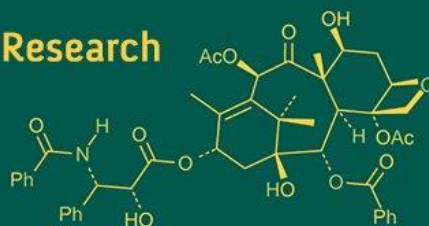


International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2026): 5.29
IJABR 2026; SP-10(7): 1387-1398
www.biochemjournal.com
Received: 15-04-2026
Accepted: 18-05-2026

Narendra Kumar
Scientist-SG, CARS Jagadapur,
Indira Gandhi Krishi
Vishwavidyalaya (IGKV),
Raipur, Chhattisgarh, India

Sunil Kumar
Principal Scientist, College of
Agriculture (CoA), Indira Gandhi
Krishi Vishwavidyalaya (IGKV),
Raipur, Chhattisgarh, India

AK Thakur
Principal Scientist, CARS
Jagadapur, Indira Gandhi
Krishi Vishwavidyalaya (IGKV),
Raipur, Chhattisgarh, India

MC Bhambri
Professor, College of Agriculture
(CoA), Indira Gandhi Krishi
Vishwavidyalaya (IGKV),
Raipur, Chhattisgarh, India

TP Chandrakar
Principal Scientist, CARS
Jagadapur, Indira Gandhi
Krishi Vishwavidyalaya (IGKV),
Raipur, Chhattisgarh, India

DP Singh
Professor, College of Agriculture
(CoA), Indira Gandhi Krishi
Vishwavidyalaya (IGKV),
Raipur, Chhattisgarh, India

Krishna
Guest Scientist, Regional
Agricultural Research Station
(RARS), Bilaspur, Indira Gandhi
Krishi Vishwavidyalaya (IGKV),
Raipur, Chhattisgarh, India

Rama Mohan Savu
Senior Scientist, College of
Agriculture (CoA), Indira Gandhi
Krishi Vishwavidyalaya (IGKV),
Raipur, Chhattisgarh, India

Corresponding Author:
Narendra Kumar
Scientist-SG, CARS Jagadapur,
Indira Gandhi Krishi
Vishwavidyalaya (IGKV),
Raipur, Chhattisgarh, India

Effect of crop establishment methods, nutrient levels, and cow urine foliar spray on growth of finger millet (*Eleusine coracana* L. Gaertn.) under organic production system

Narendra Kumar, Sunil Kumar, AK Thakur, MC Bhambri, TP Chandrakar, DP Singh, Krishna and Rama Mohan Savu

DOI: <https://www.doi.org/10.33545/26174693.2026.v10.i7Sq.9238>

Abstract

A field experiment was conducted during the summer seasons of 2021 and 2022 at the Research-cum-Instructional Farm, S.G. College of Agriculture and Research Station, Kumhrawand, Jagdalpur, Chhattisgarh, to evaluate the effect of crop establishment methods, nutrient levels, and foliar spray of cow urine on the growth of finger millet (*Eleusine coracana* L. Gaertn.) under an organic production system. The experiment was laid out in a split-split plot design with three replications. The treatments comprised three crop establishment methods [M_1 : Square transplanting, M_2 : Line transplanting and M_3 : Random transplanting], four nutrient levels [N_1 : 100% Recommended Dose Of Nutrients (RDN), N_2 : 75% RDN, N_3 : 50% RDN and N_4 : Control] and three levels of foliar spray of cow urine [F_1 : 20% cow urine spray, F_2 : 10% cow urine spray and F_3 : No spray]. The results revealed that crop establishment methods and nutrient levels significantly influenced all the growth and physiological parameters of finger millet. Square transplanting (M_1) recorded significantly higher plant height, dry matter accumulation, Leaf Area Index (LAI), Crop Growth Rate (CGR), Relative Growth Rate (RGR), Net Assimilation Rate (NAR), and higher tiller production at the later stages of crop growth, while random transplanting (M_3) consistently recorded the lowest values. Among the nutrient levels, 100% RDN (N_1) significantly enhanced plant height, tiller production, dry matter accumulation, LAI, CGR, RGR, and NAR throughout the crop growth period compared with lower nutrient levels and the control. Foliar application of 20% cow urine (F_1) significantly improved plant height, dry matter accumulation, and leaf area index over the no-spray treatment, although its effect on CGR, RGR, and NAR was generally non-significant. The interaction between square transplanting and 100% RDN ($M_1 \times N_1$) recorded the highest values for plant height, tiller production, dry matter accumulation, and leaf area index, indicating the synergistic effect of optimum crop geometry and adequate nutrient availability. The study concluded that square transplanting combined with 100% recommended dose of nutrients under an organic production system was the most effective treatment for promoting vigorous growth and physiological performance of finger millet under the Bastar Plateau conditions of Chhattisgarh. Foliar application of 20% cow urine may be adopted as a supplementary organic input to enhance vegetative growth and support sustainable finger millet cultivation.

Keywords: Finger millet, organic farming, crop establishment methods, square transplanting, nutrient levels, cow urine, growth, physiological parameters

Introduction

Finger millet (*Eleusine coracana* L. Gaertn.), commonly known as ragi, is one of the most important small millets cultivated in India and several countries of Africa. Owing to its exceptional adaptability to drought, low soil fertility, and rainfed conditions, it is recognized as a climate-resilient crop suitable for marginal and tribal farming systems. In India, finger millet occupies about 1.13 million hectares with an annual production of 1.98 million tonnes and an average productivity of 15.95 q ha⁻¹ (Anonymous, 2024)^[2]. Karnataka is the leading producer, followed by Tamil Nadu, Andhra Pradesh, Odisha, Jharkhand, Uttarakhand, and Chhattisgarh. Although finger millet has traditionally been cultivated in the tribal regions of Chhattisgarh, its productivity remains far below the national average because of poor soil fertility, inadequate nutrient management, and the continued adoption of traditional crop

Establishment practices. The Bastar Plateau of Chhattisgarh possesses favourable agro-climatic conditions for finger millet cultivation; however, the crop is predominantly grown under low-input organic conditions where suboptimal management practices restrict crop growth and overall performance. Finger millet is regarded as a "nutri-cereal" because of its superior nutritional composition compared with major cereals. It is an excellent source of calcium, iron, dietary fibre, phosphorus, potassium, and essential amino acids, particularly methionine, which is deficient in many cereal grains. The grain is gluten-free and possesses a low glycaemic index, making it highly suitable for diabetic patients and individuals suffering from gluten intolerance. These nutritional attributes, coupled with its resilience to adverse climatic conditions, have increased its importance in addressing food and nutritional security, particularly among resource-poor communities.

The growing awareness of environmental degradation, declining soil health, and consumer demand for chemical-free food has accelerated interest in organic farming. Organic agriculture aims to sustain crop production by maintaining ecological balance through the use of renewable biological resources while minimizing dependence on synthetic fertilizers and pesticides. In finger millet cultivation, nutrient management under organic systems largely depends on Farmyard Manure (FYM), compost, green manures, oil cakes, biofertilizers, and other indigenous organic inputs. Nevertheless, efficient utilization of these inputs through appropriate agronomic management is essential to achieve vigorous crop growth and improve soil health under organic production systems. Among various agronomic practices, crop establishment method plays a pivotal role in determining the early growth and subsequent development of finger millet. Proper crop establishment influences plant population, root growth, canopy architecture, light interception, soil moisture utilization, nutrient uptake, and microbial activity in the rhizosphere. Different establishment methods, such as transplanting, line sowing, and direct seeding, create distinct crop environments that influence vegetative growth and resource-use efficiency. Selection of an appropriate establishment method is therefore considered one of the most effective non-monetary interventions for improving crop growth, particularly under organic farming where nutrient availability depends largely on biological processes and soil microbial activity. Nutrient management is another critical component influencing the growth of finger millet under organic cultivation. Organic nutrient sources, especially farmyard manure, improve soil physical, chemical, and biological properties by increasing soil organic carbon, enhancing water-holding capacity, improving soil structure, and stimulating microbial activity. These improvements facilitate gradual nutrient release, promote root proliferation, increase chlorophyll synthesis, and support vigorous vegetative growth. Therefore, optimization of nutrient levels is essential for maximizing the efficiency of organic nutrient sources and ensuring sustainable crop development.

