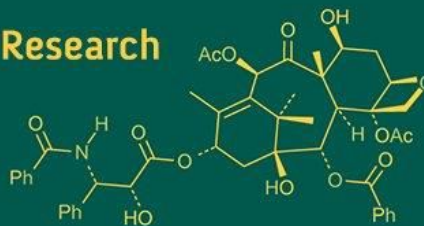
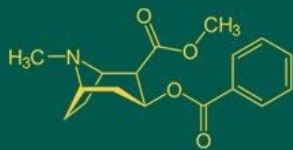


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## Effect of integrated nutrient management practices on growth, yield attributes and soil nutrient status in irrigated rice (*Oryza sativa* L.)

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### Abstract

A field experiment was conducted during *kharif* 2024 at the Instructional Farm, BTC College of Agriculture & Research Station, Bilaspur, Chhattisgarh, to assess the effect of integrated nutrient management (INM) on growth, yield, and nutrient uptake of rice (*Oryza sativa* L.) under irrigated conditions. The experiment, laid out in a Randomized Block Design with 11 treatments and three replications, involved combinations of chemical fertilizers (RDF: 100:60:40 NPK kg ha<sup>-1</sup>) and biofertilizers—Blue-Green Algae (BGA), *Azospirillum*, phosphorus-solubilizing bacteria (PSB), and potassium-mobilizing bacteria (KMB). Results revealed that INM treatments significantly improved growth and yield attributes compared to control. The treatment with 75% RDF + BGA + PSB + KMB (T<sub>6</sub>) recorded the highest plant height (144.21 cm), effective tillers (11.21 plant<sup>-1</sup>), panicle length (27.95 cm), grain weight per panicle (2.53 g), grain yield (32.15 q ha<sup>-1</sup>), and straw yield (46.30 q ha<sup>-1</sup>). Enhanced available N (274.91 kg ha<sup>-1</sup>), P<sub>2</sub>O<sub>5</sub> (13.37 kg ha<sup>-1</sup>), and K<sub>2</sub>O (260.42 kg ha<sup>-1</sup>) were also observed under INM. These findings indicate that combining 50-75% RDF with multiple biofertilizers can sustain or enhance rice productivity while reducing chemical fertilizer usage, contributing to soil health and environmental sustainability.

**Keywords:** Integrated nutrient management, rice, biofertilizers, yield, soil fertility, sustainability

### Introduction

Rice (*Oryza sativa* L.), a member of the poaceae family, is a major staple crop for over half of the global population and a key source of carbohydrates, protein, vitamins (B1, B2, B3, tocopherol), and minerals (iron, phosphorus, calcium). India is among the leading producers, with Chhattisgarh known as the “Rice Bowl of India,” though recent years have seen a decline in productivity. Rice cultivation requires essential macronutrients such as nitrogen, phosphorus, and potassium. Nitrogen supports chlorophyll synthesis and energy metabolism, while biofertilizers like Blue-Green Algae (BGA) and *Azospirillum* enhance nitrogen supply through biological fixation. Phosphorus is crucial for reproductive growth but is often poorly available in soils; phosphorus-solubilizing bacteria improve its availability. Potassium, vital for cell functions, is largely unavailable in soils but can be mobilized by specific potassium-solubilizing microorganisms. Excessive dependence on chemical fertilizers can degrade soil health and pollute the environment, whereas exclusive organic inputs may fail to meet nutrient demands. Integrated Nutrient Management (INM), combining organic, inorganic, and biofertilizers, optimizes nutrient use efficiency, sustains soil fertility, and enhances growth, yield, and nutrient uptake, particularly under irrigated conditions.

