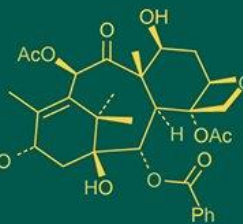
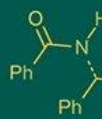


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Sankalp Singh
M.Sc. Student, Department of
Soil Science and Agricultural
Chemistry, Institute of
Agricultural Sciences,
Bundelkhand University,
Jhansi, Uttar Pradesh, India

Awanish Kumar
Assistant Professor,
Department of Soil Science and
Agricultural Chemistry,
Institute of Agricultural
Sciences, Bundelkhand
University, Jhansi, Uttar
Pradesh, India

Satyavir Singh
Assistant Professor,
Department of Soil Science and
Agricultural Chemistry,
Institute of Agricultural
Sciences, Bundelkhand
University, Jhansi, Uttar
Pradesh, India

Dr. Chetan Anand Dubey
Assistant Professor,
Department of Geology,
Bundelkhand University,
Jhansi, Uttar Pradesh, India

Ashish Kumar Tiwari
Research Scholar, Department
of Agronomy, Institute of
Agricultural Sciences,
Bundelkhand University,
Jhansi, Uttar Pradesh, India

Corresponding Author:
Sankalp Singh
M.Sc. Student, Department of
Soil Science and Agricultural
Chemistry, Institute of
Agricultural Sciences,
Bundelkhand University,
Jhansi, Uttar Pradesh, India

Response of integrated nutrient management on growth, yield and soil health of durum wheat under Bundelkhand region

Sankalp Singh, Awanish Kumar, Satyavir Singh, Chetan Anand Dubey and Ashish Kumar Tiwari

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Abstract

Wheat (*Triticum durum* L.) is a major cereal crop with significant nutritional and economic importance, yet its productivity in the Bundelkhand region of Uttar Pradesh remains below the national average due to soil fertility decline, moisture stress, and imbalanced nutrient management. A field experiment was conducted during the Rabi season of 2024-25 at the Students' Research Farm, Department of Soil Science and Agricultural Chemistry, Bundelkhand University, Jhansi, to evaluate the effect of integrated nutrient management (INM) on growth, yield, and soil health of durum wheat. The experiment was laid out in a Randomized Block Design (RBD) with three replications, comprising eight treatments: T₀ - RDF only (control), T₁ - 100% RDF + 10 t ha⁻¹ FYM, T₂ - 100% RDF + 15 t ha⁻¹ FYM, T₃ - 100% RDF + 10 t ha⁻¹ vermicompost (VC), T₄ - 100% RDF + 15 t ha⁻¹ VC, T₅ - 100% RDF + 5 t ha⁻¹ FYM + 10 t ha⁻¹ VC, T₆ - 100% RDF + 10 t ha⁻¹ FYM + 5 t ha⁻¹ VC, and T₇ - 100% RDF + 10 t ha⁻¹ FYM + 10 t ha⁻¹ VC. Results indicated that INM significantly improved growth parameters, including plant height and tiller number, at all growth stages compared to the control. Yield attributes such as number of effective tillers, ear length, spikelets per ear, grains per ear, and grain weight were markedly enhanced under integrated treatments. Among all treatments, T₇ produced the highest grain yield (44.35 kg plot⁻¹), followed by T₆, demonstrating the superior effect of combined organic and inorganic nutrient application. Soil health parameters, including water holding capacity, soil organic carbon, and available N, P, and K, were significantly improved under INM, indicating enhanced soil fertility and sustainability. The study concluded that integrated application of 100% RDF with FYM and vermicompost (T₇) is the most effective and sustainable nutrient management practice for improving growth, yield, and soil health of durum wheat under Bundelkhand conditions. The findings provide a strong basis for adopting INM in cereal-based cropping systems to achieve higher productivity and soil sustainability.

Keywords: Durum wheat, Integrated nutrient management, Farmyard manure, Vermicompost, Growth, Yield, Soil health

Introduction

Wheat (*Triticum* spp.) is one of the most widely cultivated cereal crops in the world and serves as a primary source of food for nearly 35-40% of the global population. Globally, wheat is grown on about 220-225 million ha with an annual production exceeding 785 million tonnes, contributing nearly 30% of total global cereal production. The European Union, China, India, the United States, Russia, and Canada are the major wheat-producing regions worldwide. India ranks second after China in wheat production, with an estimated production of over 110 million tonnes and an average productivity of around 3.4-3.5 t ha⁻¹ during 2022-23 (Anonymous, 2023) [4].

