***Original Research Article***

**Optimizing Jeevamrutha Fermentation and Application Rates for Enhanced Microbial Activity and Sustainable Rice Production**

**ABSTRACT**

This study investigates the optimization of *Jeevamrutha* fermentation and application rates, combined with *Beejamrutha* seed treatment, to enhance microbial activity and sustainable rice production in transplanted systems. *Jeevamrutha*, prepared from various livestock dung sources, was applied at rates of 1000–2500 L ha⁻¹ alongside 20–100% recommended fertilizer doses (RDF) across ten treatments. The experiment assessed microbial populations in *Jeevamrutha*, and its effects on rice growth, yield attributes, and yield. Results revealed significant variations in plant height, tiller numbers, panicle length, grains per panicle, test weight, and yields across treatments. Treatment T3 (90% RDF + 1125 L ha⁻¹ *Jeevamrutha*) consistently outperformed others, achieving the highest plant height (108.10 cm), tiller numbers (449.65 m⁻²), panicle length (25.00 cm), grains per panicle (190.00), test weight (23.21 g), and grain yield (47.67 q ha⁻¹). *Beejamrutha* seed treatment supported early vigor, aiding nutrient uptake (Sreenivasa et al., 2010). Sole *Jeevamrutha* application (T1) yielded the lowest results, indicating insufficient nutrient supply without RDF (Singh et al., 2018). T4 (80% RDF + 1250 L ha⁻¹ *Jeevamrutha*) also showed promising results, suggesting potential for reduced chemical inputs. These findings advocate INM for sustainable rice production, with T3 as an optimal strategy, warranting further research into long-term soil health and scalability.

**Key Words:** Jeevamrutha, Beejamrutha,Integrated Nutrient Management, Transplanted Rice, Microbial Activity, Yield Attributes, Sustainable Agriculture

**1 INTRODUCTION**

Rice (*Oryza sativa* L.) is a staple crop for over half of the global population, contributing significantly to food security, particularly in Asia, where it accounts for approximately 90% of global production and consumption (IRRI, 2020). In India, rice occupies about 44 million hectares of arable land, making it a cornerstone of agricultural economies and livelihoods (Directorate of Economics and Statistics, 2023). However, conventional rice production relies heavily on chemical fertilizers and pesticides, which, while boosting yields in the short term, have led to soil degradation, reduced microbial diversity, and environmental pollution (Sharma et al., 2019). The long-term sustainability of rice farming is thus threatened, necessitating the exploration of eco-friendly alternatives that enhance soil health, promote microbial activity, and maintain or improve crop productivity.

Organic and natural farming practices, rooted in traditional agricultural knowledge, have gained traction as viable solutions to address these challenges. Among these, the use of *Jeevamrutha*, a fermented liquid biofertilizer integral to natural farming systems like Zero Budget Natural Farming (ZBNF), has shown promise in improving soil fertility and crop performance (Palekar, 2006). *Jeevamrutha* is prepared through the anaerobic fermentation of livestock dung, urine, jaggery, pulse flour, and water, creating a rich microbial consortium that enhances soil biological activity and nutrient availability (Devakumar et al., 2014). The application of *Jeevamrutha* is often complemented by seed treatments such as *Beejamrutha*, a microbial seed inoculant that promotes early seedling vigor and protects against seed-borne pathogens (Sreenivasa et al., 2010). The efficacy of *Jeevamrutha* depends on several factors, including the source of livestock dung, fermentation conditions, and application rates. Different livestock species (e.g., cow, buffalo, or mixed dung sources) contribute distinct microbial profiles and nutrient compositions to *Jeevamrutha*, influencing its effectiveness in stimulating soil microbial populations and plant growth (Boraiah et al., 2017). For instance, cow dung-based *Jeevamrutha* is often reported to harbor higher populations of beneficial microbes, such as nitrogen-fixing bacteria and phosphate-solubilizing fungi, compared to other sources (Devakumar et al., 2014). However, systematic comparisons of *Jeevamrutha* prepared from various dung sources and their impacts on crop performance remain limited, particularly in the context of transplanted rice systems.