Recently, indigenous organic liquid formulations have received considerable attention as economical and eco-friendly alternatives for enhancing crop growth. Among these, cow urine is widely recognized as a natural bio-enhancer because it contains appreciable quantities of nitrogen, potassium, sulphur, micronutrients, amino acids,

enzymes, hormones, and beneficial microorganisms. Foliar application of cow urine provides readily available nutrients directly to the foliage, stimulates physiological and metabolic activities, enhances chlorophyll formation, improves photosynthetic efficiency, and promotes cell division and vegetative growth. Its low cost, easy availability, and compatibility with organic farming make it an attractive input for sustainable crop production. Although the individual effects of crop establishment methods, organic nutrient management, and cow urine application on crop performance have been reported by several researchers, information on their combined influence under organic production systems is still limited. Furthermore, very little research has been conducted under the agro-ecological conditions of the Bastar Plateau of Chhattisgarh, where finger millet is primarily cultivated by tribal farmers under resource-constrained conditions. Scientific information on the interaction of these management practices is essential for developing integrated organic production strategies that enhance crop growth while maintaining soil health and environmental sustainability.

Materials & Methods

A field experiment was conducted during the summer seasons of 2021 and 2022 at the Research-cum-Instructional Farm, S.G. College of Agriculture and Research Station, Kumhrawand, Jagdalpur, affiliated with Indira Gandhi Krishi Vishwavidyalaya (IGKV), Raipur, Chhattisgarh. The experimental site is located in the Bastar Plateau Agro-climatic Zone (Zone VII) at an altitude of 552 m above mean sea level with a tropical climate and an average annual rainfall of about 1405 mm, most of which is received during June to September. Before sowing, composite soil samples (0-15 cm depth) were collected and analyzed. The experimental soil was slightly acidic (pH 6.3 and 6.2), low in available nitrogen (227.39 and 229.63 kg ha⁻¹), medium in available phosphorus (12.67 and 13.24 kg ha⁻¹), and medium in available potassium (278.56 and 278.71 kg ha⁻¹) during 2021 and 2022, respectively. The experiment was laid out in a split-split plot design with three replications. The main plot treatments comprised three crop establishment methods: M₁ - Square transplanting, M₂ - Line transplanting, and M₃ - Random transplanting. The sub-plot treatments consisted of four nutrient levels: N₁ - 100% recommended dose of nutrients (RDN), N₂ - 75% RDN, N₃ - 50% RDN, and N₄ - Control. The sub-sub plot treatments included three levels of cow urine foliar spray: F₁ - 20% cow urine spray, F₂ - 10% cow urine spray, and F₃ - No foliar spray. The experiment was conducted under an organic production system to evaluate the effects of crop establishment methods, nutrient levels, and foliar application of cow urine on the growth of finger millet. Observations recorded during both years were subjected to statistical analysis, and pooled analysis was performed for interpretation of the results.

Results & discussion

1. Plant population m⁻²

The data presented in Table 1 indicate that plant population of finger millet was significantly influenced by crop establishment methods at both 30 DAT and harvest during 2021, 2022, and in the pooled analysis. Among the establishment methods, M₃ (Random transplanting) recorded significantly higher plant population at harvest

(32.50, 31.56, and 32.03 m⁻² during 2021, 2022, and pooled analysis, respectively), whereas the lowest plant population was observed under M₁ (Square transplanting) during both years and in the pooled analysis. The higher plant population under random transplanting may be attributed to the accommodation of a greater number of plants per unit area, while the wider spacing adopted under square transplanting resulted in comparatively lower plant density. Similar observations were reported by Sarawale *et al.* (2017) [43], who found that crop establishment methods and planting geometry significantly influenced plant stand in finger millet. Nutrient levels and foliar spray of cow urine did not exert a significant effect on plant population at either observation stage. This is likely because plant population is primarily determined by planting geometry and seedling establishment, whereas nutrient application and foliar sprays are imposed after crop establishment. Similar findings were reported by Vanukuri *et al.* (2022) [52]. Overall, the results indicate that crop establishment method was the principal factor governing plant population in finger millet, whereas nutrient levels and foliar application of cow urine had no significant influence.

2. Plant height (cm)

The data presented in Table 2 revealed that plant height of finger millet was significantly influenced by crop establishment methods and nutrient levels at all growth stages during 2021, 2022, and in the pooled analysis. Foliar spray of cow urine significantly affected plant height at 30 DAT, 60 DAT, and harvest, whereas its effect was non-significant at 90 DAT. Among the crop establishment methods, M₁ (Square transplanting) recorded significantly taller plants at all growth stages and remained at par with M₂ (Line transplanting), while the shortest plants were observed under M₃ (Random transplanting) during both years and in the pooled analysis. The superior performance of square transplanting may be attributed to optimum plant spacing, better light interception, improved aeration, and efficient utilization of soil moisture and nutrients, resulting in enhanced vegetative growth. Similar findings were reported by Subbaiah *et al.* (2005), Ravindra *et al.* (2012), Rao *et al.* (2014), Kumar (2018), Singh and Sharma (2018), Chandra (2021), and Rajan (2022) [8, 20, 34, 39, 40, 48]. Nutrient levels also had a significant effect on plant height. N₁ (100% RDN) produced significantly taller plants.

Table 1: Effect of crop establishment methods, level of nutrients and foliar spray of cow urine on plant population of finger millet

Treatment	Plant population (m ⁻²)					
	At 30 DAT			At harvest		
	2021	2022	Mean	2021	2022	Mean
Crop Establishment Methods						
M1-Square transplanting	25.00	25.00	25.00	24.75	24.75	24.75
M2- Line transplanting	31.75	31.44	31.60	29.47	30.83	30.15
M3- Random transplanting	33.42	33.10	33.26	32.50	31.56	32.03
SE(m)±	0.13	0.31	0.12	0.30	0.17	0.16
CD at 5%	0.50	1.23	0.48	1.19	0.66	0.65
Level of nutrients						
N1-100%RDN	29.98	29.96	29.97	29.26	29.04	29.15
N2- 75% RDN	30.15	30.09	30.12	28.94	28.94	28.94
N3- 50% RDN	30.04	29.78	29.91	28.63	29.13	28.88
N4- Control	30.06	29.56	29.81	28.80	29.07	28.94
SE(m)±	0.25	0.23	0.14	0.22	0.28	0.19
CD at 5%	NS	NS	NS	NS	NS	NS
Foliar Spray of Cow Urine						
F1-20% Foliar Spray of Cow Urine	29.93	29.78	29.85	28.96	29.18	29.07
F2-10% Foliar Spray of Cow Urine	29.99	29.74	29.86	28.89	28.90	28.90
F3- No Spray	30.25	30.03	30.14	28.88	29.06	28.97
SE(m)±	0.15	0.24	0.15	0.18	0.23	0.16
CD at 5%	NS	NS	NS	NS	NS	NS

whereas the shortest plants were recorded under N₄ (Control) during both years and in the pooled analysis. The increased plant height under higher nutrient levels may be attributed to balanced nutrient availability and the beneficial effect of FYM in improving soil properties, microbial activity, and nutrient uptake, thereby promoting vigorous vegetative growth. These findings corroborate those of Varalakshmi (2005), Shekara (2010), Harika (2019), and Kumar and Rana (2019) [16, 21, 45, 53]. Foliar application of cow urine significantly increased plant height at 30 DAT, 60 DAT, and harvest. F₁ (20% cow urine spray) recorded the tallest plants and remained at par with F₂ (10% cow urine spray), while F₃ (No spray) recorded the lowest plant height during both years and in the pooled analysis. The improvement in plant height with cow urine application may be attributed to the supply of readily available nutrients, amino acids, and natural growth-promoting substances that enhanced nutrient absorption, photosynthesis, and overall

vegetative growth. The non-significant effect at 90 DAT suggests that the response to foliar nutrition diminished as the crop approached maturity. Similar results were reported by Sharma *et al.* (2019) and Jain *et al.* (2021) [19, 43].

The interaction effect between crop establishment methods and nutrient levels on plant height at 60 and 90 DAT was significant during 2021, 2022, and in the pooled analysis (Table 3). At 60 DAT, the interaction M₁ (Square transplanting) × N₁ (100% RDN) recorded the maximum plant height during both years and in the pooled analysis. However, during 2021, it remained statistically at par with M₂ (Line transplanting) × N₁ (100% RDN) and M₁ (Square transplanting) × N₂ (75% RDN). The lowest plant height was recorded under M₃ (Random transplanting) × N₄ (Control). A similar trend was observed at 90 DAT, where M₁ × N₁ produced significantly taller plants during both years and in the pooled analysis, whereas M₃ × N₄ recorded the minimum plant height. The superior performance of M₁

$\times N_1$ may be attributed to optimum plant spacing combined with adequate nutrient availability, which enhanced light interception, nutrient uptake, root development, and photosynthetic efficiency, resulting in vigorous vegetative growth. These findings are in agreement with those reported by Kumar (2018), Chandra (2021), and Rajan (2022) [8, 20, 34]. The interaction effect between crop establishment methods and nutrient levels on plant height at harvest was significant during 2021, 2022, and in the pooled analysis (Table 3). The interaction M_1 (Square transplanting) $\times N_1$ (100% RDN) recorded significantly taller plants, whereas the lowest plant height was observed under M_3 (Random transplanting) $\times N_4$ (Control) during both years and in the pooled analysis. The superior performance of $M_1 \times N_1$ may be attributed to optimum plant spacing and adequate nutrient availability, which enhanced light interception, nutrient uptake, root growth, and photosynthetic efficiency, thereby sustaining vegetative growth up to harvest. Improved soil conditions and gradual nutrient release from FYM under 100% RDN further promoted cell elongation and plant vigor. These findings are in agreement with the reports of Rao *et al.* (2014), Kumar *et al.* (2017), and Meena *et al.* (2020) [24, 26, 39].