Among wheat species, bread wheat (*Triticum aestivum* L.) accounts for more than 90% of the total wheat area, while durum wheat (*Triticum durum* L.) contributes about 5-8% and is valued for its superior grain quality, particularly for pasta and semolina production. Wheat is nutritionally rich, containing 8-15% protein, 60-68% carbohydrates, essential minerals, dietary fiber, and B-complex vitamins, making it a vital component of human and animal diets (Sharma, 2000; Rueda-Ayala *et al.*, 2011) [24, 25].

In India, wheat is cultivated across diverse agro-ecological regions except Kerala and is classified into six major wheat-growing zones. Uttar Pradesh is the leading wheat-producing

state, contributing nearly 30% of national wheat production. However, despite having the largest area under wheat cultivation, productivity in many parts of Uttar Pradesh, particularly Bundelkhand and eastern regions, remains below the national average due to delayed sowing, moisture stress, nutrient imbalance, declining soil organic carbon, and poor soil fertility (Anonymous, 2023) [4].

Recent reviews have highlighted that the stagnation of wheat productivity in South Asia is strongly linked to intensive cropping systems, excessive reliance on chemical fertilizers, and neglect of soil biological health (Ladha *et al.*, 2020; Jat *et al.*, 2019) [10, 14]. Continuous and indiscriminate use of inorganic fertilizers especially nitrogen has resulted in nutrient imbalance, reduced fertilizer use efficiency, soil acidification, depletion of micronutrients, and deterioration of soil physical and biological properties (Meena *et al.*, 2018; Kumar *et al.*, 2022) [11, 12, 18]. Long-term studies indicate that exclusive chemical fertilization can reduce soil organic carbon by 15-30%, adversely affecting soil water retention and crop resilience under climate stress (Lal, 2020) [15].

Integrated Nutrient Management (INM), which involves the combined use of chemical fertilizers, organic manures, and biofertilizers, has emerged as a sustainable approach to enhance crop productivity while restoring soil health. Recent meta-analyses and reviews (Agegnehu *et al.*, 2019; Zhang *et al.*, 2021; Kumar *et al.*, 2023) [2, 13, 32] reported that INM can improve wheat yield by 10-25%, increase nutrient use efficiency by 15-30%, and significantly enhance soil organic carbon, microbial biomass, and water holding capacity. Organic inputs such as farmyard manure (FYM) and vermicompost improve soil aggregation, moisture retention, and nutrient buffering capacity, while inorganic fertilizers provide readily available nutrients to meet immediate crop demand.

Biofertilizers, particularly phosphate-solubilizing bacteria (PSB) and plant growth-promoting rhizobacteria (PGPR), further enhance nutrient availability by mobilizing native soil phosphorus and improving root growth. Recent studies indicate that PSB application can increase phosphorus use efficiency by 20-40% and improve wheat yield under nutrient-deficient soils (Panhwar *et al.*, 2014; Chen *et al.*, 2022) [6, 20].

Considering the declining soil fertility, increasing input costs, climate variability, and low wheat productivity in Bundelkhand, the adoption of integrated nutrient management practices is essential for sustainable durum wheat production. However, region-specific information on the combined use of RDF, organic manures, and soil health improvement in durum wheat under Bundelkhand conditions remains limited. Therefore, the present study entitled "Response of Integrated Nutrient Management on Growth, Yield and Soil Health of Durum Wheat (*Triticum durum* L.)" was conducted during the rabi season of 2024-25 at the Students' Research Farm, Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Bundelkhand University, Jhansi (U.P.), with the following objectives.