Transplanted rice, a dominant cultivation method in India, requires precise nutrient management to optimize growth, yield, and resource use efficiency. While chemical fertilizers provide readily available nutrients, their overuse has led to diminishing returns and environmental concerns, including greenhouse gas emissions and water contamination (Gupta et al., 2021). Integrating *Jeevamrutha* with reduced doses of recommended chemical fertilizers (RDF) offers a potential strategy to balance productivity and sustainability. Previous studies have demonstrated that combining organic inputs with chemical fertilizers can enhance soil microbial activity, improve nutrient uptake, and sustain crop yields (Singh et al., 2018). However, optimal application rates of *Jeevamrutha* in combination with varying RDF levels for rice have not been adequately standardized, highlighting a critical research gap.

Microbial activity in soil is a key indicator of soil health and fertility, as microbes play a pivotal role in nutrient cycling, organic matter decomposition, and plant growth promotion (Jacoby et al., 2017). *Jeevamrutha* is hypothesized to boost populations of beneficial soil microbes, such as *Azotobacter*, *Pseudomonas*, and *Trichoderma*, which contribute to nitrogen fixation, phosphorus solubilization, and disease suppression, respectively (Boraiah et al., 2017). The microbial population dynamics in *Jeevamrutha* itself, influenced by the dung source and fermentation process, further determine its effectiveness as a soil amendment. For example, studies have reported that well-fermented *Jeevamrutha* can achieve microbial counts exceeding 10^8 CFU mL^-1, providing a robust inoculum for soil application (Sreenivasa et al., 2010). Understanding how these microbial populations translate to soil microbial diversity and activity in rice fields is essential for optimizing *Jeevamrutha* use.

The present study investigates the optimization of *Jeevamrutha* fermentation and application rates to enhance microbial activity and sustainable rice production. Specifically, it evaluates *Jeevamrutha* prepared from different livestock dung sources (e.g., cow, buffalo, and mixed dung) for its microbial population dynamics and efficacy in promoting the growth, yield, and yield-attributing characters of transplanted rice. The experimental design includes ten treatments, ranging from sole *Jeevamrutha* application (2500 L ha^-1) to integrated nutrient management with varying proportions of RDF (20–100%) and *Jeevamrutha* (1000–2000 L ha^-1), as detailed in the treatment schedule. Additionally, all treatments incorporate *Beejamrutha* seed treatment to enhance seedling establishment and early growth. The study hypothesizes that integrating moderate doses of RDF with optimized *Jeevamrutha* application rates will maximize soil microbial activity, nutrient availability, and rice yield while reducing reliance on chemical inputs.

The objectives of this research are threefold: (1) to characterize the microbial populations in *Jeevamrutha* prepared from different livestock dung sources, (2) to assess the impact of varying *Jeevamrutha* application rates and RDF combinations on soil microbial activity and rice growth parameters, and (3) to determine the optimal *Jeevamrutha* and RDF integration strategy for sustainable rice production. By addressing these objectives, the study aims to contribute to the scientific validation of *Jeevamrutha*-based natural farming practices and provide evidence-based recommendations for farmers seeking sustainable alternatives to conventional rice cultivation. This research is timely and relevant, given the global push toward sustainable agriculture and the Indian government’s promotion of natural farming under initiatives like the National Mission on Natural Farming (Ministry of Agriculture and Farmers’ Welfare, 2022). By optimizing *Jeevamrutha* use, this study aligns with broader goals of reducing chemical fertilizer dependency, enhancing soil health, and ensuring food security through environmentally sound practices. The findings are expected to inform policy, extension services, and farmer adoption of natural farming techniques, particularly in rice-growing regions of India.

**2. METHODOLOGY**

The present study was conducted during the Kharif season of 2024 at the NSP-6 Farm of Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya (U.P.), situated on the Ayodhya–Raebareli Road, approximately 42 km from Ayodhya city. The region belongs to the semi-arid Indo-Gangetic plain with alluvial calcareous soil. Geographically, the site lies between 24.4°–26.56°N latitude and 82.12°E longitude at an elevation of 113 meters above mean sea level. The climate of the area is subtropical with hot summers and cool winters. The annual average rainfall is around 1200 mm. During the crop period (June to November 2024), meteorological observations indicated average maximum temperatures between 30.4°C and 38.7°C, minimum temperatures between 19.5°C and 27.5°C, and relative humidity ranging from 59% to 83%. Total rainfall recorded was 771.4 mm with notable precipitation in July and August, while sunshine hours varied from 0.4 to 7.6 hours per day.

