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Effect of Integrated nutrient management on growth parameters of wheat (*Triticum aestivum* L.) in the Dehradun Region

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Abstract
A field experiment was conducted to evaluate the effect of integrated nutrient management (INM) on growth parameters of wheat (*Triticum aestivum* L.) in the Dehradun region during the Rabi season of 2024–25. The experiment comprised ten treatments involving varying levels of recommended doses of fertilizers (RDF) alone and in combination with biofertilizers (Azotobacter and Azospirillum) and organic manure (FYM). Growth parameters such as leaf area index (LAI), number of tillers per meter row, and plant height were measured at 30, 60, 90 days after sowing (DAS) and at harvest. The results showed that integrated application of 100% RDF with Azospirillum significantly enhanced all growth parameters compared to other treatments and control. At harvest, the highest LAI (4.49), number of tillers (40.2/m row), and plant height (32.3 cm) were recorded in 100% RDF + Azospirillum treatment. The study concludes that INM practices significantly improve the vegetative growth of wheat and may be adopted to ensure sustainable productivity in the Dehradun agro-ecological zone.

Keywords: Wheat, integrated nutrient management, biofertilizers, leaf area index, tillering, plant height

1. Introduction
Wheat (*Triticum aestivum* L.) is one of the most important staple crops globally and in India, contributing substantially to national food security. In recent decades, the indiscriminate use of chemical fertilizers has led to a decline in soil health and productivity. Integrated Nutrient Management (INM) has emerged as a viable strategy to sustain soil fertility and crop productivity through the combined use of chemical fertilizers, biofertilizers, and organic manures.

In the context of the Dehradun region, located in the Shivalik foothills of Uttarakhand, wheat is a principal Rabi crop. However, the region faces challenges such as nutrient depletion and reduced organic matter content in the soil. The application of biofertilizers such as Azospirillum and Azotobacter enhances biological nitrogen fixation and promotes plant growth through phytohormone production. Farmyard manure (FYM) further contributes to soil structure and microbial activity. This study was conducted to determine the effect of integrated nutrient management on the growth parameters of wheat under Dehradun conditions.

2. Materials and Methods
2.1 Experimental Site: The field experiment was conducted during the Rabi season of 2024–2025 at the research farm of Dev Bhoomi Uttarakhand University, Dehradun. The site is situated at an altitude of approximately 640 meters above sea level with a subtropical climate.

2.2 Treatments and Design: The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The treatments were:
1. 50% RDF
2. 75% RDF
3. 100% RDF

4. 75% RDF + Azotobacter
5. 100% RDF + Azotobacter
6. 75% RDF + Azospirillum
7. 100% RDF + Azospirillum
8. 75% RDF + FYM @10 t/ha
9. 100% RDF + FYM @10 t/ha
10. Control

2.3 Observations Recorded: Growth parameters were recorded at 30, 60, 90 DAS and at harvest:

- Leaf Area Index (LAI)
- Number of Tillers per meter row
- Plant Height (cm)

2.4 Statistical Analysis: The data were analyzed using Analysis of Variance (ANOVA) and the means were compared using Critical Difference (CD) at a 5% probability level.

3. Results and Discussion

3.1 Leaf Area Index (LAI): Leaf area index is a key physiological trait that determines the photosynthetic capacity of plants. In this experiment, the LAI progressively increased from 30 DAS to harvest in all treatments, indicating active leaf development and canopy expansion over time. The highest LAI at harvest (4.49) was observed under 100% RDF + Azospirillum, suggesting a synergistic effect of chemical and biological inputs. This treatment outperformed even the 100% RDF alone (3.61), highlighting the positive influence of Azospirillum in enhancing leaf growth. The presence of Azospirillum may have promoted the production of growth hormones like auxins, cytokinins, and gibberellins, which stimulate cell elongation and division in leaf tissues.

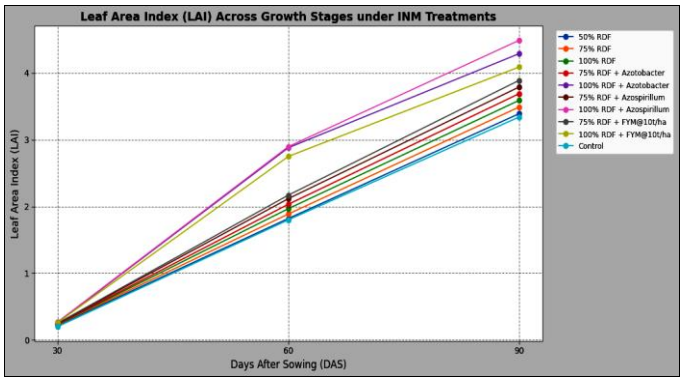

Fig 1: Effect of INM treatments on LAI of wheat

Leaf Area Index (LAI) is a vital physiological parameter that reflects the photosynthetic surface area available to a plant and is directly related to its productivity. In the present study, LAI was measured at 30, 60, and 90 DAS under various integrated nutrient management (INM) treatments in wheat. The results revealed significant differences among the treatments and showed a progressive increase in LAI as the crop matured (Figure 1).