3. Number of tillers m^{-2}

The data presented in Table 4 revealed that the number of tillers of finger millet was significantly influenced by crop establishment methods and nutrient levels at 30, 60, and 90 DAT during 2021, 2022, and in the pooled analysis. The effect of foliar spray of cow urine was variable across the growth stages. Among the crop establishment methods, M_2 (Line transplanting) recorded the highest number of tillers at 30 DAT during both years and in the pooled analysis. However, at 60 and 90 DAT, M_1 (Square transplanting) produced the maximum number of tillers and remained statistically at par with M_2 (Line transplanting), whereas M_3 (Random transplanting) consistently recorded the lowest number of tillers at all growth stages. The higher tiller production under square transplanting at later stages may be attributed to optimum plant spacing, reduced inter-plant competition, and better utilization of light, moisture, and nutrients, which promoted vigorous tiller development. Similar findings were reported by Subbaiah *et al.* (2005), Rao *et al.* (2014), and Ghosh *et al.* (2020) [13, 39, 48]. Nutrient levels significantly influenced tiller production throughout the crop growth period. N_1 (100% RDN) recorded the

highest number of tillers at all observation stages, whereas N_4 (Control) recorded the lowest during both years and in the pooled analysis. The superior performance under 100% RDN may be attributed to balanced nutrient availability through FYM, which improved soil physical properties, microbial activity, root growth, and nutrient uptake, thereby enhancing tiller initiation and survival. These findings are in agreement with Somashekara *et al.* (2015) [47]. Foliar spray of cow urine had a variable effect on tiller production. The effect was non-significant at 30 DAT, indicating that early tillering was not influenced by foliar application. However, F_1 (20% cow urine spray) recorded significantly higher tiller numbers at 60 DAT (during 2022 and pooled analysis) and at 90 DAT (during 2021 and pooled analysis), remaining statistically at par with F_2 (10% cow urine spray). F_3 (No spray) consistently recorded the lowest number of tillers. The beneficial effect of cow urine may be attributed to its readily available nutrients and naturally occurring growth-promoting substances, which enhanced physiological activities and tiller development during the active vegetative stage. Similar observations were reported by Sharma *et al.* (2019) and Jain *et al.* (2021) [19, 43].

The interaction effect between crop establishment methods and nutrient levels on the number of tillers m^{-2} at 60 and 90 DAT was significant during 2021, 2022, and in the pooled analysis (Table 5). At 60 DAT, the interaction M_1 (Square transplanting) $\times N_1$ (100% RDN) recorded the highest number of tillers during both years and in the pooled analysis. It remained statistically at par with M_2 (Line transplanting) $\times N_1$ (100% RDN) during 2021 and M_1 (Square transplanting) $\times N_2$ (75% RDN) during 2022. The lowest number of tillers was recorded under M_3 (Random transplanting) $\times N_4$ (Control). A similar trend was observed at 90 DAT, where $M_1 \times N_1$ produced the maximum number of tillers during both years and in the pooled analysis. It remained at par with $M_2 \times N_1$ and $M_1 \times N_2$ during 2022, while the minimum number of tillers was recorded under $M_3 \times N_4$. The superior performance of $M_1 \times N_1$ may be attributed to optimum crop geometry combined with adequate nutrient availability, which enhanced light interception, nutrient uptake, root growth, and photosynthetic efficiency, resulting in greater tiller production. These findings are in agreement with those of Kumar (2018), Narayan (2018), Harika (2019), and Kumar (2022) [16, 20, 22, 27].

Table 2: Effect of crop establishment methods, level of nutrients and foliar spray of cow urine on plant height of finger millet at different growth stages

Treatment	Plant height (cm)											
	At 30 DAT			At 60 DAT			At 90 DAT			At harvest		
	2021	2022	Mean	2021	2022	Mean	2021	2022	Mean	2021	2022	Mean
Crop Establishment Methods												
M1	27.25	27.71	27.48	59.10	60.38	59.74	76.16	78.87	77.52	77.93	79.85	78.89
M2	26.89	26.85	26.87	56.08	57.58	56.83	72.98	74.17	73.57	74.80	76.22	75.51
M3	25.61	25.95	25.78	53.97	55.37	54.67	67.31	71.32	69.32	68.45	73.32	70.88
SE(m)±	0.35	0.35	0.37	0.85	0.75	0.80	0.86	1.24	1.04	0.83	1.20	0.98
CD at 5%	1.37	1.37	1.44	3.34	2.93	3.13	3.38	4.88	4.08	3.26	4.69	3.85
Level of nutrients												
N1	31.72	31.98	31.85	67.30	69.04	68.17	86.12	87.63	86.88	88.12	89.93	89.02
N2	29.80	29.55	29.68	62.29	63.66	62.98	77.03	80.34	78.68	79.56	82.01	80.79
N3	25.13	25.64	25.39	55.23	56.60	55.91	68.82	73.06	70.94	69.93	74.47	72.20
N4	19.68	20.17	19.93	40.70	41.80	41.25	56.63	58.13	57.38	57.30	59.45	58.37
SE(m)±	0.36	0.58	0.38	0.61	0.64	0.66	0.91	0.85	0.84	0.97	0.81	0.87
CD at 5%	1.08	1.72	1.12	1.82	1.90	1.95	2.71	2.52	2.48	2.89	2.40	2.58

Foliar Spray of Cow Urine												
F1	27.36	27.74	27.55	57.43	58.85	58.14	73.69	76.28	74.99	75.60	77.86	76.73
F2	26.89	27.23	27.06	56.53	58.01	57.27	72.26	74.63	73.45	73.73	76.29	75.01
F3	25.50	25.54	25.52	55.18	56.46	55.82	70.50	73.46	71.98	71.86	75.24	73.55
SE(m)±	0.43	0.57	0.46	0.70	0.71	0.69	1.14	0.74	0.87	1.22	0.73	0.91
CD at 5%	1.22	1.61	1.31	1.98	2.02	1.97	NS	2.11	2.47	3.48	2.07	2.58

Treatment detail - M1-Squar transplanting, M2- Line transplanting, M3-Random transplanting, N1-100% RDN, N2-75% RDN, N3- 50% RDN, N4-Control, F1-20% Foliar Spray of Cow Urine, F2-10% Foliar Spray of Cow Urine, F3- No Spray

Table 3: Interaction effect between crop establishment methods × level of nutrients on plant height

Treatments	Plant Height (cm)											
	At 60 DAT				At 90 DAT				at harvest			
	N1:100% RDN	N2:75% RDN	N3:50% RDN	N4: Control	N1:100% RDN	N2:75% RDN	N3:50% RDN	N4: Control	N1:100% RDN	N2:75% RDN	N3:50% RDN	N4: Control
2021												
M1-Squar transplanting	70.43	67.47	56.86	41.64	93.75	80.41	70.98	59.51	94.95	85.30	71.99	59.50
M2- Line transplanting	67.56	61.59	54.81	40.34	86.74	77.66	71.29	56.22	90.00	79.37	72.63	57.22
M3- Random transplanting	63.92	57.81	54.03	40.12	77.88	73.02	64.18	54.17	79.41	74.02	65.18	55.17
SE(m)±	1.06				1.58				1.68			
CD at 5%	3.15				4.59				5.00			
2022												
M1-Squar transplanting	72.54	68.47	57.86	42.64	94.17	86.02	75.04	60.26	96.86	87.03	75.27	60.23
M2- Line transplanting	69.06	63.09	56.31	41.84	86.56	78.26	73.78	58.08	88.76	80.26	75.78	60.08
M3- Random transplanting	65.52	59.41	55.63	40.92	82.16	76.74	70.35	56.04	84.16	78.74	72.35	58.04
SE(m)±	1.11				1.27				1.40			
CD at 5%	3.29				3.79				4.15			
Mean												
M1-Squar transplanting	71.48	67.97	57.36	42.14	93.96	83.22	73.01	59.88	95.90	86.17	73.63	59.87
M2- Line transplanting	68.31	62.34	55.56	41.09	86.65	77.96	72.54	57.15	89.38	79.81	74.20	58.65
M3- Random transplanting	64.72	58.61	54.83	40.52	80.02	74.88	67.27	55.11	81.79	76.38	68.77	56.61
SE(m)±	1.04				1.34				1.50			
CD at 5%	3.10				3.99				4.46			

