Efficiency of plant nutrient enhancer for sustainable agriculture in diverse agro-ecosystem

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Summary

Agriculture is a dominant sector in India, thanks largely to the Green Revolution. Though it has enhanced agricultural production, productivity, and the country's economy, long-term studies show that synthetic fertilizers and agrochemicals injudiciously deplete soil fertility and disrupt the soil ecology. In this context, a few traditional farming practices (such as Homa farming, Biodynamic farming, Agroecological farming, Permaculture, and Natural farming, under the umbrella of "Organic farming") appear to be a viable alternative for resolving the majority of the problems associated with conventional input-intensive agriculture. Natural farming, in particular, is lately become a catchphrase amongst farmers, policymakers, and stakeholders. In its broadest meaning, natural farming is practicing agriculture that adheres to nature's laws by considering the balance of natural biodiversity around the farm to ensure the least disruption to agroecology. The nutrient management in natural farming practice broadly revolves around the management of plant nutrient enhancers *viz; Jeevamrut*, *Ghanjeevamrut and Beejamrut* coupled with other components like Achchhadan *(mulching)*, *and mix cropping*. Different farm-based fermented concoctions, named as *Jeevamrut*, *Ghanjeevamrut* and *Beejamrut*, are added to the soil or used to treat seeds to revitalize the soil microflora, and so to enhance soil fertility. The different studies revealed that nutritional and microbial analysis of the *Jeevamrut* exhibited the presence of different macro- and micro-nutrients and a large population of essential microbes including *Azotobacter* sp., *Actinomycetes* sp., and phosphate solubilizers. The microbial counts increased from its initial values with time as the incubation progressed. Different reviews have been reported for variations in the microbial counts (bacteria and fungi) as well as nutrient contents in the *Jeevamrut* prepared from different sources. Application methods of the *Jeevamrut* have also their impact on its efficiency. The solid form of the *Jeevamrut, Ghanjeevamrut*; also have great nutritional content and culturable microbial count compared to the *Jeevamrut* and FYM. The impact of application methods of a fermented concoction called *Beejamrut*, have also been varied for germination, vigor, and protection of seeds, seedlings, etc., from soil- and seed-borne pathogens, according to different studies.

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Introduction

An era of modern agriculture in India began from 1967, with the dominance of the Green Revolution–that which mainly characterized by monocropping systems and synthetic agrochemicals. No doubt that the green revolution has enhanced agricultural production and productivity and thereby the country's economy. It is very clear from Fig.1 that commodity-wise consumption of chemical pesticides in India is increasing from 2018-19 to 2020-21, however, it was reduced for almost all the commodities during 2021-22, might be thanks to awareness in farming community regarding ill-effects of their injudicious use. Studies showed that using synthetic fertilizers and agrochemicals lead to indiscreetly depletes soil fertility and disrupts the soil ecology resulting in to:

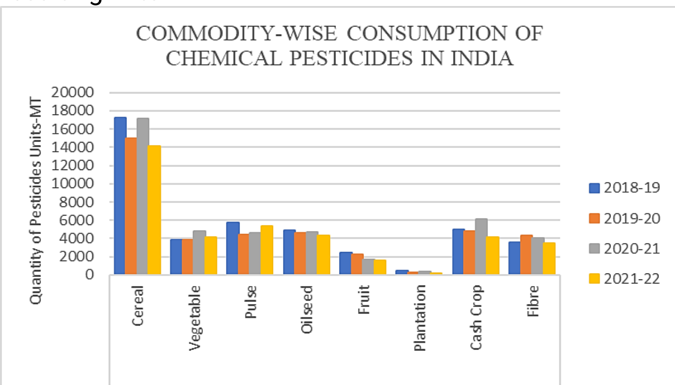

Figure 1. Commodity-wise consumption of chemical pesticides in India Source: *http://www.niti.gov.in*

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- compaction of soil structure, like a decrease in soil volume and porosity or an increase in soil bulk density, due to mechanical stress on soil from agricultural machinery traffic.
- Low organic matter content - e.g., Reduced presence of decaying organisms
- Poor water holding capacity – e.g., The amount of organic matter in the soil
- Increase in salinity, sodicity and land submergence - caused by extensive land clearing
- Adverse effect on flora and fauna of soil – Extensive use of fossil fuels, destruction of natural habitats, climatic changes, pollution
- Deterioration in factor productivity
- A problem associated with – Residual toxicity