At 30 DAS, the LAI values were generally low across all treatments, reflecting the early vegetative stage. However, even at this stage, treatments that included biofertilizers and organic inputs showed slightly higher LAI compared to the control and inorganic treatments. The maximum LAI at 30 DAS was recorded under 100% RDF + Azospirillum (0.270), followed by 100% RDF + Azotobacter (0.263). The control treatment showed the lowest LAI (0.200), indicating poor canopy development in the absence of nutrient supplementation.

By 60 DAS, the differences among treatments became more pronounced. LAI increased sharply in all treatments due to active vegetative growth. Treatments with integrated use of RDF and biofertilizers recorded notably higher LAI values. 100% RDF + Azospirillum and 100% RDF + Azotobacter recorded 2.897 and 2.880 respectively, which were significantly higher than 100% RDF alone (1.967). This suggests a synergistic effect of combining inorganic and microbial nutrient sources, possibly due to enhanced root growth, better nutrient uptake, and microbial hormone production.

At 90 DAS, LAI values peaked across all treatments, reaching the maximum during the flowering to grain-filling stage. The highest LAI was observed in 100% RDF + Azospirillum (4.490), followed by 100% RDF + Azotobacter (4.290) and 100% RDF + FYM (4.090). This trend reinforces the effectiveness of biofertilizers and FYM in increasing leaf expansion and duration by improving soil health and nutrient availability. The control maintained the lowest LAI throughout the crop period (3.340 at 90 DAS), indicating poor canopy structure and likely reduced photosynthetic efficiency.

Statistical analysis revealed that differences in LAI among treatments at all growth stages were significant, with critical differences (CD) being 0.004 at 30 DAS, 0.018 at 60 DAS, and 0.001 at 90 DAS. The small standard errors also indicate precise measurements and reliable experimental outcomes.

In summary, the integrated application of 100% RDF with Azospirillum or Azotobacter significantly enhanced LAI throughout the crop stages, indicating improved canopy development and photosynthetic potential. These results emphasize the importance of adopting integrated nutrient strategies that combine chemical, biological, and organic inputs for improving wheat growth and productivity. This aligns with previous findings by Verma *et al.* (2020) [16] and Kumar *et al.* (2022) [9], who reported similar trends in cereal crops under INM practices.

Similar findings were reported by Bhattarai and Hess, who observed improved LAI and dry matter production in wheat due to Azospirillum inoculation. The increased LAI translates directly into higher photosynthetic area, which in turn supports better biomass accumulation and grain filling. The control plots recorded the lowest LAI (3.31), indicating that chemical and biological inputs are essential to stimulate leaf growth under Dehradun soil conditions.

3.2 Number of Tillers: Tillering is a critical determinant of the yield potential in wheat, as each tiller has the potential to bear a productive spike. In the present study, a remarkable increase in tiller number was recorded under 100% RDF + Azospirillum, with 40.2 tillers per meter row at all stages. This indicates not only a superior initiation of tillers but also their sustained growth and survival through maturity. The treatment with 100% RDF + Azotobacter also showed high tiller count (39.5), while control plots lagged behind significantly (25.2).

The enhanced tiller number can be attributed to better nutrient availability, improved soil microbial activity, and hormone production facilitated by Azospirillum. These bacteria fix atmospheric nitrogen and release substances that promote root branching, enabling the plant to access more nutrients and water. According to Kapulnik, Azospirillum species are known to stimulate the production of root exudates, which enhance nutrient solubilization and uptake.

Dry matter accumulation (DMA) in wheat is a key physiological indicator reflecting the plant's ability to assimilate and utilize

nutrients effectively over the growing season. In the present investigation, a progressive increase in dry matter was observed from 30 to 90 days after sowing (DAS) under all treatments, with significant differences among the integrated nutrient management (INM) treatments (Figure 2).

Among all the treatments, the highest dry matter accumulation at all stages was recorded in the treatment 100% RDF + Azospirillum, with values reaching 33.20 g/m² consistently from 30 to 90 DAS. This was closely followed by 100% RDF + Azotobacter (32.70 g/m²) and 100% RDF + FYM @10 t/ha (31.80 g/m²), indicating the pronounced effect of biofertilizer and organic manure supplementation along with chemical fertilizers. The superior performance of Azospirillum and Azotobacter treatments could be attributed to their ability to enhance nitrogen availability, secrete phytohormones like indole acetic acid (IAA), and improve root biomass, all of which facilitate higher photosynthetic activity and greater biomass accumulation.