Table 4: Effect of crop establishment methods, level of nutrients and foliar spray of cow urine on number of tillers at different growth stages

Treatment	Number of tillers m ⁻²								
	At 30 DAT			At 60 DAT			At 90 DAT		
	2021	2022	Mean	2021	2022	Mean	2021	2022	Mean
Crop Establishment Methods									
M1-Squar transplanting	61.03	55.43	58.03	85.02	87.29	86.15	98.46	104.76	101.61
M2- Line transplanting	69.08	67.08	68.08	78.04	79.76	78.90	96.48	100.26	98.37
M3- Random transplanting	59.58	57.81	58.70	66.29	66.53	66.41	78.41	81.94	80.17
SE(m)±	1.32	1.54	1.27	1.78	1.70	1.45	1.58	1.12	1.17
CD at 5%	5.18	6.03	5.00	7.00	7.67	7.83	6.19	4.39	4.58
Level of nutrients									
N1-100%RDN	78.89	74.08	76.48	92.52	96.80	94.66	114.33	120.51	117.42
N2- 75% RDN	67.21	63.06	65.14	85.62	83.97	84.79	102.30	106.72	104.51
N3- 50% RDN	58.85	57.49	58.17	69.35	75.34	72.34	89.51	94.51	92.01
N4- Control	47.97	45.79	46.88	57.44	54.01	55.72	58.34	60.88	59.61
SE(m)±	1.62	1.49	1.23	1.43	1.81	1.27	2.00	1.77	1.67
CD at 5%	4.81	4.42	3.66	4.25	5.38	3.78	5.95	5.27	4.95
Foliar Spray of Cow Urine									
F1-20% Foliar Spray of Cow Urine	64.63	61.27	62.95	78.34	80.41	79.37	95.20	98.76	96.98
F2-10% Foliar Spray of Cow Urine	63.20	59.97	61.58	75.97	77.21	76.59	90.78	95.21	92.99
F3- No Spray	61.86	59.08	60.47	74.38	74.97	74.68	87.38	92.99	90.19
SE(m)±	1.46	0.99	0.88	1.37	1.32	0.79	1.76	1.99	1.58
CD at 5%	NS	NS	NS	NS	3.74	2.23	4.99	NS	4.48

Table 5: Interaction effect between crop establishment methods × level of nutrients on number of tillers

Treatments	At 60 DAT				At 90 DAT			
	N1:100% RDN	N2:75% RDN	N3:50% RDN	N4: Control	N1:100% RDN	N2:75% RDN	N3:50% RDN	N4: Control
	2021				2021			
M1-Squar transplanting	103.62	95.13	76.90	64.43	131.18	110.35	95.08	57.25
M2- Line transplanting	97.51	91.35	66.55	54.12	117.10	110.62	95.02	63.18
M3- Random transplanting	76.43	70.37	64.59	53.77	94.71	85.91	78.43	54.59
SE(m)±	2.48				3.47			
CD at 5%	7.37				10.30			
	2022				2022			
M1-Squar transplanting	108.20	100.00	91.97	48.97	132.40	123.56	108.80	54.27
M2- Line transplanting	98.79	81.26	75.83	59.17	128.70	107.63	93.47	71.24
M3- Random transplanting	83.41	70.64	58.21	53.88	100.43	88.96	81.24	57.12
SE(m)±	3.13				3.07			
CD at 5%	9.31				9.13			
	Mean				Mean			
M1-Squar transplanting	105.91	97.56	84.44	56.70	131.79	116.96	101.94	55.76
M2- Line transplanting	98.15	86.31	71.19	56.64	122.90	109.12	94.25	67.21
M3- Random transplanting	79.92	70.50	61.40	53.82	97.57	87.44	79.84	55.85
SE(m)±	2.20				2.89			
CD at 5%	6.55				8.58			

4. Dry matter accumulation (g plant⁻¹)

The data presented in Table 6 revealed that dry matter accumulation of finger millet was significantly influenced by crop establishment methods, nutrient levels, and foliar spray of cow urine at all growth stages during 2021, 2022, and in the pooled analysis. Among the crop establishment methods, M₁ (Square transplanting) recorded significantly the highest dry matter accumulation at all growth stages. It remained statistically at par with M₂ (Line transplanting) at 30 DAT during both years and in the pooled analysis, and at 60 DAT and harvest during 2022. The lowest dry matter accumulation was recorded under M₃ (Random transplanting). The higher dry matter accumulation under square transplanting may be attributed to optimum crop geometry, better light interception, and efficient utilization of soil moisture and nutrients, resulting in enhanced photosynthesis and biomass production. Similar findings were reported by Kumar (2018), Chandra (2021), and Kumar (2022) [8, 20, 22]. Nutrient levels significantly affected dry matter accumulation throughout the crop growth period. N₁ (100% RDN) recorded the highest dry matter accumulation at all growth stages, whereas N₄ (Control) recorded the lowest during both years and in the pooled analysis. The increased dry matter accumulation under 100% RDN may be attributed to improved nutrient availability through FYM, which enhanced vegetative growth, leaf area development, and photosynthetic efficiency. These results are in agreement with Varalakshmi (2005), Shekara (2010), Harika (2019), and Kumar and Rana (2019) [16, 21, 45, 53]. Foliar application of cow urine also significantly increased dry matter accumulation at all growth stages. F₁ (20% cow urine spray) recorded the highest dry matter accumulation and remained statistically at par with F₂ (10% cow urine spray) at harvest during both years, at 30 DAT and 90 DAT during 2021 and in the pooled analysis, and at 60 DAT during 2022. The lowest dry matter accumulation was observed under F₃ (No spray) during both years and in the pooled analysis. The improvement in dry matter accumulation with 20% cow urine spray may be attributed to the supply of readily available nutrients and natural growth-promoting substances, which enhanced photosynthetic activity and biomass production. Similar results have been reported by

Devakumar *et al.* (2014), Panse *et al.* (2017), and Sutar *et al.* (2008) [11, 30, 49].

The interaction effect between crop establishment methods and nutrient levels on dry matter accumulation was non-significant at 60 DAT during 2021, but significant during 2022 and in the pooled analysis. At 90 DAT, the interaction effect was significant during both years and in the pooled analysis (Table 7). At 60 DAT, the interaction M₁ (Square transplanting) × N₁ (100% RDN) recorded the highest dry matter accumulation during 2022 and in the pooled analysis, whereas the lowest dry matter accumulation was observed under M₃ (Random transplanting) × N₄ (Control). A similar trend was observed at 90 DAT, where M₁ × N₁ recorded significantly the highest dry matter accumulation during 2021, 2022, and in the pooled analysis, while M₃ × N₄ produced the lowest dry matter accumulation. The superior performance of M₁ × N₁ may be attributed to the combined effect of optimum crop geometry and adequate nutrient availability, which enhanced light interception, nutrient uptake, photosynthetic efficiency, and biomass accumulation. Similar findings were reported by Varalakshmi (2005), Somashekara (2015), Kumar (2018), Chandra (2021), and Rajan (2022) [6, 20, 34, 47, 53].

The interaction effect between crop establishment methods and nutrient levels on dry matter accumulation at harvest was significant during 2021, 2022, and in the pooled analysis (Table 7). The interaction M₁ (Square transplanting) × N₁ (100% RDN) recorded significantly the highest dry matter accumulation during both years and in the pooled analysis, whereas the lowest dry matter accumulation was observed under M₃ (Random transplanting) × N₄ (Control). The superior performance of M₁ × N₁ may be attributed to the combined effect of optimum crop geometry and adequate nutrient availability, which enhanced light interception, nutrient uptake, photosynthetic efficiency, and biomass accumulation. Uniform spacing under square transplanting, together with balanced nutrient supply through 100% RDN, ensured efficient utilization of soil moisture and nutrients, resulting in greater dry matter production up to harvest. These findings are in agreement with Varalakshmi (2005), Kumar (2018), Chandra (2021), and Rajan (2022) [8, 20, 22, 34, 53].

