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Vikash Sharma
School of Agriculture, Dev Bhoomi
Uttarakhand University,
Dehradun, Uttarakhand, India

Preeti Handa Kakkar
School of Agriculture, Dev Bhoomi
Uttarakhand University,
Dehradun, Uttarakhand, India

Anjali Adhikari
School of Agriculture, Dev Bhoomi
Uttarakhand University,
Dehradun, Uttarakhand, India

Corresponding Author:
Preeti Handa Kakkar
School of Agriculture, Dev Bhoomi
Uttarakhand University,
Dehradun, Uttarakhand, India

Effect of integrated nutrient management on growth, yield and economics of Wheat (*Triticum aestivum* L.) under subtropical hill conditions

Vikash Sharma, Preeti Handa Kakkar and Anjali Adhikari

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Abstract

A field experiment entitled “Growth Response of Wheat (*Triticum aestivum* L.) to Optimized Ratios of Organic and Chemical Fertilizer Blends” was conducted during the rabi season of 2025–26 at the experimental farm of Mahinder Agriculture Farm Solan-Arki region of Himachal Pradesh, India. The study aimed to evaluate the effect of integrated nutrient management using different combinations of organic manure and chemical fertilizers on growth, yield and economics of wheat cultivation. The experiment was laid out in a Randomized Block Design (RBD) with eight treatments and three replications. The treatments included control, 100% Recommended Dose of Fertilizers (RDF), 100% organic manure and various combinations of organic and inorganic nutrient sources. The results revealed significant improvement in growth and yield parameters due to integrated nutrient management. Among all treatments, application of 50% Organic + 100% RDF recorded maximum plant height (110.2 cm), tillers per plant (9.1), leaf area index (4.58), dry matter accumulation (33.2 g plant⁻¹), grain yield (52.4 q ha⁻¹), straw yield (68.8 q ha⁻¹) and biological yield (121.2 q ha⁻¹). The same treatment also recorded the highest net return (₹57,300/ha) and benefit-cost ratio (2.21). The study concluded that integrated application of organic manure and chemical fertilizers enhances productivity, profitability and sustainability of wheat cultivation under subtropical agro-climatic conditions. “The study highlights the importance of integrated nutrient management as a sustainable strategy for improving wheat productivity and maintaining soil health under hill agro-ecosystems.”

Keywords: Wheat, integrated nutrient management, organic manure, RDF, sustainable agriculture, soil fertility, grain yield

1. Introduction

Wheat (*Triticum aestivum* L.) is one of the most important cereal crops in the world and serves as a staple food for a large proportion of the global population. It contributes significantly to food and nutritional security by supplying carbohydrates, proteins, vitamins and essential minerals. In India, wheat is the second most important cereal crop after rice and plays a crucial role in ensuring national food security, particularly in the Indo-Gangetic Plains and hill agro-ecosystems.

India is the second-largest producer of wheat globally, contributing approximately 13.18% of total world wheat production during 2019–2020 (MoA & FW, 2019). The crop is cultivated over an area of about 29.14 million hectares with an annual production of nearly 102.19 million tonnes (GoI, 2019). Wheat is primarily grown as a rabi crop and is generally sown during October–November and harvested between February and April under suitable climatic conditions (Dhamija *et al.*, 2020) [4]. The optimum temperature for wheat cultivation ranges between 20–25 °C, which favors proper growth and grain development (Tripathi and Mishra, 2017) [26].

With the continuous increase in population and food demand, achieving higher wheat productivity has become a major agricultural priority. Over the past several decades, the intensive use of chemical fertilizers has significantly enhanced crop productivity and contributed to the Green Revolution. However, continuous and imbalanced application of inorganic fertilizers has resulted in declining soil fertility, nutrient imbalance, reduced soil organic carbon

and deterioration of soil physical, chemical and biological properties. These problems are particularly severe in fragile hill ecosystems where soils are shallow and nutrient-deficient (He *et al.*, 2024; Hyder *et al.*, 2021) ^[8, 9].

