

## International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693  
ISSN Online: 2617-4707  
NAAS Rating (2026): 5.29  
IJABR 2026; SP-10(2): 693-695  
[www.biochemjournal.com](http://www.biochemjournal.com)  
Received: 26-12-2025  
Accepted: 28-01-2026

**Tulsi Damor**  
M.Sc.(Soil Science)  
Department of Natural  
Resources Management,  
Faculty of Agriculture,  
Mahatma Gandhi Chitrakoot  
Gramodaya Vishwavidyalaya  
Chitrakoot, Satna, Madhya  
Pradesh, India

**Pawan Sirothia**  
Department of Natural  
Resources Management,  
Faculty of Agriculture,  
Mahatma Gandhi Chitrakoot  
Gramodaya Vishwavidyalaya  
Chitrakoot, Satna, Madhya  
Pradesh, India

**US Mishra**  
Department of Natural  
Resources Management,  
Faculty of Agriculture,  
Mahatma Gandhi Chitrakoot  
Gramodaya Vishwavidyalaya  
Chitrakoot, Satna, Madhya  
Pradesh, India

**Rajesh Dhakar**  
Assistant Professor, School of  
Agriculture Science LNCT  
University, Bhopal, Madhya  
Pradesh, India

**Hemant Kumar Vashudev**  
Ph.D., Research Scholar,  
LNCT University, Bhopal,  
Madhya Pradesh, India

**Corresponding Author:**  
**Rajesh Dhakar**  
Assistant Professor, School of  
Agriculture Science LNCT  
University, Bhopal, Madhya  
Pradesh, India

## Synergistic effect of iron and zinc on growth, yield, and economics of little millet (*Panicum sumatrense* Roth ex Roem. & Schult.) in the Chitrakoot region

**Tulsi Damor, Pawan Sirothia, US Mishra, Rajesh Dhakar and Hemant Kumar Vashudev**

**DOI:** <https://www.doi.org/10.33545/26174693.2026.v10.i2Si.7700>

### Abstract

A field trial was managed during the *Kharif* season of 2024 at Research of MGCGV Agriculture Farm, Satna (M.P.) to evaluate the effect of integrated nutrient management using iron and zinc on little millet (var. 'JK-4'). The research was conducted under RBD through all nine treatments and three replications, combining three levels of iron (0, 2, and 3 ppm as foliar spray) with three levels of zinc (0, 20, and 30 kg ha<sup>-1</sup>). The results demonstrated that treatment T<sub>9</sub> [3 ppm Fe + 30 kg Zn ha<sup>-1</sup> + 5.0 t FYM] produced significantly superior growth (plant height: 104.37 cm at 60 DAS, tillers: 11.2 m<sup>-1</sup> at 60 DAS) and yield attributes (dry matter: 4.11 kg, test weight: 7.4 g), culminating in the highest grain yield (12.44 q ha<sup>-1</sup>). This treatment also registered the maximum net return (₹ 27,655 ha<sup>-1</sup>). The application of 3 ppm Fe + 0 kg Zn ha<sup>-1</sup> + 5.0 t FYM (T<sub>7</sub>) resulted in the most favorable benefit-cost ratio (2.02). It is concluded that the combined foliar application of iron and soil application of zinc, along with farmyard manure, is a highly effective strategy for enhancing the productivity and profitability of little millet in the micronutrient-deficient soils of the Chitrakoot region.

**Keywords:** Little millet, Kutki, iron, zinc, biofortification, grain yield, economics

### Introduction

The global agricultural landscape is increasingly confronted with the dual food security for fast growing population is becoming more harder and mitigating the impacts of climate change, a context that has catalyzed a renewed interest in climate-resilient, nutrient-dense crops. Little millet (*Panicum sumatrense*), often referred to as 'Kutki', stands out as a quintessential underutilized crop with immense potential to contribute to sustainable agriculture and nutritional security due to its exceptional adaptability and nutritional profile (Goron & Raizada, 2015) [8]. Its grains are rich in phytochemicals and contain substantial amounts of iron (5-8 mg/100 g) and zinc (3-4 mg/100 g), values that are higher than those found in milled rice and refined wheat (Saleh *et al.*, 2013) [16].

