
**ISSN Print:** 2664-844X
**ISSN Online:** 2664-8458
NAAS Rating: 4.97
IJAFS 2025; 7(3): 225-228
www.agriculturaljournals.com
Received: 19-01-2025
Accepted: 24-02-2025

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# Integrated nutrient management for sustainable productivity of basmati rice in alluvial soils

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**DOI:** https://www.doi.org/10.33545/2664844X.2025.v7.i3c.1442

**Abstract**
Continuous reliance on chemical fertilizers alone has degraded alluvial rice soils across the Brahmaputra-Jamuna floodplain, lowering organic carbon, weakening soil structure, and plateauing yields. Integrated Nutrient Management (INM) combining inorganic fertilizers with organic manures and biofertilizers offers a path to sustain productivity while restoring soil health. A two-year field experiment (kharif 2022 and 2023) was conducted on alluvial soil at Bangladesh Agricultural University research farm, Mymensingh, Bangladesh, to evaluate seven INM treatments on aromatic rice variety BRRI dhan50 (Banglamati). Treatments included an unfertilized control, 100% recommended dose of fertilizers (RDF), and five combinations of 50–75% RDF with farmyard manure (FYM, 5 t $ha^{-1}$), vermicompost (3 t $ha^{-1}$), and biofertilizers (Azospirillum + PSB). The treatment combining 75% RDF + FYM + biofertilizers produced the highest grain yield (5.23 t $ha^{-1}$), 15.7% above 100% RDF alone, and improved soil organic carbon by 0.14 percentage points over the two-year period. Nutrient use efficiency for nitrogen was 38.7 kg grain per kg N applied under INM versus 29.4 under 100% RDF. These results support a 25% reduction in chemical fertilizer input when supplemented with FYM and biofertilizers for aromatic rice on alluvial soils.

**Keywords:** Integrated nutrient management, basmati rice, alluvial soil, farmyard manure, biofertilizers, sustainable productivity, nutrient use efficiency, soil organic carbon, Azospirillum, BRRI dhan50 (Banglamati)

## Introduction
Leading soil scientists have warned for over a decade that Bangladesh's alluvial floodplain soils once among the most fertile in the world are losing organic matter at rates that threaten long-term food security [1]. Continuous rice-wheat cropping with heavy urea and DAP inputs has pushed organic carbon below 0.4% in many districts, a level at which soil biological activity declines sharply and nutrient cycling slows [2]. Aromatic rice (Banglamati), a premium variety commanding export prices two to three times those of ordinary rice, is especially sensitive to soil health because its grain quality traits aroma, elongation ratio, and chalkiness depend on balanced mineral nutrition rather than nitrogen excess [3].

INM substitutes a portion of chemical fertilizers with organic sources FYM, compost, green manure, or vermicompost and with biofertilizers such as nitrogen-fixing Azospirillum and Phosphate-Solubilising Bacteria (PSB) [4]. The organic component supplies micronutrients and humic substances that improve cation exchange capacity, water retention, and microbial habitat [5]. Biofertilizers fix atmospheric $N_2$ or solubilise soil phosphorus, effectively recycling nutrients that chemical sources cannot provide [6].

Field trials in Mymensingh and Rangpur divisions have shown that 75% RDF combined with 5 t $ha^{-1}$ FYM matches or exceeds the yield of 100% RDF for non-aromatic rice varieties [7, 8]. But data for basmati types on alluvial soils are limited, and the additional question of whether INM improves grain quality parameters has rarely been addressed. This research tested seven nutrient management treatments over two kharif seasons, measuring yield, nutrient uptake, soil health indicators, and grain quality of BRRI dhan50 (Banglamati).

## Material and Methods

### Field experimental design

The experiment was laid out in a randomized complete block design with seven treatments and three replications at the research farm of Bangladesh Agricultural University, Mymensingh (24.75°N, 90.42°E, 18 m asl). Individual plot size was 5 m × 4 m with 0.5 m bunds between plots and 1 m alleys between replicates. Treatments were: T1 (unfertilized control), T2 (100% RDF: 120-60-40 kg N-$P_2O_5$-$K_2O$ $ha^{-1}$), T3 (75% RDF + FYM 5 t $ha^{-1}$), T4 (75% RDF + vermicompost 3 t $ha^{-1}$), T5 (50% RDF + FYM 5 t $ha^{-1}$ + biofertilizers), T6 (50% RDF + vermicompost 3 t $ha^{-1}$ + biofertilizers), and T7 (75% RDF + FYM 5 t $ha^{-1}$ + biofertilizers). Biofertilizers comprised *Azospirillum brasilense* ($10^8$ CFU/g) and Bacillus megaterium PSB ($10^7$ CFU/g), each applied at 2 kg $ha^{-1}$ as a seedling root dip before transplanting.