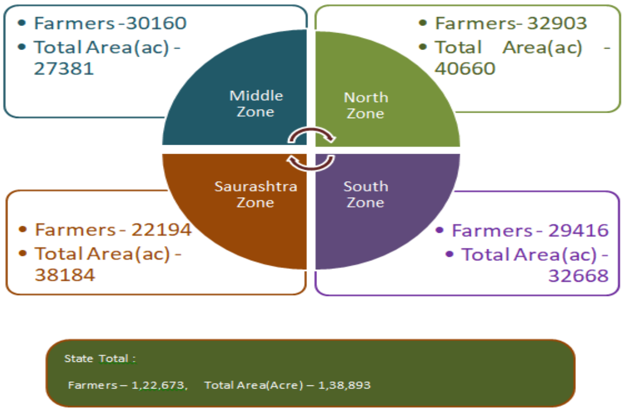

Figure 2. Scenario of natural farming in Gujarat

In this context, a holistic approach towards agriculture is a need of the hour, which take care of farming with the harmony of nature, food security and safety, advancement towards sustainability, cost-effective farming and empowerment of the farming community along with low input sustainable agriculture. Few traditional farming practices, such as *Homa* farming, Biodynamic farming, Agroecological farming, Permaculture, and Natural farming, under the umbrella of "Organic farming"; appear to be a viable alternative for resolving the majority of the problems associated with conventional input-intensive agriculture (Sarangthem et al. 2023; Bana et al. 2022).

Natural Farming

Natural farming, in particular, is lately become a catchphrase amongst farmers, policymakers, and stakeholders. In its broadest meaning, natural farming is practicing agriculture that adheres to nature's laws by considering the balance of natural biodiversity around the farm to ensure the least disruption to agroecology. According to NITI Aayog "Natural Farming is a chemical-free alias traditional farming method. It is considered as agroecology based diversified farming system which integrates crops, trees and livestock with functional biodiversity" (http://www.niti.gov.in), while FAO (1998) defined it as a method which uses holistic production management systems which promote and enhance agroecosystem health, including biodiversity, biological cycles and soil biological activity. The concept finds its roots in Japan, where it is called *shizen nōhō*, also referred to as "the Fukuoka Method", "the natural way of farming" or "do-nothing farming", established by Masanobu Fukuoka. Similar concepts of natural farming (*aka* zero-budget natural farming, ZBNF) have been strongly advocated in India by Shripad Dabholkar, Bhaskar Save, and Subhash Palekar. The natural farming practice broadly revolves around: *Jeevamrut*, *Ghanjeevamrut*, *Beejamrut*, *Achchhadan (mulching)*, *Waapsaa, and mix cropping*. Further, natural farming practices in India are centred on traditional indigenous practices, which reduce externally purchased inputs, use of on-farm biomass *i.e.*, biomass mulching, cow dung-urine formulations, periodic soil aeration, and exclusion of all types of synthetic chemical inputs and reduction of dependency on purchased inputs. Contrary to organic farming, no external organic inputs, such as biofertilizer, compost, or vermicompost, or exotic and expensive bioproduct, *etc.* are permitted in the NF practices.

In India, Government is promoting Natural Farming through schemes viz., *Paramparagat Krishi Vikas Yojana* (PKVY) and *Rashtriya Krishi Vikas Yoja*na (RKVY). In India and at the international level, scientists and farmers realize the importance and science behind the natural way of farming. In Gujarat, 1,22,673 farmers have already adopted natural farming covering 1,38,893 acres (https://naturalfarming.niti.gov.in, 2022, Figure 2).

The major challenges faced by farmers in natural farming can be classified into three major groups:

a. Plant Nutrient management
b. Plant protection management
c. Market management of natural produces

This paper aims to review the studies on the efficiency of plant nutrient enhancers for sustainable agriculture in diverse agro-ecosystem.