### Materials and Methods

The field experiment, “Growth parameters, yield and nutrient uptake as influenced by integrated nutrient management in rice under irrigated conditions”, was conducted during *kharif* 2024 at the Instructional Farm, BTC College of Agriculture & Research Station, Bilaspur, Chhattisgarh (Chhattisgarh plains zone; sandy clay loam soil; pH 6.8; available N-275.2 kg ha<sup>-1</sup>, P<sub>2</sub>O<sub>5</sub>-12.68 kg ha<sup>-1</sup>, K<sub>2</sub>O-282.17 kg ha<sup>-1</sup>). The climate is sub-humid with 1200-1400 mm annual rainfall, mostly from June to September. The experiment followed a Randomized Block Design (RBD) with 11 treatments (Table 1) and three replications, using rice variety Sanjeevani at 20 × 10 cm spacing and a recommended fertilizer dose (RDF) of

100:60:40 NPK kg ha<sup>-1</sup>. Treatments included different combinations of RDF, Blue-Green Algae (BGA), *Azospirillum*, phosphorus-solubilizing bacteria (PSB), and potassium-mobilizing bacteria (KMB). Biofertilizers were applied via root dipping and BGA at 10 kg ha<sup>-1</sup> one week after transplanting. Twenty-five-day-old seedlings were transplanted manually. Observations include growth parameters such as plant height, plant population, effective tillers, Yield attributes-panicle length, grains per panicle, test weight, and grain and straw yield and available N, P, K were recorded. Uptake was calculated from content × yield.

## Results and Discussion

### Growth attributes

The data pertaining to all growth attributes i.e. plant height (cm), number of effective tillers plant<sup>-1</sup> and plant population (m<sup>-2</sup>) are presented in Table 2.

#### Plant height (cm)

As shown in Table 2, the tallest plants were recorded under T<sub>6</sub> (144.21 cm), followed by T<sub>2</sub> (137.98 cm), T<sub>3</sub> (134.69 cm), T<sub>9</sub> (136.56 cm), T<sub>11</sub> (139.38 cm). These treatments were statistically at par. The lowest plant height at harvest was observed under the control (T<sub>1</sub>) with 123.04 cm. The consistent superiority of T<sub>6</sub> at all stages (except 30 DAT) highlights the beneficial synergistic effect of integrating 75% RDF with BGA, PSB, and KMB, enhancing nutrient uptake and growth. similar finding was reported by Reddy *et al.* (2019) [10], who found that the combined use of RDF and biofertilizers like BGA and PSB significantly improved plant growth attributes in rice. Similarly, Kumar and Singh (2021) [4] reported that the application of *Azospirillum* and PSB with reduced fertilizer doses could match or surpass the full RDF treatment in terms of growth and yield. The results further confirm the potential of INM practices to reduce chemical fertilizer use while sustaining crop performance.

#### Number of effective tillers plant<sup>-1</sup>

At harvest, T<sub>6</sub> showed the highest effective tillers (11.21), which was significantly superior over all the treatments except T<sub>7</sub> and T<sub>11</sub>. Treatments T<sub>11</sub> (10.88) and T<sub>7</sub> (10.07) were statistically at par with T<sub>6</sub>. The lowest number of tillers was recorded under the control (T<sub>1</sub>) 6.24. The significantly higher values in T<sub>6</sub> and T<sub>11</sub> might be attributed to the synergistic effect of RDF with BGA, PSB, KMB, and *Azospirillum*, which improved nutrient availability (especially N and P), root development, and overall plant vigour leading to higher tillering. These findings are in conformity with the results of Subba Rao (2001) [14], who emphasized the role of biofertilizers like *Azospirillum* and PSB in improving tiller number by enhancing nutrient uptake. Sharma *et al.* (2014) [11] also found that integrated use of organic and inorganic sources significantly increased effective tillers and yield attributes in rice. Yadav *et al.* (2017) [17] concluded that combining 75% RDF with BGA and microbial consortia resulted in higher tillering due to better nitrogen fixation and phosphorus solubilization.