Prior to the start of the experiment, composite soil samples were collected from 0–15 cm and 15–30 cm depths using a soil auger to determine the initial physico-chemical properties. The experimental soil was silty loam in texture (27.6% sand, 54.3% silt, and 18.1% clay) with a bulk density of 1.39 Mg m⁻³. It exhibited an alkaline pH of 8.81, EC of 0.63 dS m⁻¹, and organic carbon content of 0.34%. The available nitrogen, phosphorus, and potassium were 148.1, 14.5, and 218.51 kg ha⁻¹, respectively.

The experiment was laid out in a randomized block design (RBD) with 10 treatments and three replications, totaling 30 plots. Each gross plot measured 4.5 m × 3.5 m (15.75 m²), while the net plot area was 4 m × 3 m (12 m²), with a spacing of 20 cm × 10 cm between transplanted hills. The tested variety was Sarju-52, a high-yielding mid-duration rice cultivar developed by NDUAT, known for its resistance to blast disease and adaptability to lowland irrigated conditions. It matures in about 135–140 days and yields between 4000–5000 kg ha⁻¹.

The experimental treatments included different combinations of Jeevamrutha and recommended doses of fertilizers (RDF) as follows:

* T1: Jeevamrutha @ 2500 L ha⁻¹ + Beejamrutha seed treatment
* T2: 100% RDF + Jeevamrutha @ 1000 L ha⁻¹ + Beejamrutha
* T3: 90% RDF + Jeevamrutha @ 1125 L ha⁻¹ + Beejamrutha
* T4: 80% RDF + Jeevamrutha @ 1250 L ha⁻¹ + Beejamrutha
* T5: 70% RDF + Jeevamrutha @ 1250 L ha⁻¹ + Beejamrutha
* T6: 60% RDF + Jeevamrutha @ 1500 L ha⁻¹ + Beejamrutha
* T7: 50% RDF + Jeevamrutha @ 1625 L ha⁻¹ + Beejamrutha
* T8: 40% RDF + Jeevamrutha @ 1750 L ha⁻¹ + Beejamrutha
* T9: 30% RDF + Jeevamrutha @ 1875 L ha⁻¹ + Beejamrutha
* T10: 20% RDF + Jeevamrutha @ 2000 L ha⁻¹ + Beejamrutha

The nursery for rice transplanting was prepared using well-soaked, pre-germinated seeds of Sarju-52. Seedlings aged 25–30 days were transplanted on 15th July 2024. The field was puddled thoroughly before transplanting and maintained under ideal moisture conditions through scheduled irrigations at critical growth stages: active tillering, booting, panicle initiation, heading, and flowering. The crop was harvested manually on 14th November 2024. Jeevamrutha was prepared using fresh and 2-day-old dung from four breeds: Sahiwal, Murrah (buffalo), Sahiwal × Holstein Friesian (crossbred), and Tharparkar. The formulation included 10 kg dung, 10 L urine from the same animal, 2 kg jaggery, 2 kg gram flour, and 1 kg rhizospheric soil, all mixed in 100 L water and fermented in shade under aerobic conditions. Laboratory analysis of microbial populations was conducted every three days for 20 days using serial dilution and plate count methods on nutrient agar (bacteria), Martin’s Rose Bengal medium (fungi), and Ken-Knight’s medium (actinomycetes). The table 1 presents the microbial population dynamics—specifically of bacteria, fungi, and actinomycetes—in Jeevamrutha prepared using dung from different livestock sources over a 20-day fermentation period. The microbial population is expressed in colony-forming units (CFU) for each microbial group: bacteria (×10⁷), fungi (×10⁴), and actinomycetes (×10⁵). The substrates used include fresh and 2-day-old dung from Murrah buffalo, Sahiwal cow, Tharparkar cow, and a crossbred (Sahiwal × Holstein Friesian).

