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Natural farming in rice cultivation: Implications for soil health, productivity, and profitability

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Abstract

Natural farming has emerged as a low-input, climate-resilient alternative to conventional rice cultivation, relying on locally derived formulations such as *Jeevamrit*, *Beejamrit*, *Ghanajeevamrit*, and *panchagavya* in place of synthetic fertilizers and agrochemicals. This review synthesizes findings of studies to evaluate the impact of natural farming on soil health, productivity and profitability of rice. Natural farming inputs, particularly when combined with organic amendments such as vermicompost, FYM, or biofertilizers, improved soil organic carbon, microbial abundance, and enzyme activity relative to conventional or unamended systems, while broadly sustaining nutrient availability despite the absence of synthetic fertilizers. However, natural farming inputs applied alone consistently produced only modest improvements in growth and yield over untreated controls or even lower yield than conventional farming. Despite these yield limitations, natural farming achieved higher net returns and superior benefit-cost ratios than conventional farming due to reduced expenditure on purchased fertilizers and plant-protection chemicals. This highlights that productivity of natural farming is strongly shaped by soil biological and nutrient dynamics and the importance of integration of natural farming practices to balance productivity and profitability in sustainable rice cultivation systems.

Keywords: Natural farming, rice, yield, profitability, soil health

1. Introduction

Rice (*Oryza sativa* L.) is the staple food for more than half of the world's population and forms the backbone of food security across Asia, including India, which ranks among the largest producers and consumers of rice globally. Meeting the escalating demand for rice, driven by population growth, has historically relied on intensive use of chemical fertilizers, pesticides, and high-yielding varieties introduced during the Green Revolution. While this approach boosted food grain production, it has also been linked to declining soil health, depletion of soil microflora, groundwater contamination, rising cultivation costs, and adverse effects on farmer and consumer health. These concerns have renewed global interest in ecological and low-input farming systems that can sustain productivity while restoring soil fertility and reducing dependence on external inputs.

Natural farming has gained particular attention as one such alternative. Rooted in the principles pioneered by Masanobu Fukuoka and later popularised in India as Zero Budget Natural Farming (ZBNF) by Subhash Palekar, natural farming emphasizes the use of on-farm and locally available resources such as *Jeevamrit*, *Beejamrit*, *Ghanajeevamrit*, and *panchagavya*, prepared largely from cow dung, cow urine, and other organic materials, in place of synthetic fertilisers and agrochemicals. These formulations are believed to enrich the soil microbial community and enhance nutrient cycling, thereby improving indicators of soil health such as organic carbon content, microbial abundance, and enzyme activity, while also promoting biodiversity. On this basis, natural farming is positioned as a low-cost, climate-resilient approach suited to small and marginal farmers, particularly in rainfed regions. Recognizing its potential, several Indian states, including Andhra Pradesh, Himachal Pradesh, Karnataka, and Gujarat, have launched large-scale programmes to promote its adoption, and national policy bodies have set ambitious targets for transitioning conventional farmland to organic and natural farming systems.

Despite this growing policy push, the scientific evidence on how natural farming performs relative to conventional and integrated nutrient management systems remains mixed. Several field studies suggest that natural farming inputs improve soil biological properties, including organic carbon build-up, microbial population, and enzyme activity, even in the absence of synthetic fertilizers. However, evidence on growth and yield performance is less consistent; while some studies report yields under natural farming comparable to or exceeding those under conventional practices, others indicate a persistent yield gap, particularly when natural inputs are applied alone, without any supplementary organic or inorganic nutrient source. This suggests that the productivity of natural farming systems may be closely tied to underlying soil biological and nutrient dynamics, and that integration with organic amendments such as vermicompost, farmyard manure, or biofertilizers could be key to narrowing this yield gap. At the same time, natural farming is widely believed to lower cultivation costs and improve farm profitability through reduced expenditure on purchased fertilizers and plant-protection chemicals, but the extent of this economic advantage, and whether it is sufficient to offset any yield shortfall, varies across studies, crops, and agro-climatic regions.