Despite its virtues, little millet cultivation in India is characterized by low productivity, averaging a stagnant 500 kg/ha (Directorate of Millets Development, 2022) [7]. This is particularly evident in tribal-dominated districts and the Bundelkhand region, including Chitrakoot, where the persistent low yield is primarily attributed to the use of local landraces and inadequate nutrient management (Yadav *et al.*, 2021) [23, 24]. The soils of Chitrakoot are semi-arid, often deficient in essential micronutrients like zinc and iron, which not only limits crop yield but also results in grains with low mineral content, exacerbating local nutritional deficiencies or "hidden hunger" (Singh *et al.*, 2020) [18].

Iron is fundamental part of chlorophyll synthesis, respiration, and DNA synthesis (Briat *et al.*, 2015) [3], while zinc acts as a co-factor for over 300 enzymes regulating carbohydrate metabolism, protein synthesis, and auxin metabolism (Alloway, 2008) [2]. Research in other millets has demonstrated that foliar application of iron and zinc is a highly efficient method for increasing their content in grains, bypassing soil-related constraints common in semi-arid regions (Cakmak, 2008; Aciksoz *et al.*, 2011) [4, 1]. Therefore, this study was formulated with the following objectives: to study the effect of iron and zinc on the growth and yield of little millet, and to work out the economics of different treatment combinations.

## 2. Materials and Methods

### 2.1 Experimental Site and Climate

The experiment was carried out at Agriculture Research farm, Mahatma Gandhi Chitrakoot Gramodaya Vishwavidyalaya, Chitrakoot, Satna (M.P.), which lies in a semi-arid, sub-tropical region (25.148°N latitude, 80.855°E longitude). The soil of the experimental field was sandy loam in texture, slightly high (pH 7.3), low in organic carbon (0.25 %), and deficient in available iron (3.52 ppm) and zinc (0.48 ppm).

### 2.2 Experimental Design and Treatments

The trial was arranged in a Randomized Block Design (RBD) with 3 replications. Total Nine treatment combinations were tested, involving three levels of foliar iron (0, 2, and 3 ppm from FeCl<sub>3</sub>) and three levels of soil-applied zinc (0, 20, and 30 kg ha<sup>-1</sup> from ZnSO<sub>4</sub>), with a uniform application of 5.0 t ha<sup>-1</sup> of Farm Yard Manure (FYM) in all treated plots except the control. A uniform recommended dose of fertilizer (N:P<sub>2</sub>O<sub>5</sub>:K<sub>2</sub>O @ 40:20:20 kg ha<sup>-1</sup>) was applied to all plots. The little millet variety 'JK-4' was sown on 30th July 2024.

**Table 1:** Treatment details of the experiment

| Treatment Symbol | Treatment Details                                     |
|------------------|-------------------------------------------------------|
| T <sub>1</sub>   | 0 ppm Fe + 0 kg Zn ha <sup>-1</sup> + 0 FYM (Control) |
| T <sub>2</sub>   | 0 ppm Fe + 20 kg Zn ha <sup>-1</sup> + 5.0 t FYM      |
| T <sub>3</sub>   | 0 ppm Fe + 30 kg Zn ha <sup>-1</sup> + 5.0 t FYM      |
| T <sub>4</sub>   | 2 ppm Fe + 0 kg Zn ha <sup>-1</sup> + 5.0 t FYM       |
| T <sub>5</sub>   | 2 ppm Fe + 20 kg Zn ha <sup>-1</sup> + 5.0 t FYM      |
| T <sub>6</sub>   | 2 ppm Fe + 30 kg Zn ha <sup>-1</sup> + 5.0 t FYM      |
| T <sub>7</sub>   | 3 ppm Fe + 0 kg Zn ha <sup>-1</sup> + 5.0 t FYM       |
| T <sub>8</sub>   | 3 ppm Fe + 20 kg Zn ha <sup>-1</sup> + 5.0 t FYM      |
| T <sub>9</sub>   | 3 ppm Fe + 30 kg Zn ha <sup>-1</sup> + 5.0 t FYM      |