Materials and Methods

The field experiment was conducted during the Rabi season of 2024-25 at the Chemical Research Farm, Department of Soil Science and Agricultural Chemistry, Institute of Agricultural Sciences, Bundelkhand University, Jhansi

(U.P.), located in the Bundelkhand agro-climatic region. The experiment was laid out in a Randomized Block Design (RBD) with three replications and comprised eight treatments involving different combinations of recommended dose of fertilizers (RDF), farmyard manure (FYM), and vermicompost (VC). The treatments included T₀ (RDF only - control), T₁ (100% RDF + 10 t ha⁻¹ FYM), T₂ (100% RDF + 5 t ha⁻¹ FYM), T₃ (100% RDF + 10 t ha⁻¹ vermicompost), T₄ (100% RDF + 15 t ha⁻¹ vermicompost), T₅ (100% RDF + 5 t ha⁻¹ FYM + 10 t ha⁻¹ vermicompost), T₆ (100% RDF + 10 t ha⁻¹ FYM + 5 t ha⁻¹ vermicompost), and T₇ (100% RDF + 10 t ha⁻¹ FYM + 10 t ha⁻¹ vermicompost). The durum wheat variety HI-8802 was sown in rows spaced 20 cm apart, following recommended agronomic practices. Organic manures were applied as per treatments before sowing, while inorganic fertilizers were applied according to the recommended dose. Irrigation was provided uniformly as per crop requirement to ensure optimal soil moisture throughout the growing period. All intercultural operations, including weed and pest management, were carried out uniformly across treatments. Observations on growth parameters, yield attributes, and grain yield were recorded at appropriate stages, and soil samples were collected after harvest to assess changes in soil fertility. The experimental data were statistically analyzed using analysis of variance (ANOVA) appropriate for RBD, and treatment means were compared at the 5% level of significance.

Results and Discussion

Growth Parameters

Integrated nutrient management (INM) practices significantly influenced the growth performance of durum wheat throughout the crop growth period. Plant height measured at 30, 60, 90 DAS and at harvest showed a consistent and significant increase under integrated nutrient treatments compared to the control (RDF alone). Among all treatments, T₇ (100% RDF + 10 t ha⁻¹ FYM + 10 t ha⁻¹ vermicompost) produced the tallest plants at all growth stages, followed by T₆ (100% RDF + 10 t ha⁻¹ FYM + 5 t ha⁻¹ vermicompost) (Table-1 & Fig.-1).

The improved plant height under integrated nutrient application can be attributed to the synergistic interaction between organic and inorganic nutrient sources. Chemical fertilizers ensure immediate nutrient availability, particularly nitrogen, while FYM and vermicompost improve soil aggregation, microbial biomass, and nutrient buffering capacity (Table-1 & Fig.-1). Recent reviews by Zhao *et al.* (2021) and Lal *et al.* (2022) [16, 33] emphasized that INM enhances nutrient synchrony and root growth, leading to sustained vegetative development in cereals. Similar improvements in wheat growth under INM were reported by Dwivedi *et al.* (2014), Singh *et al.* (2020) [7, 28].

The number of tillers plant⁻¹ was also significantly affected by nutrient management practices. The highest tiller count was recorded under T₇, followed by T₆, whereas the control showed the lowest tiller production. Enhanced tillering under integrated treatments may be attributed to improved nutrient availability during early vegetative stages and favorable soil physical conditions. Organic inputs stimulate microbial activity and phytohormone production, particularly cytokinins, which play a key role in tiller initiation (Table-1 & Fig.-1). A global review by Agegnehu *et al.* (2019) [2] highlighted that INM significantly improves

tiller density and biomass accumulation in wheat and other cereals. These findings corroborate earlier reports by Afzal *et al.* (2005), Singh *et al.* (2011), and Yadav *et al.* (2019) [1, 29, 30].

Yield Attributes

Yield attributes of durum wheat responded positively to integrated nutrient management. The number of effective tillers per meter row length increased significantly under INM treatments, with T₇ recording the maximum value, statistically at par with T₆. Increased effective tillers reflect better tiller survival due to balanced nutrient supply during critical growth stages (Table-2 Fig.-2). According to a review by Kumar *et al.* (2023) [13], INM reduces tiller mortality by ensuring continuous nutrient availability and reducing intra-plant competition. Similar findings were reported by Singh *et al.* (2018) [27].

