁	Control	No addition of any inputs except labour for operations including weeding
T ₂	Complete Natural Farming	1. Beejamrit +Ghanajeevamrit + Jeevamrit; 2. Crop residue mulching; 3. Intercropping) [Pre-monsoon dry sowing/multi-variate cropping with multiple crops during fallow + Prophylactic/preventive method of application of Neemastra, Dashparni ark, Brahmastra, Neem seed kernel extract,

		border crop, trap crop, seed treatment with Trichoderma, Pesudomonas and Curative application of leaf extracts of Datura, vitex, Agniaster, sour butter milk, 2 G extract and use of bio-control agents and mechanical traps]
T ₃	Organic Farming Package	Standard organic farming package recommended by AINP-OF
T ₄	Integrated Crop Management with NF pest control (ICM-NF)	50 % nutrient application through organic manures and 50% nutrient application through inorganic sources with pre-monsoon dry sowing / multi-variate cropping with multiple crops during fallow + Prophylactic/preventive method of application of Neemastra, Dashparni ark, Brahmastra, Neem seed kernel extract, border crop, trap crop, seed treatment with Trichoderma, Pesudomonas and Curative application of leaf extracts of Datura, vitex, Agniaster, sour butter milk, 3G extract and use of bio-control agents and mechanical traps
T ₅	Integrated Crop Management with Chemical Pest Control (ICM-CP)	50 % nutrient application through organic manures and 50% nutrient application through inorganic sources with application of need-based pesticides for pest management

Note: Intercropping in all the treatments

Data Collection: Yields of all crops in the system were recorded and converted to a “system equivalent yield” in terms of a primary crop unit (e.g. soybean-equivalent kg/ha for soybean-maize systems, cassava-equivalent for cassava intercrops, etc.). This allows the combined productivity of intercrops to be expressed as a single yield number per hectare per year for comparison. Economic data were gathered on the cost of cultivation (input costs including fertilizers, pesticides, labor for each treatment) and net returns (profit, Rs/ha, computed as gross output value minus cost of cultivation) for each treatment and location. Soil health parameters measured included soil organic carbon (%) at 0–15 cm depth (initial vs post-trial), and in some locations, soil biological properties such as microbial population counts (bacteria, fungi, actinomycetes colony-forming units), microbial diversity indices, and enzyme activities were analyzed under select treatments. All comparisons in this report emphasize Complete NF relative to Control, Organic package, and Integrated management with chemicals, as these represent the extremes of input use (zero, all-NF, all-organic, and conventional, respectively).

4.1 Yield, Profitability and Quality

Yield: Results across the diverse locations showed that system yields under Complete Natural Farming (NF) were largely comparable to those under organic and conventional integrated management, though with some variability. Mean system productivity recorded in different locations during 2020-21 to 2022-23 under complete natural farming is given in Table 19. In about half of the trial locations, NF achieved *higher or equal yields* relative to the other treatments, whereas in other cases, NF yielded less, especially in the initial year. A key observation is that the performance of NF is highly context-specific, dependent on the crop, region, and perhaps the transition stage of the soil.

Table 19. System productivity of major cropping systems under natural farming

Cropping Systems	Location (States)	Productivity (kg/ha/year) (on equiv. basis)
1. Soybean + maize—vegetable pea+ green coriander (<i>Soybean equivalent</i>)	Bajaura (HP), Gangtok (Sikkim), Almora (Uttarakhand)	6475
2. Soybean + maize – wheat + mustard (<i>Soybean equivalent</i>)	Bhopal, Jabalpur (MP), Raipur (CG)	3346
3. Cowpea + maize / Groundnut + Sesame– Fennel + cauliflower/cabbage (<i>Cowpea equivalent</i>)	Ajmer, Udaipur (RJ), SK Nagar (GJ)	9209
4. Cassava +vegetable cowpea - greengram (<i>Cassava equivalent</i>)	Thiruvananthapuram (Kerala)	36093
5. Rice + <i>dhaincha</i> - maize+cowpea (fodder) (<i>Rice equivalent</i>)	Karjat (MH), Ranchi (JH), Narendrapur (WB)	4095
6. Turmeric + cowpea– greengram (<i>Turmeric equivalent</i>)	Umiyam (Meghalaya), Calicut (Kerala)	14147
7. Maize + cowpea (fodder) – wheat + chickpea (bed planting) (<i>Maize equivalent</i>)	Modipuram (UP), Ludhiana (PB), Pantnagar (UK)	4989
8. Cotton + green gram - sorghum +chickpea (<i>Cotton equivalent</i>)	Coimbatore (TN), Dharwad (Karnataka)	1227

Multi-location results of 3 years (2020-21, 2021-22 and 2022-23) in terms of productivity (Table 19) is summarized in below.

- Soybean + maize- vegetable pea + coriander (green leaf) recorded mean system yield (Soybean equivalent) of 6475 kg/ha/year at Bajaura (Himachal Pradesh), Almora (Uttarakhand) and Gangtok (Sikkim) under complete natural farming. Yield gain under Natural Farming was 5% over organic farming/integrated crop management.
- Soybean + maize-wheat + mustard recorded system yield (soybean equivalent) of 3346 kg/ha/year at Bhopal and Jabalpur (Madhya Pradesh) and Raipur (Chhattisgarh) under complete natural farming. Yield under Natural Farming was comparable with Integrated crop management and organic farming.
- Cowpea + maize / Groundnut + Sesame – Fennel + cauliflower/cabbage recorded system yield (Cowpea equivalent) of 9209 kg/ha/year at SK Nagar (Gujarat), Ajmer & Udaipur (Rajasthan) under complete natural farming. Yield gain under Natural Farming over Integrated crop management and organic farming was found.

- Cassava + vegetable cowpea - greengram recorded system yield (Cassava equivalent) of 36093 kg/ha/year at Thiruvananthapuram (Kerala) under complete natural farming. Yield under natural farming was found to be on par with that of organic and integrated crop management during the first year.
- Rice + dhaincha – sorghum/maize + cowpea recorded system yield (rice equivalent) of 4095 kg/ha/year at Karjat (Maharashtra) and Ranchi (Jharkhand) under complete natural farming.
- Turmeric + cowpea - greengram recorded system yield (turmeric equivalent) of 14147 kg/ha/year at Umiam (Meghalaya) under complete natural farming.
- Maize + cowpea – wheat + chickpea evaluated at Modipuram (Uttar Pradesh) and Ludhiana (Punjab) recorded system yield (maize equivalent) of 4989 kg/ha/year, respectively, under complete natural farming involving practices such as intercropping, mulching and application of concoctions of natural farming.
- Cotton + greengram – sorghum + chickpea cropping system evaluated at Coimbatore (Tamil Nadu) and Dharwad (Karnataka) recorded system yield (cotton equivalent) of 1227 kg/ha/year under complete natural farming.

Yield improvement due to need based weeding:

Table 20 presents data on yield improvement in different cropping systems due to the intervention of need-based, chemical-free weeding during the rabi season under natural farming practices across various locations in India. Comparing the yields from 2022–23 (without weeding) to 2023–24 (with need-based weeding), substantial yield improvements were observed. The highest yield increase of 27.6% was recorded in the “Maize + cowpea – wheat + chickpea” and “Soybean + maize – wheat + mustard” systems at locations such as Pantnagar, Ludhiana, Modipuram, Bhopal, Jabalpur, and Raipur. Other notable improvements include 22.3% in cotton-based systems at Coimbatore and Dharwad, and 22.2% in groundnut-based systems at Ajmer, Udaipur, and SK Nagar. The lowest yield improvement (11%) was observed in the Maize + soybean – vegetable pea + green coriander system at Almora, Bajaura, and Gangtok. Overall, the data indicates that targeted, chemical-free weeding interventions significantly boost crop productivity under natural farming conditions.

Table 20. Improvement in yield of different cropping systems due to need based weeding

Cropping systems	Location name	Yield-2022-23 (no weeding)	Yield-2023-24 (need based weeding)	% increase in yield
Maize + cowpea - Wheat + chickpea	Pantnagar, Ludhiana & Modipuram	1762	2249	27.6
Cotton +green gram –Sorghum +chickpea	Coimbatore & Dharwad	2802	3427	22.3

Cropping systems	Location name	Yield-2022-23 (no weeding)	Yield-2023-24 (need based weeding)	% increase in yield
Soybean + maize - Wheat + mustard	Bhopal, Jabalpur & Raipur	1762	2249	27.6
Rice + Dhaincha - Maize + cowpea	Karjat, Ranchi & Narendrapur	6608	7586	14.8
Ground nut + sesame - Fennel + cabbage	Ajmer, Udaipur & SK Nagar	1188	1451	22.2
Maize + soybean- Vegetable pea+ green coriander	Almora, Bajaura, & Gangtok	6394	7097	11.0

Quality of Produce: Quality analysis was made for turmeric grown under natural farming and other practices (Table 21). The quality analysis of turmeric grown under different farming practices at Calicut reveals that natural farming (NF) achieved the highest curcumin content (5.3%), significantly surpassing other treatments, including control (4.4%) and organic farming (OF) (4.2%). Oil content was also highest in NF and ICM-CP treatments (4.6%), compared to the control (4.0%). For oleoresin, OF recorded the highest value (11.8%), followed by NF (11.4%) and control (11.1%). These results indicate that NF positively influences curcumin and oil content, while OF leads in oleoresin yield. The differences were statistically significant, highlighting the potential of NF to improve turmeric quality parameters critical for market value and medicinal properties.

Table 21. Quality of turmeric under various management practices

Treatment	Curcumin (%)	Oil (%)	Oleoresin (%)
Control	4.4	4	11.1
NF	5.3	4.6	11.4
OF	4.2	4.3	11.8
ICM-NF	4.4	4.4	11.3
ICM-CP	4.3	4.6	10.9

Input costs and Profitability

A striking outcome across all regions was the substantial reduction in paid out input costs under Complete Natural Farming compared to both organic and conventional systems. By eschewing expensive chemical fertilizers and commercial pesticides, and even reducing reliance on bulk organic manures, NF only incur costs for preparing on-farm inputs (which mainly involve labor and small quantities of jaggery, gram flour, etc. for bio-ferments) and for regular field operations.

Cost of Cultivation: In almost every trial, NF's cost of cultivation was the lowest (apart from zero-input control). For example, at Ajmer, the NF cost was only Rs. 25,640/ha, which is 61% lower than

the organic package cost of cultivation (Rs. 65,200) and 50% lower than the integrated management cost. At Coimbatore (Tamil Nadu), NF cost was Rs. 78,210, which was 46–48% lower than costs under organic and ICM. In Udaipur, NF cost (Rs. 81,805) was about 18% less than organic. Even in cases where NF yields were lower, cost savings persisted; e.g. Modipuram, NF cost Rs. 72,480, which was 32% below organic's and 23% below ICM's. These trends held across the locations and cropping systems, the multi-location average cost reduction under NF was about 15–30% relative to ICM, and in some cases, much higher. The cost savings come largely from zero chemical fertilizer and pesticide expenses, and reduced use of off-farm organic inputs. NF relies on dung and urine (often freely available on-farm), crop residues, for preparing the bio-inoculants. The core NF inputs (Beejamrit, Jeevamrit, Ghanajeevamrit) are inexpensive: it was estimated that their use at recommended rates can contribute ~23% of a crop's nitrogen requirement, while mulch and intercropping contribute an additional 9% and 24% of N needs respectively, significantly offsetting fertilizer needs. However, it was observed from characterization of NF practices by farmers that many farmers still apply some vermicompost, manure, etc. in initial NF years to prevent yield decline. This flexibility in using locally available organics helps keep costs low.

Net Returns (Profitability): Reduced costs, combined with moderate yields, translated into competitive, and often improved, net returns for NF. In regions where NF matched or marginally higher yield than other treatments, its profits were higher. For example, in Almora (Uttarakhand) with soybean + maize- vegetable pea + coriander (green leaf) cropping system, NF net return was Rs. 2,65,436/ha, essentially equivalent to the high returns of organic practice (only 0.45% lower), a remarkable outcome given NF's minimal input application. In Himachal/Uttarakhand sites (Bajaura, Almora) with the same cropping system, aggregate analysis showed NF's 15% cost reduction led to a 19% higher net profit on average compared to organic/ICM. Even where NF yield was comparable (soybean+maize in MP), the cost savings gave NF a +15% net return advantage over ICM. In some cases, NF's profitability was dramatically better than organic despite yield differences. At Ajmer with cowpea + maize / Groundnut + Sesame– Fennel + cauliflower/cabbage system yield, NF's net profit was reported as ₹82,093/ha.

In summary, Complete Natural Farming proved economically competitive, primarily by cutting input costs and maintaining reasonable yields, especially for the cropping systems involving legumes. Across eight major cropping system types, NF reduced cultivation costs by 16% on average, which translated to net return increases of 7–19% in several systems compared to organic/ICM. Farmers can thus save money up front and can earn equal or greater profits, provided yields are maintained. This strong profitability, even without price premiums, is a critical incentive for NF adoption. It must be noted that achieving those yields often required careful adherence to NF practices (timely application of Jeevamrit, mulching, etc.) and sometimes transitional use of organic manures. Nevertheless, the data suggest that NF can be more profitable than input-heavy organic or conventional farming in many scenarios, validating its core principle of low-cost production.

4.2 Soil health and biodiversity

Healthy soil is the foundation of Natural Farming, and the trials measured key soil parameters to gauge NF's impact. The data show clear benefits to soil organic carbon and biological health under NF. Over the 3 years, most NF plots accrued more soil carbon and supported more robust microbial communities than their control or chemical management. Soil organic carbon (SOC) and evidence of enhanced soil biodiversity (microbial abundance and diversity) under NF are given below.



Inputs preparation and application in NF plots at ICAR-NRCSS, Ajmer

Physical properties: Variations in soil physical properties among treatments were observed. Organic farming recorded the lowest bulk density (1.19 Mg m^{-3}) and particle density (2.37 Mg m^{-3}), alongside the highest hydraulic conductivity (1.74 cm hr^{-1}), infiltration rate (2.52 cm hr^{-1}), porosity (51.88%), and water holding capacity (49.38%). Complete NF also showed favourable soil structure with bulk density at 1.23 Mg m^{-3} and high infiltration (2.17 cm hr^{-1}). In contrast, the control plot exhibited higher bulk density (1.33 Mg m^{-3}), lower porosity (49%), and reduced water holding capacity (46%), indicating relatively compacted soil. These results collectively point to the positive impact of natural and organic farming systems in enhancing soil physical parameters compared to conventional practices (Table 22).