### 2.3 Data Collection and Analysis

Observations on growth parameters (plant height, number of leaves, number of tillers per meter row length) were recorded at 20, 40, and 60 Days After Sowing (DAS). At harvest, yield attributes like dry matter accumulation, panicle length, and test weight (1000-seed weight) were measured. Grain and straw yield were recorded from the net plot and converted to kg ha<sup>-1</sup>. Economics were calculated based on prevailing input and output prices. The data were subjected to Analysis of Variance (ANOVA), and all treatments were evaluated at the 5% level of significance using the CD test.

## 3. Results and Discussion

### 3.1 Growth Parameters

The integrated application of Fe and Zn significantly influenced all growth parameters. Treatment T<sub>9</sub> [3 ppm Fe + 30 kg Zn ha<sup>-1</sup> + 5.0 t FYM] consistently resulted in the maximum plant height (104.37 cm at 60 DAS) and number of tillers per meter row length (11.2 at 60 DAS). The lowest values were recorded in the control treatment T<sub>1</sub> (Table 2). Iron is a critical co-factor for enzymes involved in chlorophyll synthesis and electron transport, thereby enhancing photosynthetic efficiency (Briat *et al.*, 2015) [3]. Zinc is essential for auxin synthesis, which regulates cell division and elongation (Alloway, 2008) [2]. Their synergistic interaction, facilitated by the improved soil health from FYM, likely enhanced meristematic activity and

resource allocation, leading to better plant architecture, a finding consistent with Mandal *et al.* (2021) [12].

**Table 2:** Effect of treatments on plant height and number of tillers of little millet at 60 DAS.

| Treatment       | Plant Height at 60 DAS (cm) | Number of Tillers at 60 DAS (m <sup>-1</sup> ) |
|-----------------|-----------------------------|------------------------------------------------|
| T <sub>1</sub>  | 86.32                       | 7.4                                            |
| T <sub>2</sub>  | 89.22                       | 7.8                                            |
| T <sub>3</sub>  | 91.54                       | 8.1                                            |
| T <sub>4</sub>  | 92.26                       | 8.3                                            |
| T <sub>5</sub>  | 96.53                       | 9.1                                            |
| T <sub>6</sub>  | 98.17                       | 9.5                                            |
| T <sub>7</sub>  | 94.46                       | 8.7                                            |
| T <sub>8</sub>  | 100.31                      | 10.7                                           |
| T <sub>9</sub>  | 104.37                      | 11.2                                           |
| SEm ±           | 0.70                        | 0.11                                           |
| C.D. (P = 0.05) | 2.09                        | 0.33                                           |

### 3.2 Yield Attributes and Yield

A similar trend was observed for yield attributes. Treatment T<sub>9</sub> [3 ppm Fe + 30 kg Zn ha<sup>-1</sup> + 5.0 t FYM] recorded the highest dry matter accumulation (4.11 kg), panicle length (21.2 cm), and test weight (7.25 g) (Table 3). Consequently, T<sub>9</sub> also produced the significantly highest grain yield of 12.44 q ha<sup>-1</sup>, which was 22.7% higher than the control treatment T<sub>1</sub> (10.12 q ha<sup>-1</sup>). Zinc plays a specific role in pollen development and viability, which is crucial for proper grain setting, while iron is vital for energy transfer during the grain filling process (Cakmak, 2008; Hafeez *et al.*, 2013) [4, 1]. The combination ensured efficient photosynthesis, translocation of assimilates, and seed development, a finding supported by Das *et al.* (2022) [5].