Ear length was significantly enhanced under integrated nutrient treatments. The longest ears were observed under T₇, followed by T₆, while the control recorded the shortest ears. Improved ear length may be attributed to better assimilate partitioning and nutrient translocation during reproductive growth (Table-2 Fig.-2). A recent synthesis by Ramesh *et al.* (2020) [23] reported that organic amendments improve photosynthate movement to developing spikes, enhancing ear morphology. These results are in agreement with Dwivedi *et al.* (2014), Kumar *et al.* (2022), and Sharma *et al.* (2021) [7, 13, 25].

The number of spikelets ear⁻¹ and grains ear⁻¹ also showed significant improvement under integrated nutrient management. T₇ produced the highest spikelet and grain numbers, followed by T₆, while the control showed the lowest values. Enhanced spikelet formation and grain setting under INM may be due to improved pollen viability, reduced floret abortion, and balanced nutrient supply during anthesis (Table-2 Fig.-2). A comprehensive review by Chen *et al.* (2022) [6] emphasized that integrated fertilization improves reproductive efficiency and grain sink capacity in wheat. These findings align with Singh *et al.* (2011), El-Lattief (2014), Nehra *et al.* (2001), and Ahmad (2006) [3, 8, 19, 29].

Grain weight ear⁻¹ was significantly influenced by nutrient management practices. The highest grain weight was recorded under T₇, followed by T₆, while the control recorded the lowest value. Improved grain weight under INM may be attributed to prolonged grain filling duration and enhanced soil moisture retention due to organic amendments (Table-2 Fig.-2). Recent meta-analyses by Zhang *et al.* (2021) [32] and Liu *et al.* (2023) [17] reported that

organic-inorganic fertilizer combinations significantly enhance grain filling rate and thousand-grain weight in wheat.

Productivity Parameters

Grain yield of durum wheat was significantly influenced by different nutrient management practices. The highest grain yield was recorded under T₇, followed closely by T₆, while the control produced the lowest yield. The superiority of integrated treatments in improving grain yield may be attributed to cumulative improvements in growth parameters and yield attributes such as tiller density, ear length, grain number, and grain weight (Table-3 Fig.-3).

Recent reviews by Agegnehu *et al.* (2019) [2] and highlighted that INM improves nutrient use efficiency by minimizing nutrient losses, enhancing root proliferation, and improving soil biological health. These mechanisms collectively contribute to sustainable yield enhancement. Similar yield advantages under INM have been reported by Nehra *et al.* (2001), Singh and Agarwal (2001), Patel *et al.* (2014), and Yadav *et al.* (2022) [19, 21, 26, 31].

Soil Chemical Properties after Harvest

Soil health parameters improved significantly under integrated nutrient treatments after harvest. Water holding capacity increased markedly with the application of FYM and vermicompost. Organic matter improves soil aggregation, porosity, and moisture retention, which is particularly beneficial under moisture-stressed Bundelkhand conditions. A recent review by Lal (2020) [15] emphasized that organic amendments play a crucial role in enhancing soil water dynamics and resilience to drought. Similar results were reported by Bhattacharyya *et al.* (2007) [5] and Singh and Agarwal (2001) [26]. Organic carbon content increased significantly under integrated treatments compared to the control. The increase in soil organic carbon may be attributed to the addition of organic residues and enhanced microbial decomposition. Reviews by Paustian *et al.* (2019) [22] and Ramesh *et al.* (2020) [23] confirmed that INM promotes carbon sequestration and long-term soil fertility. Available nitrogen, phosphorus, and potassium status of soil also improved under integrated nutrient management. Organic manures enhance nutrient mineralization, reduce phosphorus fixation, and improve potassium availability. Recent reviews by Jat *et al.* (2019) [10] and Kumar *et al.* (2023) [13] reported that integrated fertilization significantly improves soil nutrient balance and sustainability compared to sole inorganic fertilization.