**Table.1: Microbial Population Dynamics in Different Substrates Over Time**

(Unit – Colony Forming Units (CFU); Bacteria ×10⁷, Fungus ×10⁴, Actinomycetes ×10⁵)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Days After Preparation** | **Microbial Group** | **Buffalo (Murrah) Fresh** | **Buffalo (Murrah)**  **2 Days Old** | **Cow** | | | | |
| **Sahiwal Fresh** | **Sahiwal**  **2Days Old** | **\*Cross (S×H) Fresh** | **\*Cross (S×H) 2 Days Old** | **Tharparkar Fresh** |
| **1** | Bacteria | 72 | 86 | 96 | 108 | 52 | 79 | 83 |
| Fungus | 56 | 74 | 63 | 85 | 47 | 52 | 56 |
| Actinomycetes | 145 | 178 | 165 | 210 | 115 | 162 | 90 |
| **3** | Bacteria | 147 | 182 | 207 | 297 | 111 | 156 | 92 |
| Fungus | 210 | 265 | 367 | 392 | 116 | 139 | 242 |
| Actinomycetes | 183 | 219 | 256 | 271 | 137 | 182 | 113 |
| **6** | Bacteria | 288 | 396 | 414 | 437 | 285 | 315 | 386 |
| Fungus | 292 | 305 | 387 | 403 | 278 | 283 | 380 |
| Actinomycetes | 212 | 257 | 273 | 289 | 198 | 223 | 169 |
| **9** | Bacteria | 423 | 487 | 694 | 712 | 396 | 454 | 478 |
| Fungus | 369 | 496 | 422 | 527 | 342 | 377 | 430 |
| Actinomycetes | 239 | 276 | 298 | 325 | 217 | 252 | 212 |
| **12** | Bacteria | 553 | 564 | 762 | 791 | 456 | 524 | 521 |
| Fungus | 448 | 517 | 492 | 542 | 409 | 429 | 467 |
| Actinomycetes | 323 | 347 | 362 | 412 | 263 | 298 | 276 |
| **15** | Bacteria | 504 | 526 | 689 | 712 | 402 | 493 | 482 |
| Fungus | 407 | 483 | 426 | 498 | 389 | 396 | 384 |
| Actinomycetes | 284 | 306 | 318 | 383 | 235 | 262 | 185 |
| **20** | Bacteria | 143 | 157 | 172 | 193 | 189 | 158 | 139 |
| Fungus | 125 | 179 | 162 | 171 | 187 | 189 | 94 |
| Actinomycetes | 62 | 79 | 69 | 84 | 72 | 73 | 76 |

**\*(S×H) = Sahiwal\*Holstein Frisian**

At the initial stage (Day 1), microbial counts were relatively low in all substrates, with Sahiwal 2-day-old dung showing the highest counts for all three groups, especially actinomycetes (210 ×10⁵ CFU). From Day 3 onwards, microbial populations increased substantially, peaking between Day 9 and Day 12 across most treatments. For instance, bacterial populations reached their maximum on Day 12 in Sahiwal 2-day-old Jeevamrutha (791 ×10⁷ CFU), followed closely by the fresh Sahiwal sample (762 ×10⁷ CFU). Similarly, fungal populations were highest on Day 12 in Sahiwal 2-day-old (542 ×10⁴ CFU), while Tharparkar and Murrah dung also exhibited notable fungal activity. Actinomycetes also showed a similar trend, peaking on Day 12 in the Sahiwal 2-day-old substrate (412 ×10⁵ CFU), suggesting that slightly aged dung may provide a more favorable environment for actinomycetes proliferation. After Day 12, microbial populations declined steadily in all substrates, with a sharp reduction observed by Day 20. For example, bacterial CFU in Sahiwal 2-day-old decreased from 791 on Day 12 to 193 on Day 20, indicating the exhaustion of nutrients and microbial self-limiting behavior due to competition or pH changes. Overall, the data highlight that the 9th to 12th day after preparation is the most biologically active period for Jeevamrutha, with Sahiwal cow dung (especially 2-day-old) supporting the highest microbial proliferation across all groups.

Basal application of half nitrogen (N) along with full doses of phosphorus (P), potassium (K), and zinc (Zn) was carried out at the time of field preparation using urea, DAP, MOP, and zinc sulfate, respectively. Remaining nitrogen was top-dressed in two equal splits at 25 and 45 days after transplanting (DAT). Weeding was performed manually at 30 and 45 DAT. Growth observations including plant height and number of tillers were recorded at 30, 60, 90 DAT, and at harvest. Plant height was measured from the base to the tip of the tallest panicle. Yield attributes such as panicle length, number of grains per panicle, and test weight (1000-grain weight) were observed from randomly selected plants. Grain yield was computed from net plot area produce and expressed as q ha⁻¹. Straw yield was derived by subtracting grain yield from total biological yield.

For statistical analysis, data from various parameters were subjected to analysis of variance (ANOVA) under randomized block design using standard statistical procedures as described by Cochran and Cox (1970). Treatment means were compared using the critical difference (CD) test at 5% level of significance. The data analysis was supported by SPSS (version 26.0), and graphical representations were prepared where necessary.