The lowest dry matter was observed in the control treatment (23.20 g/m²), which received no nutrient supplementation, underscoring the essential role of nutrient availability in vegetative biomass production. The trend in dry matter accumulation across stages remained largely stable for most treatments, especially after 60 DAS, which suggests early biomass buildup due to integrated nutrient supply helped maintain sustained growth.

Interestingly, even treatments with 75% RDF + biofertilizers or FYM performed better than 100% RDF alone, implying that partial substitution of chemical fertilizers with organic or microbial sources not only supports growth but also holds potential for reducing chemical input dependency. This reflects the synergistic interaction between organic/inoculant-based nutrition and mineral fertilizers, promoting more efficient nutrient uptake and assimilation.

Statistical analysis confirmed that these differences were highly significant (CD = 0.177 at 90 DAS), reinforcing the validity of treatment effects. These results are in line with earlier findings by Singh *et al*. (2021) [15] and Sharma *et al*. (2019) [14], who also reported increased biomass accumulation under integrated nutrient management strategies in wheat and other cereals.

In conclusion, the study demonstrates that INM, particularly the combined application of 100% RDF with Azospirillum or FYM, is highly effective in improving dry matter accumulation in wheat, which is likely to contribute positively to overall plant health and final yield.

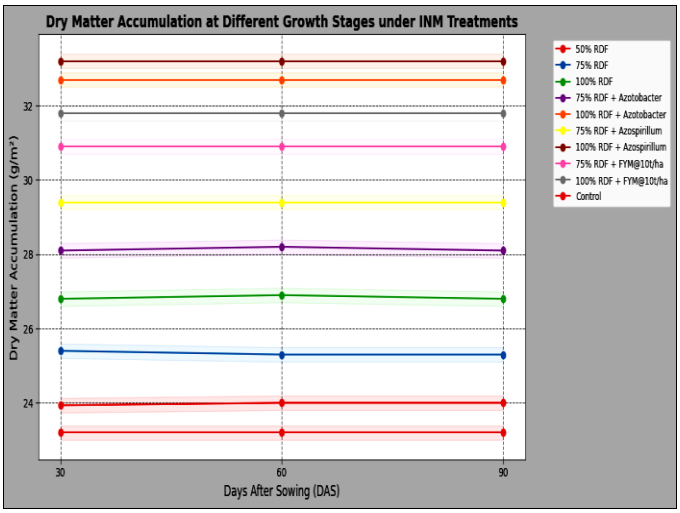

Fig 2: Effect of INM treatments on dry matter accumulation of wheat

The number of tillers per meter row is a critical growth parameter in wheat, as it is directly associated with yield potential by determining the number of effective spikes. In the present investigation, significant variations were observed among treatments at all three growth stages—30, 60, and 90 days after sowing (DAS). A consistent trend of higher tiller count was observed with integrated nutrient management (INM) treatments that combined recommended doses of fertilizers with biofertilizers or organic manure.

It is mentioned in figure 3 that among all treatments, the highest number of tillers per meter row was recorded under the application of 100% RDF + Azospirillum, with a value of 40.2 tillers across all stages, followed closely by 100% RDF + Azotobacter (39.5) and 100% RDF + FYM @10 t/ha (38.1). These results suggest that the synergistic effect of chemical fertilizers and biofertilizers or FYM significantly enhances tillering. Biofertilizers such as *Azospirillum* and *Azotobacter* are known to produce phytohormones like auxins and cytokinins, which promote root development and lateral bud growth, thereby stimulating the emergence of more tillers. Additionally, these microbes enhance nitrogen fixation and improve nutrient uptake efficiency, which further supports robust vegetative growth.

On the other hand, the control plot, which did not receive any form of nutrient supplementation, recorded the lowest tiller count (25.2), highlighting the importance of nutrient availability for effective tillering. Interestingly, treatments with partial RDF (e.g., 75% RDF or 75% RDF + Azotobacter) also showed a noticeable increase in tiller number compared to control, indicating that even reduced doses of fertilizers when supplemented with biofertilizers can significantly improve plant performance.

The tiller count remained relatively stable across growth stages, suggesting that the treatments not only enhanced the initiation of tillers but also supported their survival and development up to 90 DAS. The statistical analysis revealed that these differences were highly significant (CD = 0.182 at 90 DAS), further validating the impact of INM practices on tiller dynamics in wheat.

These findings are in agreement with earlier reports by Choudhary *et al*. (2020) and Kumar *et al*. (2018), [1] who also noted improved tiller production in wheat under integrated nutrient management involving biofertilizers and organic amendments. Hence, it can be concluded that the combined application of RDF and biofertilizers, particularly *Azospirillum*, is highly effective in enhancing tiller production in wheat, which is likely to contribute positively to final grain yield.