Table 6: Effect of crop establishment methods, level of nutrients and foliar spray of cow urine on dry matter accumulation at different growth stage

Treatment	Dry matter accumulation (g plant ⁻¹)											
	At 30 DAT			At 60 DAT			At 90 DAT			At harvest		
	2021	2022	Mean	2021	2022	Mean	2021	2022	Mean	2021	2022	Mean
Crop Establishment Methods												
M1	3.42	4.29	3.86	8.22	9.18	8.70	14.36	16.12	15.24	16.14	17.98	17.06
M2	3.29	4.09	3.69	7.62	8.73	8.18	13.46	14.89	14.17	14.70	16.83	15.77
M3	3.17	3.84	3.50	7.20	8.16	7.68	11.35	13.89	12.62	12.26	15.29	13.77
SE(m)±	0.04	0.07	0.04	0.13	0.12	0.08	0.14	0.14	0.11	0.16	0.30	0.21
CD at 5%	0.14	0.26	0.17	0.49	0.46	0.33	0.54	0.56	0.45	0.62	1.18	0.81
Level of nutrients												
N1	4.04	5.18	4.61	10.43	11.78	11.11	18.41	20.09	19.25	20.71	23.20	21.96
N2	3.58	4.65	4.11	8.89	9.90	9.40	15.36	17.48	16.42	16.81	19.70	18.25
N3	3.35	4.24	3.80	7.67	9.07	8.37	12.50	15.46	13.98	13.51	17.38	15.45
N4	2.17	2.20	2.19	3.73	4.15	3.94	5.95	6.83	6.39	6.43	7.50	6.96
SE(m)±	0.05	0.04	0.04	0.15	0.11	0.10	0.17	0.25	0.13	0.22	0.29	0.13
CD at 5%	0.16	0.12	0.11	0.45	0.34	0.29	0.49	0.74	0.38	0.66	0.85	0.40
Foliar Spray of Cow Urine												
F1	3.41	4.20	3.80	8.05	8.96	8.50	13.49	15.44	14.46	14.73	17.54	16.14
F2	3.29	4.06	3.68	7.70	8.69	8.19	13.00	15.03	14.02	14.36	16.99	15.67
F3	3.16	3.95	3.55	7.30	8.53	7.92	12.68	14.43	13.56	14.01	16.30	15.15
SE(m)±	0.05	0.05	0.04	0.11	0.11	0.08	0.17	0.26	0.15	0.19	0.28	0.17
CD at 5%	0.14	0.13	0.12	0.32	0.31	0.23	0.49	0.74	0.43	0.54	0.79	0.48

Treatment detail - M1-Square transplanting, M2- Line transplanting, M3-Random transplanting, N1-100% RDN, N2-75% RDN, N3- 50% RDN, N4- Control, F1-20% Foliar Spray of Cow Urine, F2-10% Foliar Spray of Cow Urine, F3- No Spray

Table 7: Interaction effect between crop establishment methods × level of nutrients on dry matter accumulation

Treatments	Dry matter accumulation (g plant ⁻¹)											
	At 60 DAT				At 90 DAT				At harvest			
	N1:100% RDN	N2:75% RDN	N3:50% RDN	N4: Control	N1:100% RDN	N2:75% RDN	N3:50% RDN	N4: Control	N1:100% RDN	N2:75% RDN	N3:50% RDN	N4: Control
2021												
M1-Square transplanting	11.51	9.36	8.13	3.88	19.90	17.03	14.42	6.11	23.20	19.14	15.58	6.63
M2- Line transplanting	10.38	8.83	7.56	3.73	18.53	16.14	13.24	5.93	21.21	17.17	14.01	6.42
M3- Random transplanting	9.40	8.50	7.32	3.58	16.80	12.90	9.85	5.83	17.74	14.12	10.95	6.24
SEm±	0.26				0.29				0.38			
CD at 5%	NS				0.85				1.14			
2022												
M1-Square transplanting	12.34	10.36	10.06	4.36	22.22	19.01	16.17	7.09	26.34	22.16	18.41	7.95
M2- Line transplanting	11.65	9.75	9.38	4.14	19.60	17.27	15.80	6.89	22.24	19.77	17.74	7.59
M3- Random transplanting	11.36	9.59	7.77	3.94	18.46	16.16	14.42	6.52	21.04	17.16	15.99	6.96
SEm±	0.21				0.43				0.50			
CD at 5%	0.62				1.28				1.47			
Mean												
M1-Square transplanting	11.93	9.86	9.10	4.12	21.06	18.02	15.29	6.60	24.77	20.65	17.00	7.29
M2- Line transplanting	11.02	9.29	8.47	3.93	19.06	16.71	14.52	6.41	21.72	18.47	15.87	7.00
M3- Random transplanting	10.38	9.04	7.54	3.76	17.63	14.53	12.14	6.17	19.39	15.64	13.47	6.60
SEm±	0.18				0.22				0.23			
CD at 5%	0.53				0.65				0.69			

5. Leaf area index (LAI)

The data presented in Table 8 revealed that the leaf area index (LAI) increased progressively from 30 to 90 DAT and declined at harvest due to leaf senescence. Crop establishment methods and nutrient levels significantly influenced LAI at all growth stages during 2021, 2022, and in the pooled analysis. Foliar spray of cow urine had no significant effect at 30 DAT but significantly influenced LAI from 60 DAT to harvest. Among the crop establishment methods, M₁ (Square transplanting) recorded significantly the highest LAI at all growth stages and remained statistically at par with M₂ (Line transplanting) at 30 DAT,

whereas M₃ (Random transplanting) recorded the lowest LAI during both years and in the pooled analysis. The higher LAI under square transplanting may be attributed to optimum crop geometry, better light interception, improved aeration, and efficient utilization of soil moisture and nutrients, which promoted greater leaf expansion and canopy development. Similar findings were reported by Kumar (2018), Chandra (2021), and Kumar (2022) [8, 20, 22]. Nutrient levels also exerted a significant effect on LAI. N₁ (100% RDN) recorded the highest LAI throughout the crop growth period, whereas N₄ (Control) recorded the lowest during both years and in the pooled analysis. The increased

LAI under 100% RDN may be attributed to balanced nutrient availability, particularly nitrogen, which enhanced chlorophyll synthesis, cell division, and leaf expansion, resulting in vigorous vegetative growth. These findings are in agreement with Varalakshmi (2005), Shekara (2010), Harika (2019), and Kumar and Rana (2019) [16, 21, 45, 53s]. Foliar application of cow urine had no significant effect on LAI at 30 DAT; however, its effect became significant from 60 DAT to harvest. F₁ (20% cow urine spray) recorded the highest LAI during both years and in the pooled analysis and remained statistically at par with F₂ (10% cow urine spray) at 60 DAT. The lowest LAI was recorded under F₃ (No spray). The improvement in LAI with 20% cow urine spray may be attributed to the supply of readily available nutrients and natural growth-promoting substances, which enhanced nutrient uptake, leaf expansion, and photosynthetic efficiency, leading to greater canopy development. Similar observations were reported by Sutar (2008), Devakumar (2014), and Panse (2017) [11, 30, 49].

The interaction effect between crop establishment methods and nutrient levels on leaf area index (LAI) was significant at 60 and 90 DAT during 2021, 2022, and in the pooled analysis (Table 9). At 60 DAT, the interaction M₁ (Square transplanting) × N₁ (100% RDN) recorded significantly the highest LAI, whereas the lowest LAI was observed under M₃ (Random transplanting) × N₄ (Control). A similar trend was observed at 90 DAT, where M₁ × N₁ produced the highest LAI during both years and in the pooled analysis, while M₃ × N₄ recorded the lowest LAI. The superior

performance of M₁ × N₁ may be attributed to the combined effect of optimum crop geometry and adequate nutrient availability, which enhanced light interception, nutrient uptake, leaf expansion, chlorophyll synthesis, and canopy development, resulting in a higher leaf area index. In contrast, poor crop geometry and nutrient deficiency under M₃ × N₄ restricted canopy development and leaf expansion. These findings are in agreement with Varalakshmi (2005), Thilakarathna and Raizada (2015), Kumar (2018), Rao (2019), Chandra (2021), and Kumar (2022) [8, 20, 22, 38, 50, 53].

The interaction effect between crop establishment methods and nutrient levels on leaf area index (LAI) at harvest was significant during 2021, 2022, and in the pooled analysis (Table 9). The interaction M₁ (Square transplanting) × N₁ (100% RDN) recorded significantly the highest LAI during both years and in the pooled analysis, whereas the lowest LAI was observed under M₃ (Random transplanting) × N₄ (Control). The superior performance of M₁ × N₁ may be attributed to the combined effect of optimum crop geometry and adequate nutrient availability, which enhanced light interception, nutrient uptake, chlorophyll synthesis, leaf expansion, and canopy development, resulting in a larger photosynthetic surface area. In contrast, the lowest LAI under M₃ × N₄ may be due to irregular crop geometry and inadequate nutrient availability, which restricted leaf growth and canopy expansion. Similar findings were reported by Varalakshmi (2005), Kumar (2018), Narayan (2018), Aliveni (2021), Ashoka (2021), Chandra (2021), and Rajan (2022) [1, 4, 8, 20, 27, 34, 53].

