



Evaluation of Integrated Nutrient Management Practices on Growth and Yield of Wheat (*Triticum aestivum* L.) under Northeastern Part of Rajasthan, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

An experiment was conducted during *rabi* season of 2023-24 to study the effect of organic and natural farming nutrient sources on growth and productivity of wheat. The experiment was laid out in randomized complete block design with 10 treatments and thrice in replication *viz.*, 100% RDN through chemical fertilizer, 75% RDN + 25% N through neem cake, 75% RDN + 25% N through neem cake + NP consortium, 75% RDN + 25% N through neem cake + *Jeevamrut* (500 lit/ha), 50% RDN + 50% N through neem cake, 50% RDN + 50% N through neem cake + NP consortium, 50% RDN + 50% N through neem cake + *Jeevamrut* (500 lit/ha), 50% RDN + 50% N through neem cake + NP consortium + *Jeevamrut* (500 lit/ha), 50% RDN + NP consortium + *jeevamrut* (500 lit/ha) and NP consortium + *Jeevamrut* (500 lit/ha). The results showed that application of 75% RDN + 25% N through neem cake + *Jeevamrut* (500 lit/ha) recorded significantly higher growth attributes, yield attributes and yield, and economics. The maximum grain and straw yield (6280 and 8854 kg/ha) was registered by application of 75% RDN + 25% N through neem cake + *Jeevamrut* (500 lit/ha) which was statistically at par with application of application of 100% RDN through chemical fertilizer, 75% RDN + 25% N through neem cake + NP consortium and 75% RDN + 25% N through neem cake as compared to NP consortium + *Jeevamrut* (500 lit/ha) (3885 and 3775 kg/ha) and 50% RDN + 50% N through neem cake + NP consortium + *Jeevamrut* (500 lit/ha), 50% RDN + 50% N through neem cake + *Jeevamrut* (500 lit/ha) and 50% RDN + 50% N through neem cake + NP consortium.

Keywords: Growth; *jeevamrut*; RDN; productivity; wheat.

1. INTRODUCTION

“Wheat (*Triticum aestivum* L.) $2n = 42$ being a major cereal crop has been cultivated in India and belong to family Poaceae, which account for about 60 per cent of world’s human energy requirement. Wheat is one of the most important staple food grain crops of India, which is the second leading producer of wheat next to China in the world (Usadadiya and Patel, 2013). In India, wheat is cultivated in 30.47 million hectares with total production of 106.84 million tonnes with average yield of 3507 kg/ha (DES, 2022). Wheat contributes more calories (20%) and more protein (11%), 2.7% minerals, 2% fiber, 1.7% fat, 60-70% carbohydrates to the world's diet than any other food crop” (Prasad, 2015). “Wheat is one of the world's most commonly consumed cereal grains. The important wheat growing countries are China, India, USA, and France. India ranks fourth in terms of area and production” (Igrejas and Branlard, 2020). “The cultivation of wheat in India is confined mainly to the states of Uttar Pradesh, Madya Pradesh, Punjab, Haryana, Rajasthan, Bihar, Gujarat and Maharashtra” (Tripathi and Mishra, 2017). Among all the states, Uttar Pradesh contributes maximum acreage and production; however, Punjab stands first with respect to average productivity followed by Haryana. In Rajasthan, wheat is mostly grown in Ganganagar, Hanumangarh, Alwar, Bundi, Baran and Jaipur districts.

Wheat is best grown as a *rabi* or winter season crop since the conditions during that time are conducive for growth and ensures maximum yield. In Rajasthan, wheat is grown in an area of 2.58 million hectares with total production of 9.48 million tones with average productivity of 3676 kg/ha” (DES, 2022). “The demand for food grain is expected to rise not only as a function of population growth but also as more and more people cross the poverty line with economic and social development. Integration of organic and inorganic fertilizer materials has been found to be promising not only in maintaining higher productivity of crops and for providing stability in crop production, besides, improving soil physical, chemical and biological conditions. Integrated nutrient management (INM) is practice where all the sources of nutrients namely organic, inorganic and bio-fertilizer as well as liquid organic manures can be combined and applied to soils so that crop growth is enhanced and we can get good yield with quality product. There are different organic sources like vermicompost, FYM, cakes, biofertilizers and various liquid organic manures like *jeevamrut*, *beejamrut etc*”. (Jat et al., 2015; Choudhary et al., 2024; Solanki et al 2022).