Plant Nutrient Enhancer

Table 1. *Jeevamrut:* Preparation and Composition

Ingredient	Quantity
Water	200 L
Cow Dung	10 Kg
Cow Urine	10 L
Pulse Flour	2 Kg
Jaggery	2 Kg
Soil	A handful
Dose: 500 L/ ha	

A plant nutrient enhancer is any substance or microorganism applied to plants with the aim to enhance nutrition efficiency, abiotic stress tolerance and/or crop quality traits, regardless of its nutrients content. According to the philosophy claimed by ZBNF practitioners, plants obtain 98% of their nutrients from the air, water, and sunlight. While only the remaining 2% can be met by soil and soil microorganisms (*https://ncof.dacnet.nic.in*). As a result, different farm-based fermented concoctions named as *Jeevamrut*, *Ghanjeevamrut* and *Beejamrut* are added to the soil or used to treat seeds to revitalize the soil microflora, and so to enhance soil fertility.

A. *Jeevamrut*

Briefly, the *Jeevamrut* is prepared (Table 1) by fermenting cow dung (10kg), cow urine (10 L), jaggery (2 kg), pulse flour (2 kg), and virgin soil (A handful) added and diluted in 200 L water, stir well clockwise for five minutes each in the morning and evening (Aulakh et al. 2013; Prakyath et al. 2022). The nutritional and microbial analysis of the *Jeevamrut* (Table 2) showed the presence of different macro- and micro-nutrients like N (1.96 kg/ha), P (0.173 kg/ha), K (0.280 kg/ha), Mg (46 ppm) and Cu (51 ppm) at 4.92 pH (Devakumar et al., 2014a). A large population of essential microbes including *Azospirillum* (2×10^6), PSM (2×10^6), *Pseudomonas* (2×10^2), *Trichoderma* (2×10^6), Yeast and molds (2×10^7) per mL of sample were reported by (Pathak & Ram 2013).

Table 2. Nutrient composition of *Jeevamrut* and *Beejamrut*

Samples	pH	kg/ha			ppm	
		N	P	K	Mg	Cu
Beejamrut	8.02	2.38	0.127	0.485	16	36
Jeevamrut	4.92	1.96	0.173	0.280	46	51
Cow urine	8.16	1.67	0.112	2.544	6.3	20
Cow dung	8.08	0.70	0.285	0.231	9.3	3.60
Pulse flour	6.70	1.47	0.622	0.910	12.6	12.40

Aulakh et al. (2013) studied *Jeevamrut* preparation from different sources like buffalo, Indian cow and crossbred cow and found that *Jeevamrut* prepared from Indian cow had the highest bacterial count (8.9×10^6), fungal count (1.3×10^4) and carbon (7.19 g/L). They also revealed that the microbial counts increased from their initial values with time as the incubation progressed (Table 3). When Aulakh et al. (2013) compared bacterial and fungi count under different nutrient sources under rice-wheat and maize-wheat cropping systems, they found the highest bacterial (23.2×10^6 and 20.5×10^6) and fungi count (27.6×10^3 and 33.7×10^3) under rice-wheat cropping system and maize-wheat cropping system, respectively with soil + foliar application of *Jeevamrut* at 500 L/ha compared to chemical fertilizer and FYM at 100 and 200 kg N/ha (Table 4).

Table 3. Microbial population and nutrient content in Jeevamrut

Parameter	*Jeevamrut* preparations		
	Buffalo	**Indian cow**	**Crossbreed cow**
	Microbial counts (*cfu* / mL)		
Bacterial count	2.6×10^6 (1.9×10^3)	8.9×10^6 (1.8×10^3)*	8.6×10^6 (1.8×10^3)
Fungal	1.1×10^4 (1.6×10^3)	1.3×10^4 (1.8×10^3)	1.4×10^3 (1.7×10^3)
	Nutrient content (g/L)		
Carbon	5.99	7.19	5.47
Nitrogen	0.22	0.04	0.60
Phosphorus	0.11	0.04	0.06
Potassium	1.09	0.28	0.75
Sulphur	0.46	0.43	0.39
*Figure in parenthesis shows initial values			

Table 4. Effect of *Jeevamrut* on soil microbial population (cfu/g soil)

Nutrient Source	Rice-wheat cropping systems		Maize-wheat cropping systems	
	Bacteria$\times10^6$	**Fungi$\times 10^3$**	**Bacteria$\times 10^6$**	**Fungi$\times 10^3$**
Chemical fertilizer	22.3	23.5	18.4	29.0
FYM at 100 kg N/ha	22.1	25.7	18.3	31.6
FYM at 200 kg N/ha	21.6	24.2	18.4	28.8
Unfertilized control	21.3	25.6	17.0	29.9
CD (P=0.05)	NS	NS	NS	NS
***Jeevamrut* (Soil + Foliar) at 500 L/ha**	23.2	27.6	20.5	33.7
Control	20.4	21.9	15.6	25.9
SEm±	1.35	1.52	0.99	1.46
CD (P=0.05)	NS	5.0	3.2	4.8

Devakumar et al. (2014) found that *Jeevamrut* was enriched consortia of native soil microorganisms. The preparation would give best results if it is used between 9th to 12th days after preparation (Table 5).

