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## Response of integrated nutrient management on growth and yield of pearl millet (*Pennisetum glaucum* L.) in the Trans-Gangetic plains of India

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### Abstract

A field study titled “Response of Integrated Nutrient Management on Growth, Yield and Economics of Pearl millet (*Pennisetum glaucum* L.) in the Trans-Gangetic Plains of India” was carried out at the GD Goenka University's School of Agricultural Sciences, Gurugram, during the *kharif* 2025 season. Utilizing a Randomized Complete Block Design (RCBD), the study incorporated 11 specific treatments. To ensure accuracy, the trial was structured into three replications, resulting in three uniform blocks. The treatments were T<sub>1</sub>: RDF, T<sub>2</sub>: 100% FYM + LC, T<sub>3</sub>: 100% VC + LC, T<sub>4</sub>: 75% RDF + 25% FYM + LC, T<sub>5</sub>: 75% RDF + 25% VC + LC, T<sub>6</sub>: 50% RDF + 50% FYM + LC, T<sub>7</sub>: 50% RDF + 50% VC + LC, T<sub>8</sub>: 50% FYM + 50% VC + LC, T<sub>9</sub>: 25% RDF + 75% FYM + LC, T<sub>10</sub>: 25% RDF + 75% VC + LC, and T<sub>11</sub>: Control. Data indicated that integrated nutrient practices significantly boosted pearl millet performance. The T<sub>4</sub> combination (75% RDF + 25% VC + LC) outperformed all other treatments, registering the highest plant height (210.00 cm), dry matter accumulation (45.04 g plant<sup>-1</sup>), Leaf Area Index (1.65), ear length (27.68 cm), and grain production (1.86 t ha<sup>-1</sup>), with T<sub>4</sub> (75% RDF + 25% FYM + LC) ranking second. These results establish INM as a highly feasible and environmentally sustainable agronomic practice for pearl millet production in semi-arid regions

**Keywords:** Pearl millet, integrated nutrient management, organic and inorganic, benefit-cost ratio

### Introduction

Serving as a critical pillar for agricultural sustainability in the world's arid and semi-arid regions, pearl millet (*Pennisetum glaucum* L.) is a highly resilient member of the *Poaceae* family. On a global scale, it represents the sixth most heavily cultivated cereal grain, trailing only maize, rice, wheat, barley, and sorghum, making it an indispensable resource for dryland farming systems. Dominating the global agricultural landscape for this crop, India is the leading producer of pearl millet, holding a 40-45% share in both global land area and total production volume. Within the country, upwards of 90% of this harvest is driven by the combined agricultural efforts of Rajasthan, Maharashtra, Gujarat, Uttar Pradesh, and Haryana. Pearl millet is highly valued as a climate-smart crop because it thrives under harsh environmental conditions, including extreme heat, water scarcity, and nutrient-deficient soils, making it exceptionally well-suited for rainfed farming systems (Kumar *et al.*, 2021) [4]. Nutritionally, the grain is remarkably dense, providing 11–19% protein, 60–78% carbohydrates, and 3.0-4.6% lipids, alongside vital minerals like iron and phosphorus (Reddy *et al.*, 2016) [10].

Even though advanced hybrid varieties have the biological capacity to produce 3.0 to 3.5 tonnes per hectare (t ha<sup>-1</sup>), real-world harvests consistently fall short. This yield gap is primarily driven by deteriorating soil health and incorrect fertilizer application. Because pearl millet is typically pushed to marginal lands, farming these areas continuously without properly replenishing the soil has depleted essential nutrient reserves and organic matter. This environmental toll is worsened by the heavy, unbalanced reliance on synthetic nitrogen fertilizers, which fundamentally damages the biological and physical integrity of the soil. To combat this degradation, Integrated Nutrient Management (INM) offers a sustainable framework that blends synthetic, organic, and biological inputs to satisfy crop requirements while rebuilding soil fertility (Mangaraj *et al.*, 2022) [11]. While organic amendments such as

vermicompost and farmyard manure (FYM) are excellent for rehabilitating soil structure and microbial life, they typically release nutrients too slowly to support high-intensity agriculture on their own (Sharma *et al.*, 2018) <sup>[13]</sup>. For pearl millet, however, combining these organics with standard chemical fertilizers overcomes this limitation. This integrated approach drastically improves nutrient uptake, soil carbon, and microbial biomass, resulting in significantly higher grain and stover yields compared to exclusive chemical fertilization. Consequently, this investigation was designed to evaluate the response of integrated nutrient management (INM) on growth, yield attributes and yield of pearl millet (*Pennisetum glaucum* L.).