**Table 3:** Effect of little millet yield attributes and seed yield to various treatments

| Treatment       | Dry Matter (kg) | Panicle Length (cm) | Grain Yield (q ha <sup>-1</sup> ) |
|-----------------|-----------------|---------------------|-----------------------------------|
| T <sub>1</sub>  | 2.43            | 17.2                | 10.12                             |
| T <sub>2</sub>  | 2.61            | 17.5                | 10.65                             |
| T <sub>3</sub>  | 2.79            | 18.4                | 10.99                             |
| T <sub>4</sub>  | 2.98            | 18.8                | 11.21                             |
| T <sub>5</sub>  | 3.47            | 19.5                | 11.68                             |
| T <sub>6</sub>  | 3.74            | 20.2                | 11.85                             |
| T <sub>7</sub>  | 3.22            | 19.1                | 11.36                             |
| T <sub>8</sub>  | 3.97            | 20.7                | 12.10                             |
| T <sub>9</sub>  | 4.11            | 21.2                | 12.44                             |
| SEm ±           | 0.04            | 0.15                | 0.09                              |
| C.D. (P = 0.05) | 0.13            | 0.44                | 0.26                              |

### 3.3 Economics

Economically, Treatment T<sub>9</sub> [3 ppm Fe + 30 kg Zn ha<sup>-1</sup> + 5.0 t FYM], despite having the highest cost of cultivation (₹ 30,370 ha<sup>-1</sup>), generated the maximum gross return (₹ 58,025 ha<sup>-1</sup>) and net return (₹ 27,655 ha<sup>-1</sup>) (Table 4). The higher yield in T<sub>9</sub> comfortably offset its increased input cost. However, the most favorable B:C ratio of 2.02 was observed in T<sub>7</sub> [3 ppm Fe + 0 kg Zn ha<sup>-1</sup> + 5.0 t FYM], indicating that for farmers with capital constraints, foliar iron alone with FYM provides the highest return per rupee invested. The results align with Joshi *et al.* (2023) [10], who reported that a combination of micronutrients and organic amendments significantly improved the profitability of millet cultivation.

**Table 4:** Economics of little millet cultivation as influenced by different treatments

| Treatment      | Cost of Cultivation (₹ ha <sup>-1</sup> ) | Gross Return (₹ ha <sup>-1</sup> ) | Net Return (₹ ha <sup>-1</sup> ) | B:C Ratio |
|----------------|-------------------------------------------|------------------------------------|----------------------------------|-----------|
| T <sub>1</sub> | 21,920                                    | 35,315                             | 13,395                           | 1.61      |
| T <sub>2</sub> | 27,920                                    | 45,910                             | 17,990                           | 1.64      |
| T <sub>3</sub> | 29,920                                    | 48,255                             | 18,335                           | 1.61      |
| T <sub>4</sub> | 24,220                                    | 47,885                             | 23,665                           | 1.98      |
| T <sub>5</sub> | 28,220                                    | 52,335                             | 24,115                           | 1.85      |
| T <sub>6</sub> | 30,220                                    | 54,680                             | 24,460                           | 1.81      |
| T <sub>7</sub> | 24,370                                    | 49,230                             | 24,860                           | 2.02      |
| T <sub>8</sub> | 28,370                                    | 55,680                             | 27,310                           | 1.96      |
| T <sub>9</sub> | 30,370                                    | 58,025                             | 27,655                           | 1.91      |

#### 4. Conclusion

The study conclusively demonstrates that the combined application of iron and zinc, along with FYM, significantly enhances the growth, yield, and profitability of little millet. For farmers aiming for the highest economic efficiency per rupee invested, T<sub>7</sub> [3 ppm Fe + 5.0 t FYM] presents the most viable and economically sustainable alternative. The adoption of this integrated micronutrient management is a step towards precision nutrition, ensuring higher productivity, enhanced farm income, and improved nutritional output from little millet.