“Biofertilizers are also one of the important components in integrated nutrient management system. They are low cost and eco-friendly inputs, which have tremendous potential of fixing atmospheric nitrogen and can reduce the chemical fertilizer dose by 25-50%” (Pattanayak

et al., 2007). Neem cake is the residue obtained from neem seed kernels which have been crushed to extract the oil and contains approximate 5.5% N, 1.1% P and 1.5% K (Rao, 1987). "Liquid organic manure, *jeevamrut*, has the potential to play the role of promoting growth and providing resistance in the plant system. *Jeevamrut* consists of five products viz., cow dung, cow urine, pulse flour, jaggery and rhizospheric soil, it is used in widely for agriculture and horticultural crops. Application of *jeevamrut* in agriculture is a good option to supplement nutrient requirement of crops as it is easy to prepare, cost effective, easily available and eco-friendly. It is considered to be an excellent source of natural carbon, biomass, nitrogen, phosphorus, potassium, etc. like the other forms of manure, compost and vermicompost" (Sharma et al., 2024). "*Jeevamrut* established to be significant because it maintains the fertility of soil and also helps in enhancement of growth and development of plants. *Jeevamrut* also comes in one of the low-cost formulations which are responsible for the enhancement of soil with indigenous microorganisms required for better mineralization of soil and its helps in enhancement of growth of plant" (Gore and Sreenivasa, 2011) and (Singh and Lal, 2019). Devakumar et al., (2008) and Sreenivasa et al., (2010) have found the presence of many beneficial microorganisms viz., nitrogen fixers, phosphorus solubilizers, actinomycetes and fungi in *jeevamrut* and *beejamrut*. Usage of *jeevamrut* along with other manures can also prove to be beneficial.

2. MATERIALS AND METHODS

2.1 Experimental Site

A field experiment was conducted during *rabi* season of 2023-24 at Research Farm, School of Agricultural Sciences, Nirwan University, Jaipur (Rajasthan) with 76° 6' E longitude and 26°51' N latitude at an altitude of 380 meter above mean sea level. The region falls under Agro-climatic zone IIIa (Semi-Arid Eastern Plains Zone) of Rajasthan. The soil of experimental field is loamy sand, neutral alkaline in reaction with low in available nitrogen (250.13 kg/ha), medium in available phosphorus (26.05 kg/ha) and high in accessible potassium (415.04 kg/ha).

2.2 Experimental Details

The experiment was carried out in a randomized block design, comprising of 10 treatments combinations with thrice in replication (Table 1). Wheat variety RAJ 3037 was sown at 20 cm row spacing. Fertilizer application was made as per the treatments. Nitrogen in form of urea was applied 50% as a basal dose and remaining 50% in two splits at CRI and tillering stages. Phosphorus in the form of SSP was applied in full as a basal application @ 60 kg/ha. Whereas, bio-NP consortium was used for seed treatment (5 ml/kg) and soil application (1 lit/ha) along with first three irrigation as per treatments. Application of *jeevamrut* (500 lit/ha) at first three irrigation as per treatment. The net yield for seed and straw were recorded for each plot.

Table 1. Treatment details

Treatment no.	Treatment detail
T ₁	100% recommended dose of nitrogen (RDN) through chemical fertilizer
T ₂	75% RDN + 25% N through neem cake
T ₃	75% RDN + 25% N through neem cake + NP consortium
T ₄	75% RDN + 25% N through neem cake + <i>Jeevamrut</i> (500 lit/ha)
T ₅	50% RDN + 50% N through neem cake
T ₆	50% RDN + 50% N through neem cake + NP consortium
T ₇	50% RDN + 50% N through neem cake + <i>Jeevamrut</i> (500 lit/ha)
T ₈	50% RDN + 50% N through neem cake + NP consortium + <i>Jeevamrut</i> (500 lit/ha)
T ₉	50% RDN + NP consortium + <i>jeevamrut</i> (500 lit/ha)
T ₁₀	NP consortium + <i>Jeevamrut</i> (500 lit/ha)

