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# Effect of Nitrogen, Organic Manures and Zinc Foliar Spray on Different Growth Parameters of Two-Row Barley (*Hordeum distichon* L.)

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***Authors' contributions***

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

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## ABSTRACT

A field experiment was conducted during the *rabi* season 2024–25 at the Agronomy Research Farm, R.S.M. (P.G.) College, Dhampur, Bijnor (U.P.), India to study the effect of nitrogen, organic manures and zinc foliar spray on growth of barley (*Hordeum distichon* L.). The trial was laid out in a randomized block design with seven treatments and thrice replications, including recommended dose of nitrogen, poultry manure, vermicompost, and zinc foliar spray in different combinations. The results indicated that the integrated application of 80% RDN + 20% N through poultry manure + 0.5% foliar spray of $ZnSO_4$ at 30 DAS and flowering ($T_5$) significantly improved growth parameters (plant height, tillers, leaf area, plant fresh and dry weight), compared to control and sole inorganic treatments. The study concluded that integrating organic manures and foliar-applied zinc with reduced nitrogen fertilization (80% RDN + 20% N through poultry manure + 0.5% foliar spray of $ZnSO_4$ at 30 DAS and flowering) enhances growth parameters of barley while promoting sustainable nutrient management.


*Keywords: Barley; nitrogen; poultry manure; vermicompost; zinc foliar spray; yield.*

## 1. INTRODUCTION

Barley (*Hordeum distichon* L.) is the world's 4th most essential cereal crop after wheat, rice and maize with a share of about 7% of the global cereals production and 15% of coarse grains consumption. It is unjustly neglected today as a food grain. Interest in the use of barley in the food industry has increased recently (Lukinac & Jukić, 2022). Barley is grown throughout the temperate, tropical and subtropical regions of the world and can be successfully grown in adverse climatic conditions of drought, salinity and alkalinity due to its wider adaptability (Neelam et al., 2019). Barley is cultivated as *rabi* season crop and is known by its vernacular name, "Jau" in India. Barley has been recognized as two, four and six- row type based on the kernel arrangement within the spikes (Sullivan et al., 2013). Based on hulling, barley is classified into two group's known as hulled barley and hulless barley. Hulless barley refers to a type of barley having loosely adhered inedible outer hull to the kernel and this usually falls when the crop is harvested. Hulless barley is often referred as "naked barley" and barley requires minimum cleaning compared to hulled barley (Madakemohekar et al., 2018).

Barley is generally grown on marginal and sub-marginal land because of its low input requirement. Barley grain is also valued for its soothing and cooling effect on the body, easy digestion, and as a source of vitamin B complex. Besides these conventional uses, it is an important industrial crop used as raw material for beer, whisky, and brewing industries. Each 100 g of barley grain comprises 10.6 g protein, 2.1 g fat, 64.0 g carbohydrate, 50.0 mg calcium, 6.0 mg iron, 31.0 mg vitamin B1, 0.1 mg vitamin B2, and 50.0 µg folate (Vaughan & Geissler. 2009). In India, barley is mainly grown in the northern plains and concentrated in the states of Uttar Pradesh, Haryana and Rajasthan. In India, barley was cultivated on 0.605 million ha area with 1.84 million tonnes of production at an average productivity of 3049 kg/ha. In India, Rajasthan is the largest state having more than 52% in production and 46% area followed by Uttar Pradesh. In Uttar Pradesh, barley was cultivated on 0.18 million ha area with 0.54 million tonnes of production at an average productivity of 3044 kg/ha (UPAg, 2025).