Table 22. Soil physical properties observed under various management practices

Treatment details	Bulk density (Mg m^{-3})	Particle density (Mg m^{-3})	Hydraulic conductivity (cm hr^{-1})	Infiltration rate (cm hr^{-1})	Porosity (%)	Water holding capacity (%)
Control	1.33	2.65	0.49	1.70	49.00	46.00
Complete NF	1.23	2.46	1.67	2.17	50.82	48.76
Organic farming	1.19	2.37	1.74	2.52	51.88	49.38
ICM with NF	1.30	2.56	0.83	1.97	49.60	47.59
ICM with CP	1.31	2.57	0.80	1.96	49.58	47.53
CD (P=0.05)	0.05	0.12	0.07	0.09	1.52	2.03

Soil Organic carbon

One consistent outcome across regions was that soils under Complete NF tended to have equal or higher SOC% compared to soils under control or conventional management. This is attributable to NF practices like continuous mulching (returning crop residues to soil) and regular additions of bioformulations, which build soil organic matter. The changes in SOC, though modest in percentage points, represent meaningful carbon sequestration over large areas and improved soil fertility.

Every cropping system recorded an increase in SOC under NF after three years (Fig 6). For example, in the mountain legume intercropping system (Himachal Pradesh/Uttarakhand/Sikkim), SOC rose from 0.90% to 1.15% under NF. That is a relative increase of ~28%, indicating substantial carbon buildup. Likewise, in the turmeric intercropping system (Meghalaya/Kerala), SOC went from an already high 1.12% up to 1.32%. Even systems that initially had low soil carbon saw improvements: e.g., in Rajasthan/Gujarat, edged up from 0.38% to 0.39%, a small absolute change, but notable given the short time and arid conditions.

Across all locations, NF plots often matched or exceeded the SOC levels of other treatments. The detailed site data show NF's SOC was higher than the control (no-input) soil at a majority of locations. For instance, at Udaipur, NF soil had 0.71% SOC vs 0.67% in control; at Bajaura (HP), NF had 0.85% vs control's 0.66%; at Almora, 0.87% vs 0.82% in control; at Dharwad, 0.88% vs 0.76% control (15.7% higher); and at Raipur, 0.64% vs 0.57% control (12% higher). NF maintained SOC nearly at par with organic in many cases, despite far lower external inputs.

The improvement of SOC under NF has important implications. Even a 0.1% increase in SOC in the topsoil can represent several tons of carbon sequestered per hectare. These trials saw SOC increases on the order of 0.03–0.25 percentage points in 3 years (depending on system), suggesting NF practices are actively building soil carbon pools. Higher SOC contributes to better soil structure, water retention, and fertility. The mulching practice appears especially key: by keeping soil covered with residues, NF ensures continuous addition of decomposing organic matter. The data indeed show that omitting mulch (NF without mulching treatment) usually led to slightly lower SOC than Complete NF, underscoring mulching's role in carbon accrual. Similarly, the use of Jeevamrit and other microbial inoculants may stimulate soil life and carbon stabilization, though their direct contribution to SOC is smaller compared to bulk residues.

It's worth noting that the SOC gains under NF came without any external carbon inputs (like compost) beyond what the system produced (crop residues, on-farm biomass). This demonstrates NF's potential as a carbon-sequestering, regenerative practice, which can restore soil organic matter over time while sustaining production. Longer-term monitoring would be needed to see if SOC continues rising or plateaus. But these early results are promising: NF plots did not suffer the gradual SOC decline often seen under intensive chemical farming, and instead showed stability or increases in soil carbon.

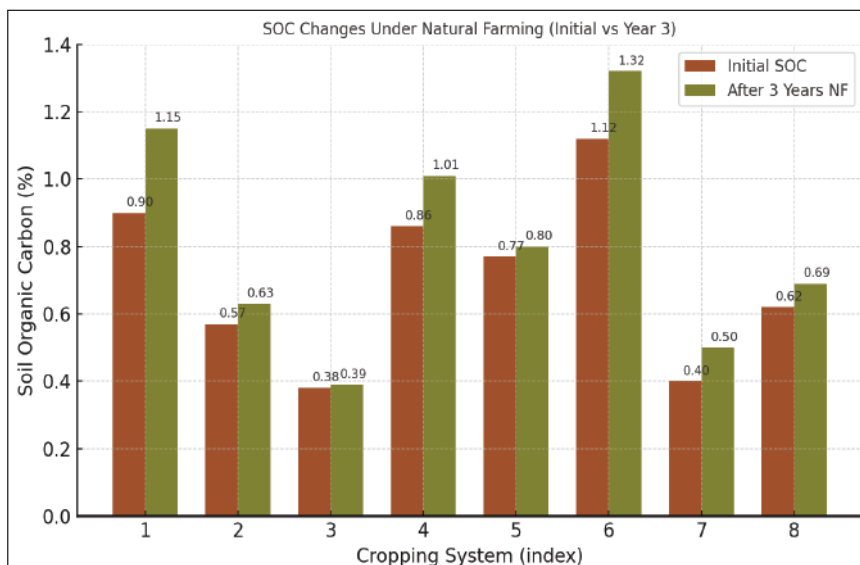


Fig 6. Change in soil organic carbon (%) from initial baseline to after 3 years of Natural Farming, for eight representative cropping systems across India. Index 1–8 correspond to: (1) Soybean+maize – vegetable pea+coriander (Himachal Pradesh/Uttarakhand/Sikkim); (2) Soybean+maize – wheat+mustard (Madhya Pradesh/Chhattisgarh); (3) Cowpea+maize/Groundnut+sesame – fennel+cauliflower (Rajasthan/Gujarat); (4) Cassava+cowpea – greengram (Kerala); (5) Rice+dhaincha – maize+cowpea (Maharashtra/Jharkhand); (6) Turmeric+cowpea – greengram (Meghalaya/Kerala); (7) Maize+cowpea – wheat+chickpea (U.P./Punjab); (8) Cotton+greengram – sorghum+chickpea (Tamil Nadu/Karnataka).

Urease activity, a key indicator of soil microbial activity, was highest in organic farming (274.80 $\mu\text{g/g soil/hr}$), followed closely by ICM-NF (269.91 $\mu\text{g/g soil/hr}$) and ICM-CP (268.19 $\mu\text{g/g soil/hr}$). Glomalin, associated with soil aggregation and stability, peaked in Organic farming (211.34 $\mu\text{g/g soil}$) and showed relatively high values in ICM-NF (202.54 $\mu\text{g/g soil}$). Consistently higher urease and glomalin compared to the control was observed under OF and NF, suggesting improved biological soil health (Fig 7).

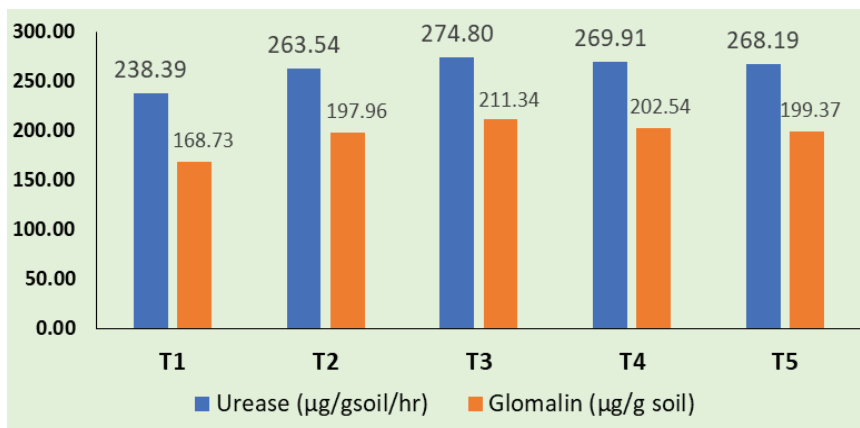


Fig 7. Urease activity and Glomalin content under various management options

Soil biodiversity and biological activity

Natural Farming's avoidance of chemicals and emphasis on organic amendments was hypothesized to enhance soil life. The study's measurements confirm that NF systems fostered a more abundant and diverse soil biota relative to chemical controls. Beneficial microbial populations (bacteria, fungi, actinomycetes), microbial diversity indices, and enzymatic activities were all higher under NF, indicating a *richer soil ecosystem* that underpins long-term soil fertility and plant health.



Soybean+maize–wheat+chickpea system (Bhopal, Madhya Pradesh)

Under Complete NF, the Chao1 richness index was 549, compared to 528 under control management. The Shannon diversity index was also higher under NF (5.02 vs 4.72). These differences, though not enormous in magnitude, consistently favored NF and suggest that eliminating chemical inputs and adding organic bio-stimulants creates a better environment for a wider array of soil organisms. A higher Shannon index indicates not only more species present but also a more balanced abundance among species (no single group dominating), which is a hallmark of a healthy soil microbiome (Fig 8).

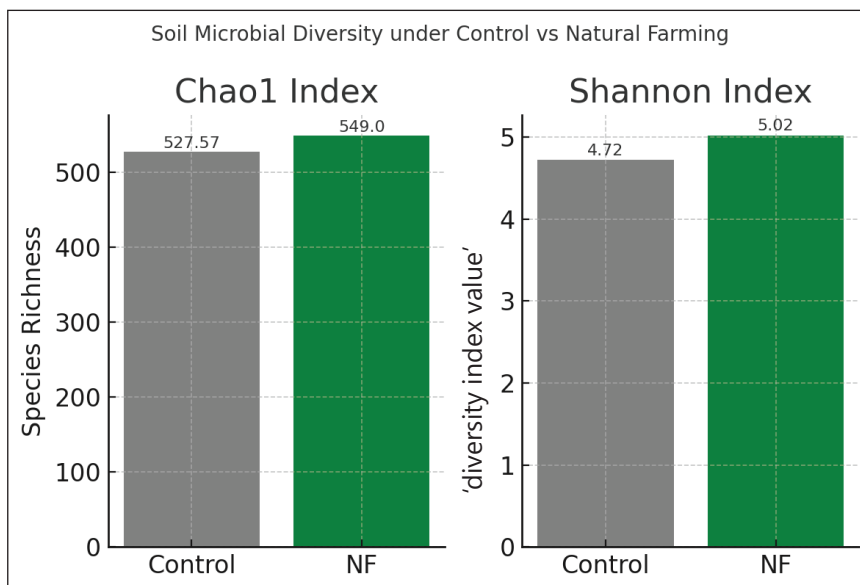


Fig 8: Soil microbial diversity under Natural Farming vs Control. Left: Chao1 index (estimated species richness); Right: Shannon index (community diversity). NF soils show higher values for both indices, reflecting greater microbial species count and more even community structure.

Specific microbial groups also thrived. At Coimbatore (cotton/greengram – sorghum/chickpea system), soil plate counts showed higher populations of bacteria, actinomycetes, and fungi under NF compared to control. For instance, NF plots had on the order of 10^7 CFU/g soil of bacteria versus 10^6 in control, and similarly elevated fungal CFUs. The report noted significantly higher microbial counts in NF, demonstrating that NF's regular organic inputs act as food for soil microbes, boosting their proliferation. Unlike chemical fertilizers (which can create salt stress and directly suppress some microbes), NF's mild, carbon-rich amendments (Jeevamrit, etc.) introduce beneficial microbes and support native ones. Over time, this leads to soils teeming with life, beneficial nitrogen-fixing bacteria, decomposers, and biocontrol agents, which can improve nutrient cycling and plant growth naturally.

Soil enzyme assays provided further evidence of heightened biological activity under NF. Enzymes like dehydrogenase (DHA) and fluorescein diacetate hydrolase (FDA) are indicators of total microbial metabolic activity in soil. In Bhopal, NF soils exhibited higher enzyme activities than controls at harvest. For example, DHA activity reached $76.7 \mu\text{g TPF/g soil/hour}$ under NF vs 64.1 in control, and similarly higher in the Rabi season. FDA, which reflects overall microbial activity (bacteria and fungi), was also elevated. These enzyme results confirm that NF soils had a more active soil food web, likely decomposing organic matter and cycling nutrients more vigorously. Enhanced enzyme activity correlates with better nutrient availability (phosphatases releasing phosphorus, etc.) and may partially compensate for lower fertilizer inputs.



Maize+cowpea under NF at Modipuram

Another intriguing finding was the effect of NF on root exudation. At Modipuram, measured “reducing sugars” in the rhizosphere vs non-rhizosphere soil as a proxy for root exudates showed significantly higher reducing sugar levels in both rhizosphere and bulk soil, 765 $\mu\text{g/g}$ in NF rhizosphere vs 433 $\mu\text{g/g}$ in control. This indicates that plants under NF (with practices like intercropping and mulching) perhaps exuded more beneficial sugars/amino acids, or that more of those exudates were preserved (less consumed by soil microbes immediately due to cooler, moister soil from mulching). The greater root exudation under NF could help feed microbial communities, creating a positive feedback loop for soil fertility. It was hypothesized that mulching plus healthy root systems in NF contribute to more abundant soil carbon substrates (like sugars), thus fostering microbes.

The Fig 9 shows the relative abundance of bacterial genera across five treatments: Control, ICM with NF, ICM with CP, NF and OF. Each coloured segment represents a bacterial genus, and the y-axis indicates the percentage contribution of each genus within the total microbial community. Summary of the relative abundance is given in Table 23.