Table 1: Effect of Integrated Nutrient Management on Growth Parameters of Durum Wheat (HI-8802) under Bundelkhand Conditions (Rabi 2024-25)

Symbol	Treatment Combination	Plant Height			Tillers plant ⁻¹ (Initial)	Effective tillers m ⁻¹ row length (Harvest)
		30 DAS	60 DAS	90 DAS		
T ₀	RDF	14.46	21.80	54.10	5.12	53.14
T ₁	100% RDF + 10 t/ha FYM	17.85	36.96	68.25	5.39	67.63
T ₂	100% RDF + 15 t/ha FYM	18.75	39.20	71.83	6.61	82.42
T ₃	100% RDF + 10 t/ha VC	18.59	37.71	69.99	6.21	81.72
T ₄	100% RDF + 15 t/ha VC	20.05	40.25	72.63	7.54	83.72
T ₅	100% RDF + 5 t/ha FYM + 10 t/ha VC	20.82	43.12	76.87	7.61	88.43
T ₆	100% RDF + 10 t/ha FYM + 5 t/ha VC	21.15	43.75	77.03	8.43	99.39
T ₇	100% RDF + 10 t/ha FYM + 10 t/ha VC	22.76	45.98	81.04	8.80	99.55
S.E.(m) ±		0.19	0.33	0.47	0.17	1.15
C.D. (p = 0.05)		0.55	0.96	1.39	0.50	3.40

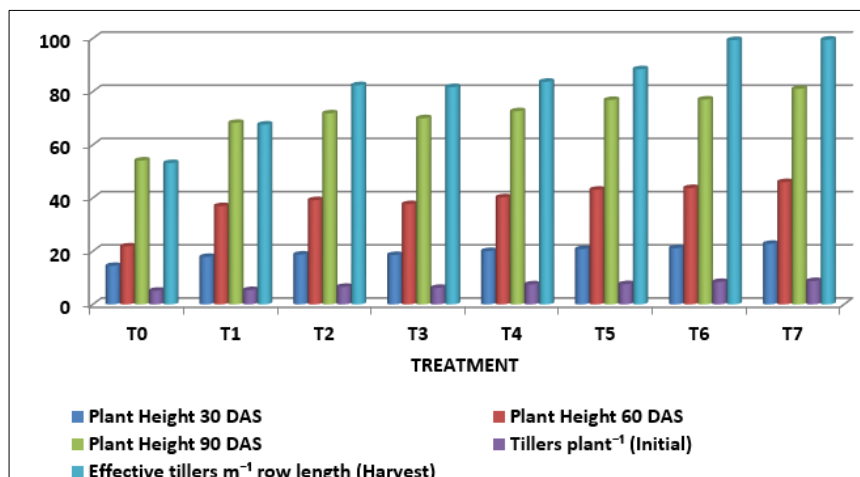


Fig1: Effect of Integrated Nutrient Management on Growth Parameters of Durum Wheat (HI-8802) under Bundelkhand Conditions (Rabi 2024-25)

Table 2: Effect of Integrated Nutrient Management on Yield Attributes of Durum Wheat (HI-8802) under Bundelkhand Conditions (Rabi 2024-25)

Symbol	Treatment Combination	Ear Length (cm)	No. of spikelets ear ⁻¹	No. of grains ear ⁻¹	Grain weight (g) ear ⁻¹
T ₀	RDF	8.52	16.10	34.70	1.16
T ₁	100% RDF + 10 t/ha FYM	10.65	17.98	39.76	1.41
T ₂	100% RDF + 15 t/ha FYM	10.81	18.84	40.23	1.45
T ₃	100% RDF + 10 t/ha VC	10.77	18.43	40.13	1.43
T ₄	100% RDF + 15 t/ha VC	10.90	19.29	40.63	1.50
T ₅	100% RDF + 5 t/ha FYM + 10 t/ha VC	11.09	19.86	41.93	1.60
T ₆	100% RDF + 10 t/ha FYM + 5 t/ha VC	11.14	20.21	42.30	1.62
T ₇	100% RDF + 10 t/ha FYM + 10 t/ha VC	11.19	20.53	42.67	1.70
S.E.(m) ±		0.02	0.14	0.11	0.01
C.D. (p = 0.05)		0.07	0.43	0.34	0.04