Barley though recognized as a hardy cereal crop due to its wider adaptability to environment has been viewed as crop for marginal lands. Barley is one of the best-adapted cereals grown in climates ranging from subarctic to subtropical (Baik, 2014). While the global concern has been focused on food and environment sustainability, the demands on cereals, especially those that are hardy and drought tolerant, such as barley has tremendously increased (Maher, 2017). Due to climate change, increased population pressure and detrimental environmental impacts on agriculture fields and continuous use of chemicals leads to decrease in organic carbon, reduction in microbial flora of soil, increasing acidity and alkalinity and hardening of soil are constantly facing many detrimental effects which finally lead to scarcity of food production (Bijay-Singh & Craswell, 2021). To overcome the situation, new mechanism must be developed to meet the increased food demands with sustainable food production that has the potentiality to provide adequate food nutrition without hampering the fields. One such mechanism that is used to meet the agricultural need is integrated nutrient management.

Nitrogen is one of the most important mineral nutrients for plants influencing growth, development, yield and protein content of grains (Aakash et al., 2023). It promotes shoot elongation, tillering and regeneration after defoliation and governs to considerable degree, the utilization of phosphorus, potassium and other elements in the plant. Nitrogen is the most limiting factor for high crop productivity but its use efficiency is low (Aakash et al., 2022). Secondly, the application of increased doses of N increases cost of production. Nitrogen as known is very crucial to plants for its growth as it forms the basic structure of protein and nucleic acid which further plays important role in plant physiological phenomenon. Chlorophyll, the most important component, green color material of every plant and the one responsible for photosynthesis have the component nitrogen. Nitrogen is one or other way associated with proper functioning of plants. Thus, barley grain yield, protein content in grain and kernel appearances are the characteristics that are strongly related to available nitrogen (Grant, 2000). Nitrogen also plays an important role in maintaining the yield attributes in barley (Assefa, 2018). Another important function of nitrogen that can impact barley production is regarding its acceptability for malting status in relation to grain protein content (Spaner et al., 2001; Zeidan, 2007).

Continuous use of chemical fertilizers is assumed to be a major cause of deterioration of soil health and increase water pollution and create eutrophication in water bodies (Krasilnikov et al., 2022). To maintain high productivity and sustainability of soil and crop, balanced use of both mineral fertilizer and organic manures is indispensable. Under such a condition, there is a great urgency to explore an alternate source, which can supplement partially or wholly the use of costly input i.e. Chemical fertilizers and also to protect the fragile ecosystem (Patyal et al., 2022). Vermicomposting is a valuable amendment and may replace the chemical fertilizers. It stimulates plant growth and may help to prevent plant diseases, besides increasing the quality of the produce. Vermicompost to supply nutrient and support beneficial microbes is being recognized recently. Vermicompost has all the characteristics to use it as most valuable organic manure (Adhikary, 2012). To overcome the problem of nutrient deficiency and to increase wheat yield, the farmers are applying chemical fertilizers. However, the chemical fertilizers are expensive and the small farmers cannot afford to use these fertilizers in suitable amount and balanced proportion. Under such condition integrated use of chemical and organic fertilizer/manures can play an important role to sustain soil fertility and crop productivity. Thus, the combine approach of chemical fertilizers and organic manure full fill the complete requirements of nutrients without deterioration effect on environment and ecosystem and bring the sustainability in Productivity (Paramesh et al., 2023).

Nitrogen and zinc are essential nutrients for the growth and development of Barley. Deficiency of these nutrients can lead to various physiological and morphological abnormalities, affecting yield and quality. Nitrogen is critical for chlorophyll formation and protein synthesis. Its deficiency affects overall plant health and productivity. And due to zinc deficiency barley plants become interveinal chlorosis, spots especially on leaf tips and delay maturity & reduce grain size and weight (Sharma et al., 2023b). Zinc is essential for enzyme activation, hormone regulation, and protein synthesis in barley. Foliar spray of micronutrients quickly help in deficiency corrections (Sharma et al., 2023a). Nutrient deficiency along with imbalanced and non-judicious fertilizers use is one of the important yield limiting factors (Bhayal et al., 2022; Singh et al., 2021). The universal deficiency of nitrogen and other nutrients followed by Zn is one of most concern. In India about 62% and 49% soils are deficient in nitrogen and phosphorous respectively. Almost 50% of the soils globally used for cereal production are Zn deficient (Gibson 2006). Hence keeping in the above facts, the experiment was carried to study the effect of nitrogen, organic manures and zinc foliar spray on growth parameters of barley.