In recent years, growing concern regarding environmental degradation and declining soil health has shifted attention toward sustainable nutrient management practices. Integrated Nutrient Management (INM), which involves the combined use of organic and inorganic nutrient sources, has emerged as an effective strategy for maintaining soil fertility and improving crop productivity. Organic nutrient sources such as farmyard manure (FYM), compost and vermicompost improve soil structure, microbial activity, water-holding capacity and gradual nutrient release, thereby enhancing soil health and sustainability. However, sole dependence on organic sources is often insufficient to meet the nutrient requirements of high-yielding wheat varieties during critical growth stages (Singh *et al.*, 2024) ^[24].

The integrated application of organic manures and chemical fertilizers ensures balanced nutrient supply, improves nutrient use efficiency and enhances crop growth and yield. Several studies have reported that integrated nutrient management significantly improves growth parameters such as plant height, tillering, leaf area index, dry matter accumulation and grain yield in wheat compared to the sole application of either organic or inorganic fertilizers (Ahmed *et al.*, 2023; Hyder *et al.*, 2021) ^[1, 9]. Moreover, balanced nutrient management has been found to enhance soil biological activity, improve nitrogen use efficiency and sustain long-term soil productivity (Devi *et al.*, 2025; He *et al.*, 2024) ^[3, 8].

Optimization of the ratio between organic and inorganic nutrient sources is an important aspect of integrated nutrient management. Appropriate combinations of nutrient sources ensure synchronized nutrient availability throughout crop growth stages and reduce nutrient losses to the environment. Previous research indicates that partial substitution of chemical fertilizers with organic manures can improve soil fertility, increase crop productivity and minimize environmental risks associated with excessive fertilizer use (Ahmed *et al.*, 2023; Singh *et al.*, 2024) ^[1, 24]. However, the response of wheat to different organic and inorganic fertilizer combinations varies depending on soil type, climatic conditions and agro-ecological regions (Rakesh *et al.*, 2025) ^[21].

Wheat cultivation in hill regions faces several production constraints including low soil fertility, poor soil structure, erratic rainfall and limited nutrient availability. These challenges necessitate the development of efficient and location-specific nutrient management strategies for sustainable crop production. Despite the recognized importance of integrated nutrient management, limited information is available regarding the optimization of organic and inorganic fertilizer ratios under the hill agro-climatic conditions of Himachal Pradesh. Furthermore, the combined influence of these nutrient combinations on growth, yield attributes and economic returns of wheat has not been adequately explored.

Therefore, the present investigation was undertaken to evaluate the effect of different ratios of organic and chemical fertilizer blends on the growth, yield and profitability of wheat under subtropical hill conditions. The findings of the study may help in identifying efficient and sustainable nutrient management practices for enhancing wheat productivity, improving soil health and promoting long-term agricultural sustainability in hill agro-ecosystems.

- Objectives
1.

To evaluate the effect of different ratios of organic and chemical fertilizer blends on wheat growth.
2.

To identify the optimum nutrient combination for maximum yield and profitability.
3.

To develop sustainable nutrient management recommendations.

2. Materials and Methods

2.1 Experimental Site

The present investigation entitled “Growth Response of Wheat (*Triticum aestivum* L.) to Optimized Ratios of Organic and Chemical Fertilizer Blends” was conducted during the rabi season of 2025–26 at the experimental farm of Mahinder Agriculture Farm Solan-Arki region of Himachal Pradesh, India. The experimental site represents typical agro-climatic conditions of the region. The area falls under a subtropical climate characterized by mild winters and warm summers. The average annual rainfall is moderate and mostly received during the monsoon season. The soil of the experimental field was sandy loam in texture with good drainage capacity.

2.2 Climate and Weather Conditions

The experimental site experiences a subtropical climate with distinct winter and summer seasons. During the rabi season, the temperature ranges between 8 °C to 25 °C, which is favorable for wheat cultivation. The relative humidity remains moderate, and occasional winter rains contribute to soil moisture availability.