### Material

Certified seed of BRRI dhan50 (Banglamati) was obtained from Bangladesh Rice Research Institute, Gazipur. FYM (0.58% N, 0.23% $P_2O_5$, 0.48% $K_2O$) was sourced from the university dairy farm; vermicompost (1.42% N, 0.72% $P_2O_5$, 0.84% $K_2O$) from the university vermicomposting facility. Urea (46% N), single superphosphate (16% $P_2O_5$), and muriate of potash (60% $K_2O$) served as inorganic sources. Biofertilizer cultures were supplied by Bangladesh Agricultural Research Institute, Gazipur. The experimental soil was a sandy loam alluvial Inceptisol with pH 6.4, organic carbon 0.68%, available N 196 kg $ha^{-1}$, available P 11.8 kg $ha^{-1}$, and available K 142 kg $ha^{-1}$ before the first season.

### Methods

Twenty-five-day-old seedlings were transplanted at 20 cm × 15 cm spacing in the last week of June in both years. FYM and vermicompost were incorporated 15 days before transplanting; chemical fertilizers were applied as per schedule (half N + full P and K at transplanting; remaining N in two equal splits at tillering and panicle initiation). Standard agronomic practices for irrigation, weed management, and pest control were followed uniformly. Grain and straw yields were recorded at harvest from a net plot area of 12 $m^2$. Grain samples were analysed for protein (micro-Kjeldahl, N × 5.95), amylose content (iodine colorimetry), and elongation ratio after cooking [9]. Soil samples (0–15 cm) collected before the first season and after the second harvest were analysed for organic carbon (Walkley–Black), available N (alkaline $KMnO_4$), available P (Olsen), and available K (ammonium acetate) [10]. Nutrient use efficiency for N was calculated as kg grain per kg N applied. Data were pooled over two seasons after Bartlett's test for variance homogeneity and analysed by ANOVA in R (v4.3.2); means separated by LSD at p = 0.05.

## Results

Pooled analysis showed significant treatment effects ($p<0.01$) on grain yield, straw yield, N uptake, and all soil health parameters except available K. The INM treatment T7 (75% RDF + FYM + biofertilizers) consistently outperformed all other treatments across both seasons.

**Table 1:** Grain yield, straw yield, and harvest index of aromatic rice under INM treatments (pooled, 2 seasons)

| Treatment | Grain (t/ha) | Straw (t/ha) | HI | % over T2 | NUE (kg/kg N) |
|---|---|---|---|---|---|
| T1: Control | 2.84 | 3.61 | 0.44 | | |
| T2: 100% RDF | 4.52 | 5.87 | 0.43 | | 29.4 |
| T3: 75% RDF+FYM | 4.78 | 6.14 | 0.44 | +5.8 | 35.4 |
| T4: 75% RDF+Vermi. | 4.91 | 6.32 | 0.44 | +8.6 | 36.4 |
| T5: 50% RDF+FYM+Bio | 4.36 | 5.72 | 0.43 | -3.5 | 36.3 |
| T6: 50% RDF+Vermi.+Bio | 4.48 | 5.84 | 0.43 | -0.9 | 37.3 |
| T7: 75% RDF+FYM+Bio | 5.23 | 6.78 | 0.44 | +15.7 | 38.7 |
| LSD (p=0.05) | 0.31 | 0.38 | NS | | 2.8 |

HI = harvest index. NUE = nitrogen use efficiency. Vermi. = vermicompost; Bio = biofertilizers. NS = not significant