The data were subjected to statistical analysis by appropriate analysis of variance as described by Gomez and Gomez (1984)

3. RESULTS AND DISCUSSION

Growth attributes: The plant height and dry matter accumulated by wheat at different growth stages (30, 60 DAS and at harvest) varied significantly among the treatments (Table 2). Significantly taller plants were recorded when application of 75% RDN + 25% N through neem cake + *Jeevamrut* (500 lit/ha) was done at 30, 60 DAS and at harvest. Though this treatment was found to be statistically at

par with 100% RDN through chemical fertilizer, 75% RDN + 25% N through neem cake + NP consortium and 75% RDN + 25% N through neem cake. Further data illustrated in Table 1 indicated that dry weight at harvest significantly increased with the application of 75% RDN + 25% N through neem cake + *Jeevamrut* (500 lit/ha) at harvest which was statically at par with application of 100% RDN through chemical fertilizer, 75% RDN + 25% N through neem cake + NP consortium and 75% RDN + 25% N through neem cake.

This might be due to organic manure can be attributed to the slow release of nitrogen and the increased availability of micro and macronutrients found in neem cake, which aid in the production of new meristematic tissues. Additionally, neem cake contains NPK (nitrogen, phosphorus, potassium) micronutrients that play a vital role in various metabolic activities of plants and serve as catalysts in activating several enzymes. Liquid organic manures contain microbial populations and plant growth-promoting substances that help improve plant growth and metabolic activities. Organic manure helps in decomposition, promotes an increase in the soil microbial population, and affects the growth of crops. The combined use of neem cake, a form of organic manure, and inorganic fertilizer will increase nutrient use efficiency and reduce environmental stress. These results are closely conformity by Shivkumar et al. (2011), Verma et al. (2018), Neelam et al. (2015), Gore and Shreenivaasa (2011) and Shahu et al. (2024).

Yield attributes: Among the various treatments, the highest number of effective tillers per square meter was recorded under the application of 75% RDN + 25% N through neem cake + *Jeevamrut* (500 L/ha) (Table 3). This was statistically at par with the treatment involving 100% RDN through chemical fertilizer. The results indicate that integrating organic amendments with chemical fertilizers enhances tillering capacity, possibly due to improved nutrient availability and soil microbial activity. In contrast, the lowest number of effective tillers (41.33) was observed in NP consortium + *Jeevamrut* 500 L/ha, which lacked sufficient nutrient supplementation, leading to reduced tillering ability. Spike length followed a similar trend, with the maximum spike length of 10.41 cm observed in 75% RDN + 25% N through neem cake + *Jeevamrut* (500 L/ha), which was statistically on par with 100% RDN through chemical fertilizer and 75% RDN + 25% N through neem cake + NP consortium. However, the lowest spike length (7.42 cm) was recorded in NP consortium + *Jeevamrut* (500 lit/ha). The improvement in spike length with 75% RDN + 25% N through neem cake + *Jeevamrut* (500 lit/ha) can be attributed to the balanced nutrient supply, particularly nitrogen from neem

cake and *Jeevamrut*, which promoted better plant growth and development. Similar findings were reported by Javiya et al. (2019) and Verma et al. (2018), highlighting the role of organic and biofertilizer amendments in enhancing crop growth. The highest number of spikelets per plant and grains per spike were obtained in 75% RDN + 25% N through neem cake + *Jeevamrut* (500 lit/ha), which was significantly superior to most other treatments. The increase in these attributes suggests improved nutrient translocation and reproductive efficiency due to the integration of organic and inorganic nutrient sources. The lowest values for these parameters were recorded in NP consortium + *Jeevamrut* (500 lit/ha), reflecting the insufficient nutrient supply for optimal spikelet and grain formation. Test weight, an indicator of grain quality, was significantly influenced by different treatments. The highest test weight was recorded in 75% RDN + 25% N through neem cake + *Jeevamrut* (500 lit/ha), which was statistically comparable to 100% RDN. The increased test weight under these treatments is attributed to improved grain filling due to balanced nutrient availability. On the other hand, the lowest test weight was observed in NP consortium + *Jeevamrut* (500 lit/ha), likely due to suboptimal nutrient uptake affecting grain development.