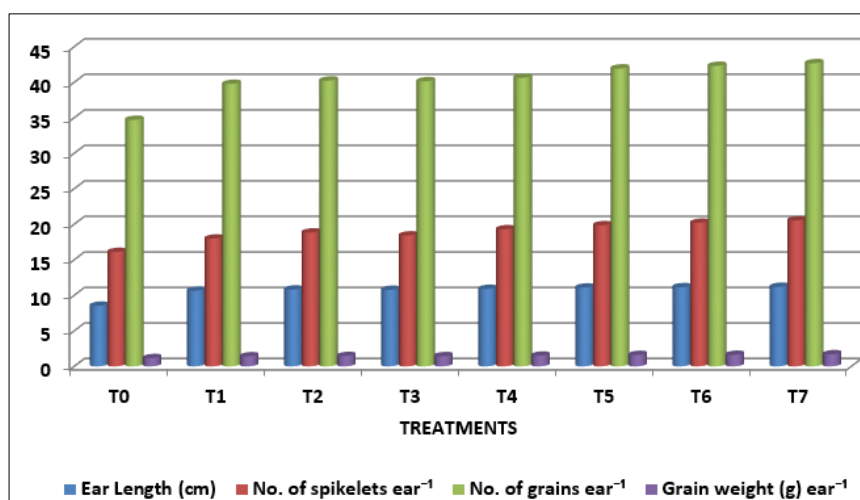


Fig 2: Effect of Integrated Nutrient Management on Yield Attributes of Durum Wheat (HI-8802) under Bundelkhand Conditions (Rabi 2024-25)

Table 3: Effect of Integrated Nutrient Management on Grain Yield and Productivity of Durum Wheat (HI-8802) under Bundelkhand Conditions (Rabi 2024-25)

Symbol	Treatment Combination	Grain Yield (kg)
T ₀	RDF	17.90
T ₁	100% RDF + 10 t/ha FYM	38.90
T ₂	100% RDF + 15 t/ha FYM	42.23
T ₃	100% RDF + 10 t/ha VC	40.96
T ₄	100% RDF + 15 t/ha VC	42.31
T ₅	100% RDF + 5 t/ha FYM + 10 t/ha VC	42.58
T ₆	100% RDF + 10 t/ha FYM + 5 t/ha VC	42.95
T ₇	100% RDF + 10 t/ha FYM + 10 t/ha VC	44.35
S.E.(m) ±		0.31
C.D. (p = 0.05)		0.93

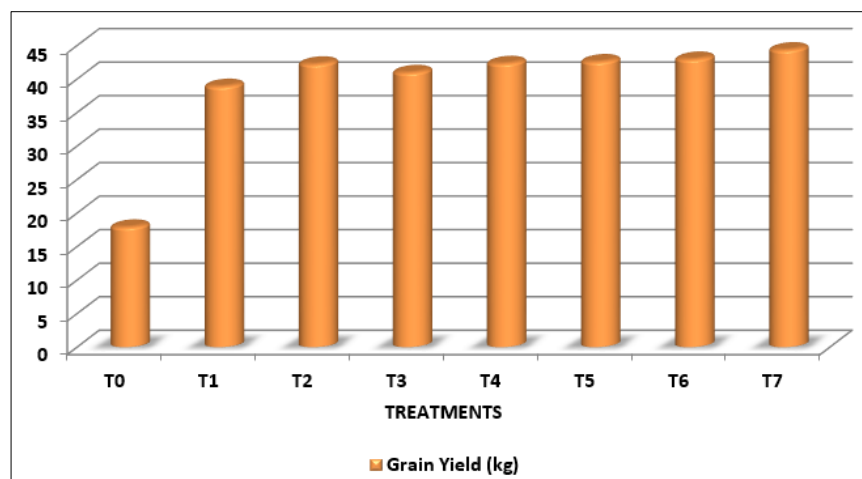


Fig 3: Effect of Different Treatments on Grain Yield (kg)

Conclusion

The findings of the present study clearly demonstrate that integrated nutrient management is an effective and sustainable approach for enhancing growth, yield, and soil health of durum wheat under Bundelkhand conditions. The combined application of inorganic fertilizers with organic sources proved superior to the sole use of chemical fertilizers.

Among the treatments evaluated, 100% RDF + 10 t ha⁻¹ FYM + 10 t ha⁻¹ vermicompost emerged as the most efficient nutrient management practice, resulting in improved growth, higher yield attributes, maximum grain yield, and enhanced soil fertility. Therefore, integrated application of RDF with FYM and vermicompost is recommended for sustainable durum wheat production in the Bundelkhand region and similar agro-climatic conditions.

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