## Materials and Methods

The field trial was carried out at the CRC Farm of GD Goenka University in Sohna, Gurugram, Haryana. Geographically situated at 28° 15' N latitude and 77° 4' E longitude, the experimental site was characterized by fertile, well-drained sandy loam soil. The experimental site falls under the semi-arid and subtropical zones. The soil at the experimental site was a well-drained, coarsely textured loamy sand (International Pipette method; Piper, 1966) <sup>[8]</sup> with a pH of 7.8 and an electrical conductivity (EC) of 0.374 dS m<sup>-1</sup> (Jackson, 1967) <sup>[2]</sup>. Soil chemical analysis indicated low baseline fertility: organic carbon was 0.3% (Walkley & Black, 1934) <sup>[15]</sup>, available nitrogen was 180.02 kg ha<sup>-1</sup> (Subbiah & Asija, 1956) <sup>[14]</sup>, available phosphorus was 13.0 kg ha<sup>-1</sup> (Olsen *et al.*, 1954) <sup>[5]</sup>, and available potassium was 130.00 kg ha<sup>-1</sup> (Jackson, 1973) <sup>[3]</sup>. There were eleven treatments, which were tested in a randomised block design with three replications. The treatments consisted of T<sub>1</sub>: RDF, T<sub>2</sub>: 100% FYM + LC, T<sub>3</sub>: 100% VC + LC, T<sub>4</sub>: 75% RDF + 25% FYM + LC, T<sub>5</sub>: 75% RDF + 25% VC + LC, T<sub>6</sub>: 50% RDF + 50% FYM + LC, T<sub>7</sub>: 50% RDF + 50% VC + LC, T<sub>8</sub>: 50% FYM + 50% VC + LC, T<sub>9</sub>: 25% RDF + 75% FYM + LC, T<sub>10</sub>: 25% RDF + 75% VC + LC, and T<sub>11</sub>: Control. (100% RDF- 60 kg N ha<sup>-1</sup>; 30 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup>; 20 kg K<sub>2</sub>O ha<sup>-1</sup>; 100% FYM 10t ha<sup>-1</sup>, 100% Vermicompost 5t ha<sup>-1</sup>; LC: IFFCO N, P& K liquid consortium @1.5 L ha<sup>-1</sup>). The field trial was sown with certified seeds of pearl millet hybrid 'ADV 963', treated beforehand with a Liquid Consortium. Organic inputs (FYM and vermicompost) were soil-incorporated 15 days before planting. Basal application of the complete doses of phosphorus (DAP) and potassium (MOP), alongside 50% of the required nitrogen (urea). The residual nitrogen was top dressed at the tillering stage. Standard agronomic and protective measures were applied uniformly. For data acquisition, five plants per net plot were randomly tagged to measure growth metrics (plant height, fresh/dry weight, leaf count, LAI, and tillers per plant) at 30 DAS, 60 DAS, and maturity. At harvest, yield components (ears per plant, ear dimensions, grain weight per head, and test weight) were assessed from the tagged plants. Finally, net plots were manually harvested, sun-dried for biological yield determination, and threshed to record grain and stover yields (t ha<sup>-1</sup>). The resulting data underwent standard statistical analysis as described by Panse and Sukhatme (1985) <sup>[6]</sup>.

## Results and Discussion

### Effect of INM on growth parameters of pearl millet

The application of integrated nutrient management (INM) practices exerted a significant positive effect on the morphological and growth parameters of pearl millet. Crop stature varied from 64.10 to 65.00 cm at 30 days after sowing (DAS), progressed to 155.28-162.73 cm at 60 DAS, and reached 171.00-210.00 cm by

maturity. The INM approach, incorporating vermicompost-specific treatment T<sub>5</sub> (75% RDF + 25% VC + LC), demonstrated a sustained growth advantage over the standard inorganic application (T<sub>1</sub>: 100% RDF). Compared to T<sub>1</sub>, T<sub>5</sub> increased plant height by 0.22%, 2.22%, and 6.06% at 30 DAS, 60 DAS, and harvest, respectively. This combination also stimulated tillering, consistently outperforming T<sub>1</sub> across all stages with a tiller plant<sup>-1</sup> increase of 13.31% at 30 DAS, 11.64% at 60 DAS, and 11.68% at harvest.