#### Plant population (m<sup>-2</sup>)

Plant population at harvest was not significantly influenced by treatments, though integrated nutrient management (INM) plots generally retained slightly higher stands. The highest population (49.96 m<sup>-2</sup>) occurred in T<sub>6</sub>, followed by T<sub>11</sub> (49.80 m<sup>-2</sup>) and T<sub>7</sub> (49.73 m<sup>-2</sup>), all combining reduced

chemical fertilizers with multiple biofertilizers, likely enhancing root growth, nutrient uptake, and plant survival. The lowest population (47.84 m<sup>-2</sup>) was in the control (T<sub>1</sub>), possibly due to nutrient deficiency causing stress and reduced vigour. These results corroborate earlier findings by Verma *et al.* (2019) [15] and Patel *et al.* (2021) [7], who reported improved stand establishment and maintenance in rice with integrated nutrient application.

### Yield attributes

The data about all yield attributes, i.e., panicle length (cm), test weight (g), grain weight (panicle<sup>-1</sup>), grain and straw yield (q ha<sup>-1</sup>) are presented in Table 3.

#### Panicle length

Panicle length was significantly affected, with T<sub>6</sub> producing the longest panicle (27.95 cm), significantly superior to several treatments, likely due to balanced nutrient supply and enhanced solubilization by PSB and KMB. T<sub>11</sub> (26.62 cm), T<sub>7</sub> (25.65 cm), and T<sub>2</sub> (24.88 cm) also performed well, while the control had the shortest (21.58 cm). Similar improvements were reported by Rani and Reddy (2020) [9] under INM.

#### Test weight

Test weight was not significantly influenced by treatments, though numerically the highest value (22.43 g) was recorded in T<sub>6</sub> (75% RDF + BGA + PSB + KMB), followed by T<sub>11</sub> (22.41 g) and T<sub>7</sub> (22.35 g). The lowest (20.93 g) was in the control, highlighting the role of nutrient inputs in grain filling. These results align with Choudhary *et al.* (2018) [1], who attributed higher test weight under INM to improved nutrient translocation and photosynthesis.

#### Grain weight

Grain weight per panicle also showed significant variation, with T<sub>6</sub> (2.53 g) highest, followed by T<sub>11</sub> (2.47 g) and T<sub>7</sub> (2.42 g), all statistically at par. T<sub>2</sub> (2.36 g) was notable among inorganic-only treatments, while the control (1.73 g) was lowest. These findings support Kumar *et al.* (2019), who reported enhanced reproductive output from combining biofertilizers with reduced fertilizer doses.

#### Grain yield

Grain yield was significantly influenced by nutrient management treatments. The highest yield (32.15 q ha<sup>-1</sup>) was recorded in T<sub>6</sub> (75% RDF + BGA + PSB + KMB), significantly superior to T<sub>3</sub>, T<sub>4</sub>, T<sub>5</sub>, and T<sub>8</sub>, likely due to synergistic effects of inorganic and biofertilizer nutrient sources. T<sub>11</sub> (31.65 q ha<sup>-1</sup>) and T<sub>7</sub> (31.14 q ha<sup>-1</sup>) were statistically at par with T<sub>6</sub>, indicating that multiple biofertilizers can offset reduced fertilizer doses. T<sub>2</sub> (100% RDF), T<sub>9</sub>, and T<sub>10</sub> also produced relatively high yields (30.96, 28.30, and 28.71 q ha<sup>-1</sup>, respectively). The lowest yield (19.20 q ha<sup>-1</sup>) occurred in the control, followed by T<sub>5</sub> (24.70 q ha<sup>-1</sup>), showing that biofertilizers alone are insufficient without basal nutrient supply. These results agree with Singh *et al.* (2014) [12], Yadav & Kumar (2020) [16], and Ghosh *et al.* (2016) [2], who reported improved yields from integrated use of RDF and biofertilizers.

#### Straw yield

Straw yield followed a similar trend, with T<sub>6</sub> producing the highest value (46.30 q ha<sup>-1</sup>), significantly superior to several

treatments, due to improved vegetative growth from better nutrient availability. T<sub>11</sub> (44.95 q ha<sup>-1</sup>), T<sub>7</sub> (44.14 q ha<sup>-1</sup>), and T<sub>2</sub> (43.47 q ha<sup>-1</sup>) were statistically at par with T<sub>6</sub>. The control recorded the lowest straw yield (26.31 q ha<sup>-1</sup>), followed by T<sub>5</sub> (34.08 q ha<sup>-1</sup>) and T<sub>8</sub> (34.55 q ha<sup>-1</sup>). These findings are consistent with Kumar *et al.* (2019) [3], Yadav *et al.* (2021) [18], and Singh *et al.* (2020) [13], confirming that integrated nutrient management with partial RDF (50-75%) plus biofertilizers enhances both grain and straw yields while reducing reliance on chemical fertilizers.