## 2. MATERIALS AND METHODS

### 2.1 Experimental Site

A field experiment was conducted during the *rabi* season, spanning from December 2024 to April 2025. The trial took place at Agronomy Research Farm, R.S.M. (P.G.) College, Dhampur (Bijnor) (Fig. 1). This farm is positioned approximately 1 kilometre east of Dhampur town, situated along the Dhampur - Moradabad Road. The farm stands at an elevation of 286 meters above mean sea level (MSL) and is situated at coordinates 29.021°N latitude and 78.508°E longitude. The location benefits from a range of amenities and resources.

### 2.2 Location and Climate

Bijnor district, located in the North-Western Plains Agro-climatic Zone of Uttar Pradesh at an altitude of 225 m above MSL, lies in the north-western corner of Moradabad Division, historically part of the Rohilkhand region, with the Ganges River forming its western boundary. It extends between 29°2′ to 29°58′ N latitude and 78°00′ to 78°57′ E longitude, covering an average area of about 1,147,967 acres, subject to fluctuations due to shifts in the Ganges and Ramganga rivers. The western edge comprises the low-lying Khaddar region adjacent to the Ganges, dominated by alluvial deposits, while elevated terraces stretch inland up to marshes beneath the Bangar cliff. The district has a tropical semi-arid climate with an average annual rainfall of 964 mm, received mainly from mid-June to mid-September.

### 2.3 Treatment Details

The experiment consisted of seven treatments, namely $T_1$ (Control), $T_2$ (100% RDN 60 kg N $ha^{-1}$), $T_3$ (100% RDN + 0.5% foliar spray of $ZnSO_4$ at 30 DAS and flowering), $T_4$ (80% RDN + 20% N through poultry manure), $T_5$ (80% RDN + 20% N through poultry manure + 0.5% foliar spray of $ZnSO_4$ at 30 DAS and flowering), $T_6$ (80% RDN + 20% N through vermicompost), and $T_7$ (80% RDN + 20% N through vermicompost + 0.5% foliar spray of $ZnSO_4$ at 30 DAS and flowering), which were evaluated to study their effect on the growth parameter performance of barley.

### 2.4 Recommended Practices

The experimental crop of barley (variety DWRUB-52) was raised under well-planned agronomic practices. Pre-sowing operations included pre-irrigation, soil sampling, ploughing, harrowing, planking, and layout, followed by sowing, at a seed rate of 120 kg $ha^{-1}$ with 20 cm row spacing after seed treatment with Carbendazim + Mancozeb. Fertilizer management involved application of 60 kg N, 30 kg $P_2O_5$, and 20 kg $K_2O$ $ha^{-1}$ along with vermicompost and poultry manure, with half N as basal and the remaining half top-dressed in two equal splits, besides 0.5% foliar sprays of $ZnSO_4$ at 30 DAS and flowering. Four irrigations were applied at critical crop stages using tubewell water. Weed control was achieved by Pendimethalin (1 Ltr a.i. $ha^{-1}$) as pre-emergence, while no insect-pest infestation was observed. Harvesting was carried out manually with sickles, followed by drying, threshing, and winnowing. Observations on growth (plant height, plant fresh and dry weights, number of tillers, leaf area,) were recorded as per standard procedures**.**

**Fig. 1. View of experiment**

### 2.5 Data Collection

To assess the effect of different treatments on crop growth and development, observations were recorded at regular intervals following standard agronomic procedures. In each net plot, five plants were randomly selected and tagged for recording growth observations. Plant height was measured in cm at 60 and 90 DAS from ground level to the topmost leaf before ear emergence and to the top of the ear after emergence. Fresh weight was recorded by destructive sampling from one meter row length at the same intervals, with plants cut at ground level and weighed immediately using an electronic balance. The same samples were used for dry matter estimation by oven-drying at 68°C ±2°C until constant weight. Leaf area was determined from these samples using the graph paper method in $cm^2$ $plant^{-1}$. The number of tillers was counted from five tagged rows of one meter length at 60 and 90 DAS.