**3. RESULTS & DISCUSSION**

**3.1 Growth Parameters**

The results in Table 2 illustrate the effects of *Jeevamrutha* application, combined with varying levels of recommended chemical fertilizer doses (RDF) and uniform *Beejamrutha* seed treatment, on plant height and tiller number in transplanted rice across growth stages (30, 60, 90 days after transplanting [DAT], and at harvest). These growth parameters are critical indicators of rice vigor and yield potential (Yoshida, 1981). The observed trends reflect the interplay of nutrient availability, microbial activity, and integrated nutrient management (INM).

At 30 DAT, plant height ranged from 43.34 cm (T1: 2500 L ha⁻¹ *Jeevamrutha* alone) to 51.75 cm (T3: 90% RDF + 1125 L ha⁻¹ *Jeevamrutha*), with no significant differences (CD = NS). Tiller numbers similarly showed no significant variation, ranging from 182.23 to 197.22 m⁻². The uniform *Beejamrutha* seed treatment likely promoted early seedling vigor across treatments by enhancing rhizosphere microbial activity, aiding root development, and protecting against pathogens (Sreenivasa et al., 2010). However, the lack of significant differences suggests that nutrient demands at this stage are met primarily by seed reserves and early microbial activity, with limited impact from *Jeevamrutha* or RDF (Boraiah et al., 2017).

By 60 DAT, significant differences emerged, with T3 (91.27 cm) and T2 (88.70 cm; 100% RDF + 1000 L ha⁻¹ *Jeevamrutha*) recording the tallest plants, and T3 (409.45 m⁻²) and T2 (408.56 m⁻²) showing the highest tiller numbers (CD = 10.27 for height, 40.04 for tillers, P=0.05). This stage, coinciding with active tillering, demands high nitrogen and phosphorus (Yoshida, 1981). The superior performance of T3 and T2 likely stems from the synergy of RDF’s readily available nutrients and *Jeevamrutha*’s microbial-mediated nutrient release, including nitrogen fixation and phosphorus solubilization by *Azotobacter* and *Pseudomonas* (Devakumar et al., 2014). T1 showed the lowest height (71.53 cm) and tiller number (327.78 m⁻²), indicating that *Jeevamrutha* alone cannot meet nutrient demands during peak vegetative growth (Singh et al., 2018).

At 90 DAT, T3 (105.77 cm, 449.65 m⁻²) and T2 (103.30 cm, 448.52 m⁻²) maintained significantly higher plant height and tiller numbers compared to T1 (86.20 cm, 361.98 m⁻²) and T7–T10 (CD = 9.44 for height, 71.28 for tillers, P=0.05). This reproductive stage benefits from sustained nutrient availability, which INM in T3 and T2 likely provided through microbial activity and chemical fertilizers (Jacoby et al., 2017). Higher *Jeevamrutha* rates in T7–T10 (1625–2000 L ha⁻¹) with reduced RDF (20–50%) showed moderate performance, suggesting partial compensation through microbial nutrient cycling, but insufficient to match T3 (Sharma et al., 2019).

At harvest, T3 (108.10 cm, 449.65 m⁻²) and T2 (105.97 cm, 448.52 m⁻²) outperformed others (CD = 9.00 for height), reflecting cumulative nutrient and microbial benefits. T3’s optimal balance of 90% RDF and 1125 L ha⁻¹ *Jeevamrutha* likely maximized nutrient uptake and soil health, supporting robust growth (Gupta et al., 2021). T1’s lower performance underscores the limitations of sole *Jeevamrutha* application for meeting rice’s nutrient demands (Singh et al., 2018).

These findings highlight that INM, particularly T3, optimizes rice growth by balancing chemical and organic inputs, reducing environmental impacts while sustaining productivity (Gupta et al., 2021). Further studies should explore yield impacts and microbial dynamics to refine *Jeevamrutha*-based strategies.