#### Available NPK in soil

The data related to available NPK in soil is presented in Table 4. Available nitrogen after harvest ranged from 230.33 kg ha<sup>-1</sup> in the control to 274.91 kg ha<sup>-1</sup> in T<sub>6</sub> (75% RDF + BGA + PSB + KMB), which was significantly higher than T<sub>1</sub>, T<sub>3</sub>, T<sub>4</sub>, and T<sub>8</sub>, and statistically at par with T<sub>11</sub> (274.65 kg ha<sup>-1</sup>) and T<sub>7</sub> (268.47 kg ha<sup>-1</sup>). The lowest N in the control highlights the need for external nutrient inputs. These findings are consistent with the results reported by Rai *et al.* (2018) [8], who observed improved nitrogen availability with the use of blue-green algae (BGA) and phosphobacteria in rice-based systems.

Available phosphorus varied from 8.75 kg ha<sup>-1</sup> in the control to 13.37 kg ha<sup>-1</sup> in T<sub>7</sub> (75% RDF + *Azospirillum* + PSB + KMB), followed closely by T<sub>6</sub> (13.27 kg ha<sup>-1</sup>) and T<sub>2</sub> (12.98 kg ha<sup>-1</sup>), all statistically at par and significantly superior to other treatments. PSB likely enhanced P

availability through solubilization of native reserves. Similar observations were made by Kumar and Yadav (2020), who reported that PSB strains improve phosphorus uptake and availability under rice cultivation.

Available potassium ranged from 232.63 kg ha<sup>-1</sup> in the control to 260.42 kg ha<sup>-1</sup> in T<sub>6</sub>, which was significantly higher than most treatments except T<sub>11</sub> (257.14 kg ha<sup>-1</sup>) and T<sub>2</sub> (255.37 kg ha<sup>-1</sup>). Higher K availability was attributed to improved microbial activity and solubilization processes. These results are in similar finding with Mishra *et al.* (2017) [6], who reported that integrated nutrient management significantly improves post-harvest soil potassium status in rice-based cropping systems.

**Table 1:** Treatment details of integrated nutrient management

| Treatments details |                                                                          |
|--------------------|--------------------------------------------------------------------------|
| T <sub>1</sub>     | Control                                                                  |
| T <sub>2</sub>     | 100% RDF (100:60:40 NPK kg ha <sup>-1</sup> )                            |
| T <sub>3</sub>     | 75% RDF                                                                  |
| T <sub>4</sub>     | BGA @ 10 kg ha <sup>-1</sup> + PSB + KMB                                 |
| T <sub>5</sub>     | <i>Azospirillum</i> + PSB + KMB                                          |
| T <sub>6</sub>     | 75% RDF + BGA @ 10 kg ha <sup>-1</sup> + PSB + KMB                       |
| T <sub>7</sub>     | 75% RDF + <i>Azospirillum</i> + PSB + KMB                                |
| T <sub>8</sub>     | 50% RDF                                                                  |
| T <sub>9</sub>     | 50% RDF + BGA @ 10 kg ha <sup>-1</sup> + PSB + KMB                       |
| T <sub>10</sub>    | 50% RDF + <i>Azospirillum</i> + PSB + KMB                                |
| T <sub>11</sub>    | 50% RDF + BGA @ 10 kg ha <sup>-1</sup> + <i>Azospirillum</i> + PSB + KMB |