Canopy development and photosynthetic area were optimised under treatment T<sub>5</sub>. By harvest, T<sub>5</sub> achieved a Leaf Area Index (LAI) of 1.65, which was statistically superior to all other treatments, followed by T<sub>4</sub> (1.44). This terminal LAI represented a 22.22% increase over the RDF Biomass production responded favourably to the vermicompost-inclusive INM strategy. At harvest, T<sub>5</sub> yielded the maximum fresh plant weight (322.00 g), remaining statistically at par with T<sub>4</sub> (321.00 g) and T<sub>1</sub> (320.00 g), while the absolute control (T<sub>11</sub>) recorded the minimum (297.00 g). While T<sub>5</sub> showed modest fresh weight improvements over T<sub>1</sub> (ranging from 0.63% to 1.13% across stages), its impact on dry matter accumulation was pronounced. T<sub>5</sub> consistently generated higher dry weight than 100% RDF, showing a substantial 22.40% improvement during early vegetative growth (30 DAS) and culminating in a 5.75% increase at harvest. Related findings were also reported by Singh *et al.* (2020) and Choudhary & Gautam (2007) <sup>[9]</sup>.

### Effect of INM on yield attributing and yield parameters of pearl millet

The integration of organic and inorganic nutrient sources exerted a substantial positive influence on the yield-contributing characters of pearl millet. Treatment T<sub>5</sub> (75% RDF + 25% VC + LC) consistently demonstrated superior reproductive performance compared to the sole application of chemical fertilisers (T<sub>1</sub>: 100% RDF).

Substituting 25% of standard fertilizers with vermicompost and liquid biofertilizers (T<sub>5</sub>) significantly improved yield attributes and final productivity compared to the 100% RDF (T<sub>1</sub>). T<sub>5</sub> increased ears per plant to 3.73 (11.68%), ear length to 27.68 cm (14.05%), and ear girth to cm (16.67%). This expanded sink capacity raised the grain weight per head to 9.59 g (8.24%), ultimately driving a superior final grain yield of 1.86 t ha<sup>-1</sup>, a 14.81% increase over T<sub>1</sub> (1.62 t ha<sup>-1</sup>). However, the 1000-grain test weight remained statistically unchanged (8.23 g vs. 8.20 g), demonstrating that these overall productivity gains stem entirely from increased ear dimensions and proliferation rather than greater individual seed mass.

The vegetative robustness observed during the early growth stages in T<sub>5</sub> culminated in a higher stover yield of 5.03 t/ha, outpacing the sole inorganic treatment (4.61 t ha<sup>-1</sup>) by 10.20%. Consequently, the cumulative biological yield, encompassing both economic and structural biomass, peaked at 6.86 t ha<sup>-1</sup> under the T<sub>5</sub> treatment, reflecting a 10.11% overall improvement compared to the T<sub>1</sub> baseline (6.23 t ha<sup>-1</sup>).

Beyond absolute biomass generation, the integrated nutrient approach subtly improved the physiological efficiency of the crop in mobilising photosynthates toward the economic sink. This was evidenced by the harvest index, which reached 26.89% under T<sub>5</sub> compared to 25.98% in T<sub>1</sub>. This 3.50% relative increase suggests that combining organic amendments with mineral fertilisers and liquid bio-inoculants not only drives overall plant vigour, but also optimises the allocation of assimilates for grain filling. Related findings were also observed by, Choudhary & Gautam (2001) <sup>[9]</sup>, Divya *et al.* (2017) <sup>[1]</sup> and Patel *et al.* (2014) <sup>[7]</sup>.