Table 5. Microbial population of *Jeevamrut* over the time after preparation

Microbes	Microbial Population (*cfu*/mL)									
	Days after Preparation									
	01	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**

Bacteria (10^5)	213	351	269	271	361	495	692	780	813	855
Fungi (10^4)	11	2	6	2	1	6	7	31	32	29
Actinomycetes (10^3)	1	1	1	1	1	2	1	9	12	8
N-Fixers (10^4)	34	29	16	46	23	09	20	27	63	69
P-Solubilizers (10^4)	61	60	12	48	37	53	61	48	50	80
	Days after Preparation									
	11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Bacteria (10^5)	843	727	447	526	562	551	402	367	339	292
Fungi (10^4)	36	17	08	21	18	14	17	06	05	04
Actinomycetes (10^3)	11	03	03	03	06	01	02	03	02	02
N-Fixers (10^4)	67	58	49	34	40	118	90	64	43	30
P-Solubilizers (10^4)	52	79	67	32	34	131	40	47	48	35

Soil application of the *Jeevamrut* at 500 L/ha in conjunction with other bio-inputs (i.e., FYM and foliar spray of *Panchgavya*) was shown to be an effective low-cost strategy for increasing groundnut pod production (Patel et al. 2018, Meena et al. 2018) Similarly, Prasanna et al. (2020) demonstrated that foliar sprays of fresh cow urine also increased the grain and stover yields of maize. However, the concentration and timing of the spray of cow urine are critical parameters to be considered, as demonstrated by Pavithra et al. (2021). The authors reported the highest rice grain production with the recommended fertilizer dose (RDF) with a single spray of 10% cow urine during the tillering stage. Boraiah et al. (2017) also showed that soil drenching of the *Jeevamrut* at the base of the plant recorded significantly higher capsicum fruit yields.

b. *Ghanjeevamru*

The *Jeevamrut* can be also applied in solid form, is termed as *Ghanjeevamrut*. It contains 100 kg cow dung (air-dried for 4-5 days) + 1 kg jaggery + 1 kg pulse flour + 3 L of cow urine and/or 2 L *Jeevamrut* + 250 g soil from undisturbed bunds/forest. These ingredients are mixed well and kept in shadow for 48 hours, then turned for 3-4 times a day. After 10 days of its preparation, this can be used in fields Prior to sowing @ 250 kg /ha as per recommended dose. Best until 6 months and store in cool and dry place (Vishnupandi & Thangaselvabai 2019; Das et al. 2020).

Table 6. Nutrient content by dry weight and microbial count of different inputs

Parameters	*Jeevamrut*	*Ghanjeevamrut*	FYM
Nitrogen (%)	0.28	1.47	0.52
Phosphorus (%)	0.17	1.28	0.25
Potassium (%)	0.20	0.90	0.44
Sulphur (%)	0.01	0.29	0.17
Microbial population (cfu/mL; cfu/g)	74.33×10^6	87.61×10^7	59.67×10^6
N-fixers (cfu/mL; cfu/g)	41.37×10^6	65.33×10^7	106.55×10^5
PSB (cfu/mL/; cfu/g)	83.55×10^6	40.00×10^7	89.37×10^5

Sharma & Chadak (2022) showed that the *Ghanjeevamrut* had the greatest nutritional content (1.47% N, 1.28 % P, 0.90%K and 0.29 % S) and culturable microbial count (Microbial population 87.61×10^7 cfu/mL; cfu/g, N-fixers 65.33×10^7 (cfu/mL; cfu/g, PSB 40.00×10^7 cfu/mL/; cfu/g) compared to the *Jeevamrut* and FYM (Table 6). Verma et al. (2021) observed that a combination of concoctions *Jeevamrut* + *Ghanjeevamrut* (1:1 ratio) along with 75% RDF, resulted in improved strawberry growth, yield and quality.

c. *Beejamrut*

Another fermented concoction, Beejamrut, is typically used to treat seeds, seedlings, and young plant materials to protect them from soil- and seed-borne pathogens (Pathak & Ram 2013; Sachin et al. 2019). Sreenivasa et al. (2010) recorded its role as N2 fixation, and P-solubilization (Table 7).