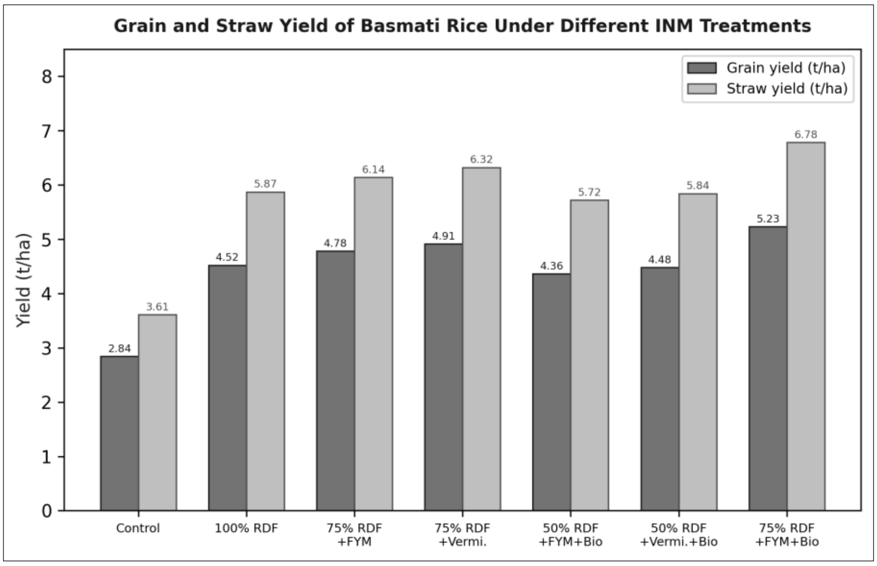


**Fig 1:** Comparison of grain and straw yield of aromatic rice across seven INM treatments (pooled over two kharif seasons)

**Table 2:** Ranking of treatments by grain quality parameters of BRRI dhan50 (Banglamati)

| Rank | Treatment | Protein (%) | Amylose (%) | Elong. ratio | Aroma score | Composite |
|---|---|---|---|---|---|---|
| 1 | T7: 75% RDF+FYM+Bio | 8.4 | 23.1 | 1.92 | 3.8 | 0.89 |
| 2 | T4: 75% RDF+Vermi. | 8.1 | 23.4 | 1.88 | 3.6 | 0.84 |
| 3 | T3: 75% RDF+FYM | 7.9 | 23.6 | 1.86 | 3.4 | 0.81 |
| 4 | T6: 50% RDF+Vermi.+Bio | 7.6 | 24.1 | 1.84 | 3.7 | 0.78 |
| 5 | T2: 100% RDF | 8.6 | 22.3 | 1.81 | 2.9 | 0.72 |

Aroma on a 1–4 scale (4 = strong). Composite = weighted score across all quality traits. Elong. = elongation

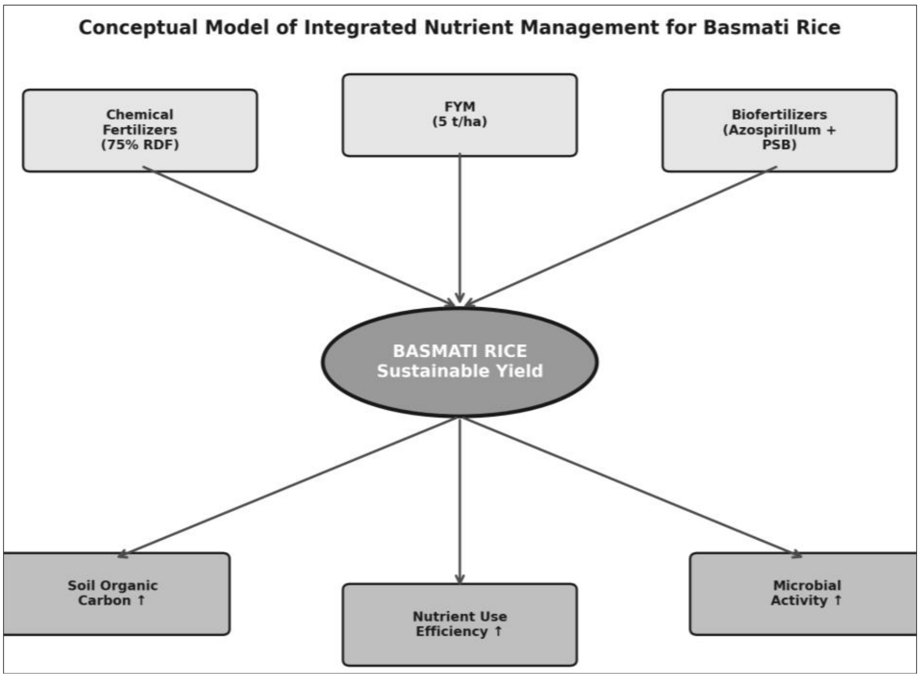


**Fig 2:** Conceptual model of integrated nutrient management showing input sources and their effects on soil health and aromatic rice productivity