### 2.6 Statistical Analysis

The data obtained from growth, yield attribute, yield and quality parameters were subjected to analysis of variance (ANOVA) using Statistical Tool for Agricultural Research (STAR) software (version STAR 2.0.1, IRRI, Los Baños, Philippines), while the significance of differences between treatment mean values was determined using the Least significant difference (LSD) test at 5% level.

## 3. RESULTS AND DISSCUSSION

### 3.1 Effect on Plant Height (cm)

Data pertaining to the effect of nitrogen, organic manure and zinc foliar spray on plant height are given in Table 1 and Fig. 2. The plant height was significantly influenced by nitrogen, organic manures, and zinc foliar spray. The tallest plants were recorded under 80% RDN + 20% N through poultry manure + 0.5% foliar spray of $ZnSO_4$ ($T_5$), which was statistically at par with 100% RDN + $ZnSO_4$ foliar spray ($T_3$). The increase in height under integrated nitrogen management may be attributed to improved nutrient supply, better root development, and enhanced photosynthetic activity. Similar findings were reported Neelam et al., (2019), who observed maximum barley plant height at higher nitrogen levels, and by Ankush et al., (2022), who highlighted the role of foliar zinc spray in stimulating vegetative growth.

### 3.2 Effect on Number of Tillers ($m^{-1}$ Row Length)

The number of tillers also showed significant improvement with integrated nitrogen management (Table 1 and Fig. 2). The highest number of tillers was recorded in 80% RDN + 20% Poultry manure + 0.5% Foliar spray of $ZnSO_4$ ($T_5$), Organic manures provide slow-release nutrients, while nitrogen ensures rapid tiller initiation, and zinc enhances hormonal activity leading to better tiller survival. These results are in agreement with Vishwajna et al., (2023) who reported increased tiller numbers in wheat under combined nitrogen and poultry manure, and with (Singh & Debbarma, 2023) who observed higher tiller count in barley with integrated nitrogen and zinc application.

### 3.3 Effect on Leaf Area ($cm^2$ $Plant^{-1}$)

At 60 DAS, a significant variation in leaf area was observed among the treatments, with the highest value recorded under 80% RDN + 20% N through poultry manure + 0.5% foliar spray of $ZnSO_4$ at 30 DAS and flowering stage ($T_5$), which was statistically at par with all treatments except the control ($T_1$), where the lowest leaf area was noted (Table 1), which was significantly lower compared to the other treatment. At 90 DAS, the superiority of $T_5$ persisted, registering the maximum leaf area (Table 1 and Fig. 1) and remaining comparable with $T_3$ (100% RDN + 0.5% foliar $ZnSO_4$), $T_6$ (80% RDN + 20% N through vermicompost), $T_2$ (100% RDN 60 kg N $ha^{-1}$), and $T_4$ (80% RDN + 20% N through poultry manure), while being significantly superior to the other treatments. The improvement in leaf area under $T_5$ can be ascribed to the combined effect of a steady nitrogen supply from inorganic fertilizer and poultry manure, which enhanced chlorophyll synthesis and leaf expansion, along with foliar-applied Zn that improved photosynthetic efficiency, delayed senescence, and promoted cell elongation. Larger leaf area ensured greater interception of solar radiation and higher photosynthetic activity, thereby contributing to better crop growth. These findings are in line with Patyal et al., (2022), who reported enhanced leaf area and dry matter accumulation in wheat with integrated use of RDF and vermicompost, and Ankush et al., (2022) who observed that foliar-applied Zn significantly increased leaf area by stimulating chlorophyll formation and delaying leaf senescence.