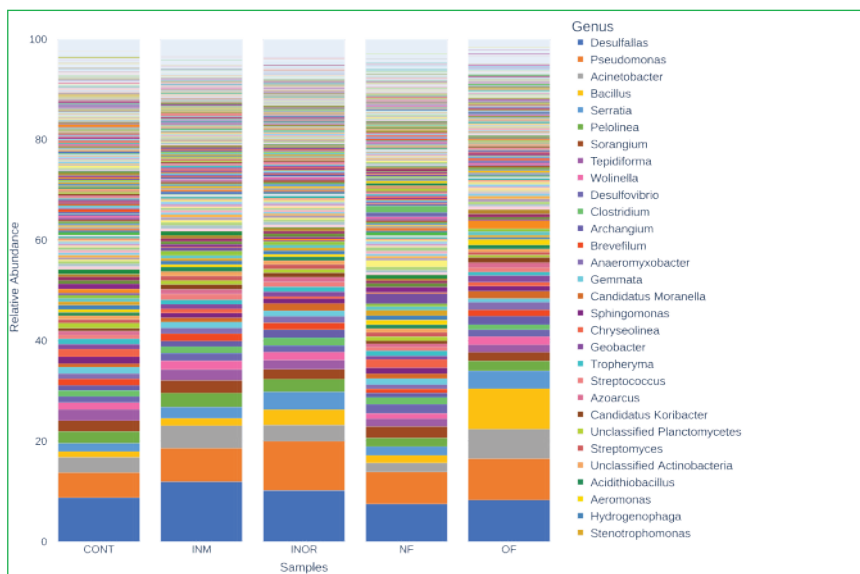
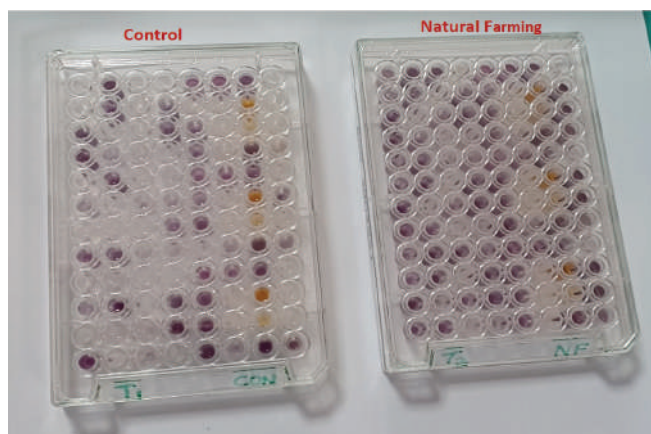


Fig 9. Proportion of different bacterial genera under different management practices in soybean + maize - wheat + mustard system

Table 23. Significance of relative abundance of bacterial genera observed under soybean + maize – wheat + mustard (Bhopal, Madhya Pradesh)

S. No.	Observation / Practice	Significance
1	Overall diversity	All treatments show a highly diverse bacterial community, with many genera contributing to the composition, as indicated by multiple color bands.
2	Dominant genera	<i>Desulfovibrio</i> , <i>Pseudomonas</i> , and <i>Acinetobacter</i> are among the most abundant genera across treatments, forming the largest segments in the bars.
3	Natural Farming (NF)	NF exhibits a balanced distribution with higher presence of beneficial genera like <i>Clostridium</i> , <i>Brevundimonas</i> , and <i>Sphingomonas</i> , known for nutrient cycling and stress mitigation.
4	Organic Farming (OF)	OF shows increased abundance of beneficial microbes (<i>Azoracis</i> , <i>Akkermansia</i> , <i>Hydrogenophaga</i>) compared to control, enhancing soil health.
5	Control	Control plots have slightly higher proportions of <i>Desulfovibrio</i> and <i>Pseudomonas</i> , indicating less functional diversification without amendments.
6	Integrated Crop Management with CP	Similar to control but with slight increases in <i>Bacillus</i> and <i>Serratia</i> , likely due to organic nutrient inputs.

S. No.	Observation / Practice	Significance
7	Integrated Crop Management with NF (ICM)	Community structure closer to NF, showing improved microbial balance from partial adoption of natural farming elements.
8	Functional implications	Higher <i>Bacillus</i> , <i>Streptomyces</i> , and <i>Acinetobacter</i> in NF and OF suggest better natural biocontrol potential.
9	Carbon cycling microbes	Genera like <i>Clostridium</i> and <i>Geobacter</i> are more abundant in NF and OF, indicating enhanced carbon cycling and decomposition.
10	Nitrogen fixers	<i>Azoarcus</i> and <i>Anaeromyxobacter</i> are more abundant in NF and OF, supporting biological nitrogen fixation.
11	Pathogen suppression	<i>Sphingomonas</i> and <i>Brevundimonas</i> in NF and OF help suppress soil-borne pathogens.
12	Hydrocarbon degraders	<i>Hydrogenophaga</i> and <i>Sorangium</i> occur more in OF and NF, improving soil detoxification capacity.
13	Microbial evenness	NF and OF have more even genus distribution, indicating a stable and healthy microbial ecosystem.
14	Soil health benefits	NF and OF enhance beneficial microbial guilds linked to nutrient cycling and plant health.
15	Reduced dominance	In NF and OF, no single genus dominates, reducing risks from opportunistic pathogens.
16	ICM's partial benefits	ICM is better than control but less effective than NF in fostering microbial richness.
17	Environmental resilience	Higher diversity in NF and OF boosts resilience to environmental stresses like drought and degradation.
18	Overall conclusion	NF supports richer, more functional, and balanced microbial communities compared to conventional systems.



Functional diversity assessment (Control and Natural Farming)

The functional diversity assessment shows that Natural Farming (NF) soils exhibited higher microbial activity and diversity compared to the control. Across major carbon source categories, carbohydrates, polymers, carboxylic and ketonic acids, amino acids, and amines/amides (Fig 10), NF consistently recorded higher optical density (OD at 590 nm) values, indicating enhanced microbial utilization (Fig 11) of these substrates.

The improvement was particularly notable for carboxylic and ketonic acids, where NF had a clear advantage over control. This broader carbon utilization reflects a more metabolically versatile microbial community in NF systems, likely due to organic amendments and microbe-rich inputs enhancing soil biological activity. The summary indices further confirm this trend: the Shannon Diversity Index increased from 3.33 in control to 3.41 in NF, while the Average Well Colour Development (AWCD) rose from 1.67 to 2.08. The carbon utilization pattern at the individual compound level also showed NF outperforming control for most substrates, including D-xylose, D-mannitol, N-acetyl-D-glucosamine, D-malic acid, L-asparagine, and L-threonine. Such increases in both diversity and metabolic activity suggests that NF fosters a more functionally diverse microbial community, which can enhance nutrient cycling, organic matter decomposition, and overall soil health resilience.

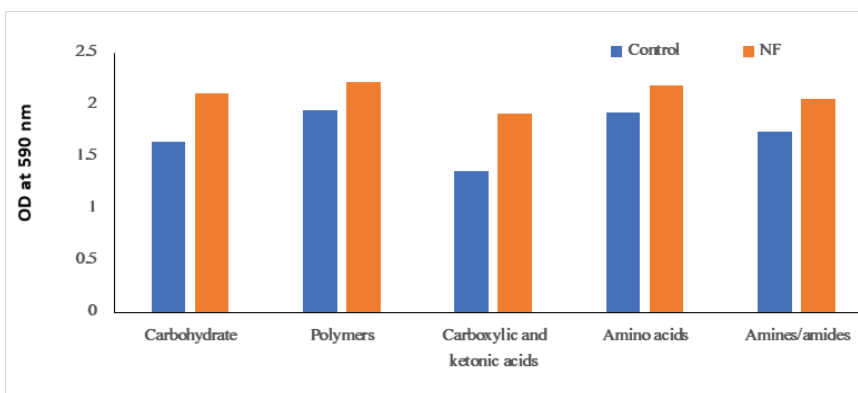


Fig 10. Optical density across major carbon sources under Natural Farming (Bhopal, Madhya Pradesh)

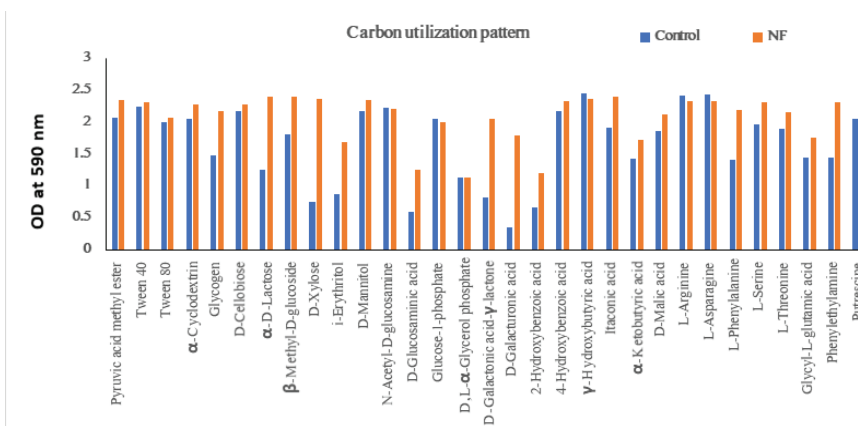


Fig 11. Carbon utilization pattern under Natural Farming compared to control

Beyond microflora, it is likely that soil faunal diversity (earthworms, arthropods) also benefited under NF due to the absence of pesticides and increased organic matter. Farmer surveys in the project revealed multi-tier cropping and agroforestry components on some NF farms – such diversity generally

correlates with richer above-ground biodiversity as well. It can be inferred that NF creates a more life-friendly agro-ecosystem.

In summary, Natural Farming markedly improved soil biological health in the trial locations. Higher microbial counts, greater species diversity, and stronger enzyme activities were consistently observed. These indicate that NF is not only conserving soil life but actively enhancing it, likely leading to resilient nutrient cycling and disease suppression in the long term. Such thriving soil biology is a cornerstone of sustainable productivity and is a key advantage of NF over input-intensive farming, where soil life is often diminished.



Soybean + maize – wheat + mustard under complete natural farming at Bhopal

4.3 Climate Change Mitigation and Adaptation Benefits

Natural Farming, by its nature, aligns with many principles of climate-smart agriculture. The trials, while not explicitly designed as climate studies, provided insights into how NF practices contribute to the mitigation of climate change (through reduced emissions and carbon sequestration) and adaptation/resilience (through resource conservation and diversification). Key NF interventions, crop residue mulching, intercropping, reduced irrigation and elimination of synthetic inputs, have direct implications for water savings, carbon footprint, and system resilience. Synthesized findings and implications related to the climate benefits of NF are given below.

Mitigation: Lower Emissions and Carbon Sequestration

One of the most direct climate benefits of NF is the avoidance of synthetic fertilizers and pesticides, which are major sources of greenhouse gas emissions in conventional farming. Manufacturing of chemical nitrogen fertilizers is energy-intensive (fossil-fuel based), and their application in fields leads to emissions of nitrous oxide (N_2O), a potent GHG. By relying on on-farm organics and biological N fixation, NF drastically cuts these emissions at both production and application stages. The input profile of NF (zero synthetic N, P, K) indicates a far lower carbon footprint per hectare compared to chemical-intensive farming. Each NF farmer essentially eliminates the CO_2 emissions associated with perhaps hundreds of kg of urea or other fertilizers that would otherwise be used.

Another mitigation aspect is carbon sequestration in soils, as evidenced by the SOC increases discussed earlier. NF plots gained soil carbon (e.g. +0.25% SOC in 3 years in some systems), meaning atmospheric CO₂ was converted into plant biomass and then into stable soil humus. If scaled up, such SOC increases across millions of hectares could sequester significant amounts of carbon. For example, raising SOC by 0.1% in the top 15 cm means roughly an additional 2.5–3.0 tonnes of carbon stored per hectare. The NF trial in Himachal/Uttarakhand saw an increase from 0.90 to 1.15% SOC, roughly a 0.25% gain, which would equate to 6–7 t C/ha sequestered (over 3 years). While these are rough estimates, it illustrates NF's potential to turn farms into carbon sinks rather than carbon sources. Importantly, this was achieved while maintaining yield, showing that carbon sequestration and production can go hand in hand in regenerative systems.

Additionally, by eliminating chemical pesticides (many of which are petroleum-derived) and using farm-made botanical extracts for pest management, NF avoids emissions related to pesticide manufacture and reduces chemical residues in the environment. The use of cow dung/urine-based inputs (Jeevamrit, etc.) recycles nutrients and carbon within the farm system, leveraging livestock integration (many NF farmers keep cattle, goats, etc., to supply manure and urine. Integration of livestock, as recommended in NF, can further enhance nutrient cycling and provide biogas (a renewable energy source).

In terms of energy use, NF drastically reduces the need for energy-intensive inputs transport and irrigation pumping. With fewer purchased inputs, the supply-chain emissions (transportation of fertilizers/pesticides) drop. Also, NF's mulching and moisture conservation often allow for reduced irrigation frequency, which means less energy (diesel or electricity) is used for pumping water. Whapasa practice (irrigating alternate furrows during the cooler part of the day) is known to reduce water consumption significantly and minimize evaporation losses. Less irrigation not only saves water (an adaptation benefit) but also saves fuel/electricity, indirectly cutting emissions.

Adaptation: Resilience through diversity and resource conservation

Natural Farming practices enhance the farming system's resilience to climate variability – such as droughts, erratic rains, or pest outbreaks, thereby aiding climate change adaptation. Several mechanisms emerged from the study:

- **Improved Water Retention and Drought Resistance:** The combination of mulching in NF significantly improves soil moisture dynamics. Mulch cover reduces evaporation from the soil and keeps the soil cooler, while alternate-row irrigation ensures the soil is not over-saturated and retains air pockets along with moisture. By conserving soil moisture, NF crops are more buffered against dry spells. For instance, in the Rajasthan sites, mulched NF plots withstood intermittent drought better than non-mulched ones – as suggested by the fact that removing mulching (treatment NF-2) tended to reduce yields and possibly required more irrigation. In the cassava + cowpea system (Kerala), which faces heavy rains followed by dry spells, NF yields remained on par with others, possibly because mulch moderated the microclimate. Thus, NF's

water stewardship can be seen as a climate adaptation advantage, helping maintain productivity under rainfall extremes.