Given these inconsistencies, there is a need to consolidate existing evidence on the agronomic and economic performance of natural farming in rice cultivation. This review therefore examines the effects of natural farming inputs, both alone and in combination with organic amendments and reduced doses of chemical fertilizers, on soil health parameters, growth attributes, yield of rice, and evaluates the profitability of natural farming relative to conventional farming in terms of net returns and benefit-cost ratio. By synthesizing findings across diverse studies, this review aims to clarify the conditions, particularly the role of integration with organic and biological inputs, under which natural farming can serve as a productive and economically viable alternative for sustainable rice cultivation.

2. Effects on Rice Growth Parameters

Research indicates that rice growth parameters respond most strongly when natural farming inputs are combined with organic amendments or reduced doses of chemical fertiliser, while natural farming inputs applied alone tend to produce only modest gains.

Several studies point to the benefit of pairing natural farming formulations with organic amendments such as vermicompost and farmyard manure (FYM). Combined use of vermicompost and *jeevamrit* significantly enhanced rice growth, recording greater plant height, dry-matter accumulation and tiller number than FYM alone ^[1]. Likewise, another study observed that FYM and vermicompost applied together with *jeevamrit*, *beejamrit* and *panchagavya* improved plant height, leaf number and leaf area index relative to unmanured controls, suggesting that the benefit scales with the number of complementary organic and natural inputs integrated ^[2].

Similar gains were found when natural farming inputs are combined with reduced, rather than eliminated doses of chemical fertilizer. Liquid bioformulations applied with 75 per cent recommended NPK improved plant height and effective tillers over the unfertilized control ^[3]. A study reported a comparable trend at a higher fertilizer threshold: a 90 per cent fertilizer dose combined with *jeevamrit* and *beejamrit* seed treatment produced the greatest plant height, tiller density and panicle length, exceeding *jeevamrit* applied alone ^[4]. Together,

these findings indicate that even a modest retained fraction of synthetic nutrients can meaningfully amplify the growth response to natural farming inputs.

In contrast, natural farming inputs applied in isolation, without organic or inorganic supplementation, show a more limited growth response. A study found that a purely natural-farming treatment (*Beejamrit* + *Jeevamrit* + *Ghanajeevamrit*, without vermicompost or rock phosphate) performed only modestly better than the untreated control, and clearly underperformed a vermicompost + biofertilizer + rock phosphate combination, which recorded the tallest plants, highest tiller count and greatest dry matter accumulation at 45 DAT, 90 DAT and at harvest ^[5]. These findings suggest that the growth-promoting effect of natural farming is not intrinsic to the natural inputs alone but is strongly conditioned on their integration with organic amendments or a residual level of chemical fertility.

3. Effects on Yield Attributes and Productivity

The pattern observed for growth parameters extends to yield attributes and yield. Combinations of natural farming inputs with organic amendments or integrated nutrient management consistently outperform natural inputs applied alone, which in turn frequently fall short of conventional yields. Combined vermicompost and *jeevamrit* substantially raised grains per panicle, test weight, grain and straw yield, over FYM alone in black rice ^[1]. Similarly, 90 per cent recommended fertilizer combined with *jeevamrit* and *beejamrit* seed treatment produced markedly higher grains per panicle, test weight and grain yield than *jeevamrit* applied without fertilizer, indicating that *jeevamrit* alone cannot fully meet rice nutrient requirements, though moderate fertilizer reduction supplemented with *jeevamrit* can sustain productivity ^[4]. The recommended fertilizer dose combined with FYM substantially improved tiller number, filled grains, test weight, and yield compared with FYM combined with cattle urine alone, while comparable performance was achieved when FYM was replaced with an equivalent quantity of vermicompost or poultry manure along with *jeevamrit* ^[6]. Similarly, another study found that a purely natural-farming treatment (*beejamrit* + *jeevamrit* + *ghanajeevamrit*, without vermicompost or rock phosphate) underperformed the vermicompost + biofertilizer + rock phosphate combination in overall productivity ^[5].

