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Growth Performance of Barley (*Hordeum vulgare* L.) as Influenced by Zn and Fe Fertilizations in Northern Rajasthan, India

Surya Sain [a++], Pradeep Kumar [a#*], J. S. Ranawat [a#], Satdev [b†], Rishi Dev Jaryal [c#] and U. S. Shwkhawat [d†]

[a] Department of Agronomy, Faculty of Agriculture, Tantia University, Sri Ganganagar, Rajasthan-335001, India.
[b] Department of Soil Science, Faculty of Agriculture, Tantia University, Sri Ganganagar, Rajasthan-335001, India.
[c] Department of Agricultural Extension, Faculty of Agriculture, Tantia University, Sri Ganganagar, Rajasthan-335001, India.
[d] Department of Genetics and Plant Breeding, Faculty of Agriculture, Tantia University, Sri Ganganagar, Rajasthan-335001, India.

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 of 2025–26 at the Agricultural Research Farm, Tantia University, Sri Ganganagar, Rajasthan, to assess the effects of fertility levels and $ZnSO_4$ and $FeSO_4$ application on the growth of barley (*Hordeum vulgare* L.) variety DWRB-137. Eight treatments were evaluated in a randomised block design with three replications. The

[++] M.Sc. Student; [#] Assistant Professor; [†] Professor;
**Corresponding author: E-mail: pradeepsevta11@gmail.com;*

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treatments included a control, the full recommended dose of fertiliser (RDF) alone, 100% RDF combined with either or both micronutrients, and 75% RDF combined with zinc and/or iron sulphate. Application rates of $ZnSO_4$ and $FeSO_4$ were 20 kg ha^{-1} where included. Germination, plant height, tiller number, dry matter accumulation and spike length were assessed. Germination ranged from 84.33% under the control to 85.83% under T5, but treatment differences were not statistically significant. T5 (100% RDF with $ZnSO_4$ and $FeSO_4$) recorded the greatest plant height at harvest (105.03 cm), highest tiller number (335.00 m^{-2}), greatest dry matter accumulation (1032.13 g m^{-2}) and longest spikes (14.18 cm). Treatments combining individual micronutrients with 100% RDF generally recorded lower values than T5, while the combined treatment with 75% RDF also showed improved growth attributes relative to the control. These findings suggest that applying $ZnSO_4$ and $FeSO_4$ with 100% RDF can improve the measured growth characteristics under the field conditions examined. Further research is required to determine whether these responses remain consistent across growing seasons and locations.

Keywords: Barley; Hordeum vulgare L.; recommended dose of fertiliser; zinc sulphate; ferrous sulphate; micronutrient management; growth attributes; dry matter accumulation; tillering.

1. Introduction

Barley (*Hordeum vulgare* L.) is one of the oldest cultivated cereal grains and remains among the most widely grown cereals worldwide, being cultivated across 47.3 million hectares with a global production of 143.0 million tonnes and an average productivity of 3008 kg ha^{-1}, which makes it the fourth largest cereal crop after maize, wheat, and rice, contributing approximately seven percent to global cereal production (Food and Agriculture Organization of the United Nations, 2025; Lukinac & Jukić, 2022). The leading barley-producing countries include Russia, Germany, France, Ukraine, and Australia, while in India, it ranks as the fourth most important cereal crop after rice, wheat, and pearl millet, with the country producing 1.78 million tonnes from 0.66 million hectares at a productivity of 2695 kg ha^{-1}, and the major growing states being Rajasthan, Uttar Pradesh, Haryana, Punjab, and Madhya Pradesh (Ministry of Agriculture and Farmers Welfare, 2024).

The crop is often characterized as a "poor man's crop" due to its low input requirements and remarkable adaptability to drought, salinity, alkalinity, and marginal lands, and farmers preferentially cultivate it where wheat production is constrained by limited inputs, insufficient irrigation water, or unfavourable environmental conditions (Lukinac & Jukić, 2022); field evidence from north-western India also indicates that barley productivity varies with genotype and sowing date (Kharub et al., 2025). A field experiment with barley in Uttar Pradesh reported higher grain yield under a combined biofertiliser and zinc treatment than under the control, suggesting that crop responses to zinc can depend on accompanying nutrient inputs (Sumit et al., 2023).

Iron is an essential micronutrient involved in photosynthesis, respiration and the formation of haem and iron–sulphur cofactors (Briat et al., 2007); iron deficiency can limit crop growth when soil iron is poorly available, and foliar micronutrient nutrition has been discussed as one possible intervention in cereals (Saquee et al., 2023). A barley field study in Ethiopia also found that Zn and Fe foliar application schedules influenced plant growth, yield components and grain mineral concentrations, although its treatments and environment differed from those examined here (Hagos et al., 2026). Evidence from bread wheat further indicates that foliar Fe and Zn applications can alter grain mineral concentrations, but these findings cannot be assumed to apply directly to barley (Ram et al., 2024).