- **Diversified Cropping Systems:** NF inherently promotes polycultures and rotations (intercropping legumes with cereals, multi-tier cropping with trees, *etc.*) as noted in farmer practice surveys. This diversity is a buffer against climate shocks. If one crop in the mix fails (due to a pest or weather event), the other can still yield, reducing total loss. For example, in the soybean + maize intercrop, maize might handle drought differently than soybean, so one can compensate if the other suffers. The trials demonstrated that intercropping contributed significantly to nutrient management (estimated 24% of N needs from intercrop legumes), which also means resilience in nutrient supply. Additionally, diversity in cropping provides habitat for beneficial insects and strengthens ecosystem services like pollination and natural pest control, which can become more crucial under climate stress. Some NF farmers integrated fruit trees (agroforestry) and practiced multi-layer cropping, which further enhances resilience (trees can stabilize soil and provide income even if the annual crop fails).
- **Reduced Pest and Disease Pressure:** NF's pest management strategy uses botanical extracts (Neem-based sprays like Neemastra, Dashparni ark, *etc.*) and emphasizes prophylactic measures. Avoiding synthetic pesticides helps conserve predator insects and overall biodiversity, which can keep pest populations in check naturally. In a changing climate, pest and disease patterns become more erratic; a biologically diversified system (like NF) is more likely to adapt without collapse. It is important that NF farmers should do "need-based chemical-free weeding" and prophylactic botanical sprays for pest control. When practiced, this integrated approach can prevent major outbreaks, making the crop stand more stable year to year. Avoiding chemical pesticides also means less risk of development of resistance, secondary pest outbreaks and accumulation of pesticide residues in the harvested produces.
- **Soil Health and Climate Resilience:** The improvements in soil structure and organic matter under NF translate to resilience against both drought and floods. Higher SOC soils have better aggregation, infiltration, and water-holding capacity, so they can absorb heavy rains with less runoff (mitigating flood erosion) and hold water longer during droughts. For instance, an SOC increase from 0.8% to 1.0% might significantly improve a soil's available water capacity. Farmers practicing NF in semi-arid regions likely noticed that mulched, carbon-rich soils stayed moist and plants did not wilt as quickly under heat. Thus, the soil health gains discussed earlier (higher SOC, active microbes) inherently boost the system's ability to adapt to climate extremes.

Conclusions

The multi-location research on Natural Farming resulted the following conclusions:

- **Agronomic Performance:** Natural Farming can match conventional yields in some low nutrient requiring cropping systems and even surpass yields in certain legume-supported rotations.

However, performance is variable; in some high-intensity grain systems, NF yields initially lag due to lower readily available nutrients. Over a 2–3-year period, as soil fertility builds, yield gaps tend to close. Appropriate management (timely weeding, pest control, and using available farmyard manure if needed) can mitigate initial shortfalls. NF showed particular strength in dryland/intercrop systems, while irrigated monocrop systems may need longer transition or hybrid approaches initially.

- **Economic Viability:** NF's drastically lower input costs consistently translate into improved net profitability or at least profit parity relative to input-intensive organic and conventional farming. Farmers save on cultivation costs without sacrificing much yield in some of the cropping systems, which is a recipe for higher income. Caution is needed in the very first years in certain systems (e.g., rice–wheat in heavy soils) where a combination of yield dip could cause income loss, a phased adoption or initial supplementation with organic inputs can help maintain income. Overall, NF offers a high profit-to-cost ratio and reduces farmers' financial risk by cutting down cash expenditures on inputs.
- **Soil and Environmental Health:** The NF practice regimen leads to healthier soils, as evidenced by increased soil organic carbon, enhanced microbial activity, and presumably better soil structure. Biodiversity is promoted both below and above ground (soil biota, insect life, *etc.*), contributing to an agro-ecosystem that is self-regulating and sustainable. NF avoids chemical pollution of soil and water, thus providing environmental benefits like cleaner water runoff and safer food (residue-free). It aligns well with regenerative agriculture and climate-smart goals by sequestering carbon and reducing emissions.
- **Climate Resilience:** NF-managed farms are more resilient to climate stresses due to mulch-driven moisture conservation, diversified cropping, and reliance on local resources. They are less vulnerable to input supply shocks (e.g., fertilizer price spikes) and adapt better to erratic weather. Thus, NF could be a viable climate adaptation strategy for smallholders – a way to continue farming productively under increasingly unpredictable conditions.

In conclusion, the evaluation across diverse agro-ecological regions demonstrates that Natural Farming is a viable agroecological alternative that can deliver comparable yields, higher profits, and improved soil health in selected cropping systems and areas. While not without challenges, its benefits to farmers (cost savings, resilience) and to the environment (soil restoration, reduced emissions) are compelling. With supportive policies, farmer training, and market development, NF has the potential to scale up and contribute significantly to sustainable agriculture and climate change mitigation efforts in India and beyond. The evidence from this multi-location research provides a strong basis for moving forward with Natural Farming as a key component of future farming systems.

06

Documentation and Validation of Indigenous Technical Knowledge (ITK) in Natural Farming

Indigenous Technical Knowledge (ITK) forms the backbone of India's traditional agricultural heritage, encompassing time-tested practices developed, refined, and transmitted across generations through farmers' experiential learning and local ecological understanding. In the context of Natural Farming, ITKs hold immense value as they are inherently low-cost, resource-efficient, and environmentally sustainable, relying on locally available biological and natural materials. Recognizing their potential to address current challenges of soil degradation, declining farm profitability, and environmental concerns, the All-India Network Programme on Natural Farming (AINP-NF) has undertaken systematic documentation and scientific validation of these practices across diverse agro-climatic zones of the country. This initiative aims to capture the rich diversity of ITKs, ranging from soil fertility enhancement and pest-disease management to crop diversification and water conservation and evaluate their efficacy through research trials. The outcome will not only safeguard this invaluable traditional wisdom but also integrate it into evidence-based, farmer-friendly natural farming protocols for wider adoption and policy support. The glimpses of ITKs documented and validated are given in Table 24.

Table 24. Glimpse of ITKs documented and validated

ITK / Practice	Preparation	Target crop / problem	Best dose	Validated benefits (highlights)
3G Extract (Ginger+Garlic +Green chilli, 5%)	Fresh paste steeped; filtered; spray 5%	Cotton & Okra (sucking pests), Okra, Maize (Fall Army worm)	5% spray	Up to ~74% reduction in cotton sucking pests; Yields: Cotton ~1.5–2.1 t/ha; Okra ~11.8 t/ha; Maize ~5.0 t/ha
Teekha Sat (chilli+garlic+ neem+dhatuira in cow urine; boiled)	Boil mix in cow urine to half, sieve; spray	Cole crops (sucking pests), Brinjal (SFB)	5–10% spray	Higher curd yield (cauliflower ~17.5 t/ha; cabbage ~15.5 t/ha); in brinjal up to ~50% SFB suppression at 10%
Neem oil (3%)	Mix neem oil with seed	Stored grain pests in maize & black gram	3% of grain weight	Min. damage: Maize 11.53%; Black gram 9.52% after 90 days
Neem seed kernel powder (3%)	Dry powder mixed with grain	Stored pests in maize & black gram	3% of grain weight	Min. damage: Maize 14.51%; Black gram 9.99%

Dashparni (multi-plant ferment)	Ferment for 40 days with cow dung and cow urine; spray	Tomato diseases; Onion purple blotch; Brinjal SFB	10% spray	Tomato yield ~18.9 t/ha, B:C ~5.9; Onion PDI ~7.5% with 8.7 t/ha; Brinjal fruit yield ~17.2 t/ha
Neemastra (Neem+cow urine/cow dung)	48 fermentation; filter; spray	Tomato diseases; Onion purple blotch	10% spray	Tomato yield ~18.2 t/ha, B:C ~5.6; Onion PDI ~11% with 8.1 t/ha
Cow urine foliar	Fresh cow urine diluted; foliar spray	Tomato, Bottle gourd, Bitter gourd	10% spray	Yield increases over 5%: Tomato +8.3%, Bottle gourd +9.1%, Bitter gourd +11.3%
Cow dung extract foliar	Decomposed 3–4 days; filter; foliar	Cabbage, Radish, Red cherry pepper	10% (FP) & 15%	Yield gains vs control across all three; 15% best for red cherry & radish
Compost tea (soil & foliar)	Aqueous extract; rich in microbes & enzymes	Soybean	Soil: 1250 L/ha; Foliar: 100%	Higher yields and B:C vs water control

Proven Efficacy in Pest Control and Yield Improvement: Traditional ITK formulations, made from local ingredients like plant extracts, cow dung, and cow urine – have been scientifically validated to significantly reduce pest infestations (by 50–80%) and boost crop yields (by 18–25% or more) in natural farming systems. For example, a herbal “3G” *extract* (ginger, garlic, green chili) cut sucking pest incidence by over 50–70% in cotton, raising cotton yield ~25% above control. Similarly, a spicy herbal spray “*Teekha sat*” in vegetables achieved ~58% reduction in aphids and markedly higher yields and profits. These results show that ITKs can match or outperform chemical inputs for pest management in a natural farming context.

Use of Low-Cost, Locally Available Resources: A common thread in ITK is reliance on readily available farm resources – cow dung, cow urine, plant leaves, ash, *etc.* – aligning perfectly with natural farming’s low-cost ethos. Farmers ferment and apply these materials as biopesticides or biofertilizers, reducing dependence on synthetic chemicals. Trials in Sikkim showed that spraying cow dung and urine extracts (5–15% concentrations) significantly improved vegetable yields over water-only control. Optimal results often matched the dose traditionally used by farmers (e.g. 10% cow urine gave the best yield in tomatoes and gourds). These findings validate that farmer wisdom in preparation and dosing of ITKs is often scientifically sound, and such inputs can be made on-farm.

- **Enhanced Farm Economics and Sustainability:** Integrating ITKs can increase net farm income and improve benefit–cost ratios while maintaining ecological balance. In trials, ITK treatments produced higher marketable yields and returns than controls or conventional practices. For

example, a 5% *Teekha sat* spray in cauliflower yielded 17.5 tons/ha with a net return of ₹2.21 lakh/ha and B:C ratio 5.37, versus 11.1 tons/ha and B:C 3.07 under no-treatment control. Similarly, foliar application of fermented *Panchagavya* (an ITK nutrient tonic) at 10% concentration boosted soybean yields by ~52% and raised the B:C ratio from 2.6 to 3.4. These improvements in productivity and profitability come with reduced agrochemical use, confirming that ITKs advance both economic and environmental sustainability in natural farming.



Effect of soil and foliar application of Panchagavya on soybean at Udaipur (Control and Panchagavya @ 10% at 45 & 60 DAS)

The ITK validation program was implemented in multiple regions of India – notably Rajasthan (Ajmer & Udaipur), Tamil Nadu (Coimbatore), Sikkim (Gangtok), and West Bengal (Narendrapur). The major region-wise findings are summarized below:

Rajasthan (Ajmer & Udaipur)

- Ajmer (Arid Rajasthan): Local farmers utilize an indigenous biopesticide known as “*Katyasani*” in Merta, Rajasthan. This ITK formulation is prepared by fermenting a mixture of desi cow urine (20 L) with botanicals like *Aak* (*Calotropis*) leaves (5 kg), *Datura* leaves (5 kg), *Neem* leaves or kernels (5 kg/1.5 kg), plus cow buttermilk (2 kg) and even pieces of copper metal. This fermented concoction is reputed to repel a range of crop pests, and its documentation provides a recipe for other natural farming practitioners.
- Udaipur (Semi-Arid Rajasthan): Extensive ITK trials in Udaipur yielded multiple important findings: *Pest Management in Vegetables*: A 5% “Teekha sat” spray – a pungent herbal extract – proved most effective against sucking pests in cruciferous vegetables. In cauliflower, Teekha sat treatment produced a curd yield of 17,500 kg/ha, highest among five ITKs tested, with a 58.1% reduction in aphid infestation. Cabbage showed a similar trend: Teekha sat yielded 15,480 kg/ha and cut aphid incidence ~58%, slightly outperforming neem oil (0.5%) which yielded 14,520 kg/ha with ~56.6% pest reduction.

- **Biofertilizer/Nutrient Management:** Udaipur trials on Panchagavya – a fermented blend of cow dung, urine, milk, curd, ghee, *etc.*, revered in natural farming – demonstrated its value as a growth promoter. Foliar application of Panchagavya at 10% concentration, twice (45 and 60 days) after sowing, gave the highest soybean yield (≈ 1365 kg/ha), significantly above the control (894 kg/ha). Thus, integrating Panchagavya sprays at optimal timing can markedly improve crop productivity and economic returns in organic systems.



Dashparni Ark preparation

Tamil Nadu (Coimbatore)

- Coimbatore (Humid Tropics): Field experiments in Coimbatore focused on ITKs for pest management in field crops (cotton, okra, and maize). The “3G extract” (a fermented mix of ginger, garlic, and green chili) emerged as a highly effective natural pesticide across all three crops. At 5% concentration, 3G extract consistently suppressed major sucking pests by ~50–73% and improved yields. In cotton, for example, 3G spray achieved up to 72% reduction in aphids and 64–74% reduction in jassids, thrips, and whiteflies, translating to a seed cotton yield of 2051 kg/ha, about 25.6% higher than the untreated control. Okra and maize showed similar benefits: okra yield reached ~12 t/ha with 3G treatment, and maize yield ~4.9 t/ha with a 56% fall armyworm reduction. Other ITKs tested (e.g. a *lantana-calotropis* leaf extract and a cow dung–urine mix) were less effective, confirming 3G extract as the best indigenous pest remedy for South Indian conditions. These findings are significant for natural farming in humid regions – farmers can adopt a simple kitchen-based recipe (grinding ginger, garlic, chili) to control pests instead of chemical pesticides. The low cost and multi-crop efficacy of 3G extract make it a promising component of natural farming pest management.

Sikkim (Gangtok)

- Gangtok (Hill/North-East Region): Sikkim, a fully organic state, has a rich tradition of ITKs which were scientifically validated under low-cost protected cultivation conditions. Cow dung and cow urine extracts – cornerstones of natural farming – proved effective as both fertilizers and pest deterrents. Farmers typically use a 10% concentration based on tradition. Experiments confirmed that all ITK treatments significantly increased vegetable yields over the control, and the 10%

“farmer’s practice” dose was near-optimal. For instance, in cabbage grown under poly-tunnels, foliar spraying of cow dung extract (10%) yielded 8.0 kg/m², more than double the control yield (3.8 kg/m²). Higher doses (15%) offered no extra benefit, while a lower 5% dose was inferior (about 22–28% less yield than the 10% dose). Likewise, cow urine @10% gave the best results in tomato, bottle gourd, and bitter melon, with yields ~8–11% higher than using 5% urine. These outcomes scientifically validate Sikkimese farmers’ practice of using moderate concentrations of cow excreta for boosting crop growth in natural farming.