2.3 Experimental Details

Particulars	Details
Crop	Wheat (<i>Triticum aestivum</i> L.)
Variety	HPW-360
Season	Rabi (2025–26)
Experimental Design	Randomized Block Design (RBD)
Number of Treatments	8
Number of Replications	3
Plot Size	4 m × 3 m (12 m ²)
Spacing	22.5 cm × 10 cm
Sowing Depth	4–5 cm

2.4 Experimental Design

The experiment was laid out in a Randomized Block Design (RBD) with eight treatments and three replications. Each treatment was randomly allocated within each replication to minimize experimental error and ensure unbiased comparison.

2.5 Treatment Details

The treatments consisted of different ratios of organic and chemical fertilizer blends

Treatment	Description
T ₁	Control (no fertilizer)
T ₂	100% Recommended Dose of Fertilizers (RDF)
T ₃	100% Organic (FYM/Vermicompost)
T ₄	25% Organic + 75% RDF
T ₅	50% Organic + 50% RDF
T ₆	75% Organic + 25% RDF
T ₇	50% Organic + 100% RDF
T ₈	Farmers’ Practice

The organic manure was applied on an equivalent nitrogen basis and incorporated into the soil during final land preparation.

2.6 Field Preparation

The experimental field was prepared by ploughing followed by harrowing to obtain a fine tilth. All weeds and crop residues were removed before layout. The field was then leveled and divided into plots according to the experimental design.



Plate 1: Land preparation of the experimental field before sowing of wheat crop at experimental farm, Solan Arki, Himachal Pradesh

2.7 Sowing of Crop

Wheat seeds of variety HPW-360 were sown on 25th November 2025 using line sowing method. The recommended spacing of 22.5 cm between rows and 10 cm between plants was maintained. The sowing depth was kept at 4–5 cm.



Plate 2: Seed sowing in experimental plots under irrigated conditions

2.8 Fertilizer Application

Chemical fertilizers were applied as per the recommended dose of fertilizers (RDF). Nitrogen was applied in split doses, while phosphorus and potassium were applied as basal dose at the time of sowing.

Organic manures (FYM or vermicompost) were applied uniformly in respective treatments and incorporated into the soil 2–3 weeks before sowing to ensure proper decomposition and nutrient availability.



Plate 3: Basal fertilizer application in experimental plots under irrigated conditions.

2.9 Crop Management Practices

All agronomic practices were carried out uniformly for all treatments:

- **Irrigation:** Applied at critical stages such as tillering, booting and grain filling
- **Weeding:** Manual weeding was done at 30 DAS
- **Plant Protection:** Necessary plant protection measures were adopted to control pests and diseases
- **Thinning:** Done at early stage to maintain uniform plant population

2.10 Observations Recorded

Growth parameters were recorded at different growth stages.

a) A Plant Height (cm)

Measured from the base of the plant to the tip of the spike at 30 and 45 DAS.

b) Number of Tillers per Plant

Counted from randomly selected plants in each plot at 30 and 45 DAS.

c) Leaf Area Index (LAI)

Recorded at 60 and 75 DAS using standard methods.



Plate 4: Recording of observations from different wheat treatment plots at vegetative growth stage

d) Dry Matter Accumulation (g plant^{-1})

Plants were uprooted, oven-dried and weighed at different growth stages.

e) Harvesting and Yield Recording

The crop was harvested at physiological maturity during March–April 2026. The harvested produce from each plot was threshed and cleaned. Grain yield and straw yield were recorded and expressed on per hectare basis.

2.11 Statistical Analysis

The experimental data were statistically analyzed using Analysis of Variance (ANOVA) appropriate for the Randomized Block Design (RBD) as described by Gomez and Gomez (1984) [7]. The significance of treatment effects was tested at the 5% level of probability ($P = 0.05$). Whenever the treatment effects were found to be significant, the treatment means were compared using Critical Difference (CD), also referred to as Least Significant Difference (LSD), at the 5% level of significance. Treatment means were compared at 5% level of significance using appropriate statistical methods such as Critical Difference (CD) or Least Significant Difference (LSD).