Where natural farming inputs have been evaluated without any organic or inorganic supplementation, several farm-level studies report a marked yield gap relative to conventional systems, though the magnitude varies considerably across regions and cropping systems. A study recorded lower rice grain yield under natural farming (19.66 q/acre) than under conventional farming (25.02 q/acre), a gap of about 21 per cent ^[7]. Substantially larger decline of 74.49 per cent in paddy yield under natural farming compared to conventional systems ^[8]. In a rice-wheat + lentil system observed a steep yield drop under natural farming (2,247 kg/ha) relative to conventional farming (6,083 kg/ha), attributing the reduction to insufficient nutrient availability and greater weed competition in the absence of chemical inputs ^[9].

These findings reinforce that rice productivity under natural farming is strongly dependent on the extent of integration with organic or chemical nutrient sources. Where such integration is absent, the yield gap relative to conventional farming can range from moderate to severe, underscoring that natural farming inputs alone are generally insufficient to meet the nutrient demands of high-yielding rice.

4. Impact on Soil Health

4.1 Soil reaction

Natural farming practices appear to influence soil chemical properties primarily through the buffering action of the organic inputs applied, though the direction and magnitude of this effect vary across studies. Soil pH was significantly influenced by farming practices, with ZBNF recorded significantly higher pH than both organic and conventional farming systems. This increase was attributed to the regular application of organic amendments such as *jeevamrit*, *beejamrit*, and crop-residue mulch, which may help buffer soil acidity and create a more favorable soil environment [10]. A study evaluated the chemical composition of these inputs and reported that *beejamrit* is alkaline (pH 8.02) and relatively rich in nitrogen (2.38%) and potassium (0.485%), while *jeevamrit* is acidic (pH 4.92) and comparatively higher in phosphorus (0.173%) and micronutrients such as magnesium (46 ppm) and copper (51 ppm), suggesting that the two formulations may exert complementary, rather than uniform, effects on soil reaction depending on their relative proportions and frequency of application [11].

The soil pH under conventional farming to range from 6.49 to 7.15, compared with 6.42 to 7.56 under ZBNF, and electrical conductivity (EC) to range from 0.143-0.255 dS m⁻¹ under conventional farming against 0.142-0.272 dS m⁻¹ under ZBNF, indicating broadly comparable soil chemical properties between the two systems. These findings suggest that while natural farming inputs have the capacity to measurably shift soil reaction, particularly under sustained ZBNF management, this effect is not universally large enough to distinguish natural farming from conventional systems, and is likely mediated by input composition, application frequency, and site-specific soil buffering capacity [12].

4.2 Physical properties

Natural farming practices, particularly the use of crop residue mulch have also been linked to improvements in soil physical properties and moisture regime. A study reported consistently higher soil moisture content in ZBNF plots, attributing this primarily to the mulch layer, which reduced evaporation losses and enhanced moisture conservation [10]. Complementing these findings on mulch-driven moisture retention, a study examined the influence of different liquid organic and inorganic inputs on soil physico-chemical properties and reported an improvement in water-holding capacity ranging from 3.3 to 8.5 per cent, indicating that natural farming's liquid formulations can contribute to enhanced soil moisture retention [13]. Dead mulching with crop residues increases earthworm abundance by conserving moisture, buffering soil temperature fluctuations, and supplying a continuous source of organic material for feeding and reproduction, linking the physical effects of mulching to the biological improvements in soil health [14].

4.3 Soil chemical properties

4.3.1 Soil Carbon

The direct contribution of natural farming inputs to soil carbon appears limited, but their indirect effect on carbon stabilisation and microbial activity is more pronounced, particularly when combined with other organic sources. *Jeevamrit* and *beejamrit* themselves contain only small amounts of carbon and are therefore unlikely to directly raise soil carbon levels; however, by stimulating heterotrophic microbial activity and accelerating the breakdown of fresh plant residues, they can promote faster stabilisation of organic matter in the soil rather than causing any

long-term depletion of soil carbon [15].