Balanced nutrient management can combine mineral fertilisers with organic inputs to support crop growth. Barley field experiments have reported improved performance under some integrated nutrient management treatments (Karol et al., 2023), while studies of foliar phosphorus and micronutrients in barley (El-Azizy, 2021) and foliar nano-NPK and micronutrient treatments in wheat (Al-Juthery et al., 2020) used different treatment designs. In a barley study conducted in Uttarakhand, a treatment combining 75% of the recommended fertiliser dose with farmyard manure improved several measured growth and yield attributes under the reported conditions (Shivani et al., 2024). A multi-year study involving spring barley and other cereals on marginal sandy soils likewise reported that mineral and combined organic–mineral fertilisation produced comparable yields in that experimental setting (Žydelis et al., 2025).

Nevertheless, the response of barley variety DWRB-137 to $ZnSO_4$ and $FeSO_4$ applied together at different recommended fertiliser dose levels under the field conditions of Sri Ganganagar has not been addressed in the evidence outlined above. The present comparison therefore examines a locally defined combination of fertility levels and micronutrient treatments.

1.1 Objective

The objective of this study was to evaluate the effects of 100% and 75% of the recommended fertiliser dose, applied alone or in combination with $ZnSO_4$ and $FeSO_4$, on germination, plant height, tiller number, dry matter accumulation and spike length of barley (*Hordeum vulgare* L.) variety DWRB-137 under the study conditions in northern Rajasthan.

2. Materials and Methods

The experiment was conducted during 2025–26 at the Agricultural Research Farm, Faculty of Agriculture, Tantia University, Sri Ganganagar. The region falls under agro-climatic zone I-B, i.e., the Irrigated North Western Plain Zone of Rajasthan. The topography of the experimental field was fairly uniform and level. Initial soil samples were collected randomly from different locations in the experimental field at a depth of 0–15 cm before sowing. A composite sample was prepared and analysed for soil properties. The data indicated that the soil of the experimental field was sandy loam in texture, with low organic carbon (0.47%) and available nitrogen (217 kg/ha), medium in available phosphorus (16.05 kg/ha) and potassium (120.01 kg/ha); and neutral in pH

(7.12). A total of eight treatments were arranged in a randomised block design, namely, T_1: Control, T_2: 100% RDF, T_3: 100% RDF + $ZnSO_4$@20 kg ha^{-1}, T_4: 100 % RDF + $FeSO_4$@20 kg ha^{-1}, T_5: 100 % RDF + $ZnSO_4$ @20 kg ha^{-1} + $FeSO_4$@20 kg ha^{-1}, T_6: 75 % RDF + $ZnSO_4$@20 kg ha^{-1}, T_7: 75 % RDF + $FeSO_4$@20 kg ha^{-1} and T_8: 75 % RDF + $ZnSO_4$ @20 kg ha^{-1} + $FeSO_4$@20 kg ha^{-1} with three replications. Observations on yield attributes and yield, including number of pods/plant, grains/pod, test weight, grain yield/plant, straw yield/plant and biological yield/plant were recorded at harvest. The recorded data were statistically analysed using appropriate procedures for the randomised block design to determine the significance of treatment effects (Panse & Sukhatme, 1967).

3. Results and Discussion

3.1 Germination %

The germination percentage of barley ranged from 84.33% (T1) to 85.83% (T5). The highest germination was recorded under T5 (100% RDF NPK + $ZnSO_4$ @ 20 kg ha^{-1} + $FeSO_4$ @ 20 kg ha^{-1}), followed by T6 (85.67%) and T3 (85.55%), while the control (T1) recorded the lowest value (84.33%). However, differences among treatments were not statistically significant, indicating that germination was not appreciably affected by nutrient application under the conditions of this study. The absence of a statistically significant treatment effect indicates that the fertiliser combinations did not measurably alter germination under the conditions evaluated.

