



RESEARCH ARTICLE

Effect of crop geometry and nutrient levels on productivity of transplanted finger millet (*Eleusine coracana* L.) under irrigated conditions

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Abstract

A field experiment was conducted during the rabi season of 2025–26 at SRM College of Agricultural Sciences, Tamil Nadu, India, to study the effects of crop geometry and nutrient management practices for transplanted finger millet in irrigated conditions. The experiment was laid out in a split plot design with 3 replications. The finger millet variety ATL-1 was transplanted at 21 days after sowing (DAS). Growth, physiological, yield attributes and yield parameters were recorded during the crop period. Among the treatments, 30 × 10 cm spacing combined with split application of 50 % recommended dose of fertilisers (RDF) at basal + 25 % at active tillering + 25 % at flowering recorded superior growth and physiological performance, including higher plant height, dry matter production, tiller count, leaf area index and chlorophyll content. The same treatment also produced higher yield attributes and recorded maximum grain yield (1415 kg ha⁻¹), straw yield (4330 kg ha⁻¹). The study indicated that optimum crop geometry combined with split nutrient application enhanced growth, physiological efficiency and yield of transplanted finger millet under irrigated conditions. The heatmap analysis based on normalised values further confirmed that the M₂S₃ treatment exhibited the best overall performance across all observed growth, yield attributes and yield parameters.

Keywords: crop geometry; finger millet; nutrient management; split application; yield

Introduction

Finger millet (*Eleusine coracana* L.) is an ancient millet crop belonging to the family Poaceae and is widely cultivated across the semi-arid tropics of Africa and Asia. India is the largest producer of finger millet, contributing nearly 37 % of global production (1). In India, finger millet is widely cultivated in Karnataka, Andhra Pradesh, Tamil Nadu, Uttarakhand and Odisha. The crop occupied approximately 11.62 lakh ha with a production of 16.92 lakh ha with a productivity of 1456 kg ha⁻¹ (2). The grain is valued for its exceptional nutritional quality being rich in calcium, iron, phosphorus, magnesium and dietary fibre and plays a significant role in ensuring food and nutrition security among resource-poor farming communities (3). In addition, its tolerance to drought, salinity and low soil fertility makes it a resilient crop under changing climatic conditions, leading to its recognition as a “climate smart super food” during the international year of millets 2023.

Crop geometry is a key agronomic factor influencing resources utilisation, canopy development and crop productivity. Appropriate plant spacing improves light interception, nutrient uptake and tiller production, whereas excessively close spacing can intensify inter-plant competition and restrict crop growth (4).

Nutrient management plays a crucial role in enhancing growth and yield by ensuring an adequate and timely supply of

essential nutrients throughout the crop growth period. In finger millet, the synchronisation of nutrient use efficiency and productivity. Previous studies have demonstrated that balanced and split applications of fertiliser can enhance biomass production, tiller development and grain yield compared with conventional single-dose fertiliser application (5, 6).

Transplanting offers advantages over direct sowing by ensuring uniform plant establishment and facilitating better management of crop geometry. Information on the interaction between crop geometry and split applications of nitrogen, phosphorus and potassium (NPK) in transplanted finger millet under irrigated conditions remains limited. Therefore, the present investigation was undertaken to evaluate the combined effect of crop geometry and nutrient management for improving growth, physiological parameters, yield attributes and yield of transplanted finger millet under irrigated conditions (7, 8).

Materials and Methods

The field experiment was laid out in a split plot design with 3 replications during rabi season of 2025–26 at SRM College of Agricultural Sciences, Tamil Nadu, India situated at an altitude of above 55 m above mean sea level and falling under the North Eastern Agro-climatic Zone of Tamil Nadu (12. 38° N latitude 79. 73° E

