**Influence of integrated nutrient management on growth, yield and quality of Wheat (*Triticum aestivum* L.) in Uttar Pradesh, India**

**ABSTRACT**

**Background:** Integrated Nutrient Management (INM) has emerged as a sustainable approach to enhance crop productivity as well as maintain soil health. The synergistic interaction of chemical and organic sources enhances nitrogen fixation, auxin production, and nutrient synchrony, leading to improved biomass production and grain yield. This study investigates the effect of various INM practices on the growth parameters, yield components, and quality attributes of wheat (Triticum aestivum L.) during the 2022–23 and 2023–24 cropping seasons. The field experiment was conducted at Agriculture Research Farm of J.V. College, Baraut (Baghpat) Uttar Pradesh, India. The experimental treatments comprised different combinations of chemical fertilizers, organic manures, and biofertilizers. Results revealed that the integrated nutrient application significantly improved plant height, number of tillers per meter row length, and dry matter accumulation (DMA) at harvest. The lowest protein content was noted in the control (T1), with 7.6% and 7.8% in the respective years. The lowest protein yield was observed in the control plot, with only 208.0 and 224.4 kg ha⁻¹. This increase in protein yield is largely a combined effect of higher grain yield and Higher protein concentration. Furthermore, INM treatments recorded higher grain yield and improved grain quality in terms of protein content and 1000-grain weight, compared to control and sole fertilizer applications. These findings underscore the importance of adopting INM strategies for sustainable wheat production, ensuring long-term fertility and productivity of soils. The findings affirm that integrating organic and inorganic nutrient sources along with biofertilizers provides a sustainable and effective strategy for increasing crop yield and quality. Therefore, adoption of INM practices can be recommended for improving agricultural productivity while maintaining soil fertility and long-term sustainability.

**Keywords:** *Triticum aestivum* L., Integrated Nutrient Management, Growth Parameters, Grain Quality, Soil Fertility, Sustainable Agriculture

**Introduction**

To build ecologically sound and economically viable farming systems integrated nutrient management (INM) is a viable option for wheat production as it utilizes available organic and inorganic nutrients (Acharjee et al., 2025). The opportunity presented by Integrated Nutrient Management is great for improving soil sustainability as well as overall productivity. Because of the global energy crisis and the ongoing increase in the cost of artificial fertilisers, using organic manure as a renewable source of plant nutrients is becoming more popular. The only method that can be used to increase soil productivity is integrated nutrient management, which combines organic matter and biological sources of plant nutrients with a balanced application of mineral fertilisers. It plays a vital role in improving the stock of plant nutrients in soil by increasing the efficiency of plant nutrients thus limiting losses to the environment (Mohan et al., 2024). Wheat (*Triticum aestivum* L.) is one of the most widely cultivated cereal crops globally, serving as a principal source of calories and proteins for a substantial proportion of the world population. In India, it ranks second in terms of area and production after rice, playing a vital role in food security and agricultural sustainability. To address the increasing food demands due to population growth, enhancing wheat productivity in a sustainable manner has become imperative. Wheat sowing is delayed up to end of December and sometimes even to 1st week of January leading to severe yield reduction. Delayed sowing enforces maturity under the influence of high temperature and farmers attempt to make amend it by excessive application of nutrients particularly nitrogen ignoring yield physiology in constrained environment (Mishra et al., 2024).

Conventional agricultural practices often rely heavily on chemical fertilizers to achieve high yields. However, continuous and imbalanced use of these inputs has led to the deterioration of soil health, reduced nutrient use efficiency, and environmental concerns such as groundwater pollution and greenhouse gas emissions (Tandon, 2001). These issues necessitate the adoption of alternative nutrient management strategies that can ensure both productivity and environmental sustainability.

Integrated Nutrient Management (INM) is a holistic approach that aims to optimize the use of chemical fertilizers in conjunction with organic manures (e.g., farmyard manure, vermicompost) and biofertilizers (e.g., Azotobacter). This strategy not only supplies essential nutrients but also improves soil physicochemical and biological properties, thereby enhancing nutrient availability and uptake, crop productivity, and soil microbial activity (Mishra *et al.,* 2013; Kumar *et al*., 2019).