**Table 2:** Effect of integrated nutrient management practices on growth attributes of rice

| Treatments                                                                               | Plant height (cm) | Number of effective tillers plant <sup>-1</sup> | Plant population |
|------------------------------------------------------------------------------------------|-------------------|-------------------------------------------------|------------------|
| T <sub>1</sub> Control                                                                   | 123.04            | 6.24                                            | 47.84            |
| T <sub>2</sub> 100% RDF (100:60:40 NPK kg ha <sup>-1</sup> )                             | 137.98            | 8.93                                            | 49.54            |
| T <sub>3</sub> 75% RDF                                                                   | 134.69            | 8.34                                            | 48.75            |
| T <sub>4</sub> BGA @ 10 kg ha <sup>-1</sup> + PSB + KMB                                  | 133.24            | 7.78                                            | 48.67            |
| T <sub>5</sub> <i>Azospirillum</i> + PSB + KMB                                           | 127.42            | 6.49                                            | 48.10            |
| T <sub>6</sub> 75% RDF + BGA @ 10 kg ha <sup>-1</sup> + PSB + KMB                        | 144.21            | 11.21                                           | 49.96            |
| T <sub>7</sub> 75% RDF + <i>Azospirillum</i> + PSB + KMB                                 | 138.47            | 10.07                                           | 49.73            |
| T <sub>8</sub> 50% RDF                                                                   | 128.12            | 7.02                                            | 48.49            |
| T <sub>9</sub> 50% RDF + BGA @ 10 kg ha <sup>-1</sup> + PSB + KMB                        | 136.56            | 8.80                                            | 49.03            |
| T <sub>10</sub> 50% RDF + <i>Azospirillum</i> + PSB + KMB                                | 135.16            | 8.71                                            | 48.96            |
| T <sub>11</sub> 50% RDF + BGA @ 10 kg ha <sup>-1</sup> + <i>Azospirillum</i> + PSB + KMB | 139.38            | 10.88                                           | 49.80            |
| SEm (±)                                                                                  | 3.34              | 0.44                                            | 1.86             |
| CD (5%)                                                                                  | 9.87              | 1.29                                            | NS               |

**Table 3.** Effect of integrated nutrient management practices on yield attributes and yield of rice

| Treatments                                                                               | Panicle length (cm) | Test weight (g) | Grain weight (panicle <sup>-1</sup> ) | Grain yield (q ha <sup>-1</sup> ) | Straw yield (q ha <sup>-1</sup> ) |
|------------------------------------------------------------------------------------------|---------------------|-----------------|---------------------------------------|-----------------------------------|-----------------------------------|
| T <sub>1</sub> Control                                                                   | 21.58               | 20.93           | 1.73                                  | 19.20                             | 26.31                             |
| T <sub>2</sub> 100% RDF (100:60:40 NPK kg ha <sup>-1</sup> )                             | 24.88               | 22.18           | 2.36                                  | 30.96                             | 43.47                             |
| T <sub>3</sub> 75% RDF                                                                   | 23.18               | 21.60           | 2.18                                  | 26.13                             | 37.23                             |
| T <sub>4</sub> BGA @ 10 kg ha <sup>-1</sup> + PSB + KMB                                  | 22.56               | 21.40           | 2.11                                  | 27.11                             | 36.33                             |
| T <sub>5</sub> <i>Azospirillum</i> + PSB + KMB                                           | 21.78               | 21.13           | 1.86                                  | 24.70                             | 34.08                             |
| T <sub>6</sub> 75% RDF + BGA @ 10 kg ha <sup>-1</sup> + PSB + KMB                        | 27.95               | 22.43           | 2.53                                  | 32.15                             | 46.30                             |
| T <sub>7</sub> 75% RDF + <i>Azospirillum</i> + PSB + KMB                                 | 25.65               | 22.35           | 2.42                                  | 31.14                             | 44.14                             |
| T <sub>8</sub> 50% RDF                                                                   | 22.12               | 21.23           | 1.92                                  | 25.03                             | 34.55                             |
| T <sub>9</sub> 50% RDF + BGA @ 10 kg ha <sup>-1</sup> + PSB + KMB                        | 23.81               | 21.76           | 2.32                                  | 28.30                             | 39.91                             |
| T <sub>10</sub> 50% RDF + <i>Azospirillum</i> + PSB + KMB                                | 23.30               | 21.66           | 2.25                                  | 28.71                             | 39.50                             |
| T <sub>11</sub> 50% RDF + BGA @ 10 kg ha <sup>-1</sup> + <i>Azospirillum</i> + PSB + KMB | 26.62               | 22.41           | 2.47                                  | 31.65                             | 44.95                             |
| SEm (±)                                                                                  | 1.09                | 1.06            | 0.06                                  | 1.62                              | 1.58                              |
| CD (5%)                                                                                  | 3.21                | NS              | 0.19                                  | 4.79                              | 4.67                              |