2.10. Results and Discussion

2.10.1 Plant Height (cm)

The data presented in Table revealed that plant height of wheat increased progressively with advancement in crop growth stages under different fertilizer treatments. Among all treatments, application of 50% Organic + 100% RDF recorded the maximum plant height at all growth stages, measuring 26.3 cm at 30 DAS, 52.8 cm at 45 DAS, 82.4 cm at 60 DAS and 110.2 cm at harvest. This treatment was found significantly superior over the control and most other treatments. The enhanced plant height may be attributed to balanced nutrient availability through combined application of organic manure and chemical fertilizers, which improved nutrient uptake, root growth and photosynthetic activity. The treatment receiving 50% Organic + 50% RDF also performed remarkably well with plant height of 106.5 cm at harvest.

In contrast, the control treatment recorded the lowest plant height throughout the crop period, with only 82.3 cm at harvest. The poor growth under control may be due to inadequate nutrient availability resulting in restricted vegetative growth. Integrated nutrient management treatments showed better performance compared to sole organic or sole chemical fertilizer application, indicating synergistic effects of nutrient sources. Similar findings were reported by Singh *et al.* (2019) [25], Kumar and Yadav (2020) [11] and Sharma *et al.* (2021) [23], who observed increased plant height in wheat under integrated nutrient management practices.

Table 1: Effect of integrated nutrient management on plant height of wheat at different growth stages

Treatment	30 DAS	45 DAS	60 DAS	At Harvest
Control (no fertilizer)	18.4	36.2	58.4	82.3
100% Recommended Dose of Fertilizers (RDF)	24.6	48.8	76.5	102.4
100% Organic (FYM/Vermicompost)	22.8	45.2	70.6	96.8
25% Organic + 75% RDF	23.5	46.4	72.8	98.2
50% Organic + 50% RDF	25.2	50.4	79.2	106.5
75% Organic + 25% RDF	21.9	43.6	68.7	94.4
50% Organic + 100% RDF	26.3	52.8	82.4	110.2
Farmers' Practice	20.6	40.2	64.5	89.6
SEm ($\pm$)	0.62	1.12	1.46	1.85
CD ($P \leq 0.05$)	1.88	3.41	4.43	5.62

2.10.2 Number of Tillers per Plant

The number of tillers per plant was significantly influenced by different fertilizer combinations as shown in Table 2. Maximum tillers per plant were observed under 50% Organic + 100% RDF treatment, recording 5.2, 7.6 and 9.1 tillers at 30, 45 and 60 DAS, respectively. This was closely followed by 50% Organic + 50% RDF treatment. Increased tillering under integrated nutrient treatments may be due to continuous nutrient release from organic sources coupled with readily available nutrients from chemical fertilizers, which promoted vigorous vegetative growth and higher tiller formation.

The control treatment recorded the minimum number of tillers at all growth stages. Lower tiller production under nutrient deficient conditions may be attributed to poor root development and reduced metabolic activity. The results clearly indicated that combined nutrient application enhanced nutrient use efficiency and promoted better crop establishment. Similar results were reported by Sharma *et al.* (2018) [23], Patel *et al.* (2020) [18] and Meena and Verma (2022) [13], who observed significantly higher tiller production in wheat with integrated nutrient management.

Table 2: Number of Tillers per Plant of Wheat

Treatment	30 DAS	45 DAS	60 DAS
Control (no fertilizer)	2.8	4.5	5.4
100% Recommended Dose of Fertilizers (RDF)	4.6	6.8	8.2
100% Organic (FYM/Vermicompost)	4.2	6.2	7.5
25% Organic + 75% RDF	4.4	6.5	7.8
50% Organic + 50% RDF	4.9	7.2	8.6
75% Organic + 25% RDF	3.9	5.8	7.0
50% Organic + 100% RDF	5.2	7.6	9.1
Farmers' Practice	3.5	5.2	6.3
SEm ($\pm$)	0.12	0.18	0.24
CD ($P \leq 0.05$)	0.36	0.55	0.73

2.10.3 Leaf Area Index (LAI)

The observations presented in Table 3 indicated significant variation in leaf area index among different treatments. The highest LAI was recorded under 50% Organic + 100% RDF treatment with values of 3.65, 4.58 and 4.12 at 60, 75 and 90 DAS, respectively. Increased LAI under integrated nutrient treatments may be due to enhanced cell division, leaf expansion and chlorophyll synthesis resulting from balanced nutrient availability.