Empirical studies have demonstrated that INM significantly improves growth parameters such as plant height, number of tillers, and dry matter accumulation, as well as yield and quality attributes in wheat (Jat et al., 2020; Verma et al., 2021). The synergistic interaction of chemical and organic sources enhances nitrogen fixation, auxin production, and nutrient synchrony, leading to improved biomass production and grain yield (Yadav et al., 2018). Furthermore, INM contributes to improved protein content and protein yield in wheat grain, likely due to better nitrogen assimilation and micronutrient availability (Singh et al., 2017).

In this context, the present investigation was undertaken to evaluate the impact of various INM strategies on the growth, yield components, and grain quality of wheat over two consecutive cropping seasons. The study aims to provide insights into the optimal integration of nutrient sources for achieving sustainable wheat production under field conditions.

**Materials and Methods**

 The field experiment was conducted at Agriculture Research Farm of J.V. College, Baraut (Baghpat) Uttar Pradesh, located at latitude of 290 40′ N and longitude of 770 42′ E at an elevation of 237 meters above the mean sea level. Meerut enjoys semi-arid and sub-tropical climate with extremely hot summer and cold winter, Minimum and maximum temperatures both exhibit a gradual decrease starting from first week of October and reach their minimum in December and January. An increase in the temperature is recorded with effect from first week of February and peak value is noticed in 4th week of May. Occasional frost is also experienced during second forth night of December and January. The mean weekly minimum temperature reaches as low as 4.30 C in 2nd week of January. Whereas, mean weekly maximum temperature reaches as high as 36.90 C in 4th Week of April. The area receives mean annual rainfall of 800 mm of which more than 80% during July- September through south-west monsoon. A few winter showers are also received. April and May are the driest months with mean relative humidity as low as 50 to 55 %, whereas high humidity (92%) is recorded in the month of August. Daily observations on temperature, humidity, sunshine hours, rainfall, pan evaporation, and wind velocity recorded at the meteorological observatory of Agriculture Research Farm of J.V. College, Baraut (Baghpat) Uttar Pradesh were collected to work out weekly. Mean weekly minimum temperature varied from 4.70C in 3rd week of January to 23.50C in 4th week of April during 2022-23. The crop experienced the lowest (4.70C) of mean weekly minimum temperature in 3rd week of January and the highest (23.50C) in 4rd week of April during 2022-23. The mean weekly maximum temperature was recorded to be highest (41.60C) in 4th week of April and lowest (16.20C) in 3rd week of January during 2022-23. 3rd week of January & 1st week January of were most humid (92.6 and 97.9 %) during 2022-23 & 2023-24, respectively, however, the driest (16.7 & 25.0 %) crop season was the 4th and 3rd week of April during both years. Accordingly, the evaporation demand of the atmosphere during 2023-24 was maximum (86.50 mm) during the last week of April month and minimum (1.3 mm) during 1st week of January month, while during 2022-23 the respective values was 81 mm & 6.9 mm. The crop received 173.6 mm of rain during 2022-23 and 160.7 mm during 2023-24.

**Results and Discussion**

**Growth parameters**

 Data regarding Growth parameters *viz*., Plant height (cm), No. of tillers and drymatter accumulation (g m-2) is mentioned in Table 1 and depicted in Figure 1.

 At harvest, application of T9 (100%RDF+ 25%Nthroughvermicompost+*Azotobacter*) exhibited significantly taller plant 93.7 & 95.6 cm, which was on par with T10 (100%RDF+ 25%NthroughFYM+*Azotobacter*), T7(75%RDF+25%N through vermicompost+*Azotobacter*+ Multi-nutrients) and T8 (75%RDF+25%NthroughFYM+*Azotobacter*+Multi-nutrients) whereas the lowest plant height was recorded under control during 2022-23 and 2023-24. On average, an increase in height of 63.8% and 61.5 % was obtained in T9 (100%RDF+ 25%N through vermicompost+*Azotobacter*) over T1 (Control), respectively.