Consistent with this stabilisation pathway, several studies report measurable increases in soil organic carbon (SOC) under natural farming, especially where multiple components are combined. The combined application of *ghanajeevamrit*, *jeevamrit*, and mulching recorded the highest SOC (1.08%) among the treatments evaluated, compared with 0.81% under the untreated control [16]. Similarly, combined application of green manure, farmyard manure (FYM), vermicompost, and rice crop residues significantly enhanced SOC (0.63%), alongside broader improvements in available nitrogen, phosphorus, potassium, micronutrients, and microbial population across agroecosystems. Both natural and organic farming enhanced microbial biomass and nutrient cycling in the rhizosphere, which could be attributed to addition of organic inputs such as FYM, which supply readily available carbon sources that stimulate microbial growth [17]. Similarly, a study found that residue retention, reduced tillage, and organic nutrient additions enhanced active carbon pools, microbial activity, and overall soil quality relative to conventional management [18].

4.3.2 Soil Nutrients

Alongside its effects on carbon dynamics, natural farming has also been evaluated for its capacity to sustain nutrient availability in the absence of synthetic fertilisers, with evidence pointing to broadly comparable, though not identical, nutrient status relative to conventional systems. A study found that combined application of green manure, FYM, vermicompost, and rice crop residues improved available nitrogen (403 kg ha⁻¹), phosphorus (63 kg ha⁻¹), and potassium (117 kg ha⁻¹), underscoring the value of integrating multiple organic sources for nutrient supply [17]. At a systems level, natural farming enhanced soil nutrient availability to levels broadly comparable with conventional farming despite the absence of synthetic fertilisers, with available phosphorus, potassium, and micronutrients such as iron, zinc, copper, and manganese showing no significant differences among ZBNF, organic, and conventional treatments. The exception was extractable nitrogen, which remained higher under conventional farming than under either ZBNF or organic systems, suggesting that while natural farming can sustain most nutrient pools through ecological cycling processes, nitrogen availability may remain comparatively more dependent on synthetic inputs [10].

Natural farming's liquid formulations have also shown potential to enhance nutrient availability when paired with reduced chemical fertilisation, highlighting the integration-driven benefits observed for growth and yield. Alemayehu [3] found that combined application of liquid bioformulation (LBF) with NPK fertigation improved nutrient availability and sustained the supply of nitrogen and phosphorus more effectively across the rice growing period than conventional fertilisation alone. Specifically, LBF combined with multiple-split NPK fertigation increased soil available N, P, and K by 16-46 per cent, 2-27 per cent, and 5-12 per cent respectively over initial levels during the summer season, and by 34-91 per cent, 16-75 per cent, and 39-50 per cent respectively during the rainy season, demonstrating that a substantial proportion of the recommended fertiliser dose could be replaced by LBF while still improving, rather than compromising, nutrient availability.

These findings support the observation that natural farming broadly sustains nutrient availability despite the absence of synthetic fertilisers, particularly for phosphorus, potassium, and micronutrients, while nitrogen supply appears more sensitive to the degree of integration with organic or reduced chemical

inputs reinforcing the recurring that the nutritional adequacy of natural farming, like its effects on growth and yield, is strongly conditioned on the extent to which it is combined with complementary nutrient sources.

4.4 Biological properties

Natural farming's most consistent soil benefit emerges in its effects on microbial populations, particularly when combined with other organic sources. The combined application of green manure, FYM, vermicompost, and rice crop residues significantly enhanced soil microbial populations, with green manure incorporation during the kharif season alongside FYM, vermicompost, and rice residues increasing bacterial counts by 139 per cent, fungal counts by 79 per cent, and actinomycete counts by 20 per cent relative to untreated soil [17]. A similar integration-driven benefit was reported that liquid organic manures combined with a reduced level of recommended fertiliser significantly enhanced bacterial ($2.3\text{--}3.31 \times 10^7$ cfu g⁻¹ soil), fungal ($1.32\text{--}3.41 \times 10^5$ cfu g⁻¹ soil), and actinomycete ($1.56\text{--}1.96 \times 10^8$ cfu g⁻¹ soil) populations at the critical growth stage relative to untreated soil, attributing the enhancement to the conducive microbial environment created by the liquid formulations [19].