This might be due to overall improvement in vigor and crop growth as explained in preceding paragraphs due to organic compounds like plant nutrients and polysaccharides released during the decomposition of organic matter, which leads to an increased number of crop leaves and tillers. Combined effect of organic manure, biofertilizers and chemical fertilizers in balanced proportions, which play a very important role in decomposition and the easy release of different nutrients. Their uptake by the crop results in higher dry matter accumulation and its translocation to different plant parts, enhancing growth and yield parameters, ultimately leading to higher yields. *Jeevamrut* contains major and micronutrients that are rapidly available, easily absorbed, and help in the faster growth and development of plant components. Similar result finding by Desai et al. (2015), Dalvi et al. (2020) and Naik et al. (2024).

Yield: The study found that the application of 75% RDN combined with 25% nitrogen from neem cake and *Jeevamrut* resulted in the highest grain and straw yield, comparable to 100% RDN through chemical fertilizers and 75% RDN + 25% N through neem cake + NP consortium. The enhanced yield under these treatments is attributed to better nutrient availability, improved soil properties, and microbial activity promoting efficient nutrient uptake. Conversely, the lowest grain and straw yields were observed in the NP consortium + *Jeevamrut* treatment, where the absence of inorganic nutrient supplementation limited crop growth and productivity. Similarly, biological yield followed the same trend, with T₄ achieving the highest biomass accumulation due to improved physiological and metabolic functions resulting from the synergy of organic and inorganic nutrients. Interestingly, while the harvest index was not significantly affected across treatments, T₁₀ recorded the highest value despite its low biological yield, indicating a greater proportion of grain relative to total biomass. On the other hand, T₅ exhibited the lowest harvest index, suggesting inefficient biomass partitioning. Organic amendments act as a reservoir of essential nutrients, improving soil structure and microbial activity, which in turn promotes vegetative growth, tillering, and assimilate accumulation. Additionally, *Jeevamrut* contributes growth-promoting substances, further supporting yield enhancement. These findings are consistent with previous studies conducted by Yadav et al. (2009), Kumar et al. (2012), Shah and Kumar (2014), Neelam et al. (2015) and Dalvi et al. (2020) which emphasize the benefits of integrated nutrient management in sustainable crop production.

Economics: The economic viability of different nutrient management practices was evaluated based on cost of cultivation, gross returns, net returns, and benefit-cost (B:C) ratio (Table 5). The highest gross returns (₹185,570 ha⁻¹) and net returns (₹141,760 ha⁻¹) were recorded under the application of 75% Recommended Dose of Nitrogen (RDN) + 25% N through neem cake + *Jeevamrut* (500 L/ha). This treatment also exhibited a favorable benefit-cost ratio (3.24), indicating its economic feasibility. The second-highest net returns (₹152,390 ha⁻¹) and the highest benefit-cost ratio (5.89) were observed in the treatment with 100% RDN through chemical fertilizers, which had a lower cost of cultivation (₹25,860 ha⁻¹), making it the most cost-effective approach. The treatment involving 75% RDN + 25% N through neem cake + NP consortium also demonstrated economic viability, with net returns of ₹130,033 ha⁻¹ and a benefit-cost ratio of 3.02. Conversely, the lowest net returns (₹57,463 ha⁻¹) and the lowest benefit-cost ratio (1.03) were recorded in 50% RDN + 50% N through neem cake + *Jeevamrut*, primarily due to its high cost of cultivation (₹55,750 ha⁻¹) and lower yield performance. Similarly, treatments T₆ and T₇, which involved higher organic inputs, resulted in relatively low benefit-cost ratios of 1.05 and 1.10, respectively, due to increased production costs. Among the lower-cost treatments, NP consortium + *Jeevamrut* had the lowest cost of cultivation (₹22,600 ha⁻¹) but yielded lower gross returns (₹88,288 ha⁻¹), resulting in moderate net returns (₹65,688 ha⁻¹) and a benefit-cost ratio of 2.91. Similarly, 50% RDN + 50% N through neem cake + NP consortium exhibited a reasonable benefit-cost ratio (2.84) due to its lower input costs.