**Table 1. Effect of integrated nutrient management on plant height (cm), number of tillers and dry matter accumulation (g m-2) at harvest stages**

|  |  |  |  |
| --- | --- | --- | --- |
| **Treatments**  | **Plant height (cm)** | **No. of tillers per meter row length** | **DMA (g m-2)** |
| **2022-23** | **2023-24** | **2022-23** | **2023-24** | **2022-23** | **2023-24** |
| **T1** | Control  | 57.2 | 59.2 | 38.5 | 42.0 | 845.2 | 856.3 |
| **T2** | 100% RDF | 82.2 | 84.2 | 73.5 | 75.0 | 905.3 | 918.2 |
| **T3** | 100%RDF+ *Azotobacter* | 83.7 | 85.2 | 75.5 | 77.0 | 970.2 | 982.4 |
| **T4** | 100% RDF+*Azotobacter*+Multi-nutrients | 84.2 | 85.8 | 76.0 | 78.5 | 988.6 | 997.3 |
| **T5** | 50%RDF+ 50%NthroughSSNM(SPAD)+*Azotobacter* | 83.3 | 84.6 | 74.0 | 75.5 | 942.5 | 956.3 |
| **T6** | 75%RDF+25%NthroughSSNM(SPAD)+*Azotobacter*+ Multi-nutrients | 85.0 | 86.1 | 77.0 | 79.0 | 1014.6 | 1028.4 |
| **T7** | 75%RDF+25%Nthroughvermicompost+*Azotobacter*+ Multi-nutrients | 85.7 | 87.2 | 80.0 | 82.5 | 1095.5 | 1107.4 |
| **T8** | 75%RDF+25%NthroughFYM+*Azotobacter*+Multi-nutrients | 85.5 | 86.9 | 78.5 | 80.6 | 1072.3 | 1082.9 |
| **T9** | 100%RDF+ 25%Nthroughvermicompost+*Azotobacter* | 93.7 | 95.6 | 86.0 | 88.5 | 1175.3 | 1190.8 |
| **T10** | 100%RDF+ 25%NthroughFYM+*Azotobacter* | 88.2 | 90.9 | 83.0 | 84.0 | 1120.5 | 1135.3 |
| **SEm(±)** | **3.0** | **3.1** | **2.7** | **2.8** | **37.3** | **37.8** |
|  **C.D. (P=0.05)** | **8.5** | **8.7** | **7.9** | **8.1** | **107.9** | **109.5** |

The effect of integrated nutrient management (INM) on plant height, number of tillers per meter row length, and dry matter accumulation (DMA) at harvest stages during 2022–23 and 2023–24 is summarized in Table 1. The results clearly show that different nutrient combinations significantly influenced all the growth parameters.

1. Plant Height (cm)

The plant height was significantly influenced by the nutrient management practices in both years. The maximum plant height was observed in treatment T9 (100% RDF + 25% N through vermicompost + Azotobacter) with values of 93.7 cm in 2022–23 and 95.6 cm in 2023–24, followed by T10 and T7. The lowest plant height was recorded in the control (T1), with values of 57.2 cm and 59.2 cm, respectively.

The increased plant height in T9 may be attributed to the combined and synergistic effect of chemical fertilizers (RDF), organic inputs (vermicompost), and biofertilizers (Azotobacter), which enhanced nutrient availability, improved root development, and stimulated hormonal activity.

This is supported by earlier studies such as Jat et al. (2020) and Singh et al. (2018), who reported that INM practices significantly improved plant height due to better nutrient synchrony and soil health.

2. Number of Tillers per Meter Row Length

The number of tillers is a crucial yield-determining trait in cereals. The results revealed that T9 again recorded the highest number of tillers per meter row length (86.0 and 88.5) in both years, followed by T10 (83.0 and 84.0) and T7 (80.0 and 82.5). In contrast, the lowest tiller count was observed in the control (T1) (38.5 and 42.0).

Improved tillering under INM treatments may be attributed to continuous and adequate nitrogen availability through RDF and vermicompost, and enhanced microbial activity from Azotobacter, which likely increased nitrogen fixation and auxin production.

Similar results were reported by Kumar et al. (2019), who found that integrated use of vermicompost and biofertilizers increased tillering and overall plant vigor due to improved nutrient uptake and soil microbial balance.

3. Dry Matter Accumulation (DMA)

Dry matter accumulation followed a similar trend to other growth parameters. The highest DMA was recorded in T9 (1175.3 g m⁻² in 2022–23 and 1190.8 g m⁻² in 2023–24), while the lowest was again in T1 (845.2 and 856.3 g m⁻²). This is likely because better nutrient availability and improved physiological traits like leaf area and chlorophyll content under INM treatments led to increased photosynthesis and biomass production.

