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Influence of Nitrogen and Micronutrient Application on the Yield Components and Productivity of Pearl Millet (*Pennisetum glaucum* L.)

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Abstract

A field study was carried out during the Kharif season of 2024 at the research farm of Vivekananda Global University, Jaipur, on loamy sand soil. The experiment involved nine treatment combinations of nitrogen and micronutrient applications, including: 100% recommended dose of nitrogen (RDN) with soil application of FeSO_4 at 10 kg/ha; 100% RDN with soil application of ZnSO_4 at 25 kg/ha; 100% RDN with foliar application of 1.0% FeSO_4 at 25 and 50 days after sowing (DAS); 100% RDN with foliar application of 0.5% ZnSO_4 at 25 and 50 DAS; 75% RDN + 25% nitrogen via farmyard manure (FYM) with soil-applied FeSO_4 (10 kg/ha); 75% RDN + 25% FYM with soil-applied ZnSO_4 (25 kg/ha); 75% RDN + 25% FYM with foliar spray of 1.0% FeSO_4 at 25 and 50 DAS; 75% RDN + 25% FYM with foliar spray of 0.5% ZnSO_4 at 25 and 50 DAS; and a control with 100% RDN applied through chemical fertilizers. The layout followed a Randomized Block Design (RBD) with three replications.

The findings revealed that the treatment T_4 (100% RDN + 0.5% foliar spray of ZnSO_4) significantly outperformed others in terms of yield attributes such as earhead length, number of effective tillers, test weight, grain yield (1949 kg/ha), and biological yield (6242 kg/ha).

Keywords: Nitrogen management, micronutrient application, foliar spray, zinc sulfate (ZnSO_4), grain yield

Introduction

Pearl millet (*Pennisetum glaucum* L.), commonly known as Bajra in India, ranks as the fifth most important cereal globally and the fourth in India after rice, wheat, and maize. It plays a crucial role as a staple food crop in the arid and semi-arid regions of Africa and South Asia. In India, it serves as a primary dietary component for economically disadvantaged populations. Additionally, its dry stover holds significant value in livestock-based farming systems across many parts of the country. Nutritionally, pearl millet is not only comparable to other cereals but also stands out as a rich source of protein, energy, essential vitamins, and minerals (Rao *et al.*, 2006) [10]. Moreover, it offers abundant dietary fiber, phytochemicals, micronutrients, and nutraceutical compounds, which is why it is now appropriately recognized as a "nutricereal."

Low soil fertility and irregular rainfall patterns are among the primary challenges limiting crop productivity in arid and semi-arid regions. Effective soil fertility practices, particularly the management of nutrients like nitrogen (N), play a vital role in enhancing the growth and yield of pearl millet. Nitrogen is a critical macronutrient required for plant development, particularly in promoting vegetative growth. It is integral to numerous metabolic processes, as it forms part of essential cellular structures and biologically active compounds. Nitrogen is also a key element in chlorophyll and amino acids, both of which are crucial for capturing solar energy through photosynthesis. Adequate nitrogen supply ensures rapid leaf area expansion and stem development, thereby contributing to higher yields and better grain quality. Additionally, nitrogen improves the efficiency of phosphorus and potassium uptake by plants. In Indian soils, nitrogen is often the most limiting nutrient and its application has shown a significant positive response in pearl millet cultivation (Jadhav *et al.*, 2011) [4].

Pearl millet, being a nutrient-demanding crop, responds variably to nitrogen application depending on soil and environmental conditions. Zinc (Zn) also holds a unique place in plant

nutrition, as it is the only metal that serves as a component of all six classes of enzymes—oxidoreductases, transferases, hydrolases, lyases, isomerases, and ligases (Broadley *et al.*, 2007) [3]. Zinc contributes to vital physiological functions including photosynthesis, protein formation, gene expression, auxin metabolism, and the maintenance of cellular membranes. It also plays a role in detoxifying reactive oxygen species, which collectively influence crop biomass and grain yield. Enhancing zinc concentration in edible plant parts is therefore essential for both plant and human health. Moreover, zinc interacts with other micronutrients, influencing their uptake and movement within the plant (Bell and Dell, 2008) [12].

On the other hand, applying iron (Fe) fertilizers can correct iron deficiencies in the soil, leading to improved crop growth and yield, which ultimately helps boost farmer income (Vikash *et al.*, 2015) [12].