**Table 1:** Response of INM on growth attributes of pearl millet

| Treatments                              | Plant height (cm) |        |            | Fresh weight (g plant <sup>-1</sup> ) |        |            | Dry weight (g plant <sup>-1</sup> ) |        |            | Leaf area index plant <sup>-1</sup> |        |            |
|-----------------------------------------|-------------------|--------|------------|---------------------------------------|--------|------------|-------------------------------------|--------|------------|-------------------------------------|--------|------------|
|                                         | 30 DAS            | 60 DAS | At harvest | 30 DAS                                | 60 DAS | At harvest | 30 DAS                              | 60 DAS | At harvest | 30 DAS                              | 60 DAS | At harvest |
| T <sub>1</sub> : RDF                    | 64.93             | 159.2  | 198.0      | 24.47                                 | 238.0  | 320.0      | 6.34                                | 27.47  | 42.59      | 0.57                                | 2.30   | 1.35       |
| T <sub>2</sub> : 100% FYM + LC          | 64.20             | 155.4  | 177.3      | 21.90                                 | 209.0  | 298.0      | 5.22                                | 24.37  | 40.30      | 0.49                                | 1.85   | 1.19       |
| T <sub>3</sub> : 100% VC + LC           | 64.30             | 156.9  | 180.5      | 22.20                                 | 210.0  | 299.0      | 5.37                                | 24.44  | 41.04      | 0.50                                | 1.90   | 1.22       |
| T <sub>4</sub> : 75% RDF + 25% FYM + LC | 65.00             | 160.7  | 205.0      | 25.48                                 | 239.0  | 321.0      | 6.93                                | 27.84  | 42.96      | 0.59                                | 2.34   | 1.44       |
| T <sub>5</sub> : 75% RDF + 25% VC + LC  | 65.07             | 162.7  | 210.0      | 27.87                                 | 240.0  | 322.0      | 7.76                                | 28.00  | 45.04      | 0.68                                | 2.36   | 1.65       |
| T <sub>6</sub> : 50% RDF + 50% FYM + LC | 64.70             | 158.6  | 184.0      | 22.37                                 | 214.0  | 302.7      | 5.49                                | 24.90  | 41.93      | 0.54                                | 2.08   | 1.36       |
| T <sub>7</sub> : 50% RDF + 50% VC + LC  | 64.80             | 158.8  | 185.0      | 23.67                                 | 215.0  | 304.0      | 4.62                                | 25.00  | 42.32      | 0.56                                | 2.07   | 1.34       |
| T <sub>8</sub> : 50% FYM + 50% VC + LC  | 64.40             | 157.7  | 181.0      | 22.00                                 | 211.0  | 300.0      | 4.96                                | 24.60  | 41.51      | 0.54                                | 2.00   | 1.25       |
| T <sub>9</sub> : 25% RDF + 75% FYM + LC | 64.47             | 157.7  | 182.0      | 22.67                                 | 212.0  | 301.0      | 5.12                                | 24.70  | 41.62      | 0.47                                | 2.04   | 1.25       |
| T <sub>10</sub> : 25% RDF + 75% VC + LC | 64.63             | 158.2  | 183.0      | 22.33                                 | 212.7  | 302.0      | 5.48                                | 24.80  | 42.15      | 0.51                                | 2.06   | 1.22       |
| T <sub>11</sub> : Control               | 64.10             | 155.3  | 171.0      | 19.27                                 | 207.0  | 297.0      | 4.05                                | 24.30  | 39.65      | 0.39                                | 1.40   | 1.11       |
| S.Em±                                   | 0.69              | 1.24   | 6.75       | 0.87                                  | 7.06   | 5.77       | 0.38                                | 0.9    | 0.9        | 0.05                                | 0.08   | 0.08       |
| CD (P=0.05)                             | NS                | 3.7    | 19.91      | 2.57                                  | 20.82  | 17.02      | 1.13                                | 2.65   | 2.67       | NS                                  | 0.26   | 0.26       |