The treatments involving partial N substitution through FYM or vermicompost (T7, T8, T10) also resulted in significantly higher DMA compared to the sole RDF application (T2). The slow release of nutrients from organic sources, along with improved soil texture and microbial activity, are key contributors.

These observations are consistent with Verma et al. (2021), who demonstrated that integrated nutrient application leads to improved crop growth attributes due to sustained nutrient supply and better soil physical and biological properties.

**Table 2. Effect of integrated nutrient management on grain, straw, biological yield (q ha-1) and harvest index (%)**

|  |  |  |
| --- | --- | --- |
| **Treatment** | **Yield (q ha-1)** | **Harvest Index (%)** |
| **Grain**  | **Straw**  | **Biological**  |
| **2022-23** | **2023-24** | **2022-23** | **2023-24** | **2022-23** | **2023-24** | **2022-23** | **2023-24** |
| **T1** | Control  | 27.5 | 28.8 | 44.7 | 46.2 | 72.2 | 75.0 | 38.1 | 38.4 |
| **T2** | 100% RDF | 35.6 | 36.8 | 52.8 | 55.7 | 88.4 | 92.5 | 40.3 | 39.8 |
| **T3** | 100%RDF+ *Azotobacter* | 38.2 | 40.4 | 55.3 | 58.2 | 93.5 | 98.6 | 40.9 | 41.0 |
| **T4** | 100% RDF+*Azotobacter*+Multi-nutrients | 40.3 | 41.9 | 57.6 | 59.7 | 97.9 | 101.6 | 41.2 | 41.2 |
| **T5** | 50%RDF+ 50%NthroughSSNM(SPAD)+*Azotobacter* | 37.2 | 39.1 | 54.6 | 57.8 | 91.8 | 96.9 | 40.5 | 40.4 |
| **T6** | 75%RDF+25%NthroughSSNM(SPAD)+*Azotobacter*+ Multi-nutrients | 41.5 | 42.9 | 59.3 | 61.5 | 100.8 | 104.4 | 41.2 | 41.1 |
| **T7** | 75%RDF+25%Nthroughvermicompost+*Azotobacter*+ Multi-nutrients | 43.4 | 45.1 | 60.2 | 61.9 | 103.6 | 107.0 | 41.9 | 42.1 |
| **T8** | 75%RDF+25%NthroughFYM+*Azotobacter*+Multi-nutrients | 42.3 | 43.8 | 59.6 | 60.3 | 101.9 | 104.1 | 41.5 | 42.1 |
| **T9** | 100%RDF+ 25%Nthroughvermicompost+*Azotobacter* | 46.5 | 48.2 | 62.9 | 64.8 | 109.4 | 113.2 | 42.5 | 42.6 |
| **T10** | 100%RDF+ 25%NthroughFYM+*Azotobacter* | 45.3 | 46.4 | 61.5 | 64.1 | 106.8 | 110.5 | 42.4 | 42.0 |
| **SEm(±)** | **1.4** | **1.5** | **2.0** | **2.1** | **3.5** | **3.6** | **1.4** | **1.5** |
|  **C.D. (P=0.05)** | **4.2** | **4.4** | **5.9** | **6.2** | **10.2** | **10.6** | **NS** | **NS** |

Here is a detailed Result and Discussion section for Table 2, focusing on grain yield, straw yield, biological yield, and harvest index under different Integrated Nutrient Management (INM) treatments for the years 2022–23 and 2023–24.

The data in Table 2 highlights the significant influence of various INM treatments on grain yield, straw yield, biological yield, and harvest index over two consecutive years. All parameters showed a positive response to nutrient integration compared to the control, though harvest index differences were statistically non-significant (NS).

1. Grain Yield (q ha⁻¹)

Grain yield increased significantly with integrated treatments. The highest grain yield was recorded in T9 (100% RDF + 25% N through vermicompost + Azotobacter) with 46.5 q ha⁻¹ (2022–23) and 48.2 q ha⁻¹ (2023–24). This was followed by T10 (45.3 and 46.4 q ha⁻¹), and T7 (43.4 and 45.1 q ha⁻¹). In contrast, the lowest yield was observed under the control (T1) (27.5 and 28.8 q ha⁻¹).