- The Sikkim centre also validated a fermented botanical concoction used by local farmers for insect control. This ITK consists of *Agave* leaf extract (10%) + cow urine (5%) + crushed chili (2.5%), fermented for 3 days, and traditionally applied at 0.2% dilution to combat aphids and borers. Trial results showed that increasing the dose to 0.5% markedly improved efficacy: aphid infestations in tomato, French bean, and broccoli were 80–83% lower than control with the 0.5% spray, outperforming the standard 0.2% dose (which gave ~63–70% reduction). Yields of tomato and broccoli also rose with the higher dose. This indicates that farmers can enhance pest control by tweaking traditional formulas (in this case, using a slightly higher concentration) without resorting to chemicals. It also highlights the high potency of combined fermented plant extracts and animal urine in natural farming pest management.
- Beyond these trials, Sikkim’s indigenous practices themselves offer insights for natural farming. Farmers widely use wood ash, lime, and local herbs as organic pesticides and storage preservatives. For example, mixing wood ash (20 g/kg) into seed stocks of maize, pulses, and vegetables is a common ITK to prevent storage pests and moisture damage. Wood ash is also broadcast in vegetable fields to deter soil pests like ants, cutworms, and grubs. Farmers apply table salt, lime, and ash around crop bases to repel snails and leeches in humid areas. On orchards, Sikkimese farmers paint citrus tree trunks with lime or coat them with cow dung–mud slurry to prevent fungal gummosis and borer attack. They even insert bamboo pegs into borer holes as a physical barrier. These time-tested practices, now documented, enrich the repertoire of natural farming by providing eco-friendly, locally adapted pest management techniques well-suited for hilly ecosystems.

Key findings from Validation

- 3G extract @ 5%: 40–74% reduction in cotton sucking pests; yield gains in cotton/okra/maize.
- Teekha sat @ 5–10% and neem oil 0.5%: improved cabbage/cauliflower yields and economic returns.
- Dashparni/Brahmastra @ 10%: better for tomato & onion protection; higher yields and B:C ratio.
- Cow urine @ 10%: higher yields in tomato & cucurbits; cow dung extract 10–15% for cole crops.
- Storage protection: neem oil/NSKP 3% minimized damage at 90 days in maize/black gram.



In conclusion, scaling up Indigenous Technical Knowledge alongside scientific innovation will strengthen natural farming as a holistic approach. By treating farmers as knowledge partners and honoring their innovations, we can enrich modern sustainable agriculture. The evidence in this report sends a clear signal: embracing ITK is not looking backward, but rather taking forward the best of our heritage to build a more regenerative and self-reliant farming future. Each successful ITK practice incorporated into natural farming is a step toward healthier soils, safer food, empowered farmers, and an agro-ecological equilibrium that benefits all.

07

Farmer Participatory Validation of Natural Farming Practices

This report presents a comprehensive analysis of the farmer participatory validation program, initiated in 2020, which aimed to evaluate and integrate natural farming (NF) inputs into existing organic farming packages. The program assessed the performance of Natural Farming practices (T3) against conventional Farmers' Packages (T1) and the AI-NPOF Package (T2), focusing on key metrics such as yield, cost of cultivation, and net returns.

The findings indicate that Natural Farming generally offers a significant reduction in cultivation costs when compared to the AI-NPOF package. Furthermore, in most locations and cropping systems, NF practices demonstrated an improvement in yields and net returns over traditional farmer practices. The performance of Natural Farming is highly variable, exhibiting strong context-dependency across different agro-climatic conditions and specific cropping systems. This variability underscores the importance of tailored approaches for successful implementation.

The farmer participatory validation studies analyzed in this report were conducted under the Scheduled Caste Sub Plan (SCSP) and Special Tribal Component (STC) sub-plans, commencing in 2020. The overarching objective of these initiatives was to thoroughly evaluate natural farming practices with farmers participation. The program evaluated three distinct farming packages:

- **Farmers Package (T1):** This represents the conventional or semi-conventional practices adopted by local farmers. For instance, in the Bajaura tomato-cauliflower cropping system, this package specifically included “50% of RDF of NPK + 20 t FYM/ha,” indicating a reliance on a combination of synthetic fertilizers and farmyard manure.
- **AI-NPOF Package (T2):** This refers to a standardized organic farming package, developed under All India Network Programme on Organic Farming, aimed at providing a benchmark for optimized organic practices.¹
- **Natural Farming Practice (T3):** This package is characterized by the use of specific bio-inputs central to the natural farming philosophy, including “Beejamrit, Ghanajeevamrit, Jeevamrit, Neemastra, Brahmastra and Dashparni ark” besides mulching, intercropping *etc.* These inputs are designed to promote soil health and nutrient cycling through natural processes.

Natural Farming in Tamil Nadu showed a more nuanced yield performance, with crop-specific variations. For groundnut and fodder sorghum, NF consistently outperformed Farmers' Practice. NF groundnut yield (2048 kg/ha) was 25.8% higher than FP, and fodder sorghum yield (16830 kg/ha)

was 17.3% higher than FP. NF consistently delivered higher net returns than Farmers' Practice for groundnut/fodder sorghum and cotton/sorghum (Table 25).

Table 25. Comparative Performance of Farming Practices in Cropping Systems in Tamil Nadu (2020-2022)

Treatments	Metric	Kharif Crop (kg/ha)	Rabi Crop (kg/ha)
Farmers Package	Yield	1628 (Groundnut)	14350 (Sorghum)
	Yield	1228 (Cotton)	956 (Sorghum)
	Yield	1658 (Groundnut)	1388 (Sorghum)
AI-NPOF Package	Yield	2324 (Groundnut)	18560 (Sorghum)
	Yield	1854 (Cotton)	1950 (Sorghum)
	Yield	2422 (Groundnut)	1758 (Sorghum)
Natural Farming Practice	Yield	2048 (Groundnut)	16830 (Sorghum)
	Yield	994 (Cotton)	1250 (Sorghum)
	Yield	2168 (Groundnut)	1575 (Sorghum)

Natural Farming generally demonstrates an improvement in yield over traditional Farmers' Practices in most locations, including Coimbatore (groundnut, sorghum), Ranchi (rice, wheat), and Udaipur (maize, wheat). For instance, NF groundnut yield in Coimbatore was 30.8% higher than FP, and maize yield in Udaipur was 12.3% higher than FP.



Farmer participation in validation of different inputs at Coimbatore and Thiruvananthapuram

Key Findings

- The farmer participatory validation program has provided valuable initial insights into the performance of Natural Farming practices across diverse agro-climatic zones in India.
- Natural Farming: A Promising but Context-Dependent Approach: Natural Farming consistently demonstrates its ability to reduce the cost of cultivation when compared to the AI-NPOF package. This positions NF as a more economically accessible sustainable farming option,

particularly for farmers with limited resources or those seeking to reduce reliance on external, often expensive, inputs.

- In most validated locations, including Coimbatore, Gangtok, Ranchi, and Udaipur, NF has shown a positive impact, leading to improved yields and higher net returns when compared to traditional Farmers' Practices. This indicates its strong potential for enhancing farmer livelihoods and facilitating a transition away from conventional, potentially chemical-intensive, methods. Furthermore, the performance of NF is highly variable and appears to be crop-specific and location-dependent.

08

Future Strategies for Natural Farming Research, Adoption, and Market Access

1. Future Strategies for Natural Farming Research

- Develop location-specific Natural Farming (NF) protocols integrating indigenous technical knowledge (ITK) with scientific validation.
- Undertake multi-location, long-term trials to assess the sustainability, productivity, and resilience of NF systems across agro-climatic zones.
- Quantify ecosystem services of NF (carbon sequestration, biodiversity conservation, water use efficiency) through robust methodologies.
- Assess nutrient cycling and soil health dynamics under NF using advanced soil biology and chemistry tools.
- Integrate climate-resilient cropping systems and multi-tier farming models within NF frameworks.
- Promote participatory research involving farmers, scientists, and extension agencies for co-creation of NF solutions.
- Establish a digital NF knowledge repository for sharing validated protocols, case studies, and research findings.

2. Strategies to Enhance NF Adoption

- Strengthen capacity-building programs through Krishi Vigyan Kendras (KVKs), Farmer Field Schools, and exposure visits.
- Develop model NF farms and clusters to demonstrate best practices and economic viability.
- Leverage ICT tools, mobile apps, and AI-enabled advisory platforms to provide real-time NF guidance to farmers.
- Incentivize adoption through policy support, subsidies for NF input preparation units, and certification.
- Promote farmer producer organizations (FPOs) specializing in NF produce aggregation and marketing.
- Encourage youth and women participation in NF enterprises through entrepreneurship programs and micro-financing.

3. Strategies to Strengthen NF Market Access

- Create distinct branding and labelling for NF produce to build consumer trust and premium value.
- Establish direct marketing channels such as farmers' markets, farm-to-fork platforms, and e-commerce tie-ups.
- Facilitate public procurement of NF produce for mid-day meals, hospitals, and government institutions.
- Develop infrastructure for storage, grading, and packaging of NF produce to reduce post-harvest losses.
- Promote collective marketing through FPOs, cooperatives, and self-help groups (SHGs).
- Conduct consumer awareness campaigns on the health and environmental benefits of NF produce.

4. Cross-cutting Actions for Scaling NF

- Integrate NF promotion into national and state-level agricultural policies and climate action plans.
- Foster public-private partnerships (PPP) for investment in NF research, infrastructure, and marketing.
- Monitor and evaluate NF adoption and impact through measurable indicators and feedback loops.
- Encourage convergence of NF with organic, agroforestry, and integrated farming systems for holistic sustainability.

Protocols and Packages for Natural Farming

Protocols

Natural Farming involves a set of holistic and comprehensive practices from tillage to selection of crops & varieties, raising of crops, including management of on-farm inputs for realizing optimum productivity, economic advantage and improving soil health. The generic protocols for evaluation and demonstration of Natural Farming are described below.

1. Selection of Crops and Varieties: Natural farming promotes crop diversity having multiple crops grown simultaneously. A combination of cereals, legumes, fruits, vegetables along with trap/indicator crops such as marigold, okra, sunflower, etc, on bunds is preferred choice. Monocropping should be strictly avoided. Proven intercropping methods recommended for the region can be adopted. Generally, indigenous/traditional varieties are preferred; however, improved varieties of crops can also be used under natural farming. Seed and planting materials play a very important role in crop production and care should be taken to ensure quality seeds and planting materials from a reliable source.

2. Tillage and sowing: Reduced / no tillage needs to be adopted in all the seasons. During summer, no tillage is preferred for raising green manures or multi-variate crops. Shallow tillage of 10-15 cm depth is preferred during *kharif* and *rabi* seasons. Deep tillage practices should be avoided. Sowing can be done manually or by mechanical methods. Shallow seed drills for sowing of crops are preferred.

3. Cropping during summer/fallow period

3.a. Pre-Monsoon Dry Seeding (PMDS) (rainfed areas): PMDS is a system of sowing, tilling and tending the land wherein the farmer grows crops in non-farming seasons or whenever there is no crop cover on the land. This can be practiced before the advent of monsoon, during summer, after *Kharif* and before the beginning of the *Rabi* season. The PMDS involves raising 8 to 15 diverse crops, as mixed crops, creating some special conditions for the seed germination through the beejamrit seed coating and plant survival during the dry seasons. The mulching material, which would be spread across the field as part of PMDS, acts as the catalyst to harness the water vapour from the atmosphere that drops to the land surface in the form of early morning dew. The mulching material facilitates the percolation of the dew into the soil and prevents its evaporation again. Therefore, PMDS needs to be practiced during March-May/ June, followed by *Kharif* crops, Pre-*Rabi* Dry Sowing (PRDS) and *Rabi* crops. The crops grown in PMDS and PRDS are used, ultimately, as green manure, after obtaining intermittently, some cash income and food items and green fodder for animals.

3.b. Multi-variate cropping (irrigated areas): In general, the field is left fallow, or green manure crops such as *Sesbania aculeata*, *Sesbania rostrata*, sun hemp, etc., are grown during the summer period with conventional deep tillage operations. In natural farming, either green manuring crops such as *Sesbania aculeata*, *Sesbania rostrata*, sun hemp, moong or multi-variate cropping during the fallow period in irrigated areas should be practiced under no-till/reduced till to keep the soil covered, enhance the soil microbial activities through root exudates, and incorporate the biomass having varied C: N ratio to ensure a longer period of decomposition thereby extending the period of nutrient release.

Crops of different duration and nature (cereals, pulses, oilseeds, fibre, green manures) are to be grown in mixed under multi-variate cropping. Typically, a minimum of 09 crop seeds are to be mixed and broadcast during the summer or fallow period. About 25% of the seed rate of the sole crop is to be adopted for each crop. Before the main crop is sown or planted, the biomass from multivariate cropping needs to be incorporated into the soil after harvesting of economic produce, if any, from the system. The multivariate cropping helps to reduce soil-borne pathogens through annihilation and allelopathy, besides the other benefits.

4. Poly/Inter cropping: During the main seasons, such as *kharif*, *rabi* and other seasons also poly or intercropping is also advocated under natural farming. Proven intercropping practices can be adopted with recommended row ratios. Legumes are generally preferred as intercrops. Apart from this, trap crops such as marigold, okra, sorghum and indicator crops such as sunflower should also be grown in bunds and borders. Rice fields are not normally amenable to intercropping or mulching due to anaerobic conditions created through water inundation. In rice, under natural farming, practices such as intercropping of dhaincha, growing trap crops and legumes on bunds, and also mulching with *Azolla* should be adopted. Intercropping is practiced by simultaneously growing *Azolla* with rice and continuously harvesting as and when required, providing an additional source of income to the farmer. *Sesbania aculeata* and *Sesbania rostrate* can be intercropped in rice and incorporated after 30 to 35 days using cono weeders. Direct seeding machines for simultaneous sowing of rice and green manures are available. Use of green manure as intercrops in rice helps reduce the weed infestation and contributes for nitrogen fixation. The addition of green biomass also helps improve soil organic matter.