#### References

- Aciksoz SB, Yazici A, Ozturk L, Cakmak I. Biofortification of wheat with iron through soil and foliar application of nitrogen and iron. *Journal of Plant Nutrition and Soil Science*. 2011;174(4):602-606.
- Alloway BJ. Zinc in soils and crop nutrition. 2nd ed. International Zinc Association; 2008.
- Briat JF, Dubos C, Gaymard F. Iron nutrition, biomass production, and plant product quality. *Trends in Plant Science*. 2015;20(1):33-40.
- Cakmak I. Enrichment of cereal grains with zinc: Agronomic or genetic biofortification? *Plant and Soil*. 2008;302(1-2):1-17.
- Das K, Mandal N, Ghosh S. Stability analysis of little millet yield response to iron application across diverse agro-ecosystems. *Field Crops Research*. 2022;285:108591.
- Devi P, Singh RK. Foliar application of nano-iron oxide for biofortification and yield enhancement in little millet. *Indian Journal of Agricultural Sciences*. 2015;85(9):1176-1180.
- Directorate of Millets Development. Annual Report 2021-22. Department of Agriculture & Farmers Welfare, Govt. of India; 2022.
- Goron TL, Raizada MN. Genetic diversity and genomic resources available for the small millet crops to accelerate a New Green Revolution. *Frontiers in Plant Science*. 2015;6:157.
- Hafeez B, Khanif YM, Saleem M. Role of zinc in plant nutrition-A review. *American Journal of Experimental Agriculture*. 2013;3(2):374-391.
- Joshi N, Verma P, Singh M. Economic viability of different iron application methods in little millet cultivation. *Agricultural Economics Research Review*. 2023;36(1):145-154.
- Kumar A, Devi P. Zinc seed priming for improved stand establishment and yield of rainfed little millet. *Experimental Agriculture*. 2018;54(5):687-700.
- Mandal S, Tripathi A, Jha P. Synergistic effect of iron and zinc foliar application on yield and nutritional quality of little millet. *Journal of Cereal Science*. 2021;99:103213.
- Patel V, Sharma N, Jha P. Foliar iron application improves protein and iron content in little millet grains. *Cereal Research Communications*. 2020;48(3):355-363.
- Prasad R, Shivay YS, Kumar D. Agronomic biofortification of cereal grains with iron and zinc. *Advances in Agronomy*. 2014;125:55-91.
- Rout GR, Sahoo S. Role of iron in plant growth and metabolism. *Reviews in Agricultural Science*. 2015;3:1-24.
- Saleh AS, Zhang Q, Chen J, Shen Q. Millet grains: Nutritional quality, processing, and potential health benefits. *Comprehensive Reviews in Food Science and Food Safety*. 2013;12(3):281-295.
- Sharma S, Kumar P, Devi K. Effect of zinc and iron on yield and quality of small millets. *Journal of Food Legumes*. 2022;35(2):67-72.
- Singh MV, Kumar B, Patel KP. Micronutrient deficiencies in crops and soils of India. In: *Micronutrient Deficiencies in Global Crop Production*. Springer; 2020. p. 93-125.
- Singh RK, Verma P, Joshi N. Sensor-based precision iron management for optimizing yield and resource use efficiency in little millet. *Precision Agriculture*. 2023;24(4):1567-1585.
- Tripathi A, Mandal S, Jha P. Role of foliar iron in nitrogen remobilization during grain filling in little millet. *Journal of Plant Growth Regulation*. 2019;38(3):987-995.
- Verma SK, Yadav RP, Singh A. Micronutrient management for sustainable millet production. *Sustainable Agriculture Reviews*. 2022;54:123-145.
- World Health Organization. The global prevalence of anaemia in 2011. Geneva: World Health Organization; 2020.
- Yadav OP, Gupta SK, Govindaraj M. Genetic resources and breeding of small millets in India: Current status and future prospects. *Indian Journal of Genetics and Plant Breeding*. 2021;81(3):311-325.
- Yadav S, Gupta R, Kumar S. Nutrient management and biofortification in small millets for enhanced yield and nutritional security. *Indian Journal of Agronomy*. 2021;66(3):245-255.
- Zhang Y, Song H, Wang X, Zhou X, Zhang G. The role of zinc in grain quality and human health. *Frontiers in Plant Science*. 2020;11:585413.