longitude). The crop was grown under a mean temperature of 27.80 °C (maximum: 34.06 °C; minimum: 21.54 °C) and received 40.00 mm of rainfall during the experimental period (05 January–07 May 2026). The experimental soil had a clay loamy texture with pH of 7.9, electrical conductivity (EC) of 0.2 dSm⁻¹, 0.3 % organic carbon (OC), low in available N (123 kg ha⁻¹), high in available in P (53 kg ha⁻¹), medium in available K (160 kg ha⁻¹) respectively. The main plots consisted of three levels of spacing viz, M₁- 30 × 10 cm, M₂- 20 × 10 cm and M₃- 10 × 10 cm and sub plot comprised of four levels of nutrient management practices viz, S₁- 100 % recommended dose of fertilisers (RDF) at basal, S₂- 50 % RDF at basal + 50 % RDF at active tillering, S₃- 50 % at basal + 25 % at active tillering + 25 % at flowering and S₄-Control. The RDF was 60 : 30 : 30 kg N : P₂O₅ : K₂O ha⁻¹. The finger millet variety ATL-1 (110–115 days) was used with a seed rate of 4 kg ha⁻¹. Seeds were treated with carbendazim at a rate of 2 g kg⁻¹ seeds before sowing. Finger millet seedlings were uprooted from the nursery and transplanted manually in the main field using one to two seedlings per hill according to the respective spacing treatments. Irrigation was applied at critical growth stages of finger millet, particularly during establishment, tillering, flowering and grain filling stages, to prevent moisture stress. Recommended cultural practices and plant protection measures were adopted throughout the crop growth period. Biometric observations such as plant height (Measured from ground level to the tip of the tallest plant/panicle using a meter scale and expressed in cm), leaf area index (LAI) (Determined using a leaf area meter and calculated as leaf area per unit ground area), dry matter production (DMP) (Estimated by oven-drying plant samples at 65–70 °C to constant weight and expressed as kg ha⁻¹), chlorophyll content (Measured using a SPAD chlorophyll meter and expressed as SPAD value) were recorded at 20, 40 and 60 days after transplanting (DAT) and at harvest. The experimental data were subjected to analysis of variance (ANOVA) using R-software (version 4.4.1). Treatment means were separated using Fisher's least significant difference (LSD) test ($p \leq 0.05$) using the agricolae package after confirming that the assumptions and heatmap visualisation was generated using python, where all quantitative parameters were normalised to a 0–1 scale using Min-Max method to interpret the results (9, 10).

Results and Discussion

The effect of different levels of crop geometry, nutrient management and their interaction on growth parameters, physiological parameters, yield attributes and yield parameters of transplanted finger millet was statistically significant and is presented in the following sections.

Growth parameters

Plant height and dry matter production of transplanted finger millet were significantly influenced by crop geometry and nutrient management practices at different growth stages (Table 1). Among the crop geometry treatments, M₁ (30 × 10 cm spacing) recorded higher plant height (66.1, 74.8 and 77.3 cm at 40, 60 DAT and harvest, respectively) and dry matter production (3538, 8125 and 11600 kg ha⁻¹ at 40, 60 DAT and harvest) due to less interplant competition for light, moisture and soil nutrients. Among the nutrient management treatments, S₃ (50 % RDF at basal + 25 % at active tillering + 25 % at flowering) recorded the highest plant height (67.7, 76.1 and 78.0 cm) and dry matter production (3800, 8300 and 11683 kg ha⁻¹) at 40, 60 DAT and harvest, respectively. The split

application of NPK ensured timely balanced nutrient availability during critical demand periods (early vegetative growth and internodal elongation stage). The interaction effect between crop geometry and nutrient management (M × S) was significant for plant height and dry matter production at 40, 60 DAT and harvest. Among the different treatments, 30 × 10 cm spacing along with 50 % RDF at basal + 25 % at active tillering + 25 % at flowering (M₁S₃) recorded the highest values, indicating the beneficial effect of optimum spacing combined with split nutrient application. Similar findings were reported previously (11).

Number of tiller

The number of tillers per plant was significantly affected by spacing and nutrient management at 40 DAT (Table 1). Among the crop geometry treatments, M₁ recorded higher number of tillers per plant (5.9). Adequate inter-row spacing allowed unhindered lateral bud development by reducing competition for light and space. Among nutrient management treatments, S₃ recorded higher number of tillers per plant (6.2). The synchronised nutrient supply during the tillering stage was the reason for higher tillers per plant. The interaction effect was significant at 40 DAT and the treatment combination M₁S₃ recorded the maximum number of tillers per plant. Similar observations were reported in earlier studies (4).

Physiological parameters

Physiological parameters were influenced by crop geometry and nutrient management (Fig. 1 and 2) for LAI and for total chlorophyll content. The treatment M₁S₃ exhibited a higher leaf area index (2.9, 3.7 and 2.8) and total chlorophyll content (53.0, 56.2 and 32.2), respectively at 40, 60 DAT and at harvest stage. It might be due to better light penetration which supports higher leaf area development. The decline in LAI and total chlorophyll content at the harvest stage was likely a natural consequence of leaf senescence during grain filling and maturation. This corroborates with the findings of previous researchers (12).