3.2 Plant Height (cm)

Plant height increased progressively as crop development advanced across all treatments, with significant treatment effects at all intervals. At 30 DAS, T5 recorded the tallest plants (27.36 cm), statistically at par with T3 (26.67 cm) and T4 (25.94 cm), while T1 recorded the shortest (22.54 cm). At 60 DAS, T5 continued to record maximum height (52.45 cm), followed by T3 (50.34 cm) and T4 (49.01 cm), with T1 recording minimum (45.12 cm). At 90 DAS, T5 recorded 85.34 cm, significantly superior to all treatments except T3 (82.56 cm) and T4 (80.92 cm), while T1 recorded 75.23 cm. At harvest, T5 exhibited maximum height (105.03 cm), followed by T3 (103.28 cm) and T4 (101.73 cm), with T1 recording minimum (96.18 cm), statistically at par with T6 (97.25 cm), T7 (97.48 cm), and T8 (99.64 cm). The consistently higher values under T5 suggest a favourable effect of $ZnSO_4$ and $FeSO_4$ application with 100% RDF NPK on vegetative growth. A barley field experiment using soil-applied zinc and foliar iron alongside recommended fertiliser also reported improved plant height and other growth attributes, although its application strategy differed from the present trial (Tiwari et al., 2023). El-Azizy (2021) likewise examined foliar phosphorus and micronutrient treatments in barley. A separate field study of organic, inorganic and biofertiliser treatments addressed nutrient uptake rather than the combined Zn–Fe application tested here (M. L. Jat et al., 2021). These studies provide relevant, but not directly equivalent, comparisons.

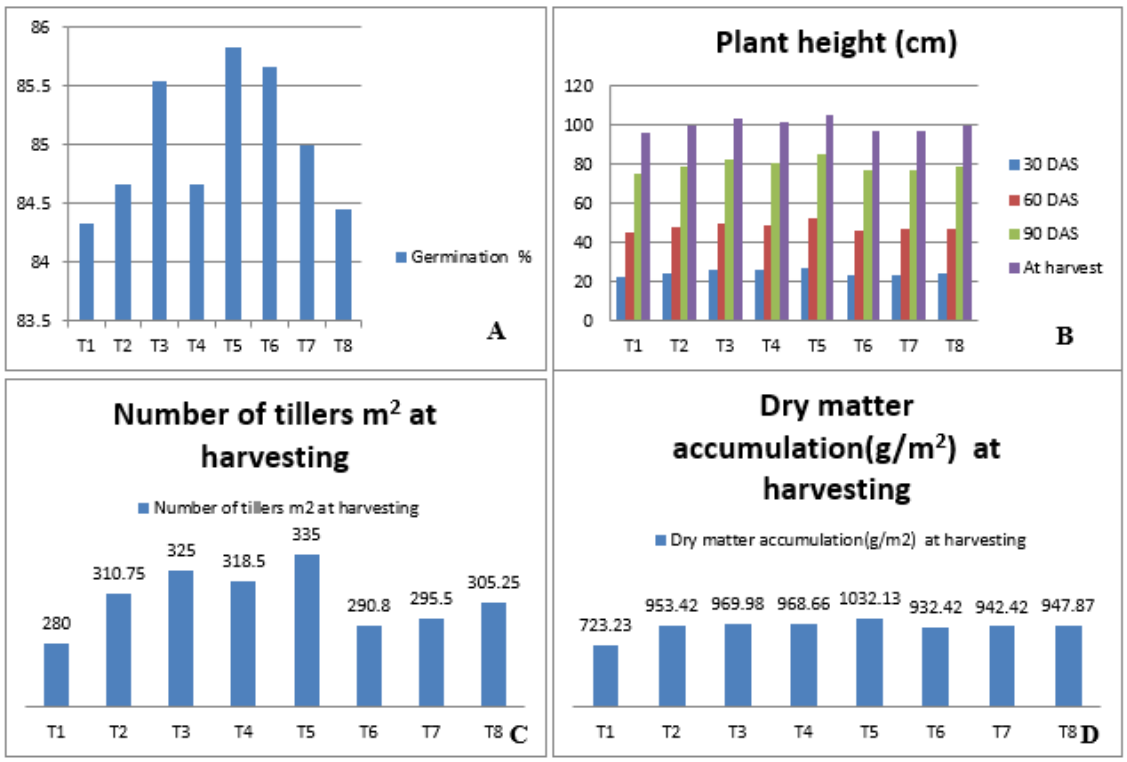

Fig. 1. Effect of micronutrient management on Germination (A), Plant height (B), Tiiler m^{-2} (C) and Dry matter accumulation (D)

3.3 Tiller m^{-2}

Nutrient treatments significantly influenced tillering capacity. T5 recorded the maximum number of tillers (335.00), followed by T3 (325.00) and T4 (318.50), while T2 recorded 310.75. Among 75% RDF treatments, T8 recorded the highest tillers (305.25), followed by T7 (295.50) and T6 (290.80). The control (T1) recorded the lowest number of tillers. The results indicate that balanced nutrient application, particularly with combined micronutrients, enhances tiller production. A barley field study reported changes in tillering and plant height with differing nitrogen and zinc rates (Singh & Debbarma, 2023). Kumar et al. (2017) reported improved barley growth under NPK fertilisation combined with biofertiliser application. Within the present experiment, T8 (75% RDF with both micronutrients) produced fewer tillers than T5 (100% RDF with both micronutrients). The present results indicate an association between the combined nutrient treatment and greater tiller production, consistent with other barley nutrient-management studies (Singh & Debbarma, 2023; Kumar et al., 2017).