Even where natural farming inputs were evaluated on their own, without additional organic amendments, they still produced measurable gains in microbial activity relative to untreated controls. Both organic and natural farming (*beejamrit* seed treatment with periodic *jeevamrit* and *ghanajeevamrit* application) significantly enhanced beneficial soil microbial populations in direct-seeded rice, with populations peaking at 60-90 days after sowing before declining slightly at harvest; organic farming recorded the highest fungal, actinobacterial, and nitrogen-fixing bacterial populations, while natural farming recorded the highest phosphate-solubilising microbial population and a comparably high fungal population, pointing to somewhat complementary microbial benefits between the two systems [20]. Similarly, a study found that *ghanajeevamrit*, *jeevamrit*, and mulching applied together substantially raised bacterial, fungal, and actinomycete populations over the untreated control across two cropping years, attributing the increase to the synergistic effect of these inputs in supplying microbial inoculum, readily available carbon, and favourable soil conditions [16]. At the systems level, a study reported that ZBNF, built on *jeevamrit* and *ghanajeevamrit*, recorded higher bacterial, fungal, and actinomycete populations than conventional farming, reinforcing that natural farming's cow-based formulations can enhance soil biological activity even in a direct comparison against synthetic-input systems. The largest microbial gains were recorded where natural farming inputs were combined with additional organic amendments [21]. The combined application of compost, vermicompost, and *panchagavya*, together with foliar liquid organic manure, produced significantly higher bacterial, fungal, and phosphorus-solubilising microbial populations than inorganic fertilisation alone, reinforcing that the addition of composted organic matter to natural farming formulations consistently strengthens the microbial response beyond what natural inputs achieve on their own [22].

4.4.1. Soil enzyme activity

Soil enzyme activity, a functional indicator of microbial metabolism, follows the same integration-dependent pattern observed for microbial populations. The highest dehydrogenase activity under combined *ghanajeevamrit*, *jeevamrit*, and mulching treatment (4.48 and 5.15 µg TPF g⁻¹ soil h⁻¹ across

two years), compared with the lowest activity under the untreated control (2.61 and 2.67 µg TPF g⁻¹ soil h⁻¹), attributing the increase to the combined effect of organic amendments and microbial inoculants in raising organic matter content, microbial biomass, and substrate availability for microbial metabolism [16]. This enzymatic and microbial enhancement appears to stem less from the direct nutrient content of natural farming inputs than from the beneficial microorganisms they introduce. A study found that although *jeevamrit* contained only low levels of directly available nitrogen, phosphorus, and potassium, it was rich in plant growth-promoting bacteria, including *Bacillus* and *Pseudomonas* species, which contributed to nutrient fixation, nutrient solubilisation, phytohormone production, and enhanced soil biological activity [23]. Similarly, another study reported that liquid formulations such as *panchagavya*, *beejamrit*, and *jeevamrit*, prepared from indigenous cow-derived products, carried high populations of beneficial microorganisms including *Azospirillum*, *Azotobacter*, phosphate-solubilising bacteria, *Pseudomonas*, lactic acid bacteria, and methylotrophs, alongside beneficial fungi and actinomycetes, which together enhanced soil biological activity and facilitated nutrient cycling and availability [24].

The studies thus indicate that natural farming formulations act primarily as microbial inoculants and biological catalysts rather than direct nutrient sources.

5. Economic Viability of Natural Farming

Natural farming's principal economic advantage lies in minimising or eliminating expenditure on purchased seed, fertilizer, and plant-protection chemicals, offering a low-input, climate-resilient alternative for small and marginal farmers, particularly in rainfed regions. Conventional farming was found to be markedly more cost-intensive, often pushing farmers into debt, whereas ZBNF supported by *beejamrit* and *jeevamrit* resulted in more favourable economic outcomes [25]. A study found that *ghanajeevamrit* and *jeevamrit* reduced nutrient-application costs and raised average net income to ₹43,859 ha⁻¹ with a benefit-cost ratio of 1.9, against ₹41,520 ha⁻¹ and 1.75 under conventional practice [26], while combined vermicompost and *jeevamrit* produced the highest benefit-cost ratio (1:6.7) among treatments evaluated in organic black rice, against 1:3.5 for FYM alone [1].