Table 8: Effect of crop establishment methods, level of nutrients and foliar spray cow urine on Leaf Area Index (LAI) at different observation period

Treatment	Leaf area index (LAI)											
	30 DAT			60 DAT			90 DAT			At harvest		
	2021	2022	Mean	2021	2022	Mean	2021	2022	Mean	2021	2022	Mean
Crop Establishment Methods												
M1	0.52	0.57	0.55	0.99	1.08	1.03	1.88	1.98	1.93	1.36	1.42	1.39
M2	0.51	0.56	0.54	0.90	0.97	0.94	1.50	1.54	1.52	1.12	1.18	1.15
M3	0.49	0.52	0.50	0.76	0.86	0.81	1.28	1.35	1.32	1.02	1.06	1.04
SE(m)±	0.00	0.01	0.01	0.02	0.02	0.01	0.02	0.03	0.02	0.03	0.01	0.02
CD at 5%	0.02	0.05	0.03	0.07	0.08	0.04	0.09	0.12	0.09	0.11	0.04	0.06
Level of nutrients												
N1	0.78	0.81	0.79	1.37	1.38	1.38	2.39	2.45	2.42	2.10	2.18	2.14
N2	0.64	0.73	0.68	1.11	1.25	1.18	1.86	1.96	1.91	1.42	1.46	1.44
N3	0.46	0.51	0.48	0.72	0.88	0.80	1.29	1.34	1.31	0.77	0.81	0.79
N4	0.16	0.16	0.16	0.33	0.36	0.35	0.68	0.74	0.71	0.38	0.42	0.40
SE(m)±	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.03	0.02	0.02	0.03	0.02
CD at 5%	0.02	0.03	0.02	0.04	0.04	0.03	0.08	0.08	0.05	0.07	0.08	0.05
Foliar Spray of Cow Urine												
F1	0.52	0.56	0.54	0.92	1.01	0.96	1.66	1.71	1.68	1.25	1.30	1.28
F2	0.51	0.55	0.53	0.88	0.96	0.92	1.56	1.62	1.59	1.16	1.21	1.18
F3	0.50	0.54	0.52	0.85	0.93	0.89	1.44	1.55	1.50	1.09	1.15	1.12
SE(m)±	0.01	0.01	0.01	0.01	0.02	0.01	0.02	0.03	0.02	0.02	0.03	0.02
CD at 5%	NS	NS	NS	0.04	0.05	0.03	0.06	0.08	0.05	0.07	0.08	0.06

Treatment detail - M1-Square transplanting, M2- Line transplanting, M3-Random transplanting, N1-100% RDN, N2-75% RDN, N3- 50% RDN, N4- Control, F1-20% Foliar Spray of Cow Urine, F2-10% Foliar Spray of Cow Urine, F3- No Spray

Table 9: Interaction effect between crop establishment methods × level of nutrients on leaf area index

Treatments	Leaf Area Index (LAI)											
	At 60 DAT				At 90 DAT				At harvest			
	N1:100%RDN	N2:75%RDN	N3:50%RDN	N4:Control	N1:100%RDN	N2:75%RDN	N3:50%RDN	N4:Control	N1:100%RDN	N2:75%RDN	N3:50%RDN	N4:Control
	2021				2021							
M1-Squar transplanting	1.48	1.27	0.84	0.36	2.57	2.32	1.83	0.78	2.38	1.69	1.00	0.48
M2- Line transplanting	1.40	1.20	0.67	0.35	2.34	1.75	1.21	0.72	2.02	1.29	0.72	0.44
M3- Random transplanting	1.24	0.85	0.64	0.28	2.25	1.51	0.82	0.54	1.90	1.28	0.58	0.32
SE(m)±	0.02				0.04				0.04			
CD at 5%	0.07				0.13				0.14			
	2022				2022							
M1-Squar transplanting	1.48	1.35	1.06	0.42	2.64	2.45	1.98	0.83	2.40	1.74	1.08	0.47
M2- Line transplanting	1.35	1.20	0.95	0.37	2.37	1.83	1.17	0.79	2.15	1.34	0.76	0.46
M3- Random transplanting	1.32	1.22	0.63	0.30	2.36	1.60	0.87	0.59	1.98	1.31	0.59	0.34
SE(m)±	0.02				0.05				0.05			
CD at 5%	0.06				0.15				0.14			
	Mean				Mean							
M1 Squar transplanting	1.48	1.31	0.95	0.39	2.60	2.39	1.91	0.81	2.39	1.71	1.04	0.47
M2 Line transplanting	1.37	1.20	0.81	0.36	2.35	1.79	1.19	0.76	2.09	1.32	0.74	0.45
M3 Random transplanting	1.28	1.04	0.63	0.29	2.31	1.55	0.85	0.56	1.94	1.29	0.59	0.33
SE(m)±	0.02				0.03				0.03			
CD at 5%	0.06				0.09				0.09			

6. Crop growth rate (CGR)

The data presented in Fig. 1-3 revealed that crop growth rate (CGR) of finger millet was significantly influenced by crop establishment methods and nutrient levels during all growth periods (30-60, 60-90 DAT, and 90 DAT to harvest) in 2021, 2022, and the pooled analysis. Foliar spray of cow urine did not significantly affect CGR at any growth stage. Among the crop establishment methods, M₁ (Square transplanting) recorded significantly the highest CGR during all growth periods. It remained statistically at par with M₂ (Line transplanting) during 2022 at 60-90 DAT and 90 DAT to harvest, whereas the lowest CGR was recorded under M₃ (Random transplanting). The higher CGR under square transplanting may be attributed to optimum crop geometry, better light interception, and efficient utilization of soil moisture and nutrients, resulting in greater biomass accumulation. Similar findings were reported by Narayan (2018), Aliveni (2021), and Rajan Kumar (2022) ^[1, 22, 27, 34]. Nutrient levels significantly influenced CGR throughout the crop growth period. N₁ (100% RDN) recorded the highest CGR during all growth stages, while N₄ (Control) recorded the lowest during both years and in the pooled analysis. At 60-90 DAT, N₂ (75% RDN) remained statistically at par with N₁ (100% RDN) during 2022. The higher CGR under 100% RDN may be attributed to balanced nutrient availability, which enhanced nutrient uptake, chlorophyll synthesis, photosynthetic efficiency, and dry matter accumulation. These findings are in agreement with Varalakshmi (2005), Shekara (2010), and Harika (2019) ^[16, 45, 53]. Foliar application of cow urine had no significant effect on crop growth rate during any growth period. However, F₁ (20% cow urine spray) recorded numerically higher CGR than F₂ (10% cow urine spray) and F₃ (No spray) throughout the crop growth period. The numerical improvement may be attributed to the supplementary supply of nutrients and natural growth-promoting substances through cow urine, which enhanced metabolic activity.

Similar observations were reported by Somashekara (2015) and Gottimukkala (2019) ^[15, 47].

7. Relative growth rate (RGR)

The data presented in Fig. 4-6 revealed that relative growth rate (RGR) of finger millet was significantly influenced by nutrient levels, whereas the effect of crop establishment methods was significant only during the later growth stages. Foliar spray of cow urine did not significantly influence RGR during any of the growth periods. Among the crop establishment methods, differences in RGR during 30-60 DAT were non-significant. However, during 60-90 DAT, M₁ (Square transplanting) and M₂ (Line transplanting) recorded significantly higher RGR than M₃ (Random transplanting) during both years and in the pooled analysis. During 90 DAT to harvest, M₁ (Square transplanting) recorded the highest RGR during 2021 and in the pooled analysis and remained statistically at par with M₂ (Line transplanting), whereas M₃ (Random transplanting) recorded the lowest RGR. The higher RGR under square transplanting may be attributed to optimum crop geometry, better utilization of light, moisture, and nutrients, which promoted efficient biomass production. Similar findings were reported by Narayan (2018), Aliveni (2021), and Rajan Kumar (2022) ^[1, 22, 27, 34]. Nutrient levels significantly influenced RGR throughout the crop growth period. N₁ (100% RDN) recorded the highest RGR at all growth stages, while N₄ (Control) recorded the lowest during both years and in the pooled analysis. At 30-60 DAT, N₁ remained statistically at par with N₂ (75% RDN) during 2021. At 60-90 DAT, N₁ and N₂ recorded statistically similar and significantly higher RGR during both years and in the pooled analysis. During 90 DAT to harvest, N₁ remained at par with N₂ during both years and with N₃ (50% RDN) during 2022. The higher RGR under 100% RDN may be attributed to balanced nutrient availability, which enhanced chlorophyll synthesis, photosynthetic efficiency, and biomass accumulation. These findings are in agreement with

Varalakshmi (2005), Shekara (2010), and Harika (2019) [16, 45, 53]. Foliar application of cow urine did not significantly influence RGR during any of the growth periods. Although F₁ (20% cow urine spray) recorded numerically higher RGR than the other treatments, the differences were statistically

non-significant. This suggests that foliar application of cow urine had only a limited influence on relative biomass accumulation compared with crop establishment methods and nutrient levels. Similar observations were reported by Somashekara (2015) [47].