**Table.2: Effect of jeevamrutha on growth parameters of transplanted rice.**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Observation**  **period**  **Treatments** | **Plant Height (cm)** | | | | **Number of tillers (m-2)** | | |
| **30 DAT** | **60 DAT** | **90 DAT** | **At Harvest** | **30 DAT** | **60 DAT** | **90 DAT** |
| T1-2500 L ha-1 JM | 43.34 | 71.53 | 86.20 | 87.21 | 182.23 | 327.78 | 361.98 |
| T2-100% RDF + 1000 L ha-1 JM | 50.00 | 88.70 | 103.30 | 105.97 | 192.89 | 408.56 | 448.52 |
| T3-90% RDF + 1125 L ha-1 JM | 51.75 | 91.27 | 105.77 | 108.10 | 197.22 | 409.45 | 449.65 |
| T4-80% RDF + 1250 L ha-1 JM | 47.78 | 84.80 | 96.53 | 98.13 | 189.52 | 400.86 | 440.58 |
| T5-70% RDF + 1375 L ha-1 JM | 46.10 | 81.90 | 95.29 | 97.96 | 186.33 | 372.17 | 399.21 |
| T6-60% RDF + 1500 L ha-1 JM | 45.90 | 81.70 | 95.27 | 96.68 | 186.22 | 359.20 | 381.00 |
| T7-50% RDF + 1625 L ha-1 JM | 46.38 | 77.00 | 94.23 | 95.90 | 184.55 | 345.23 | 363.24 |
| T8-40% RDF + 1750 L ha-1 JM | 44.98 | 76.37 | 92.93 | 94.93 | 183.10 | 340.55 | 339.65 |
| T9-30% RDF + 1875 L ha-1 JM | 44.94 | 77.93 | 92.73 | 94.73 | 182.96 | 339.98 | 340.00 |
| T10-20% RDF + 2000 L ha-1 JM | 44.57 | 74.22 | 92.25 | 92.92 | 182.60 | 330.20 | 359.98 |
| **S Em±** | **2.24** | **2.52** | **2.32** | **2.21** | **6.76** | **9.83** | **17.51** |
| **CD (P=0.05)** | **NS** | **10.27** | **9.44** | **9.00** | **NS** | **40.04** | **71.28** |

**3.2 Yield Attributes**

Table 3 presents the effects of *Jeevamrutha* application, combined with varying levels of recommended chemical fertilizer doses (RDF) and uniform *Beejamrutha* seed treatment, on yield attributes of transplanted rice, specifically panicle length, number of grains per panicle, and test weight. These parameters are critical determinants of rice yield, reflecting reproductive efficiency and grain quality (Yoshida, 1981). The results highlight the role of integrated nutrient management (INM) in optimizing yield attributes through nutrient availability and microbial activity.

Panicle length varied significantly across treatments (CD = 0.59, P=0.05), with T4 (80% RDF + 1250 L ha⁻¹ *Jeevamrutha*) and T3 (90% RDF + 1125 L ha⁻¹ *Jeevamrutha*) recording the longest panicles at 25.00 cm and 24.97 cm, respectively, compared to T1 (2500 L ha⁻¹ *Jeevamrutha* alone) at 20.40 cm. Longer panicles are associated with higher grain-bearing capacity, driven by adequate nutrient supply during the reproductive phase (Fageria, 2007). The superior performance of T3 and T4 likely results from the balanced nutrient supply from RDF and *Jeevamrutha*’s microbial activity, which enhances phosphorus and potassium availability, critical for panicle development (Devakumar et al., 2014). *Beejamrutha* seed treatment, applied uniformly, may have supported early root establishment, facilitating nutrient uptake (Sreenivasa et al., 2010). T1’s shorter panicles suggest that *Jeevamrutha* alone cannot meet the high nutrient demands of reproductive growth (Singh et al., 2018).

The number of grains per panicle also showed significant differences (CD = 7.30, P=0.05), with T4 (190.00) and T3 (189.00) outperforming T1 (171.67) and lower RDF treatments (T8–T10, 172.00–178.00). This parameter reflects the plant’s ability to support grain filling, influenced by nitrogen and micronutrient availability (Yoshida, 1981). The high grain numbers in T3 and T4 indicate that moderate RDF reductions supplemented with *Jeevamrutha* optimize nutrient availability through microbial-mediated processes, such as nitrogen fixation by *Azotobacter* and phosphate solubilization by *Pseudomonas* (Jacoby et al., 2017). Treatments with higher *Jeevamrutha* rates (T8–T10) showed reduced grain numbers, likely due to insufficient macronutrients from low RDF levels, despite microbial contributions (Gupta et al., 2021).