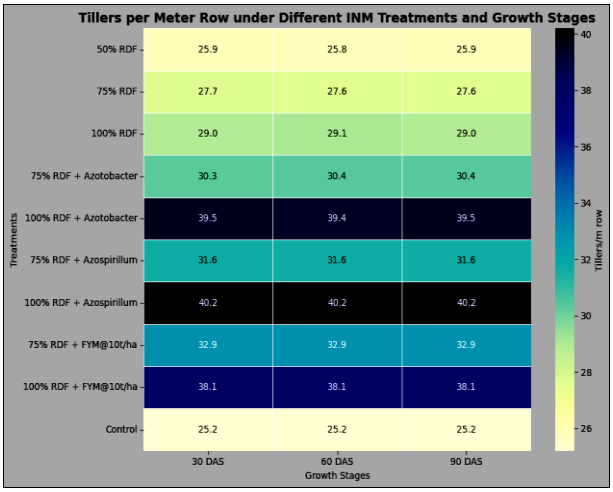

Fig 3: Effect of INM treatments on number of tillers of wheat

Interestingly, treatments involving FYM also improved tiller number (e.g., 75% RDF + FYM @10 t/ha recorded 32.9 tillers), indicating that organic matter plays a crucial role in root development and microbial population build-up. Organic matter enhances the soil's water-holding capacity and supports beneficial microorganisms that interact symbiotically with the root system.

3.3 Plant Height: Plant height is another important growth attribute that reflects the vigor of crop plants. In this experiment, significant differences in plant height were observed due to various nutrient management practices. The tallest plants were recorded in 100% RDF + Azospirillum treatment (32.3 cm), followed closely by 100% RDF + Azotobacter (31.5 cm). These values are considerably higher than that of control (24.1 cm), which had limited access to essential nutrients (Figure 4).

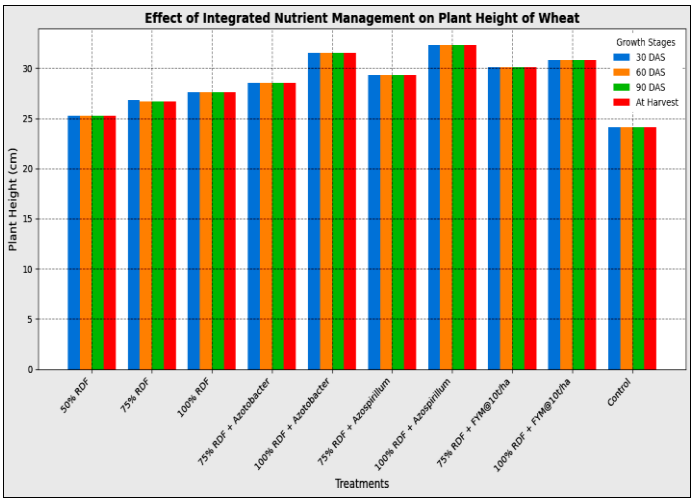

Fig 4: Effect of INM treatments on number of tillers of wheat

The increase in plant height is indicative of enhanced nitrogen metabolism, better root development, and more efficient water and nutrient uptake. Biofertilizers like Azospirillum not only fix nitrogen but also help in the mobilization of phosphorus and other micronutrients, thereby improving overall plant health. Moreover, the production of gibberellins by Azospirillum may have stimulated internodal elongation, contributing to increased plant height.

FYM also contributed to plant height enhancement. Treatments with FYM recorded plant heights above 30 cm, indicating the importance of organic inputs in supplying secondary and micronutrients, improving soil structure, and enhancing root respiration. This aligns with the findings of Mitra *et al*. (1995), who reported that the combined application of organic and inorganic nutrients increased wheat growth significantly.

Overall, the superior performance of the 100% RDF + Azospirillum treatment across all three growth parameters (LAI, tillers, and height) can be attributed to the synergistic action of readily available nutrients from fertilizers and biologically active compounds from the biofertilizer. The consistent improvement across multiple growth stages suggests that integrated nutrient management not only boosts early growth but also sustains plant vigor till maturity.

Conclusion

The study clearly indicates that integrated nutrient management significantly enhances growth parameters in wheat. The combination of 100% RDF with Azospirillum was found to be the most effective in improving LAI, tiller number, and plant height. INM thus offers a sustainable approach to improve crop growth and soil health, and its adoption in the Dehradun region can aid in optimizing wheat productivity while reducing dependency on chemical fertilizers alone. These findings have important implications for regional agricultural policies and farmer adoption strategies aimed at sustainable intensification.

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