The control treatment recorded the lowest LAI values throughout the growth period. Lower LAI under control conditions might be due to poor vegetative growth and reduced leaf development caused by nutrient deficiency. Application of combined organic and inorganic fertilizers improved soil physical properties, moisture retention and nutrient availability, which ultimately enhanced canopy development. Similar observations were reported by Verma *et al.* (2019) [27], Rai and Singh (2021) [19] and Kumar *et al.* (2023) [12].

Table 3: Leaf Area Index (LAI) of Wheat

Treatment	60 DAS	75 DAS	90 DAS
Control (no fertilizer)	1.82	2.34	2.05
100% Recommended Dose of Fertilizers (RDF)	3.24	4.15	3.76
100% Organic (FYM/Vermicompost)	2.96	3.84	3.42
25% Organic + 75% RDF	3.08	3.96	3.55
50% Organic + 50% RDF	3.42	4.36	3.92
75% Organic + 25% RDF	2.74	3.58	3.20
50% Organic + 100% RDF	3.65	4.58	4.12
Farmers' Practice	2.42	3.16	2.84
SEm ($\pm$)	0.08	0.11	0.10
CD ($P \leq 0.05$)	0.24	0.34	0.31

2.10.4 Dry Matter Accumulation (g plant⁻¹)

The dry matter accumulation of wheat increased significantly with crop age under all fertilizer treatments (Table 4). The highest dry matter accumulation was recorded in the treatment receiving 50% Organic + 100% RDF, which produced 33.2 g plant⁻¹ at harvest. This was followed by 50% Organic + 50% RDF treatment with 31.5 g plant⁻¹. Increased biomass accumulation may be attributed to enhanced photosynthetic efficiency, improved nutrient uptake and better translocation of assimilates under integrated nutrient management.

The lowest dry matter accumulation was observed under control treatment. Insufficient nutrient supply in unfertilized plots reduced photosynthetic activity and plant growth, thereby limiting biomass production. Integrated application of organic manure and fertilizers ensured sustained nutrient availability throughout crop growth stages, resulting in better dry matter production. Similar findings were reported by Patel *et al.* (2018) [18], Yadav *et al.* (2020) [28] and Chaudhary and Meena (2022) [2].

Table 4: Dry Matter Accumulation (g plant⁻¹) of Wheat

Treatment	30 DAS	60 DAS	90 DAS	At Harvest
Control (no fertilizer)	2.8	8.6	16.4	19.8
100% Recommended Dose of Fertilizers (RDF)	4.5	13.8	24.6	29.4
100% Organic (FYM/Vermicompost)	4.1	12.6	22.8	27.2
25% Organic + 75% RDF	4.2	13.1	23.4	28.1
50% Organic + 50% RDF	4.8	14.6	26.2	31.5
75% Organic + 25% RDF	3.8	11.9	21.4	25.8
50% Organic + 100% RDF	5.2	15.8	28.4	33.2
Farmers' Practice	3.4	10.4	18.6	22.5
SEm (±)	0.14	0.42	0.66	0.84
CD (P ≤ 0.05)	0.42	1.28	2.01	2.55

2.10.5 Grain Yield, Straw Yield and Biological Yield

The data presented in Table.5 demonstrated that fertilizer treatments significantly influenced grain yield, straw yield and biological yield of wheat. The highest grain yield (52.4 q ha⁻¹), straw yield (68.8 q ha⁻¹) and biological yield (121.2 q ha⁻¹) were recorded under 50% Organic + 100% RDF treatment. This treatment proved significantly superior over all other treatments due to improved nutrient availability, enhanced growth attributes and efficient translocation of photosynthates towards grain formation.