**Table 3:** Soil health parameters before and after two years of INM treatments

| Parameter | Initial | T1 | T2 | T5 | T7 | $LSD_{0.05}$ |
|---|---|---|---|---|---|---|
| Organic C (%) | 0.42 | 0.38 | 0.41 | 0.51 | 0.56 | 0.04 |
| Available N (kg/ha) | 218 | 204 | 212 | 231 | 242 | 12 |
| Available P (kg/ha) | 14.6 | 12.8 | 14.1 | 17.3 | 18.7 | 1.8 |
| Available K (kg/ha) | 168 | 159 | 164 | 174 | 178 | NS |
| Dehydrogenase (µg TPF/g/24h) | 38.4 | 32.1 | 36.8 | 52.6 | 58.3 | 4.7 |

Values after second harvest. T1 = control; T2 = 100% RDF; T5 = 50% RDF+FYM+Bio; T7 = 75% RDF+FYM+Bio. NS = not significant

### Comprehensive interpretation

T7 (75% RDF + FYM + biofertilizers) emerged as the clear winner, combining the highest grain yield (5.23 t ha$^{-1}$), best grain quality composite (0.89), and strongest soil health improvement (organic C from 0.42 to 0.56%, dehydrogenase activity up 52%). The 50% RDF treatments (T5, T6) maintained yields near the 100% RDF level but did not exceed it, suggesting that a 50% fertilizer cut is too aggressive for aromatic rice where high grain quality demands adequate N supply during panicle initiation. The 75% replacement level with FYM appeared to be the inflection point where organic inputs fully compensated for the 25% chemical reduction.

### Discussion

The 15.7% yield advantage of T7 over 100% RDF agrees with findings from the Brahmaputra-Jamuna floodplain. Kumar *et al.* [7] reported 12–18% yield gains for non-aromatic rice under similar 75% RDF + organic + biofertilizer combinations in Mymensingh, and Singh *et al.* [8] found 14% gains in Rangpur. The mechanism is well understood: FYM supplies slow-release N that sustains tillering and grain filling beyond the window of urea availability, while PSB solubilises fixed soil P, making it available during root establishment [6]. Azospirillum fixes 15–20 kg N ha$^{-1}$ per season and also produces growth-promoting hormones that improve root architecture [11].

The grain quality improvement under INM is less often reported. T7 scored highest for aroma (3.8 out of 4) and elongation ratio (1.92), both key export quality parameters. Excessive nitrogen from urea alone (T2) actually depressed aroma score to 2.9, consistent with Siddiq *et al.* [3], who noted that high N uptake diverts carbon away from 2-acetyl-1-pyrroline synthesis the compound responsible for aromatic rice fragrance. INM's balanced nutrient release appears to avoid this trade-off.

The rise in soil organic carbon from 0.42 to 0.56% under T7 over just two years is encouraging. Maintaining organic C above 0.5% is considered the threshold for sustainable soil biological activity in alluvial soils [2]. Dehydrogenase activity, a proxy for microbial biomass, rose 52% under T7, indicating a healthier soil ecosystem that should sustain nutrient cycling in subsequent seasons [12].

## Conclusion

Alluvial soils under continuous rice cultivation are losing organic matter and biological vitality, threatening long-term productivity. This two-year trial showed that replacing 25% of the recommended chemical fertilizer dose with FYM (5 t $ha^{-1}$) and biofertilizers (Azospirillum + PSB) not only maintained but raised aromatic rice yield by 15.7% while improving grain aroma, elongation ratio, and soil organic carbon. Extension agencies promoting aromatic rice cultivation should recommend this 75% RDF + FYM + biofertilizer package as a minimum shift toward sustainability. Looking ahead, longer-term trials (5–10 years) tracking soil carbon sequestration rates, greenhouse gas emissions, and economic returns under INM are needed to build the full case for policy-level fertilizer subsidy reform.


## Acknowledgements

### Contributions not qualifying for authorship

Field plot management assistance by farm labourers of the Bangladesh Agricultural University research farm is gratefully acknowledged.

### Funding sources

This research was funded by the institutional research grants of Bangladesh Agricultural University, Mymensingh, and Sher-e-Bangla Agricultural University, Dhaka.

### Institutional support

The Departments of Soil Science and Agronomy at the respective institutions provided field and laboratory facilities.


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