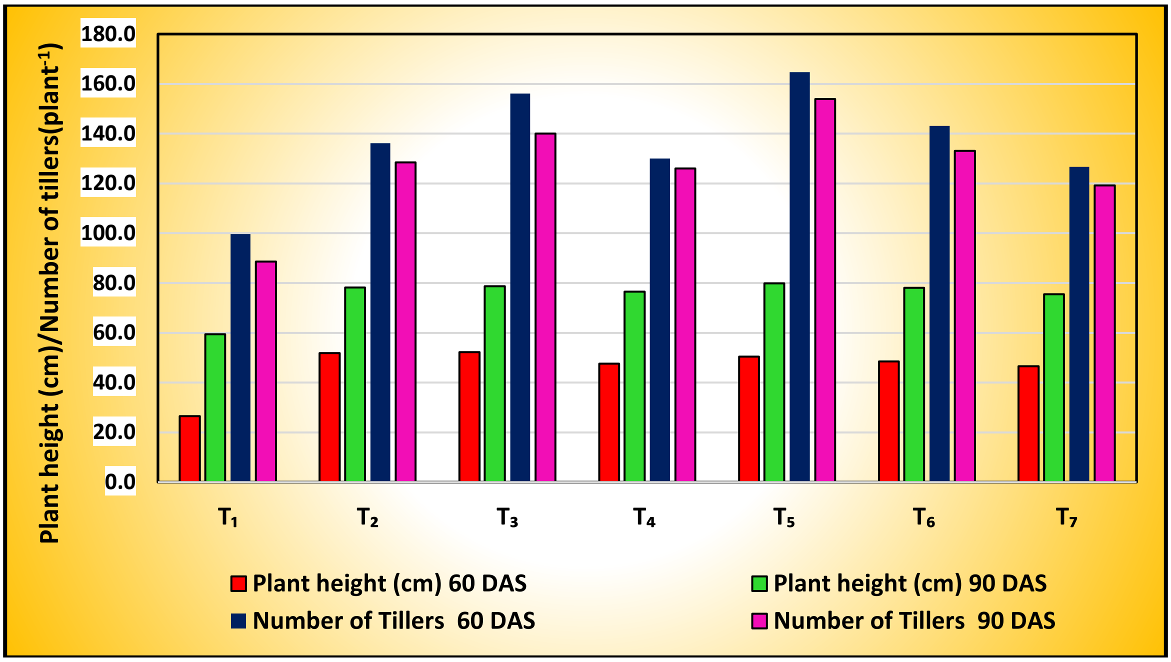


**Fig. 2. Plant height, number of tillers as influenced by nitrogen, organic manures and zinc foliar spray**

**Table 1. Plant height, number of tillers and leaf area as influenced by nitrogen, organic manures and zinc foliar spray**

| Treatment | | Plant height (cm) | | Number of tillers ($m^{-1}$ row length) | | Leaf area ($cm^2$ $plant^{-1}$) | |
|---|---|---|---|---|---|---|---|
| | | 60 DAS | 90 DAS | 60 DAS | 90 DAS | 60 DAS | 90 DAS |
| $T_1$ | Control | 26.5 | 59.4 | 99.7 | 88.7 | 119.5 | 65.0 |
| $T_2$ | 100% RDN (60 kg N $ha^{-1}$) | 51.8 | 78.2 | 136.1 | 128.4 | 161.8 | 100.8 |
| $T_3$ | 100% RDN + 0.5% Foliar Spray of $ZnSO_4$ (At 30 DAS and flowering stage) | 52.2 | 78.8 | 156.1 | 140.0 | 172.7 | 106.4 |
| $T_4$ | 80% RDN + 20% N through Poulatry manure | 47.6 | 76.5 | 130.0 | 126.1 | 159.7 | 98.5 |
| $T_5$ | 80% RDN + 20% N through PM + 0.5 % FS of $ZnSO_4$ (At 30 DAS and flowering stage) | 50.5 | 79.8 | 164.8 | 153.9 | 182.7 | 110.8 |
| $T_6$ | 80% RDN + 20% N through Vermicompost | 48.5 | 78.0 | 143.1 | 133.0 | 169.0 | 103.2 |
| $T_7$ | 80% RDN + 20% N through Vermicompost + 0.5 % FS $ZnSO_4$ (At 30 DAS and flowering stage) | 46.6 | 75.4 | 126.7 | 119.2 | 158.3 | 96.1 |
| SEm± | | 3.8 | 2.9 | 9.0 | 8.8 | 8.0 | 4.4 |
| CD (0.05) | | 11.7 | 9.0 | 27.8 | 27.2 | 24.7 | 13.6 |