**Table 4:** Effect of integrated nutrient management practices on available nitrogen, phosphorus and potassium (kg ha<sup>-1</sup>)

|                 | Treatments                                                         | Available nutrient (kg ha <sup>-1</sup> ) |                               |                  |
|-----------------|--------------------------------------------------------------------|-------------------------------------------|-------------------------------|------------------|
|                 |                                                                    | N                                         | P <sub>2</sub> O <sub>5</sub> | K <sub>2</sub> O |
| T <sub>1</sub>  | -Control                                                           | 230.33                                    | 8.75                          | 232.63           |
| T <sub>2</sub>  | -100% RDF (100:60:40 NPK kg ha <sup>-1</sup> )                     | 266.14                                    | 12.98                         | 255.37           |
| T <sub>3</sub>  | -75% RDF                                                           | 254.84                                    | 11.35                         | 251.89           |
| T <sub>4</sub>  | -BGA @ 10 kg ha <sup>-1</sup> + PSB + KMB                          | 247.24                                    | 9.24                          | 251.60           |
| T <sub>5</sub>  | -Azospirillum + PSB + KMB                                          | 242.73                                    | 9.54                          | 246.04           |
| T <sub>6</sub>  | -75% RDF + BGA @ 10 kg ha <sup>-1</sup> + PSB + KMB                | 274.91                                    | 13.27                         | 260.42           |
| T <sub>7</sub>  | -75% RDF + Azospirillum + PSB + KMB                                | 268.47                                    | 13.37                         | 255.81           |
| T <sub>8</sub>  | -50% RDF                                                           | 244.55                                    | 9.58                          | 247.24           |
| T <sub>9</sub>  | -50% RDF + BGA @ 10 kg ha <sup>-1</sup> + PSB + KMB                | 263.52                                    | 12.57                         | 254.91           |
| T <sub>10</sub> | -50% RDF + Azospirillum + PSB + KMB                                | 263.02                                    | 12.61                         | 252.65           |
| T <sub>11</sub> | -50% RDF + BGA @ 10 kg ha <sup>-1</sup> + Azospirillum + PSB + KMB | 274.65                                    | 12.28                         | 257.14           |
|                 | SEm (±)                                                            | 9.25                                      | 0.42                          | 6.76             |
|                 | CD (5%)                                                            | 27.27                                     | 1.25                          | 19.93            |

## Conclusion

The study demonstrated that integrated nutrient management (INM) involving partial application of recommended fertilizer dose (50-75% RDF) in combination with biofertilizers such as Blue-Green Algae, *Azospirillum*, phosphorus-solubilizing bacteria (PSB), and potassium-mobilizing bacteria (KMB) significantly improved growth parameters, yield attributes, and nutrient availability in rice under irrigated conditions. Among all treatments, 75% RDF + BGA + PSB + KMB (T<sub>6</sub>) consistently recorded the highest plant height, effective tillers, panicle length, grain weight per panicle, grain yield, and straw yield, while also enhancing available NPK in the soil after harvest. Integrated approaches not only sustained crop productivity comparable to or higher than 100% RDF but also reduced the need for chemical fertilizers, thereby lowering production costs and minimizing environmental risks. These findings suggest that adopting INM practices with multiple biofertilizers can be a sustainable strategy for improving rice productivity, maintaining soil fertility, and promoting eco-friendly agriculture in irrigated ecosystems.

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