The treatment receiving 50% Organic + 50% RDF also produced higher yields compared to sole fertilizer or sole organic treatments. The control treatment recorded the lowest yields because of poor nutrient supply and restricted plant growth. Integrated nutrient management improved soil fertility, microbial activity and nutrient use efficiency, thereby enhancing overall crop productivity. Similar findings were reported by Rai *et al.* (2019) ^[19], Meena *et al.* (2021) ^[13] and Kumar and Sharma (2023) ^[12] in wheat cultivation.

Table 5: Grain Yield, Straw Yield and Biological Yield of Wheat

Treatment	Grain Yield (q ha ⁻¹)	Straw Yield (q ha ⁻¹)	Biological Yield (q ha ⁻¹)
Control (no fertilizer)	24.2	36.8	61.0
100% Recommended Dose of Fertilizers (RDF)	46.4	61.2	107.6
100% Organic (FYM/Vermicompost)	41.6	56.4	98.0
25% Organic + 75% RDF	43.8	58.2	102.0
50% Organic + 50% RDF	48.6	64.5	113.1
75% Organic + 25% RDF	39.2	53.6	92.8
50% Organic + 100% RDF	52.4	68.8	121.2
Farmers' Practice	34.8	48.6	83.4
SEm (±)	1.12	1.46	2.06
CD (P ≤ 0.05)	3.41	4.43	6.25

2.10.6 Harvest Index (%)

The harvest index values presented in Table 6 showed significant differences among treatments. The highest harvest index (43.23%) was observed under 50% Organic + 100% RDF treatment, followed closely by 100% RDF treatment. Higher harvest index indicates efficient partitioning of photosynthates towards grain production under balanced nutrient supply conditions.

The control treatment recorded the lowest harvest index (39.67%), indicating poor conversion efficiency of total biomass into economic yield. Integrated nutrient treatments maintained better source-sink relationship and improved grain filling, which contributed to higher harvest index values. Similar observations were reported by Yadav *et al.* (2018) ^[28], Singh and Verma (2020) ^[25] and Patel *et al.* (2022) ^[18].

Table 6: Harvest Index (%) of Wheat

Treatment	Grain Yield (q ha ⁻¹)	Biological Yield (q ha ⁻¹)	Harvest Index (%)
Control (no fertilizer)	24.2	61.0	39.67
100% Recommended Dose of Fertilizers (RDF)	46.4	107.6	43.12
100% Organic (FYM/Vermicompost)	41.6	98.0	42.45
25% Organic + 75% RDF	43.8	102.0	42.94
50% Organic + 50% RDF	48.6	113.1	42.97
75% Organic + 25% RDF	39.2	92.8	42.24
50% Organic + 100% RDF	52.4	121.2	43.23
Farmers' Practice	34.8	83.4	41.73
SEm (±)	—	—	0.46
CD (P ≤ 0.05)	—	—	1.39