### 3.4 Effect on Plant Fresh Weight (g $m^{-1}$ Row Length)

At 60 DAS, the treatment 80% RDN + 20% N through poultry manure + 0.5% foliar spray of $ZnSO_4$ at 30 DAS and flowering stage ($T_5$) recorded the highest fresh weight, which was comparable with most treatments except $T_7$ (80% RDN + 20% N through vermicompost + 0.5% foliar spray of $ZnSO_4$) and control ($T_1$), where the lowest fresh weight was observed (Table 2 and Fig. 3). At 90 DAS, $T_5$ again registered the maximum fresh weight (Table 2 and Fig. 3.), being statistically at par with $T_3$ (100% RDN + $ZnSO_4$ foliar spray), $T_6$ (80% RDN + 20% N through vermicompost), and $T_2$ (100% RDN 60 kg N $ha^{-1}$), while significantly superior to the remaining treatments, with the lowest value under control ($T_1$). The superiority of $T_5$ may be attributed to the synergistic effect of inorganic N and poultry manure in enhancing biomass accumulation, along with Zn-mediated improvements in enzymatic activity, nutrient assimilation, and photosynthetic efficiency, which maintained plant turgidity and water content. These results are supported by Dadrwal et al., (2024), who reported higher fresh biomass in barley under integrated nutrient management, and Zulfiqar et al., (2020), who highlighted the role of foliar Zn in improving nutrient-use efficiency and biomass production.