Iron is a vital micronutrient necessary for nearly all living organisms, owing to its key role in essential metabolic activities such as DNA replication, respiration, and photosynthesis. It activates several metabolic pathways and functions as a prosthetic group in numerous enzymes. A mismatch between the availability of iron in the soil and the plant's requirement often leads to iron chlorosis. While iron is generally abundant in well-aerated soils, its bioavailability is limited due to its tendency to form insoluble ferric compounds, especially under neutral pH conditions. In plants, iron is indispensable for various physiological and biochemical processes. It is a structural component of several critical enzymes, including cytochromes involved in the electron transport chain, making it essential for diverse biological functions. Additionally, iron is directly involved in chlorophyll production and is crucial for maintaining chloroplast integrity and functionality (Solanki *et al.*, 2017) [11].

Materials and Methods

The field experiment was carried out at the research farm of Vivekananda Global University, Jaipur. Geographically, the site is located at 26°51' North latitude and 75°47' East longitude, with an elevation of 390 meters above mean sea level in the Jaipur district of Rajasthan. This area falls under Agro-climatic Zone IIIa, also known as the Semi-Arid Eastern Plain Zone of Rajasthan. The study involved nine treatment combinations, including:

- 100% Recommended Dose of Nitrogen (RDN) + soil application of FeSO₄ @ 10 kg/ha
- 100% RDN + soil application of ZnSO₄ @ 25 kg/ha
- 100% RDN + 1.0% foliar spray of FeSO₄ at 25 and 50 days after sowing (DAS)
- 100% RDN + 0.5% foliar spray of ZnSO₄ at 25 and 50 DAS
- 75% RDN + 25% nitrogen via farmyard manure (FYM) + soil-applied FeSO₄ @ 10 kg/ha
- 75% RDN + 25% FYM + soil-applied ZnSO₄ @ 25 kg/ha
- 75% RDN + 25% FYM + 1.0% foliar spray of FeSO₄ at 25 and 50 DAS
- 75% RDN + 25% FYM + 0.5% foliar spray of ZnSO₄ at 25 and 50 DAS
- 100% RDN supplied through chemical fertilizers.

Length measurement of the earhead

From each plot, five earheads were randomly chosen from the sampled plants, and their lengths were measured using a

meter scale, measuring from the neck node to the tip. The average length of these earheads was then calculated.

Number of viable tillers per plant

Tillers were counted from five randomly chosen and marked plants in each plot, and the average number of tillers per plant was calculated.

Grain test weight

A random sample of one thousand grains was taken from the fully cleaned and winnowed produce of each plot, and their combined weight was measured to determine the test weight (in grams).

Grain yield

Following threshing, winnowing, and cleaning, the yield from each plot was individually weighed in kilograms, and then the grain yield was calculated and expressed in kilograms per hectare (kg ha⁻¹).

Crop residue yield

Stover yield (kg ha⁻¹) was calculated by deducting the grain yield (kg ha⁻¹) from the total biological yield (kg ha⁻¹).

Total biomass yield

The weight of the harvested produce from each plot, after being completely sun-dried, was recorded individually before threshing and expressed as biological yield in kilograms per hectare (kg ha⁻¹). The grain-to-biomass yield ratio, or harvest index, was calculated using a standard method.

$$\text{Harvest efficiency (\%)} = \frac{\text{Harvestable produce per hectare (kg/ha)}}{\text{Total biomass yield per hectare (kg/ha)}} \times 100$$

Results and Discussion

The number of effective tillers per meter of row length, earhead length, and 1000-grain weight in pearl millet were significantly affected by the various treatment combinations applied. As shown in Table 1, the highest values for effective tillers (26.85), earhead length (36.62 cm), and test weight (7.94 g) were observed under treatment T₄, which involved 100% Recommended Dose of Nitrogen (RDN) combined with a 0.5% foliar spray of ZnSO₄ at 25 and 50 days after sowing. This was followed by treatments T₈ (75% RDN + 25% through farmyard manure (FYM) + 0.5% foliar spray of ZnSO₄ at 25 and 50 DAS), T₇ (75% RDN + 25% FYM + 1.0% foliar spray of FeSO₄ at 25 and 50 DAS), and T₆ (75% RDN + 25% FYM + soil application of ZnSO₄ @ 25 kg/ha).

The improvement in these yield attributes is likely linked to enhanced photosynthetic activity, leading to greater production of photosynthates that accumulate in the sink organs, positively influencing the number of effective tillers, earhead length, and 1000-grain weight. The notable increase in these traits may be attributed to zinc's role in the biosynthesis of indole acetic acid, which promotes the initiation of reproductive primordia and stimulates photosynthesis (Rakesh *et al.*, 2021). Additionally, nitrogen application enhances flower fertility, leaf area, and leaf longevity, thereby increasing the supply of assimilates to the developing sinks.