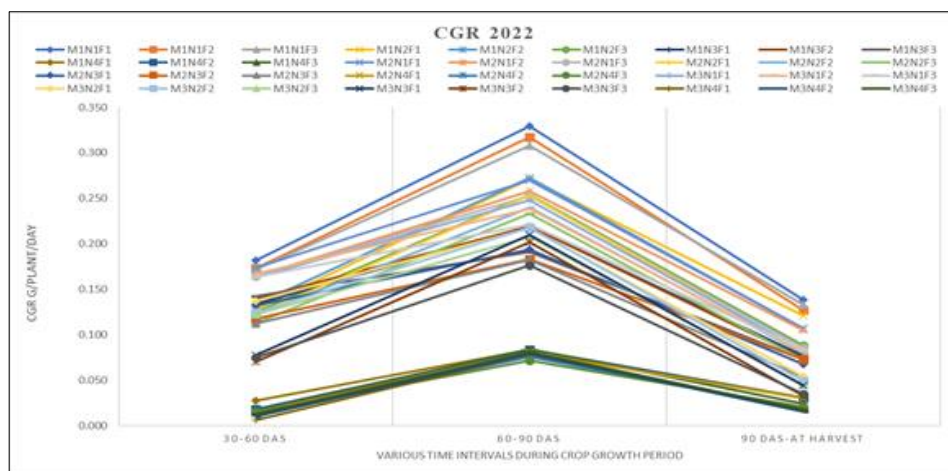


Fig 1: Effect of crop establishment methods, level of nutrients and foliar spray of cow urine, on crop growth rate (CGR) as influence different growth stages during year 2021

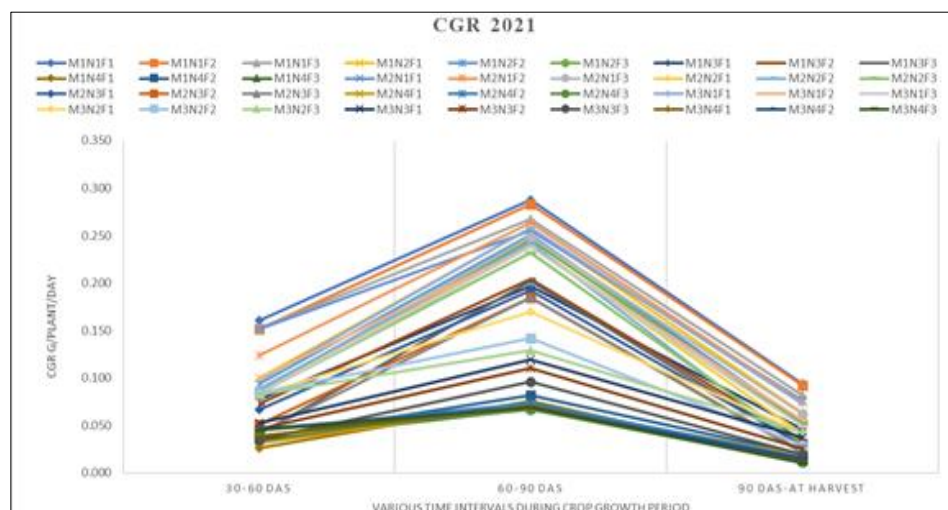


Fig 2: Effect of crop establishment methods, level of nutrients and foliar spray of cow urine, on crop growth rate (CGR) as influence different growth stages during year 2022

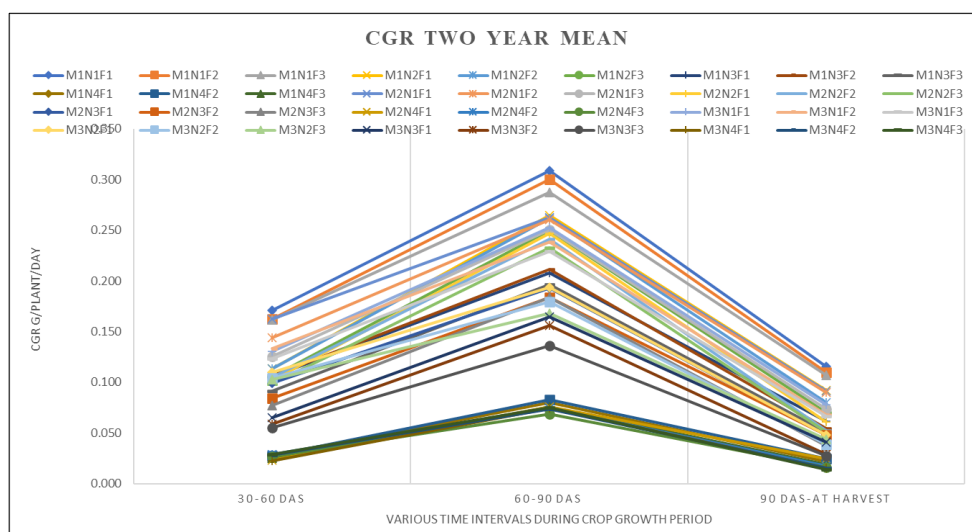


Fig 3: Effect of crop establishment methods, level of nutrients and foliar spray of cow urine, on crop growth rate (CGR) as influence different growth stages during two year mean

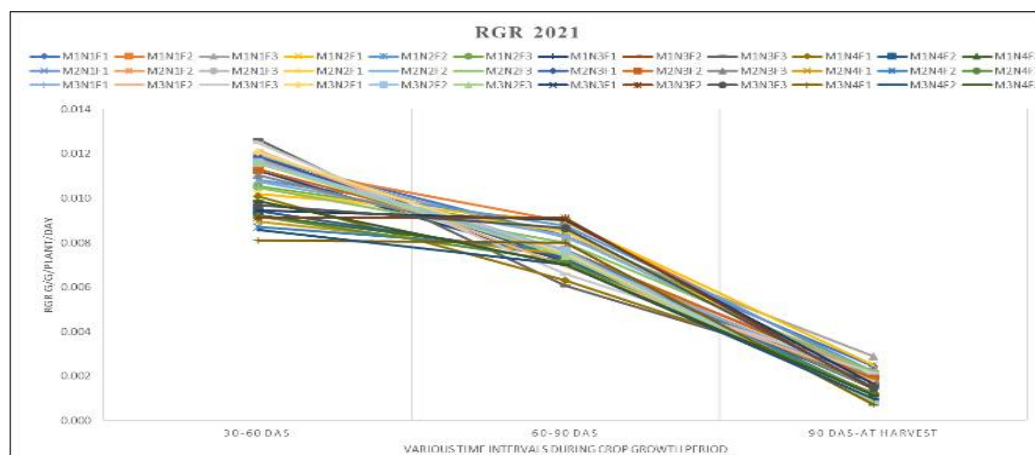


Fig 4: Effect of crop establishment methods, level of nutrients and foliar spray of cow urine on relative growth rate (RGR) as influence different growth stages during year 2021

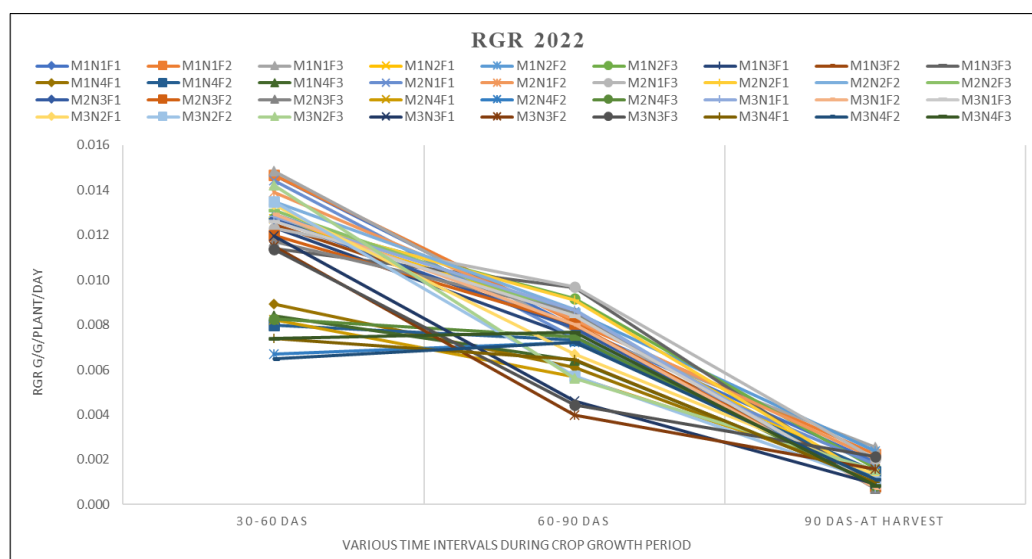


Fig 5: Effect of crop establishment methods, level of nutrients and foliar spray of cow urine on relative growth rate (RGR) as influence different growth stages during year 2022