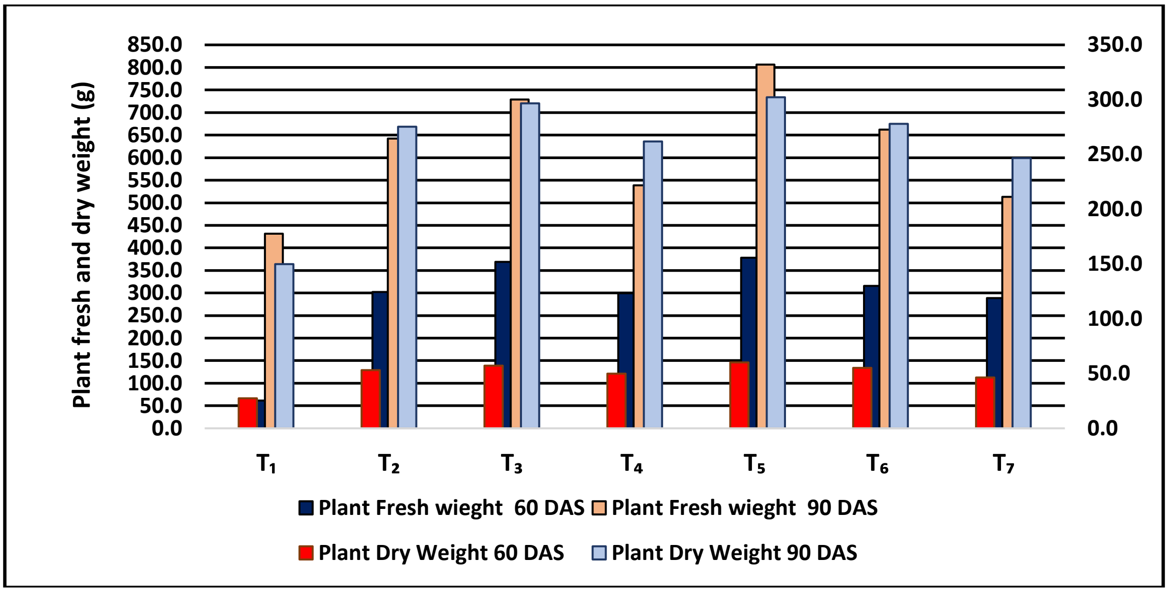


**Fig. 3. Plant fresh and dry weight influenced by nitrogen, organic manures and zinc foliar spray**

**Table 2. Plant fresh and dry matter accumulation as Influenced by nitrogen, organic manures and zinc foliar spray**

| Treatment | | Plant fresh weight (g $m^{-1}$ row length) | | Plant dry weigh (g $m^{-1}$ row length) | |
|---|---|---|---|---|---|
| | | **60 DAS** | **90 DAS** | **60 DAS** | **90 DAS** |
| $T_1$ | Control | 61.9 | 432 | 27.5 | 150.0 |
| $T_2$ | 100% RDN (60 kg N $ha^{-1}$) | 302.6 | 642 | 53.2 | 275.3 |
| $T_3$ | 100% RDN + 0.5% Foliar Spray $ZnSO_4$ (At 30 DAS and flowering stage) | 368.9 | 729 | 57.3 | 296.7 |
| $T_4$ | 80% RDN + 20% N through Poulatry manure | 299.3 | 539 | 50.0 | 262.0 |
| $T_5$ | 80% RDN + 20% N through PM + 0.5 % FS of $ZnSO_4$ (At 30 DAS and flowering stage) | 377.9 | 807 | 60.0 | 302.3 |

| Treatment | | Plant fresh weight (g $m^{-1}$ row length) | | Plant dry weigh (g $m^{-1}$ row length) | |
|---|---|---|---|---|---|
| | | 60 DAS | 90 DAS | 60 DAS | 90 DAS |
| $T_6$ | 80% RDN + 20% N through Vermicompost | 315.8 | 662 | 55.3 | 278.0 |
| $T_7$ | 80% RDN + 20% N through Vermicompost + 0.5 % FS $ZnSO_4$ (At 30 DAS and flowering stage) | 288.9 | 513 | 46.5 | 246.5 |
| SEm± | | 28.0 | 75 | 5.0 | 25.4 |
| CD (0.05) | | 86.3 | 231 | 15.3 | 78.4 |

### 3.5 Effect on Plant Dry Weight (g $m^{-1}$ Row Length)

At 60 DAS, the maximum dry matter was recorded under 80% RDN + 20% N through poultry manure + 0.5% foliar spray of $ZnSO_4$ at 30 DAS and flowering ($T_5$), which remained at par with all treatments except the control ($T_1$). At 90 DAS 80% RDN + 20% N through poultry manure + 0.5% foliar spray of $ZnSO_4$ at 30 DAS and flowering ($T_5$) again registered the highest dry matter, significantly superior to $T_1$ but comparable with other treatments and also given in Table 2. and Fig. 3. The superiority of $T_5$ may be attributed to a steady nutrient supply from poultry manure along with inorganic N, ensuring balanced nutrition throughout growth, while foliar-applied Zn enhanced carbohydrate metabolism, protein synthesis, and efficient dry matter partitioning. Similar results were reported Khyalia et al., (2024) and also reported INM practices, Fazily et al., (2020) in wheat with FYM supplementation, and Patyal et al. (2022), who observed higher dry matter accumulation with integrated RDF and vermicompost, confirming that $T_5$ provided the most favourable conditions for maximum dry matter buildup.

## 4. CONCLUSION

On the basis of study, it can be concluded that the integrated nitrogen management significantly enhanced growth parameters of barley. The treatment comprising 80% RDN + 20% N through poultry manure + 0.5% foliar spray of $ZnSO_4$ ($T_5$) significantly increased the plant height, maximum tillers, leaf area and highest fresh and dry biomass. These results revealed that the combined application of organic manures, nitrogen, and zinc not only improved vegetative growth but also ensured balanced nutrient availability for sustainable crop performance.

## DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

## COMPETING INTERESTS

Authors have declared that they have no known competing financial interests or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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