The grain and biological yields of pearl millet showed significant variation due to the application of different

nitrogen and micronutrient combinations. Across the treatments, grain yield ranged from 1367 to 1949 kg ha⁻¹, while biological yield varied between 4225 and 6242 kg ha⁻¹. The highest yields were recorded under treatment T₄, which consisted of 100% Recommended Dose of Nitrogen (RDN) combined with a 0.5% foliar spray of ZnSO₄ applied at 25 and 50 days after sowing. All treatment combinations resulted in significantly greater yields compared to the use of chemical fertilizers alone, as detailed in Table 2.

The increase in yield can be attributed to nitrogen's role in strengthening cell walls, which contributes to more robust straw and encourages prolific tillering. These findings are consistent with earlier reports by Rajput (2008) [8], Ayub *et al.* (2007) [1], and Pathan and Bhilare (2009) [7]. The combined application of nitrogen and zinc notably improved grain yield, likely due to nitrogen enhancing flower fertility and expanding leaf area and duration, thereby increasing the supply of assimilates to the developing grains (Mousavi *et al.*, 2012). Zinc also plays a crucial role in the biosynthesis of indole acetic acid, promoting the initiation of

reproductive primordia and stimulating photosynthesis directed towards these parts.

Furthermore, nitrogen and zinc together enhance physiological and molecular processes within the plant, leading to increased grain production. Zinc's involvement in various enzymatic activities, hormone synthesis, and protein production acts as a catalyst for growth and yield attributes, ultimately boosting both stover and grain yields (Jakhar *et al.*, 2006) [5].

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Table 1: Effect of nitrogen and micronutrients on yield attributes of pearl millet

Treatments	Ear head length (cm)	Effective tillers	Test weight (g)
T ₁ 100% RDN + Soil application of FeSO ₄ @ 10 Kg/ha	26.90	19.88	6.88
T ₂ 100% RDN + Soil application of ZnSO ₄ @ 25 kg/ha	34.11	26.14	7.85
T ₃ 100% RDN + 1.0% Foliar spray of FeSO ₄ at 25 and 50 Days after sowing	28.23	20.35	6.96
T ₄ 100% RDN + 0.5% Foliar spray of ZnSO ₄ at 25 and 50 Days after sowing	36.62	26.85	7.94
T ₅ 75% RDN + 25 % through FYM + Soil application of FeSO ₄ @ 10 Kg/ha	29.80	22.36	7.00
T ₆ 75% RDN + 25 % through FYM + Soil application of ZnSO ₄ @ 25 Kg/ha	35.44	26.42	7.88
T ₇ 75% RDN + 25 % through FYM + 1.0% Foliar spray of FeSO ₄ at 25 and 50 Days after sowing	31.13	25.97	7.81
T ₈ 75% RDN + 25 % through FYM + 0.5% Foliar spray of ZnSO ₄ at 25 and 50 Days after sowing	36.56	26.69	7.90
T ₉ 100% RDN through chemical fertilizers	22.62	16.12	6.09
SEm	1.04	1.21	0.26
C.D (P=0.05)	3.13	3.63	0.79

Table 2: Effect of nitrogen and micronutrients on Yield and harvest index of pearl millet

Treatments	Yield (kg ha ⁻¹)		
	Grain yield	Biological yield	HI
T ₁ 100% RDN + Soil application of FeSO ₄ @ 10 Kg/ha	1610	4883	32.93
T ₂ 100% RDN + Soil application of ZnSO ₄ @ 25 kg/ha	1762	5775	30.50
T ₃ 100% RDN + 1.0% Foliar spray of FeSO ₄ at 25 and 50 Days after sowing	1658	5111	32.51
T ₄ 100% RDN + 0.5% Foliar spray of ZnSO ₄ at 25 and 50 Days after sowing	1949	6242	31.23
T ₅ 75% RDN + 25 % through FYM + Soil application of FeSO ₄ @ 10 Kg/ha	1707	5280	32.38
T ₆ 75% RDN + 25 % through FYM + Soil application of ZnSO ₄ @ 25 Kg/ha	1805	5975	30.23
T ₇ 75% RDN + 25 % through FYM + 1.0% Foliar spray of FeSO ₄ at 25 and 50 Days after sowing	1741	5509	31.65
T ₈ 75% RDN + 25 % through FYM + 0.5% Foliar spray of ZnSO ₄ at 25 and 50 Days after sowing	1915	6162	31.20
T ₉ 100% RDN through chemical fertilizers	1367	4225	32.49
SEm	49	130	1.27
C.D (P=0.05)	146	390	NS

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