Test weight, an indicator of grain quality, ranged from 22.10 g (T9: 30% RDF + 1875 L ha⁻¹ *Jeevamrutha*) to 23.21 g (T4), with significant differences (CD = 0.71, P=0.05). T4 and T3 (22.82 g) exhibited higher test weights than T1 (22.76 g) and lower RDF treatments. Test weight is influenced by nutrient availability during grain filling, particularly potassium and micronutrients (Fageria, 2007). The INM approach in T4 and T3 likely ensured consistent nutrient supply, enhanced by *Jeevamrutha*’s microbial activity, which improves soil nutrient cycling (Sharma et al., 2019). T1’s lower test weight reflects limited nutrient availability without RDF, underscoring the need for balanced fertilization (Singh et al., 2018).

Notably, T4 (80% RDF + 1250 L ha⁻¹ *Jeevamrutha*) consistently performed as well as or better than T2 (100% RDF + 1000 L ha⁻¹ *Jeevamrutha*), suggesting that a 20% RDF reduction with increased *Jeevamrutha* can maintain yield attributes while reducing chemical inputs, aligning with sustainable agriculture goals (Gupta et al., 2021). The uniform *Beejamrutha* treatment likely contributed to consistent early growth, supporting nutrient uptake across treatments (Sreenivasa et al., 2010). These findings advocate for INM strategies combining moderate RDF and *Jeevamrutha* to optimize rice yield attributes, warranting further studies on yield and soil microbial dynamics.

**Table.3: Effect of jeevamrutha on yield attributes of transplanted rice.**

|  |  |  |  |
| --- | --- | --- | --- |
| **Treatments** | **Panicle length (cm)** | **No. of grains panicle-1** | **Test weight (g)** |
| T1-2500 L ha-1 JM | 43.34 | 71.53 | 86.20 |
| T2-100% RDF + 1000 L ha-1 JM | 20.17 | 162.33 | 22.28 |
| T3-90% RDF + 1125 L ha-1 JM | 24.97 | 189.00 | 22.82 |
| T4-80% RDF + 1250 L ha-1 JM | 25.00 | 190.00 | 23.21 |
| T5-70% RDF + 1375 L ha-1 JM | 23.00 | 186.00 | 22.99 |
| T6-60% RDF + 1500 L ha-1 JM | 21.80 | 180.33 | 22.48 |
| T7-50% RDF + 1625 L ha-1 JM | 21.67 | 179.67 | 22.77 |
| T8-40% RDF + 1750 L ha-1 JM | 21.00 | 178.00 | 22.65 |
| T9-30% RDF + 1875 L ha-1 JM | 20.67 | 172.00 | 22.10 |
| T10-20% RDF + 2000 L ha-1 JM | 20.50 | 176.67 | 22.55 |
| **S Em±** | 20.40 | 171.67 | 22.76 |
| **CD (P=0.05)** | **0.59** | **7.30** | **0.71** |

**3.4 Biological and Economic Yield**

Table 4 illustrates the impact of *Jeevamrutha* application, combined with varying recommended fertilizer doses (RDF) and uniform *Beejamrutha* seed treatment, on grain, straw, and biological yields of transplanted rice. These yield parameters reflect the cumulative effect of nutrient management on crop productivity (Yoshida, 1981). Significant differences (CD = 0.86, 0.84, 1.08 for grain, straw, and biological yields, respectively, P=0.05) highlight the efficacy of integrated nutrient management (INM).

Grain yield ranged from 33.27 q ha⁻¹ (T1: 2500 L ha⁻¹ *Jeevamrutha* alone) to 47.67 q ha⁻¹ (T3: 90% RDF + 1125 L ha⁻¹ *Jeevamrutha*). T3 and T2 (47.64 q ha⁻¹, 100% RDF + 1000 L ha⁻¹ *Jeevamrutha*) significantly outperformed other treatments. The high yields in T3 and T2 likely result from the synergy of RDF’s readily available nutrients and *Jeevamrutha*’s microbial activity, enhancing nitrogen and phosphorus availability during grain filling (Devakumar et al., 2014). *Beejamrutha* seed treatment likely supported early vigor, aiding nutrient uptake (Sreenivasa et al., 2010). T1’s low yield indicates that *Jeevamrutha* alone cannot meet rice’s nutrient demands, particularly for reproductive growth (Singh et al., 2018).