3.4 Dry Matter Accumulation (g m^{-2})

Dry matter accumulation varied significantly among treatments. T5 recorded the maximum dry matter (1032.13 g m^{-2}), significantly superior to all other treatments, followed by T3 (969.98 g m^{-2}) and T4 (968.66 g m^{-2}), which were statistically at par. T2 recorded 953.42 g m^{-2}. Among 75% RDF treatments, T8 recorded the highest accumulation (947.87 g m^{-2}), followed by T7 (942.42 g m^{-2}) and T6 (932.42 g m^{-2}), which were statistically comparable. The control (T1) recorded the lowest dry matter (723.23 g m^{-2}). The higher dry matter accumulation under T5 may reflect improved nutrient supply; however, photosynthetic efficiency and nutrient translocation were not directly measured. Shivani et al. (2024) also reported growth and yield responses to integrated nutrient management in barley. M. L. Jat et al. (2021) examined nutrient uptake under integrated nutrient management in barley, but did not directly test the Zn–Fe combination used here. Long-term effects of these treatments on soil microbial communities were not evaluated in the present experiment. A barley study of combined zinc and iron management also reported favourable growth responses (Tiwari et al., 2023), supporting cautious comparison with the present results.

3.5 Spike Length (cm)

Spike length was significantly influenced by nutrient treatments. T5 recorded the maximum spike length (14.18 cm), significantly superior to all other treatments, followed by T3 (13.40 cm) and T4 (12.90 cm). T2 recorded 12.55 cm. Among 75% RDF treatments, T8 recorded the highest spike length (12.30 cm), followed by T7 (11.85 cm) and T6 (11.60 cm). The control (T1) recorded the lowest spike length (11.00 cm). The significantly superior spike length under T5 indicates the positive influence of combined micronutrient application on reproductive growth. Tiwari et al. (2023) found that zinc and iron treatments affected ear length in barley, while Singh and Debbarma (2023) reported spike-length responses to nitrogen and zinc treatments. Both studies used treatment regimens different from the present experiment. In the present study, the 75% RDF treatments showed lower spike-length values than T5. These results indicate that combined micronutrient application with 100% RDF was associated with the greatest spike length among the treatments assessed. The observed responses in germination, plant height, tiller number and dry matter accumulation are shown in Fig. 1.

These findings should be interpreted in the context of the specific field conditions and micronutrient doses used in the experiment. Controlled-release nano-formulations were not included among the reported treatments. The reported trial did not evaluate the long-term effects of fertiliser use on soil microbial communities. In the present study, T5 produced a plant height of 105.03 cm and dry matter accumulation of 1032.13 g m^{-2}. These observations support consideration of balanced nutrient management under the study conditions (Singh & Debbarma, 2023; Kumar et al., 2017).

4. Conclusion

The field experiment indicated that fertiliser level and micronutrient treatment influenced several measured growth attributes of barley variety DWRB-137 under the conditions of Sri Ganganagar, Rajasthan. Among the eight treatments, the combination of 100% RDF with $ZnSO_4$ at 20 kg ha^{-1} and $FeSO_4$ at 20 kg ha^{-1} (T5) recorded the highest plant height at harvest (105.03 cm), tiller number (335.00 m^{-2}), dry matter accumulation (1032.13 g m^{-2}) and spike length (14.18 cm). The corresponding values under the control were lower, and the 75% RDF treatment with both micronutrients did not attain the values observed under T5. Although the highest germination percentage also occurred under T5, differences in germination among treatments were not statistically significant. These results suggest that the combined application of zinc and iron sulphates with the full recommended fertiliser dose may benefit the measured growth characteristics in the tested field environment. However, the findings are limited to the specific variety, treatment rates and growing season examined. Further trials across additional seasons, soil conditions and locations would be useful before formulating broader nutrient-management recommendations.

5. Limitations

The experiment was conducted during a single rabi season at one research farm using barley variety DWRB-137. The observed responses may therefore not represent other seasons, soils, varieties or production environments. Although eight treatments were replicated three times, additional micronutrient application rates and combinations were not examined. Soil and plant micronutrient concentrations were not presented in the reported results, limiting interpretation of nutrient uptake mechanisms. Multi-season, multi-location trials with additional treatment rates and nutrient measurements would help assess the consistency and wider relevance of these findings.

Declaration of AI Use

This manuscript was prepared through the intellectual contributions of the author(s) to the study design, data analysis, interpretation of results, and scholarly content. Grammarly and ChatGPT were used solely to assist with grammatical refinement and reference formatting during manuscript revision. The author(s) accept full responsibility for the accuracy, integrity, and final content of the manuscript.

Competing Interests

Authors have declared that no competing interests exist.

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