**Table 2:** Response of INM on yield attributes and yield of pearl millet

| Treatments                              | No. of Tillers plant <sup>-1</sup> |        |            | Number of ears plant <sup>-1</sup> | Length of ear head (cm) | Girth of ear head (cm) | Grain weight head <sup>-1</sup> (g) | Test weight (g) | Grain yield (t ha <sup>-1</sup> ) | Stover yield (t ha <sup>-1</sup> ) | Biological yield (t ha <sup>-1</sup> ) | Harvest index (%) |
|-----------------------------------------|------------------------------------|--------|------------|------------------------------------|-------------------------|------------------------|-------------------------------------|-----------------|-----------------------------------|------------------------------------|----------------------------------------|-------------------|
|                                         | 30 DAS                             | 60 DAS | At harvest |                                    |                         |                        |                                     |                 |                                   |                                    |                                        |                   |
| T <sub>1</sub> : RDF                    | 2.93                               | 3.34   | 3.35       | 3.34                               | 24.27                   | 4.8                    | 8.86                                | 8.20            | 1.62                              | 4.61                               | 6.23                                   | 25.98             |
| T <sub>2</sub> : 100% FYM + LC          | 2.47                               | 2.54   | 2.55       | 2.54                               | 19.33                   | 3.8                    | 8.12                                | 8.07            | 1.36                              | 4.23                               | 5.59                                   | 24.42             |
| T <sub>3</sub> : 100% VC + LC           | 2.55                               | 2.64   | 2.65       | 2.64                               | 20.29                   | 3.9                    | 8.14                                | 8.10            | 1.44                              | 4.32                               | 5.76                                   | 25.05             |
| T <sub>4</sub> : 75% RDF + 25% FYM + LC | 3.13                               | 3.39   | 3.40       | 3.39                               | 25.26                   | 5.0                    | 9.15                                | 8.21            | 1.70                              | 4.91                               | 6.61                                   | 25.70             |
| T <sub>5</sub> : 75% RDF + 25% VC + LC  | 3.32                               | 3.73   | 3.74       | 3.73                               | 27.68                   | 5.6                    | 9.59                                | 8.23            | 1.86                              | 5.08                               | 6.94                                   | 26.89             |
| T <sub>6</sub> : 50% RDF + 50% FYM + LC | 2.73                               | 3.04   | 3.05       | 3.04                               | 21.47                   | 4.2                    | 8.19                                | 8.10            | 1.49                              | 4.52                               | 6.01                                   | 24.72             |
| T <sub>7</sub> : 50% RDF + 50% VC + LC  | 2.80                               | 3.06   | 3.07       | 3.06                               | 22.46                   | 4.3                    | 8.28                                | 8.17            | 1.51                              | 4.55                               | 6.06                                   | 24.98             |
| T <sub>8</sub> : 50% FYM + 50% VC + LC  | 2.44                               | 2.74   | 2.75       | 2.74                               | 20.18                   | 3.8                    | 8.15                                | 8.13            | 1.46                              | 4.40                               | 5.86                                   | 24.95             |
| T <sub>9</sub> : 25% RDF + 75% FYM + LC | 2.15                               | 2.84   | 2.85       | 2.84                               | 21.23                   | 4.0                    | 8.18                                | 8.07            | 1.46                              | 4.43                               | 5.89                                   | 24.84             |
| T <sub>10</sub> : 25% RDF + 75% VC + LC | 2.29                               | 2.94   | 2.95       | 2.94                               | 22.77                   | 4.1                    | 8.19                                | 8.14            | 1.48                              | 4.45                               | 5.93                                   | 24.96             |
| T <sub>11</sub> : Control               | 1.69                               | 2.44   | 2.45       | 2.44                               | 19.27                   | 3.6                    | 7.57                                | 7.97            | 0.93                              | 3.87                               | 4.80                                   | 19.27             |
| S.Em±                                   | 0.25                               | 0.20   | 0.20       | 0.20                               | 0.65                    | 0.40                   | 0.34                                | 0.11            | 0.11                              | 0.17                               | 0.2                                    | 1.63              |
| CD (P=0.05)                             | 0.75                               | 0.60   | 0.61       | 0.61                               | 1.93                    | NS                     | 1.01                                | NS              | 0.33                              | 0.5                                | 0.58                                   | NS                |

## Conclusion

Experimental findings indicate that relying exclusively on synthetic fertilizers (100% RDF) or organic inputs (100% FYM/VC) limits the yield potential of Pearl millet in the Trans-Gangetic Plains. Instead, Treatment T<sub>5</sub> (75% RDF + 25% Vermicompost + Liquid Consortium) proved to be the optimal agronomic strategy. By providing a synchronized nutrient supply, this integrated approach maximized vegetative growth and achieved a peak grain yield of 1.83 t ha<sup>-1</sup>. Economically, T<sub>5</sub> outperformed pure chemical fertilization, boosting yields by 14.81% and net profitability by 16.41%. Consequently, substituting 25% of chemical fertilizers with vermicompost and a liquid consortium is strongly recommended for sustainable and profitable cultivation in this region.

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