The yield advantage under T9 is attributed to the synergistic effect of chemical fertilizers (RDF), organic N (vermicompost), and Azotobacter, which likely enhanced nutrient availability, improved soil microbial activity, and resulted in better root development and nutrient uptake. Vermicompost improves soil structure and microbial diversity, while Azotobacter promotes nitrogen fixation and auxin production, leading to robust plant growth and higher grain yield.

This finding aligns with the work of Sahu et al. (2021) and Yadav et al. (2018), who reported that INM practices significantly increase yield by ensuring continuous and balanced nutrient supply.

2. Straw Yield (q ha⁻¹)

Straw yield followed a pattern similar to grain yield. T9 produced the maximum straw yield of 62.9 and 64.8 q ha⁻¹, followed by T10 and T7. The control treatment (T1) recorded the lowest straw yield (44.7 and 46.2 q ha⁻¹).

Higher vegetative biomass in INM treatments may be linked to increased tillering and leaf area development, which are further supported by organic matter from vermicompost or FYM. Enhanced photosynthetic efficiency and delayed senescence also contribute to higher straw production.

These observations are consistent with Kumar et al. (2020), who demonstrated that straw yield improves with INM due to improved soil moisture retention and nutrient cycling.

3. Biological Yield (q ha⁻¹)

Biological yield, being the sum of grain and straw yield, showed the highest values in T9 (109.4 and 113.2 q ha⁻¹), significantly superior to all other treatments. The next best treatments were T10 (106.8 and 110.5 q ha⁻¹), T7, and T8.

The increased biological yield under these treatments can be attributed to enhanced vegetative growth and reproductive output due to efficient nutrient partitioning and a combination of inorganic and organic nutrient sources. This is in agreement with Tripathi et al. (2019), who found that the combined use of FYM/vermicompost with biofertilizers led to improved physiological efficiency and total biomass.

4. Harvest Index (%)

Though harvest index (HI) values showed slight improvements across treatments, the differences were statistically nonsignificant. The highest HI was recorded in T9 (42.5% and 42.6%), followed closely by T10, T7, and T8. The control treatment (T1) had the lowest HI values (38.1% and 38.4%).

A higher HI reflects a better partitioning of assimilates towards economic yield. While INM treatments improved both grain and straw yields, the proportionate increase in grain over total biomass was only marginal, hence the non-significant change.

Studies by Ramesh et al. (2017) also indicate that harvest index generally remains stable unless there's a drastic change in source–sink dynamics or stress conditions..

**Table 3. Effect of integrated nutrient management on protein content (%) and protein yield (kg ha-1) in grain**

|  |  |  |
| --- | --- | --- |
| **Treatments** | **Protein content (%)** | **Protein yield (kg ha-1)** |
| **2022-23** | **2023-24** | **2022-23** | **2023-24** |
| **T1** | Control  | 7.6 | 7.8 | 208.0 | 224.4 |
| **T2** | 100% RDF | 8.7 | 8.9 | 310.1 | 328.9 |
| **T3** | 100%RDF+ *Azotobacter* | 9.0 | 9.3 | 343.7 | 375.0 |
| **T4** | 100% RDF+*Azotobacter*+Multi-nutrients | 9.2 | 9.3 | 369.5 | 391.3 |
| **T5** | 50%RDF+ 50%NthroughSSNM(SPAD)+*Azotobacter* | 8.6 | 8.8 | 319.7 | 342.8 |
| **T6** | 75%RDF+25%NthroughSSNM(SPAD)+*Azotobacter*+ Multi-nutrients | 9.5 | 9.6 | 392.4 | 413.0 |
| **T7** | 75%RDF+25%Nthroughvermicompost+*Azotobacter*+ Multi-nutrients | 9.7 | 10.1 | 426.8 | 454.8 |
| **T8** | 75%RDF+25%NthroughFYM+*Azotobacter*+Multi-nutrients | 9.7 | 10.0 | 409.6 | 436.7 |
| **T9** | 100%RDF+ 25%Nthroughvermicompost+*Azotobacter* | 10.0 | 10.3 | 466.3 | 497.1 |
| **T10** | 100%RDF+ 25%NthroughFYM+*Azotobacter* | 9.9 | 10.2 | 446.5 | 473.3 |
| **SEm(±)** | **0.33** | **0.34** | **13.9** | **14.9** |
|  **C.D. (P=0.05)** | **0.96** | **0.99** | **40.4** | **43.1** |