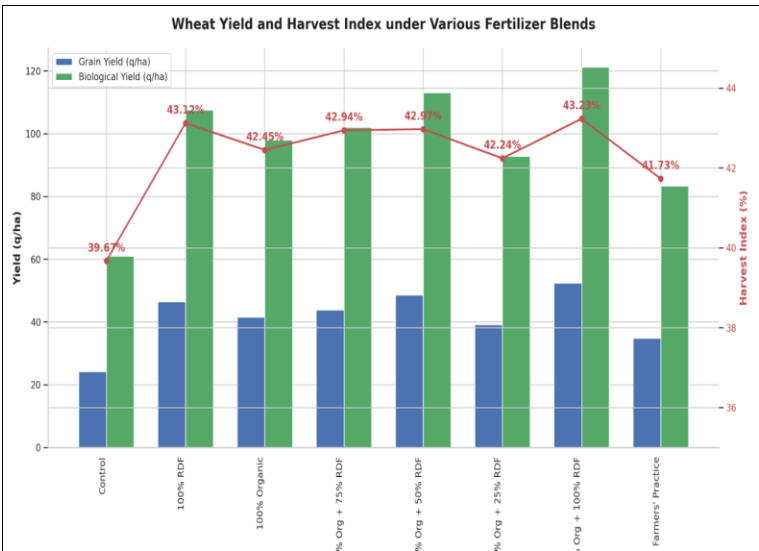


Fig 1: Effect of integrated nutrient management on harvest index of wheat

2.10.7 Economics of Different Fertilizer Treatments

The economic analysis presented in Table 7 revealed that the maximum gross return (₹104,800/ha), net return (₹57,300/ha) and benefit-cost ratio (2.21) were obtained under 50% Organic + 100% RDF treatment. Higher profitability under this treatment may be due to increased grain and straw yields resulting from balanced nutrient application. Although organic treatments involved comparatively higher

cultivation costs, integrated nutrient treatments generated better economic returns due to higher productivity. The control treatment recorded the lowest net return and benefit-cost ratio because of poor crop yield. The results indicated that integrated nutrient management is economically viable and sustainable for wheat production. Similar findings were reported by Chaudhary *et al.* (2019) ^[2], Meena and Kumar (2021) ^[13].

Table 7: Economics of Different Fertilizer Treatments in Wheat

Treatment	Cost of Cultivation (₹/ha)	Gross Return (₹/ha)	Net Return (₹/ha)	B:C Ratio
Control (no fertilizer)	28,000	48,400	20,400	1.73
100% Recommended Dose of Fertilizers (RDF)	42,500	92,800	50,300	2.18
100% Organic (FYM/Vermicompost)	46,000	83,200	37,200	1.81
25% Organic + 75% RDF	44,200	87,600	43,400	1.98
50% Organic + 50% RDF	45,600	97,200	51,600	2.13
75% Organic + 25% RDF	43,800	78,400	34,600	1.79
50% Organic + 100% RDF	47,500	104,800	57,300	2.21
Farmers' Practice	38,400	69,600	31,200	1.81
SEm (±)	520	1860	1520	0.05
CD (P ≤ 0.05)	1578	5648	4615	0.16

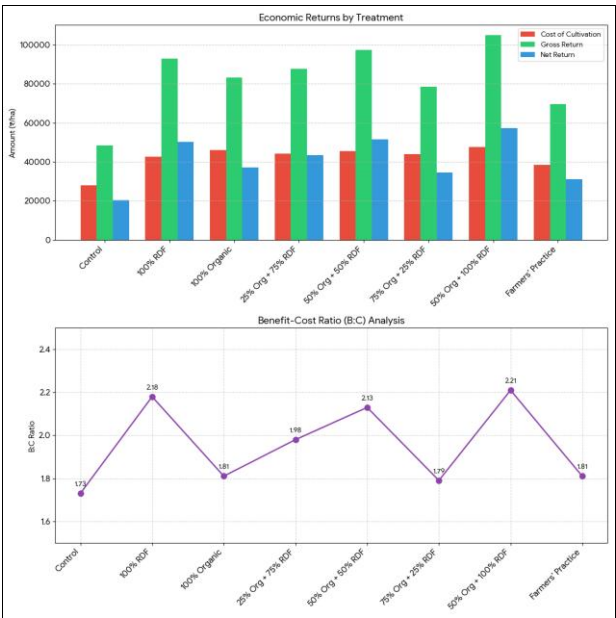


Fig 2: Economics of wheat cultivation under different nutrient management treatments

3. Conclusion

The present study demonstrated that integrated nutrient management significantly improved growth, yield and economic returns of wheat under subtropical hill conditions. Among the different treatments, application of 50% Organic + 100% RDF proved most effective in enhancing plant growth, yield attributes, grain yield and profitability. The integrated use of organic manure and chemical fertilizers improved nutrient availability and soil health, thereby contributing to sustainable wheat production. Therefore, integrated nutrient management may be recommended as an economically viable and environmentally sustainable strategy for wheat cultivation in Himachal Pradesh and similar agro-ecological regions.

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