Yield attributes

The yield attributes such as productive tillers per plant, fingers per ear head, ear heads per plant, ear head weight per plant, ear head length, finger length and 1000-seed weight, were significantly influenced by crop geometry and nutrient management practices (Table 2). Among the treatments, M₁S₃ recorded the highest values for number of productive tillers per plant (5.0), number of fingers per ear head (6.3), ear heads per plant (4.7), ear head weight per plant (23.8 g), ear head length (8.3 cm), finger length (6.9 cm) and 1000-seed weight (2.8 g). The interaction effect between crop geometry and nutrient management was significant for most yield attributes. The enhanced performance of M₁S₃ could be attributed to optimum plant spacing and synchronised nutrient availability throughout the crop growth period, promoting greater tiller production and their conversion into productive ear-bearing tillers. The phased supply of nutrients might have enhanced reproductive development, assimilate translocation and grain filling, resulting in improved yield attributed. These findings agree with the observations reported by previous researchers (11, 12).

Yield parameters

Grain yield and straw yield were significantly influenced by crop geometry and nutrient management practices (Table 2). Among crop geometry treatments, M₁ recorded the highest grain yield (1348 kg ha⁻¹) and straw yield (4115 kg ha⁻¹), respectively. Among

Table 1. Effect of crop geometry and nutrient management on growth parameters of finger millet

Treatments	Plant height (cm)			Dry matter production (kg ha ⁻¹)			No. of tillers/plant	
	20 DAT	40 DAT	60 DAT	At Harvest	20 DAT	40 DAT	20 DAT	40 DAT
Crop geometry								
M ₁	44.4	66.1	74.8	77.3	1087	3538	8125	11600
M ₂	43.9	65.2	73.8	75.3	1086	3375	7938	11438
M ₃	43.2	60.3	68.6	70.3	1069	3138	7638	11138
S.Ed	1.2	0.4	0.8	0.8	37	41.7	51.5	87.4
CD	NS	1.2*	2.4*	2.2*	NS	121.8*	150.3*	255.3*
F value	-	123.0	30.13	44.80	-	46.55	47.30	14.41
Nutrient management								
S ₁	43.9	63.9	72.2	74.3	1081.7	3267	7800	11317
S ₂	44.3	65.6	74.4	75.7	1098.3	3483	8033	11533
S ₃	44.5	67.7	76.1	78.0	1106.7	3800	8300	11683
S ₄	42.5	58.3	67.0	69.3	1036.7	2850	7467	11033
S.Ed	2.2	0.7	0.9	1.7	35.6	51.7	43.6	263.9
CD	NS	1.5*	2.2*	3.4*	NS	121.5*	102.5*	620.3*
F value	NS	114.72	54.35	26.92	-	178.5	195.91	3.43
Interaction (M × S)								
S.Ed	3.1	0.9	1.3	1.7	50.4	73.1	61.7	373.3
CD	NS	1.8*	2.6*	3.4*	NS	142.1*	119.9*	725.3*
F value	-	4.47	7.43	3.84	-	6.52	8.30	0.22

*Significant at $p \leq 0.05$; NS: non-significant ($p > 0.05$); DAT: days after transplanting.

Table 2. Effect of crop geometry and nutrient management on yield attributes and yield parameters of finger millet

Treatments	No. of productive tillers/plant	No. of earheads/plant	Earhead weight (g)	Earhead length (cm)	No. of fingers/earhead	Finger length (cm)	1000-seed weight (g)	Grain yield (kg ha ⁻¹)	Straw yield (kg ha ⁻¹)	Harvest index
Crop geometry										
M ₁	4.5	4.5	20.3	7.8	5.8	6.6	2.7	1348	4115	0.25
M ₂	4.2	4.0	17.7	7.5	5.4	6.4	2.5	1275	3951	0.24
M ₃	3.0	3.2	13.6	7.5	4.5	5.8	2.1	1082	3485	0.24
S.Ed	0.1	0.1	0.7	0.1	0.2	0.1	0.1	21.9	28.1	0.01
CD	0.3*	0.3*	1.9*	0.4*	0.5*	0.2*	0.2*	108.5*	82.1*	-
F value	165.58	111.71	51.76	65.62	32.81	52.62	40.63	78.30	270.70	-
Nutrient management										
S ₁	3.7	3.8	17.3	7.3	5.2	6.3	2.4	1212	3850	0.24
S ₂	4.4	4.3	20.8	7.7	5.7	6.5	2.6	1328	4121	0.24
S ₃	5.0	4.7	23.8	8.3	6.3	6.9	2.8	1415	4330	0.25
S ₄	2.5	2.7	6.8	5.6	3.8	5.3	1.8	985	3100	0.24
S.Ed	0.1	0.1	0.6	0.2	0.2	0.1	0.1	46.2	38.4	0.01
CD	0.6*	0.4*	1.5*	0.6*	0.6*	0.6*	0.1*	108.5*	90.2*	-
F value	62.88	105.0	401.02	50.70	60.36	27.67	146.89	48.89	588.08	-
Interaction (M × S)										
S.Ed	0.3	0.2	0.9	0.4	0.3	0.3	0.1	65.3	54.3	0.01
CD	0.6*	0.4*	1.8*	0.8*	0.7*	0.6*	0.2*	126.8*	105.5*	-
F value	5.84	5.70	16.47	3.24	3.74	0.81	8.83	3.23	22.58	-

*Significant at $p \leq 0.05$; NS: Non-significant ($p > 0.05$).