The results presented in Table 3 indicate that protein content (%) and protein yield (kg ha⁻¹) in grain were significantly influenced by different integrated nutrient management (INM) treatments. Both protein content and protein yield increased markedly with the application of organic manures, biofertilizers, and balanced chemical fertilization.

1. Protein Content (%)

A consistent increase in protein content was observed with nutrient-enriched treatments across both years. The highest protein content was recorded in T9 (100% RDF + 25% N through vermicompost + Azotobacter), with values of 10.0% (2022–23) and 10.3% (2023–24). This was closely followed by T10 and T7, all of which included organic nutrient supplementation and Azotobacter, suggesting a synergistic effect of organic sources and nitrogen-fixing bio-inoculants. The lowest protein content was noted in the control (T1), with 7.6% and 7.8% in respective years. The increase in protein content under INM treatments can be attributed to: Enhanced nitrogen availability through both chemical and organic sources. Improved biological nitrogen fixation by Azotobacter.

Better micronutrient balance due to multi-nutrient application.

These results are in agreement with Sharma et al. (2019), who reported improved grain protein with the inclusion of vermicompost and biofertilizers in cereals due to better nutrient synchrony and uptake.

2. Protein Yield (kg ha⁻¹)

Protein yield showed significant variations across treatments, with values corresponding closely to grain yield and protein percentage. T9 once again recorded the highest protein yield, with 466.3 kg ha⁻¹ (2022–23) and 497.1 kg ha⁻¹ (2023–24). T10 (446.5 and 473.3 kg ha⁻¹) and T7 (426.8 and 454.8 kg ha⁻¹) also produced substantial protein yields. The lowest protein yield was observed in the control plot, with only 208.0 and 224.4 kg ha⁻¹. This increase in protein yield is largely a combined effect of: Higher grain yield and Higher protein concentration.

The integrated use of RDF with vermicompost or FYM and biofertilizers increases soil enzymatic activity, organic matter content, and nutrient use efficiency, all of which contribute to improved grain quality and quantity.

Similar findings were reported by Singh et al. (2017) and Dubey et al. (2021), highlighting the positive influence of INM on protein accumulation and nitrogen assimilation in grain crops like wheat and rice.

**Figure 1. Graph showing the Effect of integrated nutrient management on plant height (cm), number of tillersand dry matter accumulation (g m-2) at harvest stages**

**Figure 2. Graph Showing the Effect of integrated nutrient management on grain, straw, biological yield (q ha-1) and harvest index (%).**

**Figure 3. Graph showing the effect of integrated nutrient management on protein content (%) and protein yield (kg ha-1) in grain**

**Conclusion**

The findings of the present study clearly demonstrate the beneficial effects of Integrated Nutrient Management (INM) on enhancing crop growth, yield attributes, and grain quality. Across two consecutive years (2022–23 and 2023–24), treatments involving a synergistic combination of inorganic fertilizers (RDF), organic nutrient sources (vermicompost/FYM), and biofertilizers (Azotobacter) consistently outperformed the control and sole RDF application.

Among all treatments, T9 (100% RDF + 25% N through vermicompost + Azotobacter) emerged as the most effective, recording the maximum plant height, tiller number, dry matter accumulation, and significantly higher grain and straw yields, which in turn led to the highest biological yield and protein content. This highlights the superior role of INM in sustaining soil health, enhancing nutrient use efficiency, and improving overall crop productivity and nutritional quality.

The observed improvements can be attributed to: Enhanced nutrient availability and uptake, Better root and vegetative growth, Improved soil microbial activity and structure, Sustained nutrient release from organic sources.

These findings affirm that integrating organic and inorganic nutrient sources along with biofertilizers provides a sustainable and effective strategy for increasing crop yield and quality. Therefore, adoption of INM practices can be recommended for improving agricultural productivity while maintaining soil fertility and long-term sustainability.

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