A study found that natural-farming adopters in Purulia district, West Bengal, achieved higher income than chemical-farming counterparts despite lower yield, with long-term sustainability shaped by agro-climatic and socio-economic factors [27]. Similarly, natural farming in Himachal Pradesh reduced cultivation cost by 14.3 per cent and raised net returns by 11.8-21.5 per cent over conventional farming [28]. A study reported that in Karnataka, homemade *jeevamrit* reduced material costs by around 24 per cent in paddy, with natural farming raising returns by up to 150 per cent and a benefit-cost ratio three to four times higher than under conventional practice; similarly, in Maharashtra, natural farming reduced variable costs by 13-24 per cent across major crops and raised the benefit-cost ratio by more than 15 per cent, despite only marginal gains in market price owing to the absence of dedicated markets for natural-farming produce [29]. A study reported that although natural farming incurred higher human labour costs (₹18,073.33 vs ₹16,425.00), its overall cost of cultivation was 15 per cent lower (₹40,164.98 vs ₹47,503.89), driven mainly by sharply reduced expenditure on fertilizers, chemicals, and FYM. Natural farming achieved 27 per cent higher net returns (₹16,224.35 vs ₹12,730.54) and a better return per rupee of expenditure (1.40 vs

1.27) than conventional farming, despite the yield disadvantage [7].

Studies indicate that the economic sustainability of natural farming is attributable primarily to reduced dependence on purchased inputs rather than to improved yield performance, across diverse agro-climatic regions.

6. Conclusion

The evidence reviewed indicates that natural farming's impact on rice cultivation cannot be assessed as a uniform practice, but rather depends heavily on the degree to which it is integrated with organic amendments or residual chemical inputs. When natural farming formulations such as *jeevamrit*, *beejamrit*, *ghanajeevamrit*, and *panchagavya* are applied in isolation, their effects on growth parameters and yield remain modest, and in many field-level studies rice productivity falls well short of conventional systems, with yield gaps ranging from moderate to severe depending on the region and cropping system. In contrast, combining these formulations with organic amendments like vermicompost, FYM, or biofertilizers, or with a reduced rather than eliminated dose of chemical fertilizer, consistently produces stronger outcomes in plant growth, yield attributes, and overall productivity, suggesting that natural inputs alone are generally insufficient to meet the full nutrient demands of high-yielding rice.

At the soil level, natural farming demonstrates more consistent benefits. It measurably improves biological indicators such as microbial abundance, enzyme activity, and soil organic carbon stabilisation, largely because its formulations function as microbial inoculants that stimulate nutrient cycling rather than as direct sources of nutrients. Physical properties such as moisture retention are also enhanced, primarily through associated mulching practices, while chemical properties like soil pH and nutrient availability remain broadly comparable to conventional systems, with nitrogen supply being the notable exception that stays more dependent on synthetic inputs.

Economically, natural farming shows a clear advantage. Across diverse studies and agro-climatic regions, it consistently lowers cultivation costs by reducing dependence on purchased fertilizers and agrochemicals, resulting in higher net returns and better benefit-cost ratios than conventional farming, even in cases where yields are lower. This suggests that the economic viability of natural farming stems primarily from input cost savings rather than superior productivity.

In conclusion, these findings suggest that natural farming holds strong potential as a low-cost, soil-health-enhancing, and climate-resilient strategy for rice cultivation, but achieving productivity levels comparable to conventional systems requires thoughtful integration with organic amendments or partial chemical fertilization rather than reliance on natural inputs alone. Future research and policy efforts should therefore focus on optimizing integrated nutrient management strategies that combine the ecological and economic strengths of natural farming with sufficient nutrient supplementation to close the existing yield gap, ensuring that natural farming can serve as both a productive and profitable alternative for sustainable rice cultivation.

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