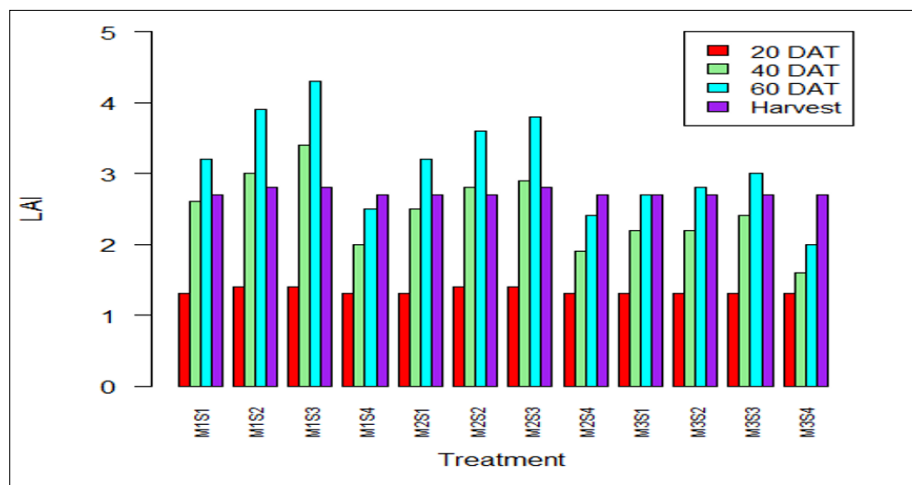


Fig. 1. Effect of crop geometry and nutrient management practices on leaf area index of finger millet

LAI: leaf area index; DAT: days after transplanting.

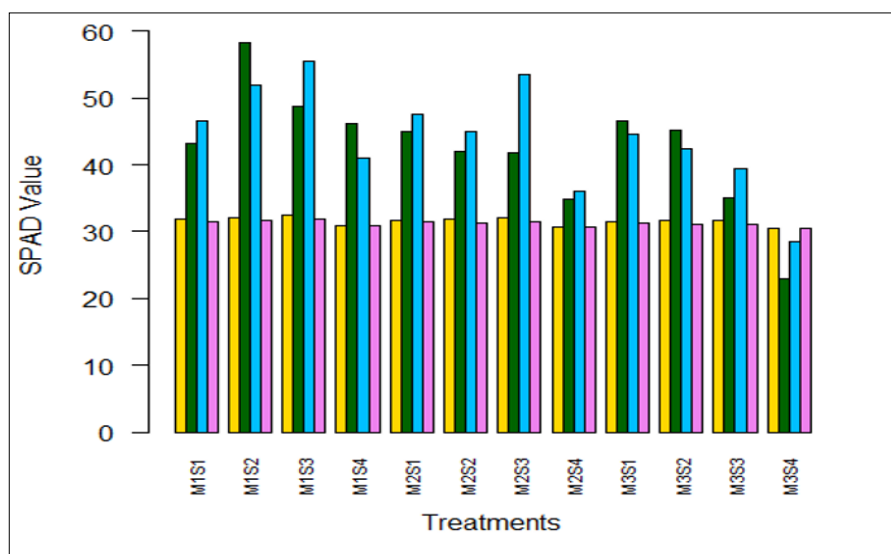


Fig. 2. Effect of crop geometry and nutrient management practices on total chlorophyll content of finger millet.

nutrient management treatments, S_3 recorded the highest grain yield (1415 kg ha^{-1}) and straw yield (4330 kg ha^{-1}). The interaction effect was significant for grain and straw yield, with the treatment combination M_2S_3 recorded the highest grain yield and straw yield. The increased yield under this treatment may be attributed to improved growth, higher dry matter production and enhanced yield attributes resulting from optimum crop geometry and continuous nutrient availability throughout the crop growth period. The higher harvest index observed under M_1S_3 indicates improved conversion of total biomass into economic yield. Similar results were reported in previous studies (13–15).