5. Concoctions (Beejamrit, Jeevamrit and Ghanajeevamrit) for active soil biology

Although many local and on-farm-based natural formulations or concoctions (mixtures) are used in chemical free farming approaches such as organic farming, *Panchagavya* farming, biodynamic farming, nateco farming, etc., the natural farming relies on on-farm prepared formulations or concoctions, among which the important ones used are seed invigoration through *Beejamrit*, re-invigorating the soil through *Jeevamrit* and *Ghanajeevamrit*. The preparation technique and detailed guidelines for the use of these formulations are described by Hari Om *et al.* (2024).

5.a. Beejamrit (Beejamrutha or Bheejamrutham) is a microbial paste made using 5 kg of fresh dung from desi cows, 5 liters of *desi* cow urine, 50-100 g of virgin soil (preferably from forests, banyan trees, or termite mounds), 50 g of calcium chloride, and 20 liters of water. The mixture is thoroughly stirred and fermented for 24 hours. It is used for seed dressing or dipping seedling roots. Seed dressing involves coating seeds with *Beejamrit* before sowing and drying them in the shade. *Beejamrit* has been shown to protect seeds and young seedling roots from soil-borne and seed-borne pathogens, reduce germination time, and enhance seedling vigor, leading to better growth. The application of beneficial microbes to seeds effectively places microbial inocula in the soil, positioning them to colonize seedling roots and protect them against soil-borne diseases and pests. Microbes improve seed germination, shoot and root length, seedling vigor, and crop performance. *Beejamrit* promotes root dry weight and root proliferation, enhancing nitrogen, nutrient, and water uptake by crop plants.

5.b. Ghanajeevamrit: Ghanajeevamrit is solid in form and is prepared using ingredients such as desi cow dung (150 kg), jaggery (1 kg), pulse flour (2 kg), virgin fertile soil for microbial culture (50-100g), and native/desi cow's urine as required.

Method 1: Mix well cow dung, jaggery, pulse flour and soil. Add a little bit of cow urine to it as needed. Dry the mixture in the shade for 2-4 days. Use in the field after drying and grinding well into small aggregates. It can be stored and used for 6 months.

Method 2: Take 1-1.5 quintal well rotten desi cow dung manure and sprinkle 8-10 liters of Jeevamrit on it. Mix well and use by broadcasting uniformly in the field. After preparing, keep it covered in the shade. It can be used for 6 months.

Method 3: Take 1.5 quintals of dry biogas slurry, a kilogram of jaggery, 2 kilograms of pulse flour and a handful of virgin soil. Mix these well and broadcast uniformly in the field. Ghanajeevamrit can also be prepared by sprinkling Jeevamrit solution on this slurry as per requirement. If Ghanajeevamrit is prepared by adding Jeevamrit solution, then there is no need to add jaggery, pulse flour and soil separately.

Method 4 (Best quality method): Make a pile of fresh cow dung partially dried up to 3-4 days up to a height of 1.5 feet. Size of the pile might be as per convenience (say 12x3 feet). Make holes with a wooden log at a distance of about 1 foot and fill up these holes with already prepared Jeevamrit. Turn the dung pile up and down after one week. Then again make the holes and fill up these holes with Jeevamrit and turn up the pile again after one week. This way this process is repeated 2-3 times. The Ghanajeevamrit will be ready in 30-35 days. Then after pounding it in small sized particles, it can be broadcast uniformly in the field or stored in shade after covering with gunny bags.

Generally, it is recommended to use 800 to 1000 kg per acre of land as a basal dose. However, this can be applied as top dressing also as per crop duration.

5.c. Jeevamrit (Jivamrita or Jeevamrita or Jeevamrutha or Jeevamrutham) is a fermented microbial culture made from on-farm ingredients: 10 kg of fresh dung from *desi* cows, 10 liters of aged desi cow urine, 1.5 kg of cane jaggery (sugar) or sweet fruit pulp, and 1.5 kg of pulse flour mixed in a barrel with 180 liters of water. A handful (50-100 g) of virgin soil from banyan tree areas, forests, or termite mounds is added as a local microflora inoculant. The mixture is stirred daily and fermented for 48 hours in the shade. During fermentation, aerobic and anaerobic bacteria in cow dung and urine multiply as they decompose the organic ingredients. Cane jaggery enhances fermentation, and pulse flour provides protein energy. *Jeevamrit* is ready after 3-4 days in summer and 6-7 days in winter and is applied to soil twice a month at a rate of 200 to 600 liters per acre, depending upon crops and soil conditions, either through irrigation water or as a foliar spray. Application of Jeevamrit or Ghanajeevamrit through drip or sprinkler irrigation is preferred. *Jeevamrit* acts as a catalyst, promoting soil microorganism activity, including earthworms, and making nutrients available to crops. Indigenous cow dung and urine produce the best *Jeevamrit* due to higher beneficial microbial populations.

6. Acchadana (Mulching of soil surface)

Natural farming promotes many types of mulching including (i) Soil mulching (tillage of the soil as normal, but to a reduced depth of 10-15 cm), (ii) Straw mulching (spread dried crop residues or straw from the previous crop), and (iii) Live mulching (raising diverse legume intercrops with cereals for supplying phosphorus, potassium, and sulphur to monocotyledons, such as rice, wheat, ragi, etc.). Crop residue mulching should be applied immediately after sowing of the crops to reduce germination of weeds in the field. Depending upon the crop residues, generally 5 to 7 tonnes are required to cover one ha area for all the crops except rice in which Azolla should be used as mulching material under natural farming. Mulching should be done in all seasons. Some of the leguminous cover crops which can be introduced in natural farming are spreading type cowpea, horse gram and calapagonium. Application of Jeevamrit through drip/micro irrigation has an accelerating effect on multi/relay crops and polythene mulching may also be recommended depending upon the soil condition and requirement.

7. Whapasa

Whapasa refers to the soil condition where a balanced concentration of water and air molecules exists in the crop root zone. Natural farming promotes this state of soil condition with the application of minimal amount of irrigation, reduced tillage, and enhanced soil humus due to residue mulching and addition of concoctions. By maintaining *Whapasa*, water use by crops can be reduced significantly. *Whapasa* soil condition in the crop root zone under field conditions is feasible through application of *Jeevamrit* using precision technologies such as micro irrigation systems, such as drip and sprinkler irrigation including sensors, controllers, etc., to deliver a measured quantity of water with *Jeevamrit* precisely in the vicinity of roots to achieve optimal soil-water-plant relations. Alternate furrow irrigation and surge irrigation can also be adopted. Flood irrigation should be avoided.

8. Weeding

Mandatory practices such as cover crops, intercropping, mulching with crop residues, polycropping etc, significantly reduce the weed infestation naturally under natural farming. Time and quantity of mulching play a very important role in reducing the weed infestation. Generally, dense mulching with crop residues immediately after sowing is preferred to manage the weeds effectively in the early stages of the crop. Non-Chemical weed management approaches such as hand weeding, shallow hoeing with tools, reduced spacing of crops, stale seed bed and other indigenous techniques can also practice as per need under natural farming.

9. Botanical concoctions for insect pest management

As such, natural farming promotes the use of various *kashaya* (decoctions) from locally sourced ingredients like cow urine, neem leaves, green chillies, garlic, tobacco, sour buttermilk, etc., to act as natural fungicides and pesticides. Some of the prominent ones used are *Agniastra*, *Bramhastra*, *Neemastra* and *Dashparni* ark. Prophylactic spray of these botanical concoctions every 15 days or in a month, depending upon the crops, is recommended under natural farming.



9.a. Agniastra is made by mixing 20 liters of cow urine with crushed tobacco powder (500 g), green chili (0.5 kg), garlic (0.25 kg), and neem leaves (5 kg). In a pot, add 20 liters of local cow urine, stir well, boil, cool, and ferment for 48 hours. After fermentation, filter the solution with a cloth. *Agniastra* spray effectively controls pests like leaf roller, stem borer, fruit borer, and pod borer. Take 6-8 liters of filtered solution and dissolve it in 200 liters of water and spray it on one acre of crop. It should be used within 3 months.

9.b. Brahmastra uses 10 liters of desi cow urine and a paste of neem, Pongamia (karanj), custard apple, castor, and datura leaves (2 kg each). The manually crushed paste is boiled until frothing appears, filtered, and fermented for 48 hours in shade, stirred twice daily. *Brahmastra* is sprayed at 6–8 liters per 200 liters of water for one acre and effectively controls sucking pests, fruit borer, and pod borer. After preparation, it should be used within one month.

9.c. Neemastra involves mixing 5 liters of desi cow urine, 1 kg of fresh cow dung, and 5 kg of neem leaf paste in 100 liters of water. Ferment the mixture for 48-96 hours, stirring twice daily, and filter with a cloth. *Neemastra* is effective against sucking pests and leaf-eating caterpillars. Prepared material is sufficient for one acre.

9.d. Dashparni ark: Dashparni ark preparation involves ingredients of water (200 liters), urine of native cow (20 liters), dung of native cow (2 kg), leaves of ten plants (Neem, Karanj, Castor, Sitaphal, Bael, Marigold, Tulsi, Dhatura, Mango, Aak etc.) 2.0 kg each, turmeric, asafoetida powder 500 g, ginger chutney 500g (heeng) powder 10 gm, dry ginger powder 200 gm, tobacco powder 1.0 kg, hot green chilli chutney 1.0 kg and desi garlic chutney 1.0 kg. Dissolve cow dung and cow urine well in water and keep it for 2 hours. Mix turmeric powder, ginger chutney and asafoetida powder well and keep it in the shade for 24 hours. Stir this mixture, mix dry ginger powder, tobacco powder, hot green chillies and deshi garlic chutney well and keep it for 24 hours. Crush the leaves of plants and press them into this mixture. Cover the mixture with a gunny bag and keep it for 30-40 days and stir it for 2-3 minutes in the morning and evening. Mix 6-8 liters of the extract of this solution in 200 liters of water and spray it on one acre of crop. Dashparni ark is used for control of borers, maggots/ caterpillars.

Botanical concoctions for disease management

10.a. Sonthastra: Ingredients for using in one acre include dry ginger 200 gm, desi cow's milk 5 liters and water 200 liters. Grind dry ginger and make powder. Mix it in 2 liters of water and boil it. Cool it when one liter is left. Boil 5 liters of indigenous cow's milk in a pot once. Cool the milk. Remove the cream of milk and use it domestically. Sieve the ginger water and boiled milk with the help of a cloth. After mixing in 200 liters of water, spray it on one acre of crop. It is used for the control of fungi.

10.b. Khatti lassi (Sour butter milk): Ingredients for one acre include water 100 liters, khatti lassi (3-5 days old) 5 liters, a small piece of copper, turmeric powder 50 gm. Keep the small piece of copper dipped for 3-5 days in khatti lassi. Mix water and khatti lassi well and spray it on the crop after dissolving 50g of turmeric powder in it. This is used to control fungal diseases. Also found to be a virus killer.

10.c. Use of cow urine: Apply 30-40 liters of cow urine along with pre-sowing irrigation for controlling soil and seed borne diseases. It also controls seedling and wilt diseases in plants. The 10-20% spray of cow urine helps in controlling canopy diseases of crops. While planting fruit crops, apply 10% urine (one liter of cow urine in 10 liter of water) in the pits filled with the mixture of soil and cow dung manure/ Ghanajeevamrit before planting orchard seedlings. After planting, occasional application of 10-20% cow urine protects the plant from bacterial and fungal diseases.

10.d. Saptdhanyankur ark: It is basically advocated to increase the grain shine and weight. The ingredients include 100 gm seeds each of sesame (oilseed), moong, urad, cowpea, moth, gram (5 types of pulse seeds) and wheat. Soak sesame seeds in a little water overnight in a bowl. On the second day, mix sesame, moong, urad, cowpea, moth, wheat, and gram seeds and soak them in water overnight. On the third day, after taking out all seven types of seeds from the water, tie them in a bundle in a coarse cotton cloth and hang them inside the house, and keep the water safe. Then after the seeds have sprouted, grind all the seeds and make them into a sauce (chutney). Prepare a mixture of 200 liters of water, 10 liters of cow urine and safe water of seeds. In this, with the help of your hands, mix the chutney of all seven types of seeds and stir it with the help of a wooden stick. After the solution is ready, cover it with a gunny bag and keep it for two hours. After that, filter it with a cloth. In this way, Saptdhanyakur extract (ark) is ready for use. Use this extract within 48 hours. This is to be used during the milk stage of grains, infancy of the fruit (small beans) and bud stage in flower crops. Use of Saptdhanyankur ark extract brings shine on the grains and reduces the dropping of flowers and fruits.

In addition to the above, depending upon the requirement, mechanical traps, pheromone traps, yellow sticky traps, bio-control agents such as *Trichoderma*, *Pseudomonas*, *Trichogramma*, *Bacillus*, etc, can also be used in the natural farming to manage insects and diseases in crops.

11. Harvesting: Sowing and harvesting can be done either manually or mechanically, depending upon the crops and availability of machinery.

Package of Practices

Based on the Multi-location Natural farming experimentation under the network project and stakeholder consultations, the details of cropping systems and practices tested under natural farming are given below.