Table 7. Nutrient status and microbial loads in *Beejamrut*

Parameter	Sreenivasa et al. (2009)	Pathak & Ram (2013)	Organisms (*cfu*/mL)	Sreenivasa et al. (2009)	Pathak & Ram (2013)
pH	8.2	7.07	Bacteria	15.4×10^4	20.4×10^4
EC	5.5 dS/m	3.40 dS/m	Fungi	10.5×10^3	13.8×10^3
Total N	40 ppm	770 ppm	Actinomycetes	6.8×10^3	3.6×10^3
Total P	155 ppm	166 ppm	Phosphate Solubilizers	2.7×10^2	4.5×10^2
Total K	252 ppm	126 ppm	N_2-fixers	3.1×10^2	5.0×10^2
Total Zn	2.96 ppm	4.29 ppm			
Total Cu	0.52 ppm	1.58 ppm			

Total Fe	15.35 ppm	282 ppm			

According to Devakumar et al. (2014), a sharp drop in the microbial population in the *Beejamrut* indicated that using it on the same day as preparation would yield optimal results. (Table 8).

Table 8. Microbial population (cfu/mL) of *Beejamrut*

Days After Preparation	Bacteria (×10^5)	Fungi (×10^4)	Actinomycetes (×10^3)	N-fixers (×10^4)	P-solubilizers (×10^4)
1	623	22	2	71	52
2	435	11	2	40	42
3	371	11	1	39	34
4	259	9	2	39	34
5	208	2	1	28	25
6	190	2	1	19	20
7	171	1	1	15	10

Results presented in table 9 showed that inoculation of the bacterial isolates from the *Beejamrut* also resulted in improvement in seed germination, seedling length, and seed vigour in soybean Sreenivasa et al. (2010).

Table 9. Germination percentage, seedling length and vigour index of soybean seeds as influenced by inoculations of different bacterial cultures isolated from *beejamrut*

S. No.	Treatments	Germination %	seedling length (cm)	Seedling Vigour index
1	T_1- Inoculated with BJ1	95	14.68	2647
2	T_2- Inoculated with BJ2	93	14.9	2560
3	T_3- Inoculated with BJ3	90	14.62	2484
4	T_4- Inoculated with BJ4	90	15.96	2746
5	T_5- Inoculated with BJ5	99	17.11	3276
6	T_6- Inoculated with BJ6	95	14.81	2669
7	T_7- Inoculated with BJ7	98	17.05	3181
8	T_8- Uninoculated control	88	10.55	1864
S Em±		0.579	0.116	25.96
CD at 1%		1.756	0.352	78.75

Further, Khatri (2020) found that treating cauliflower seed with the *Beejamrut* significantly reduced the incidence of damping-off disease.

Table 10. Incidence of Damping-off disease in Cauliflower in different treatments

Treatments	Percentage Disease Incidence
Control	36.5 ± 1.5^{c}
Beejamrut at 100 mL	19.0 ± 1^{a}
Neem extract (10%)	28.0 ± 2^{bc}
Thiram at 2 g/L	18.0 ± 1^{a}
Onion extract (10%)	20.5 ± 2^{abc}
Garlic extract (10%)	22.5 ± 2.5^{ab}
P value	<0.001
CV%	9.04
LSD	3.28

Note: Seed treatment given 24 h before sowing; Control seeds were treated with clean water

Conclusion

Natural farming is an answer to the confronts like deterioration of natural resources concerning to soil, plant and human health, as well as climate change challenges. Plant nutrient management is one of the major constraints experiences by the farmers adopting natural farming. Use of plant nutrient enhancers like *Jeevamrut, ghanjeevamrut* and *beejamrut* not only satisfy the nutrient demand of the soil by enhancing soil microbial activities, but also make the plant capable of sustaining soil and airborne diseases and insect attacks. Their preparation and application methods, as well as their blending with one-another or other organic components, improve their efficiency.

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