Heatmap analysis further supported these findings by revealing positive associations between growth parameters, yield attributes and yield. Among all treatments, M_1S_3 exhibited the most favourable overall performance, whereas M_3S_4 recorded the lowest values for all parameters as visually indicated by the red and blue spectral fields in the heatmap (Fig. 3).

Conclusion

The results of the present investigation clearly indicate that crop geometry and split application of nutrients in transplanted finger millet are key determinants of growth and productivity. Transplanting finger millet at $30 \times 10 \text{ cm}$ spacing reduced

interplant competition for light, moisture, space and soil nutrients; and enabled better vegetative growth, higher tiller initiation and more ear head development compared to closer spacings. Based on the present findings, transplanted finger millet at $30 \times 10 \text{ cm}$ spacing along with split application of recommended dose of fertilisers (RDF) (50 % basal, 25 % at active tillering and 25 % at flowering) may be recommended for achieving higher productivity under irrigated conditions.

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Authors' contributions

SK conducted field visits, collected data and performed the research design and analysis. BP was involved in the literature review, drafting of the manuscript and revision of the manuscript. MAA read and approved the final manuscript for publication. ASR participated in

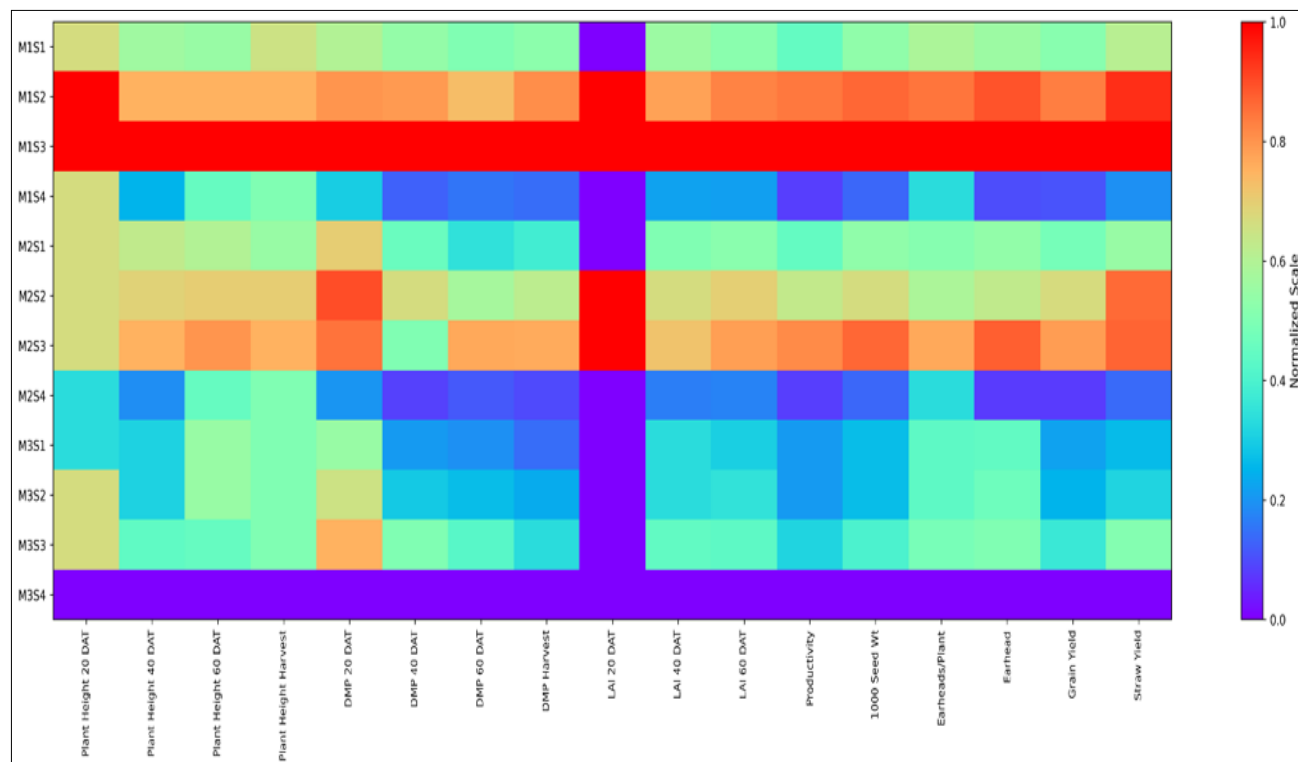


Fig. 3. Heatmap analysis of overall treatment for growth and yield attributes.

the design of the study. All authors have read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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