1. Soybean + Maize-Wheat + Mustard for Chhattisgarh and Madhya Pradesh
2. Groundnut + Sesame - Fennel + Cabbage (Gujarat and Rajasthan)
3. Rice + Dhaincha - Maize + Cowpea (Maharashtra and Jharkhand)
4. Cassava + Vegetable cowpea (bush/non trailing type)-Green gram (Kerala)
5. Maize + fodder cowpea-wheat + chickpea (Uttar Pradesh, Punjab and Uttarakhand)
6. Soybean + Maize - Garden pea + Green coriander (Himachal Pradesh, Uttarakhand and Sikkim)
7. Cotton + greengram – Sorghum + chickpea (Karnataka and Tamil Nadu)
8. Turmeric + greengram -cowpea (Kerala and Meghalaya)

Details of cropping systems and practices under Natural farming

1. Cropping System: Soybean + Maize-Wheat + Mustard

Recommended states: Chhattisgarh and Madhya Pradesh

Pre-Kharif Season (Fallow period/summer)

Time/week/date	Crops/seed to be mixed	Quantity (kg/ha)	Tillage operation	Method of sowing	Date/time/week of incorporation
Last week of April	Maize	4 kg	1 harrow, One rotavator, one tiller for mixing seeds	Broadcasting	2 weeks before sowing of next crop
	Greengram	4 kg			
	Cowpea	6 kg			
	Clusterbean	4 kg			
	Sesame	1.25 kg			
	Sunhemp	5 kg			
	Marigold	0.5 kg			
	Okra	4 kg			
	Rice bean	4 kg			

9 crops for MVC , 25% of sole crop seed rate to be taken for MVC

Kharif season: Soybean + Maize (4:2)

Land preparation		2-3 Harrowing, 1 planking
Seed treatment		Seed treatment with Beejamrit
Sowing method		Drilled/line sowing
Row ratio		4:2 (Replacement series)
Mulching material		Unchopped Paddy straw / Wheat straw
Mulching quantity (t/ha)		6 t/ha
Mulching time (days after sowing)		Immediately after sowing of crop (ground cover)
Weed management		Need based weeding using chemical free methods
Basal	Source (Quantity on dry basis)	Ghanajeevamrit @ 1000 kg/ha
	Time of application	At the time of field preparation
Top dressing / foliar application	Source (Quantity)	Jeevamrit @ 1500 lit/ha
	Time of application	Twice in a month
Time		Twice in a month
Source (Quantity)		Alternate Application of Neemastra and Brahamastra
Trap crop in borders		Okra

Rabi season: Wheat + Mustard (8:2)

Land preparation		2 harrowing, 1 Planking, broad bed preparation
Seed treatment		Seed treatment with Beejamrit
Sowing method		Drilling/Line sowing
Row ratio		8:2 (Replacement series)
Mulching material		Unchopped Paddy straw / Wheat straw
Mulching quantity (t/ha)		6 t/ha
Mulching time (days after sowing)		Immediately after sowing of crop (Ground cover)
Weed management		Need based weeding using chemical free methods
Basal	Source (Quantity on dry basis)	Ghanajeevamrit @ 1000 kg/ha
	Time of application	At the time of field preparation
Top dressing / foliar application	Source (Quantity)	Jeevamrit @ 1500 lit/ha
	Time of application	Twice in a month
Time		Twice in a month
Source (Quantity)		Alternate Application of Neemastra and Brahmastra
Trap crops in borders		Marigold

2. Cropping System : Groundnut + Sesame (6:2) - Fennel + Cabbage (2:1)

Recommended states: Gujarat and Rajasthan

Pre-Kharif Season (Fallow period/summer)

Time/week/date	Crops/seed to be mixed	Quantity (kg/ha)	Tillage operation	Method of sowing	Date/time/week of incorporation
Last week of April	Maize	4 kg	1 harrow, One rotavator, one tiller for mixing seeds	Broadcasting	2 weeks before sowing of next crop
	Greengram	4 kg			
	Cowpea	6 kg			
	Clusterbean	4 kg			
	Sesame	1.25 kg			
	Sunhemp	5 kg			
	Marigold	0.5 kg			
	Okra	4 kg			
	Rice bean	4 kg			

9 crops for MVC , 25% of sole crop seed rate to be taken for MVC

Kharif season: Groundnut + Sesame

Land preparation		Direct sowing (Sowing with minimum soil disturbance)
Seed treatment		Seed treatment with Beejamrit
Sowing method		Ridge and furrow
Row ratio		6:2 (Replacement series)
Mulching material		Fennel straw (unchopped)
Mulching quantity (t/ha)		5 t/ha
Mulching time (days after sowing)		Immediately after sowing of crop (ground cover)
Weed management		Need based chemical free method of removing weeds
Basal	Source (Quantity)	Ghanajeevamrit @ 1000 kg/ha
	Time of application	At the time of field preparation
Top dressing / foliar application	Source (Quantity)	Jeevamrit @ 1500 lit/ha
	Time of application	Jeevamrit @ 1500 lit/ha/Twice a month (with irrigation or spray on soil)
Time		Twice in a month
Source (Quantity)		Alternate application of Neemastra and Dashparni
Trap crop in borders		Marigold and tulsi

Disease	Management	
	Groundnut	Sesame
Collor rot	Seed treatment with Trichoderma 6-8 g/kg seed	-
	Seed treatment with	
Tikka disease	Foliar spray of neem oil @ 2 ml/L water	-
Powdery mildew		Spray of 2 % garlic paste
Phyllody disease		Spray of 10 % Dashparni
Insect-pest		
White grub, Termite and leaf minor	Application of Neem cake 5 q/ha at sowing, Pheromone trap @ 25/ha for mass trapping of adults, Metarhizium@5g/L water, <i>Beauveria bassiana</i> @5g/L water Spray of 10 % Dashparni	-
Hawk moth, aphid, semilooper		Azadirachtin 1500 ppm @ 5 ml/L water, Metarhizium@5g/L water, Bt @ 2ml/ L water and spray of 10 % Dashparni

Rabi season: Fennel + Cabbage

Land preparation		Direct sowing (Sowing with minimum soil disturbance)
Seed treatment		Seed treatment with Beejamrit
Sowing method		Ridge and furrow
Row ratio		2:1 (Additive series)
Mulching material		Groundnut straw (Unchopped)
Mulching quantity (t/ha)		5 t/ha
Mulching time (days after sowing)		Immediately after sowing of crop (Ground cover)
Weed management		Need based chemical free methods
Basal	Source (Quantity)	+ Ghanajeevamrit @ 1000 kg/ha
	Time of application	At the time of field preparation
Top dressing / foliar application	Source (Quantity)	Jeevamrit @ 1500 lit/ha
	Time of application	Jeevamrit @ 1500 lit/ha/ Twice a month (with irrigation or spray on soil as per rainfall availability)
Time		Twice in a month
Source (Quantity)		Application of Neemastra/ Dashparni etc. (Alternate)
Trap crops in borders		Marigold and tulsi

Disease	Management through organic sources	
	Fennel	Cabbage
Powdery mildew	Spray of 2 % garlic paste	Spray of 2 % garlic paste
Insect-pest		
White grub, Termite and leaf minor	-	Pheromone trap @ 25/ha for mass trapping of adults, <i>Beauveria bassiana</i> @5g/L water, spray of 10 % Dashparni
Aphid	Azadiractin 1500 ppm @ 5 ml/ litre and spray of 10 % dashparni	-
DBM, aphid, tobacco caterpillar and semilooper	-	Pheromone trap @ 25/ha, Azadiractin 1500 ppm @ 5 ml/ L water, SLNPV 250 LE/ha, Metarhizium@5g/L water, Bt @ 2ml/liter and Spray of 10 % dashparni

3. Rice + Dhaincha - Maize + Cowpea

Recommended States: Maharashtra, Jharkhand

Pre-Kharif Season (Fallow period/summer)

Time/week/date	Crops/seed to be mixed	Quantity (kg/ha)	Tillage operation	Method of sowing	Date/time/week of incorporation
Last week of April	Maize	4 kg	1 harrow, One rotavator, one tiller for mixing seeds	Broadcasting	2 weeks before sowing of next crop
	Greengram	4 kg			
	Cowpea	6 kg			
	Clusterbean	4 kg			
	Sesame	1.25 kg			
	Sunhemp	5 kg			
	Marigold	0.5 kg			
	Okra	4 kg			
	Rice bean	4 kg			

9 crops for MVC , 25% of sole crop seed rate to be taken for MVC

Kharif season: Rice + Dhaincha

Practices		Complete Natural Farming
Land preparation		1 Harrowing, 1 planking
Seed treatment		Seed treatment with Beejamrit
Sowing method		Flat bed method Rice + Dhaincha (3:1 ratio)
Row ratio		3:1 (Replacement series)
Mulching material		Paddy straw
Mulching quantity (t/ha)		6 t/ha
Mulching time (days after sowing)		Immediately after sowing of crop (ground cover)
Weed management		No weeding
Basal	Source (Quantity)	Ghanajeevamrit @ 1000 kg/ha
	Time of application	At the time of field preparation
Top dressing / foliar application	Source (Quantity)	Jeevamrit @ 1500 lit/ha
	Time of application	Twice in a month
Time		Twice in a month
Source (Quantity)		Application of Neemastra/ Dashparni etc. (Alternate)
Other		Bird perches in field Pheromone trap

* Glyricidia Green leaf manuring (GGLM) for Karjat Centre

** Vermicompost for Ranchi Centre

Rabi season: Maize + Cowpea (Grain)

Practices		Complete Natural Farming (T2)
Land preparation		1 harrowing, 1 Planking, flat bed preparation
Seed treatment		Seed treatment with Beejamrit
Sowing method		Flat bed
Row ratio		Maize + Cowpea (Additive series)
Mulching material		Paddy straw (Unchopped)
Mulching quantity (t/ha)		6 t/ha
Mulching time (days after sowing)		Immediately after sowing of crop (Ground cover)
Weed management		No weeding
Basal	Source (Quantity)	Ghanajeevamrit @ 1000 kg/ha
	Time of application	At the time sowing
Top dressing / foliar application	Source (Quantity)	Jeevamrit @ 1500 lit/ha
	Time of application	Twice in a month
Time		Twice in a month
Source (Quantity)		Application of Neemastra/ Dashparni etc. (Alternate)
Trap crops in borders		Marigold

4. Cassava + Vegetable cowpea (bush/non trailing type)-Green gram

State: Kerala

Pre-kharif (Fallow period/summer)

Time/week/date	Crops/seed to be mixed	Quantity (kg/ha)	Tillage operation	Method of sowing	Date/time/week of incorporation
Last week of April	Pearlmillet	1.25 kg	1-2 harrow, One rotavator, one tiller for mixing seeds	Broadcasting	2 weeks before sowing of next crop
	Sorghum	5 kg			
	Cowpea	6.25 kg			
	Clusterbean	4.0 kg			
	Sesame	1.25 kg			
	Sesbania	10 kg			
	Sunhemp	10 kg			
	Greengram	4 kg			
	Marigold	0.5 kg			

9 crops for MVC , 25% of sole crop seed rate to be taken for MVC

Kharif season: Cassava + Vegetable cowpea

Practices		Complete Natural Farming (T2)
Land preparation		2-3 Harrowing, 1 planking
Seed treatment		Seed treatment with Beejamrit
Sowing method		Ridge and furrow
Row ratio		1:1 (Additive series)
Mulching material		Dry leaves
Mulching quantity (t/ha)		6 t/ha
Mulching time (days after sowing)		Immediately after sowing of crop (ground cover)
Weed management		No weeding
Basal	Source (Quantity)	FYM @ 250 kg/ha + Ghanajeevamrit @ 1000 kg/ha
	Time of application	At the time of field preparation
Top dressing / foliar application	Source (Quantity)	Jeevamrit @ 1500 lit/ha
	Time of application	Twice in a month
Time		Twice in a month
Source (Quantity)		Alternate application of Neemastra and Dashparni
Trap crop in borders		Okra

Rabi season: Green gram

Practices		Complete Natural Farming (T2)
Land preparation		2 harrowing, 1 Planking, broad bed preparation
Seed treatment		Seed treatment with Beejamrit
Sowing method		Ridges and furrow
Row ratio		Pure crop
Mulching material		Dry leaves
Mulching quantity (t/ha)		6 t/ha
Mulching time (days after sowing)		Immediately after sowing of crop (Ground cover)
Weed management		No weeding
Basal	Source (Quantity)	FYM @ 250 kg/ha + Ghanajeevamrit @ 1000 kg/ha
	Time of application	At the time of field preparation
Top dressing / foliar application	Source (Quantity)	Jeevamrit @ 1500 lit/ha
	Time of application	Twice in a month
Time		Twice in a month
Source (Quantity)		Application of Neemastra/ Dashparni etc. (Alternate)
Trap crops in borders		Marigold

5. Maize+cowpea – wheat + chickpea

State: Uttarakhand, Uttar Pradesh and Punjab

Pre-kharif (Fallow period/summer)

Time/week/date	Crops/seed to be mixed	Quantity (kg/ha)	Tillage operation	Method of sowing	Date/time/week of incorporation
Last week of April	Pearlmillet	1.25 kg	1-2 harrow, One rotavator, one tiller for mixing seeds	Broadcasting	2 weeks before sowing of next crop
	Sorghum	5 kg			
	Cowpea	6.25 kg			
	Clusterbean	4.0 kg			
	Sesame	1.25 kg			
	Sesbania	10 kg			
	Sunhemp	10 kg			
	Greengram	4 kg			
	Marigold	0.5 kg			

9 crops for MVC , 25% of sole crop seed rate to be taken for MVC

Kharif season: Maize + Cowpea

Practices		Complete Natural Farming (T2)
Land preparation		2-3 Harrowing, 1 planking
Seed treatment		Seed treatment with Beejamrit
Sowing method		Ridge and furrow
Row ratio		1:1 (Additive series)
Mulching material		Paddy straw (unchopped)
Mulching quantity (t/ha)		6 t/ha
Mulching time (days after sowing)		Immediately after sowing of crop (ground cover)
Weed management		No weeding
Basal	Source (Quantity)	FYM@ 250 kg/ha + Ghanajeevamrit @ 1000 kg/ha
	Time of application	At the time of field preparation
Top dressing / foliar application	Source (Quantity)	Jeevamrit @ 1500 lit/ha
	Time of application	Twice in a month
Time		Twice in a month
Source (Quantity)		Alternate pplication of Neemastra and Dashparni
Trap crop in borders		Okra