Table 2. Effect of integrated nutrient management on plant height and dry matter accumulated by wheat

Treatments	Plant height (cm)			Dry matter accumulated (g m ⁻²)		
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest
T1	22.86	68.65	111.24	63.3	221.3	514.7
T2	22.20	67.93	103.43	60.0	217.7	475.7
T3	22.35	68.18	108.48	60.8	218.9	500.9
T4	25.65	72.85	119.56	77.3	238.9	556.3
T5	20.92	60.12	96.81	53.6	178.6	442.6
T6	21.26	61.43	97.45	55.3	185.2	445.8
T7	21.85	63.10	98.12	58.3	193.5	449.1
T8	21.92	65.57	100.65	58.6	205.9	461.8
T9	20.15	58.94	94.20	49.8	172.7	429.5
T10	18.64	50.16	86.45	42.2	133.8	390.8
SEm±	1.12	2.65	5.66	5.6	12.9	28.3
LSD	3.33	7.88	16.81	16.7	38.5	84.1

Table 3. Effect of integrated nutrient management on yield attributes of wheat

Treatments	No. of effective tillers (No. m ⁻²)	Spike length (cm)	Spikelets per plant (No.)	Grains per spike (No.)	Test weight (g)
T1	97.00	9.13	9.63	44.62	44.55
T2	88.00	8.68	8.68	39.44	43.60
T3	91.00	8.76	9.13	40.70	43.75
T4	104.00	10.41	10.38	47.25	45.10
T5	63.00	7.62	7.82	36.10	41.40
T6	69.00	7.69	7.89	36.42	43.42
T7	72.00	7.74	8.54	38.72	43.46
T8	77.00	7.76	8.59	38.83	43.58
T9	60.00	7.55	7.65	35.84	41.35
T10	41.33	7.42	7.40	33.55	39.85
SEm±	6.19	0.59	0.52	2.64	1.54
LSD	18.4	1.78	1.54	7.83	4.57

Table 4. Effect of integrated nutrient management on yield of wheat

Treatments	Grain yield (kg ha ⁻¹)	Straw yield (kg ha ⁻¹)	Biological yield (kg ha ⁻¹)	Harvest index (%)
T1	6020	8560	14580	41.28
T2	4990	8245	13235	37.80
T3	5825	8400	14225	41.12
T4	6280	8854	15134	41.26
T5	3475	7005	10480	32.94
T6	3840	7150	10990	34.80
T7	3935	7610	11545	34.08
T8	4026	8065	12091	33.17
T9	3420	4830	8250	41.59
T10	3085	3775	6860	44.73
SEm±	438	450	525	3.46
LSD	1303	1339	1562	NS

Table 5. Effect of integrated nutrient management on economics of wheat

Treatments	Cost of cultivation (₹ ha ⁻¹)	Gross returns (₹ ha ⁻¹)	Net returns (₹ ha ⁻¹)	Benefit cost ratio
T1	25860	178250	152390	5.89
T2	42310	153500	111190	2.63
T3	43030	173063	130033	3.02
T4	43810	185570	141760	3.24
T5	55750	113213	57463	1.03
T6	59470	122150	62680	1.05
T7	60250	126588	66338	1.10
T8	44140	130910	86770	1.97
T9	26300	101100	74800	2.84
T10	22600	88288	65688	2.91

4. CONCLUSION

It can be concluded that for achieving higher grain yield and net returns in wheat cultivation while maintaining soil health, fertilization should be carried out either with 100% Recommended Dose of Nitrogen (RDN) (120 kg N) through chemical fertilizers or with an integrated

approach of 75% RDN (90 kg N) from chemical fertilizers combined with 25% nitrogen from neem cake. This should be supplemented with either Jeevamrut (500 liters per hectare applied during the first three irrigations) or NP consortium (1 liter per hectare applied as a soil drench during the first three irrigations). These nutrient management practices ensure improved nutrient

availability, enhanced soil microbial activity, and better crop productivity while promoting sustainable agricultural practices.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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