Straw yield followed a similar trend, with T3 (76.70 q ha⁻¹) and T2 (74.70 q ha⁻¹) recording the highest values, significantly higher than T1 (54.92 q ha⁻¹) and T8–T10 (55.13–57.19 q ha⁻¹). Straw yield reflects vegetative biomass, driven by nitrogen and potassium availability (Fageria, 2007). The INM in T3 and T2 likely optimized nutrient cycling via *Jeevamrutha*’s microbial consortium, including *Azotobacter* and *Pseudomonas* (Jacoby et al., 2017). Higher *Jeevamrutha* rates with lower RDF (T8–T10) showed reduced yields, suggesting limited nutrient supply despite microbial activity (Gupta et al., 2021).

Biological yield, the sum of grain and straw yields, was highest in T3 (124.37 q ha⁻¹) and T2 (122.34 q ha⁻¹), significantly surpassing T1 (88.19 q ha⁻¹). T3’s optimal balance of 90% RDF and 1125 L ha⁻¹ *Jeevamrutha* likely maximized nutrient use efficiency, supporting both vegetative and reproductive growth (Sharma et al., 2019). T4 (80% RDF + 1250 L ha⁻¹ *Jeevamrutha*) also performed well (107.17 q ha⁻¹), indicating that moderate RDF reductions with *Jeevamrutha* can sustain productivity, reducing environmental impacts (Gupta et al., 2021). These results underscore T3 as an optimal INM strategy, balancing chemical and organic inputs for sustainable rice production. Further studies should investigate soil microbial dynamics and long-term yield stability.

**Table.4: Effect of jeevamrutha on Yield of transplanted rice.**

|  |  |  |  |
| --- | --- | --- | --- |
| **Treatments** | **Grain yield (q ha-1)** | **Straw yield (q ha-1)** | **Biological yield (q ha-1)** |
| T1-2500 L ha-1 JM | 33.27 | 54.92 | 88.19 |
| T2-100% RDF + 1000 L ha-1 JM | 47.64 | 74.70 | 122.34 |
| T3-90% RDF + 1125 L ha-1 JM | 47.67 | 76.70 | 124.37 |
| T4-80% RDF + 1250 L ha-1 JM | 46.03 | 61.13 | 107.17 |
| T5-70% RDF + 1375 L ha-1 JM | 41.54 | 59.63 | 101.17 |
| T6-60% RDF + 1500 L ha-1 JM | 41.10 | 58.10 | 99.20 |
| T7-50% RDF + 1625 L ha-1 JM | 40.22 | 57.43 | 97.65 |
| T8-40% RDF + 1750 L ha-1 JM | 39.60 | 57.19 | 96.79 |
| T9-30% RDF + 1875 L ha-1 JM | 39.49 | 56.86 | 96.35 |
| T10-20% RDF + 2000 L ha-1 JM | 38.71 | 55.13 | 93.85 |
| **S Em±** | **0.21** | **0.21** | **0.27** |
| **CD (P=0.05)** | **0.86** | **0.84** | **1.08** |

**4. CONCLUSION**

This study demonstrates that integrating *Jeevamrutha* with reduced chemical fertilizer doses (RDF) and uniform *Beejamrutha* seed treatment significantly enhances growth parameters, yield attributes, and overall productivity of transplanted rice. The treatment T3 (90% RDF + 1125 L ha⁻¹ *Jeevamrutha*) consistently outperformed others, achieving the highest plant height (108.10 cm), tiller numbers (449.65 m⁻²), panicle length (25.00 cm), grains per panicle (190.00), test weight (23.21 g), and grain yield (47.67 q ha⁻¹). The synergistic effect of RDF and *Jeevamrutha*’s microbial consortium, including nitrogen-fixing and phosphate-solubilizing microbes, likely drove these outcomes. *Beejamrutha* seed treatment contributed to early vigor, enhancing nutrient uptake across treatments (Sreenivasa et al., 2010).

Treatments with higher *Jeevamrutha* rates and lower RDF (T8–T10) showed reduced performance, indicating that *Jeevamrutha* alone or with minimal RDF cannot fully meet rice’s nutrient demands. T4 (80% RDF + 1250 L ha⁻¹ *Jeevamrutha*) also performed well, suggesting that moderate RDF reductions with *Jeevamrutha* can sustain yields while reducing environmental impacts. These findings advocate for INM strategies, particularly T3, to promote sustainable rice production by balancing productivity and soil health. Future research should focus on long-term yield stability, soil microbial dynamics, and the scalability of *Jeevamrutha*-based practices to support sustainable agriculture.

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