Rabi season: Wheat + Chickpea

Practices		Complete Natural Farming (T2)
Land preparation		2 harrowing, 1 Planking, broad bed preparation
Seed treatment		Seed treatment with Beejamrit
Sowing method		BBF (105 cm bed)
Row ratio		Two row of chickpea in between two rows of wheat on bed
Mulching material		Paddy straw (Unchopped)
Mulching quantity (t/ha)		6 t/ha
Mulching time (days after sowing)		Immediately after sowing of crop (Ground cover)
Weed management		No weeding
Basal	Source (Quantity)	FYM@ 250 kg/ha + Ghanajeevamrit @ 1000 kg/ha
	Time of application	At the time of field preparation
Top dressing / foliar application	Source (Quantity)	Jeevamrit @ 1500 lit/ha
	Time of application	Twice in a month
Time		Twice in a month
Source (Quantity)		Application of Neemastra/ Dashparni etc. (Alternate)
Trap crops in borders		Marigold

6. Soybean (Main crop) + Maize (Inter crop) - Garden pea (Main crop) + Green coriander (Inter crop)

States: Uttarakhand, Himachal Pradesh, Sikkim

Pre-kharif (Fallow period/summer)

Time/week/date	Crops/seed to be mixed	Quantity (kg/ha)	Tillage operation	Method of sowing	Date/time/week of incorporation
Last week of April	Pearlmillet	1.25 kg	1-2 harrow, One rotavator, one tiller for mixing seeds	Broadcasting	2 weeks before sowing of next crop
	Sorghum	5 kg			
	Cowpea	6.25 kg			
	Clusterbean	4.0 kg			
	Sesame	1.25 kg			
	Sesbania	10 kg			
	Sunhemp	10 kg			
	Greengram	4 kg			
	Marigold	0.5 kg			

9 crops for MVC , 25% of sole crop seed rate to be taken for MVC

Details	Kharif	Rabi/Summer
Cropping system	Soybean (Main crop) + Maize (Inter crop)	Garden pea (Main crop) + Green coriander (Inter crop)
Farming situation (Irrigated/ rainfed)	Irrigated	Irrigated
Row ratio (intercropping)	Main crop to Inter crop 2:1	Main crop to Inter crop 2:1
Spacing (main and inter crop)	Main crop 45 cm Inter crop 90 cm	Main crop 60 cm Inter crop 120 cm
Method of sowing/planting (Flat bed, BB, ridges & furrows etc)	Flat bed	Flat bed
NF Concoctions applied (name, quantity & time of application)	Beejamrit: Seeds were soaked before sowing Ghanajeevamrit @ 1000 kg /ha at sowing Jeevamrit @ 1500 litre/ ha / time twice a month Dashparni ark spray @ 5% at 30 & 45 DAS	Beejamrit: Seeds were soaked before sowing Ghanajeevamrit @ 1000 kg /ha at sowing Jeevamrit @ 1500 litre/ ha/ time twice a month Agniastara spray @ 2% at 30 & 45 DAS
Mulching material used and quantity (t/ha)	Wheat straw @ 5t/ha	Soybean straw @ 5t/ha

7. Cotton + greengram – Sorghum + chickpea

Recommended States: Karnataka and Tamil Nadu

Pre-kharif (Fallow period/summer)

Time/week/date	Crops/seed to be mixed	Quantity (kg/ha)	Tillage operation	Method of sowing	Date/time/week of incorporation
Last week of April	Pearlmillet	1.25 kg	1-2 harrow, One rotavator, one tiller for mixing seeds	Broadcasting	2 weeks before sowing of next crop
	Sorghum	5 kg			
	Cowpea	6.25 kg			
	Clusterbean	4.0 kg			
	Sesame	1.25 kg			
	Sesbania	10 kg			
	Sunhemp	10 kg			
	Greengram	4 kg			
	Marigold	0.5 kg			

9 crops for MVC , 25% of sole crop seed rate to be taken for MVC

Details	Kharif	Rabi/Summer
Cropping system	Cotton + Green gram	Sorghum + Chick pea
Farming situation (Irrigated/rain-fed)	Irrigated	Irrigated
Soil type	Sandy clay loam	
Row ratio (intercropping)	1:1	1:1
Spacing (main and inter crop)	75 x 45 cm	45 x 15 cm
Method of sowing/planting (Flat bed, BB, ridges & furrows etc)	Ridges & furrows	Ridges & furrows
NF Concoctions applied (name, quantity & time of application)	Beejamrit – Seed treatment Ghanajeevamrith @ 1000 kg/ha as basal Jeevamrit @ 1500 l / ha through irrigation twice a month Agniastra @ 3% at vegetative & Flowering stage for pest management	Beejamrit – Seed treatment Ghanajeevamrith @ 1000 kg/ha as basal Jeevamrit @ 1500 l / ha through irrigation twice a month Agniastra @ 3% at vegetative stage for pest management
Mulching material used and quantity (t/ha)	Millet straw – 5 t/ha	Cotton stalk – 5 t/ha

8. Turmeric + greengram -cowpea

State: Meghalaya and Kerala

Pre-kharif (Fallow period/summer)

Time/week/date	Crops/seed to be mixed	Quantity (kg/ha)	Tillage operation	Method of sowing	Date/time/week of incorporation
Last week of April	Pearlmillet	1.25 kg	1-2 harrow, One rotavator, one tiller for mixing seeds	Broadcasting	2 weeks before sowing of next crop
	Sorghum	5 kg			
	Cowpea	6.25 kg			
	Clusterbean	4.0 kg			
	Sesame	1.25 kg			
	Sesbania	10 kg			
	Sunhemp	10 kg			
	Greengram	4 kg			
	Marigold	0.5 kg			

9 crops for MVC , 25% of sole crop seed rate to be taken for MVC

Locations (State)	Umiam (Meghalaya)	
Details	<i>Kharif</i>	<i>Rabi/Summer</i>
Cropping system	Turmeric + Cowpea (1:1)	Green gram
Farming situation (Irrigated/ rainfed)	Rainfed	Irrigated
Row ratio (intercropping)	1:1	
Spacing (main and inter crop)	45 cm row to row	45 cm row to row
Method of sowing/planting (Flat bed, BB, ridges & furrows etc)	Flat bed	Flat bed
NF Concoctions applied (name, quantity & time of application)	Beejamrit + Ghanajeevamrit @ 1000kg/ha + Jeevamrit @ 1500 lit/ha + weed biomass as mulch @ 5t/ha (Neemastra & Agniastra for pest management)	Beejamrit + Ghanajeevamrit @ 1000 kg/ha + Jeevamrit @ 1500 lit/ha/irrigation twice in a month + weed biomass as mulch @ 5t/ha + Whapasa (irrigation in alternate furrows at noon) (Neemastra & Agniaster for pest management)
Mulching material used and quantity (t/ha)	Weed biomass as mulch @ 5 t/ha (fresh weight basis)	Weed biomass as mulch @ 5 t/ha (fresh weight basis)

Contact Address of AINP-NF Centres working on Natural Farming

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Principal Investigators at different Centres

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1.	Chhattisgarh	Raipur	Dr Adikant Pradhan, Chief Agronomist & Principal Investigator (AI-NPOF)	Indira Gandhi Krishi Vishwavidyalaya, Krishak Nagar, Raipur	9424270194 / 9098793896	raipur.npof@gmail.com
2.	Gujarat	Sardarkru- shinagar	Dr. L.J. Desai, Chief Agronomist & Principal Investigator (AI-NPOF)	Dantiwada Agricultural University, Sardar Krushinagar, Dist. Banaskantha	9429310273	sknagar.npof@gmail. com
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4.	Jharkhand	Ranchi	Dr. Sudhir Kumar Singh Assist Prof. & Principal Investigator (AI-NPOF)	Birsa Agricultural University, Kanke, Ranchi	9431970926	ranchi.npof@gmail.com
5.	Karnataka	Dharwad	Dr. B.H. Prasannakumar, Principal Scientist and Principal Investigator (AI-NPOF)	Institute of Organic Farming University of Agricultural Sciences, Krishinagar, Dharwad	9844640297	dharwad.npof@gmail. com
6.	Kerala	Calicut	Dr V. Srinivasan Principal Scientist and Principal Investigator (AI-NPOF)	ICAR-Indian Institute of Spices Research, Kozhikode (Calicut)	8075800023	calicut.npof@gmail.com
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Sl. No.	State	Location	Name & Designation	University / Institute	Phone no.	Email
9.	Madhya Pradesh	Jabalpur	Dr. V.K. Gupta, Principal Investigator (AI-NPOF)	Jawaharlal Nehru Krishi Vishwa Vidyalaya, Krishi Nagar Colony, Adhartal, Jabalpur	9893016099	jabalpur.npof@gmail.com
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11.	Meghalaya	Umiam	Dr. Neeraj Biswakarma, Scientist & Principal Investigator (AI- NPOF)	ICAR-RC-NEH Region. Umroi Road, Umiam, Meghalaya	7982726916	umiam.npof@gmail.com
12.	Punjab	Ludhiana	Dr S.S. Walia Director, School of Organic Farming & Principal Investigator (AI-NPOF)	School of Organic Farming, Punjab Agricultural University, Ludhiana	8146400134	ludhiana.npof@gmail.com
13.	Rajasthan	Ajmer	Dr. Shiv Lal, Sr. Scientist (Horticulture) & Principal Investigator (AI-NPOF) ICAR-NRCSS, Tabiji, Ajmer, 305206, Rajasthan, India	ICAR-National Research Centre on Seed Spices, Tabiji Farm, Beawar Road, Ajmer	9682359926	ajmer.npof@gmail.com shivcith@gmail.com
14.	Rajasthan	Udaipur	Dr. Ravikant Sharma, Director of Research & Principal Investigator (AI- NPOF)	Maharana Pratap University of Agriculture & Technology, Udaipur	9829321074	udaipur.npof@gmail.com
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Sl. No.	State	Location	Name & Designation	University / Institute	Phone no.	Email
17.	Uttarakhand	Almora	Dr. Amit Kumar, Scientist & Principal Investigator (AI-NPOF)	ICAR- Vivekananda Parvatiya Krishi Anusandhan Sansthan Mall Road, Almora	8527184228	almora.npof@gmail.com
18.	Uttarakhand	Pantnagar	Dr. D.K. Singh, Prof. & Principal Investigator (AI-NPOF)	Govind Ballabh Pant University of Technology and Agriculture, Pantnagar	9411320066	dhananjayrahul@rediffmail.com pantnagar.npof@gmail.com
19.	Uttar Pradesh	Modipuram	Dr. T.P. Swarnam, Head (OAS) & Principal Investigator (AI-NPOF)	ICAR- Indian Institute of Farming Systems Research, Modipuram, Meerut	8900911375	modipuram.npof@gmail.com
20.	West Bengal	Narendrapur	Dr. Gautam Chatterjee, Asst. Prof. & Principal Investigator (AI-NPOF)	SA&RD, RKMVU, PO Belur Math, District: Howrah	7980536428	gautam.ch@gm.rkmvu.ac.in

List of important Research/Review Papers Published on Natural Farming

1. Darjee S, Singh R, Dhar S, Pandey R, Dwivedi N, Sahu PK, Rai MK, Alekhya G, Padhan SR, Ramalingappa PL and Shrivastava M (2024) Empirical observation of natural farming inputs on nitrogen uptake, soil health, and crop yield of rice-wheat cropping system in the organically managed Inceptisol of Trans Gangetic plain. *Front. Sustain. Food Syst.* 8:1324798. doi: 10.3389/fsufs.2024.1324798
2. Ravisankar, N., V. Praveen Rao, J.K. Thakur, R. Krishnan, Meenu Rani, Himanshu Joshi, A.K. Prusty, M. Shamim, Meraj Alam Ansari, Raghuveer Singh, Raghavendra, KJ, T.P. Swarnam, Azad Singh Panwar, S. Bhaskar, Sunil Kumar and Rajbir Singh.2024. Science of Natural Farming: Proven Practices and their role in soil health and sustainability, *Journal of the Indian Society of Soil Science*, 72 (Special issue): 151-167
3. Sharma, SK, N. Ravisankar, N.K. Jain and S.K. Sarangi.2023. Natural Farming: Current status, research and case studies, *Indian Journal of Agronomy* 68 (XXII Biennial National Symposium Special issue):S1-S15
4. Shibasis Mukherjee, Aayushi Gupta, Rupsha Nandi, Argha Chakraborty, Aiwarya Bhattacharjee, Sukumal Sarkar, Krishnendu Ray, Sudipta Tripathi, N. Ravisankar and Gautam Chatterjee.2025. Exploring the microbial community dynamics of Jeevamrit reveals the multifaceted roles of the bacillus and Pseudomonas genera in nutrient availability and plant growth promotion in India's Zero budget natural farming, *Journal of Soil Science and Plant Nutrition*, <https://doi.org/10.1007/s42729-025-02500-1>
5. Shibasis Mukherjee, Suchana Sen, Md. Nasim Ali, Rupak Goswami, Argha Chakraborty, Krishnendu Ray, Rantim Bhattacharjee, Bhubaneswar Pradhan, N. Ravisankar, Gautam Chatterjee.2022. Microbiological properties of *Beejamrit*, an ancient Indian traditional knowledge, uncover a dynamic plant beneficial microbial network, *World Journal of Microbiology and Biotechnology*, 38 (111): 1-12

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★ ICAR-IIFSR

+ AI-NPNF (20)

0 190 380 760 Kilometers

ACZ	NPNF Centres (20 no's)
1	3
2	2
3	1
5	1
6	1
7	2
8	4
10	2

ACZ	NPNF Centres (20 no's)
1	3
2	2
3	1
5	1
6	1
7	2
8	4
10	2
12	3
13	1

1. Western Himalayan Region

- | | |
|------------------------------------|--------------------------------------|
| 1 Western Himalayan Region | 10 Southern Plateau and Hills Region |
| 2 Eastern Himalayan Region | 11 East Coast Plains & Hills Region |
| 3 Lower Gangetic Plain Region | 12 West Coast Plains & Ghat Region |
| 4 Middle Gangetic Plain Region | 13 Gujarat Plains & Hills Region |
| 5 Upper Gangetic Plain Region | 14 Western Dry Region |
| 6 Trans Gangetic Plain Region | 15 Island region |
| 7 Eastern Plateau & Hills Region | |
| 8 Central Plateau & Hills Region | |
| 9 Western Plateau and Hills Region | |
| | State boundary |