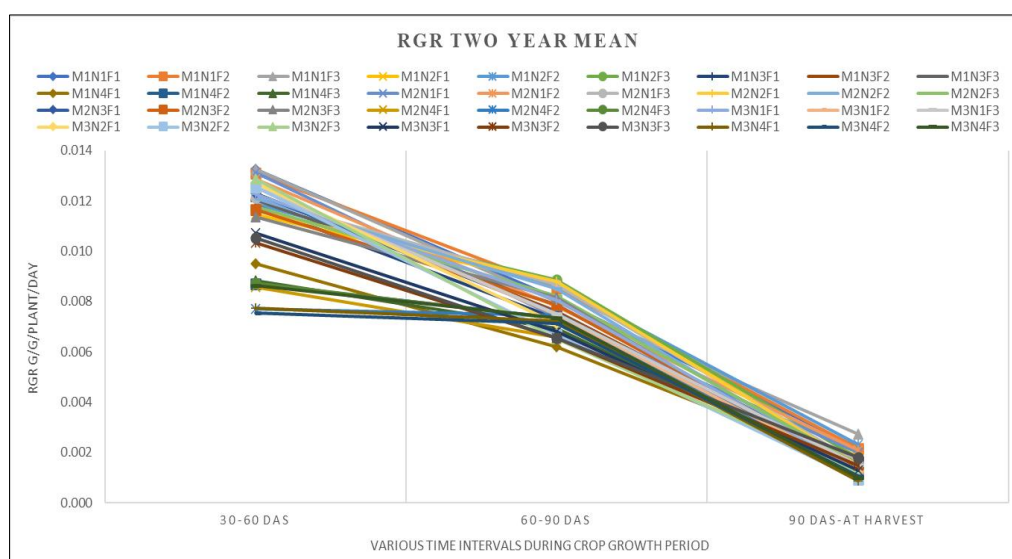


Fig 6: Effect of crop establishment methods, level of nutrients and foliar spray of cow urine on relative growth rate (RGR) as influence different growth stages during two year mean

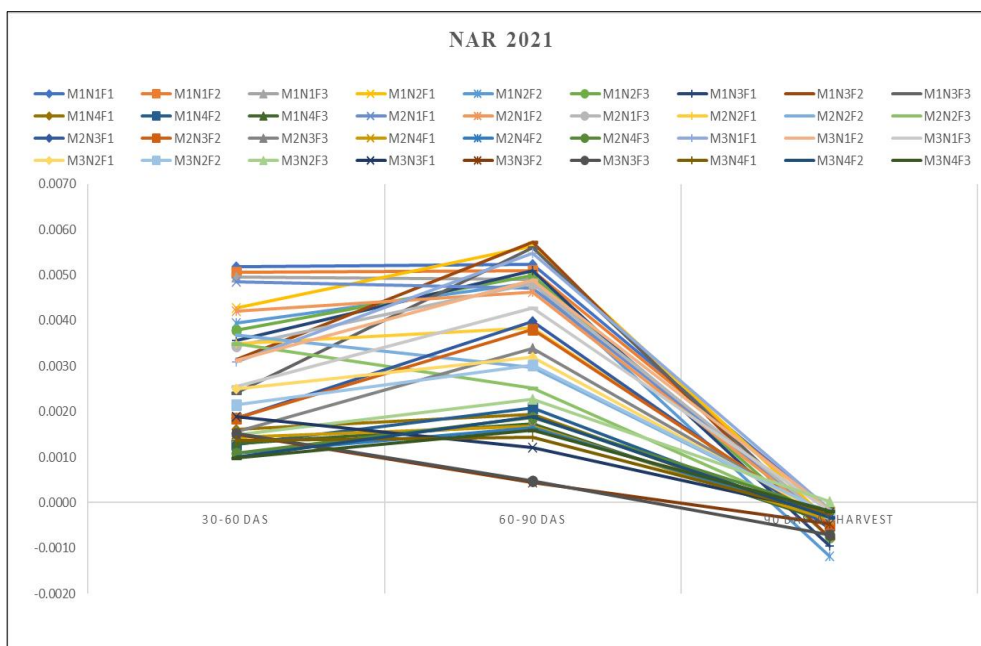


Fig 7: Effect of crop establishment methods, level of nutrients and foliar spray of cow urine on net assimilation rate (NAR) as influence different growth stages during 2021

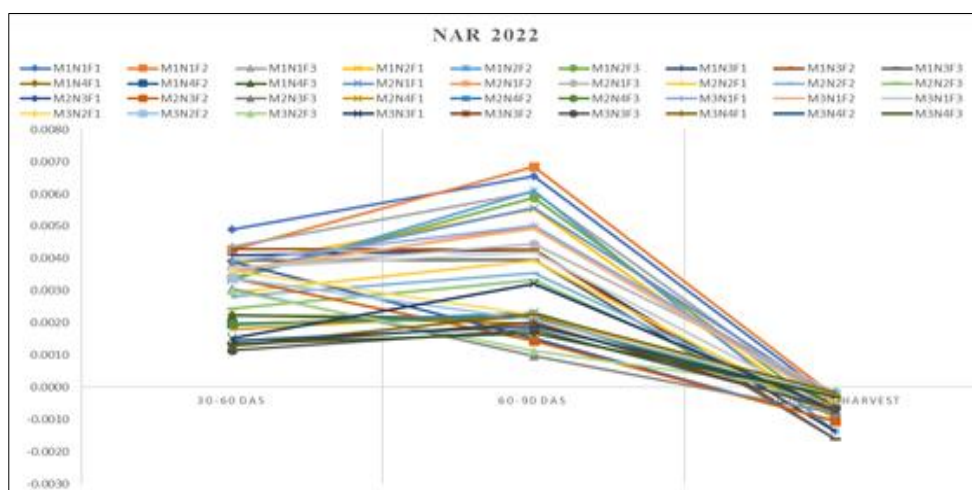


Fig 8: Effect of crop establishment methods, level of nutrients and foliar spray of cow urine on net assimilation rate (NAR) as influence different growth stages during 2022

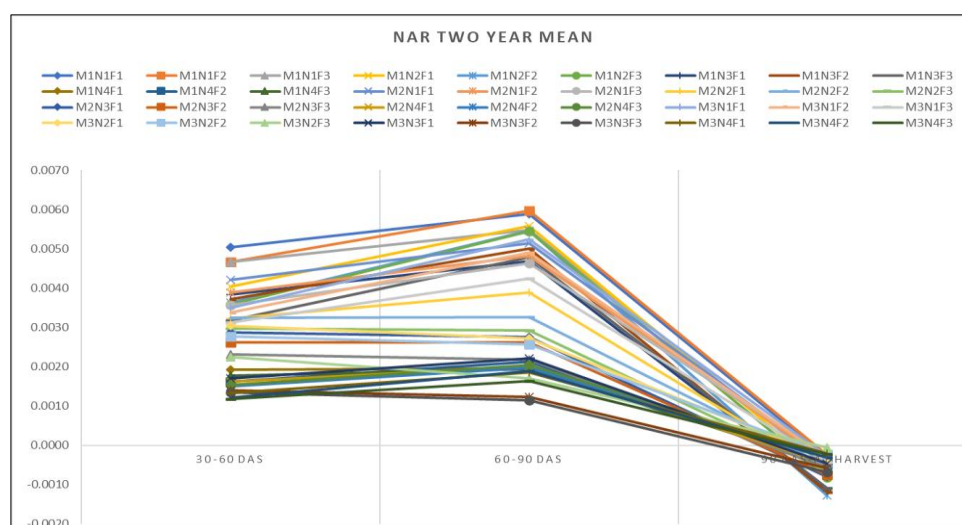


Fig 9: Effect of crop establishment methods, level of nutrients and foliar spray of cow urine on net assimilation rate (NAR) as influence different growth stages during two year mean

8. Net assimilation rate (NAR)

The data presented in Fig. 7-9 revealed that net assimilation rate (NAR) of finger millet was significantly influenced by crop establishment methods and nutrient levels during 30-60 DAT and 60-90 DAT in both years and in the pooled analysis. Foliar spray of cow urine did not significantly affect NAR during either year; however, its pooled effect was significant during both growth periods. Among the crop establishment methods, M₁ (Square transplanting) recorded significantly the highest NAR during 30-60 DAT and 60-90 DAT, remaining statistically at par with M₂ (Line transplanting) during 2021 and 2022 at 30-60 DAT. During 90 DAT to harvest, NAR declined under all establishment methods due to crop maturity, with the maximum decline observed under M₃ (Random transplanting). The higher NAR under square transplanting may be attributed to optimum crop geometry, which improved light interception, canopy architecture, and efficient utilization of soil moisture and nutrients, thereby enhancing photosynthetic efficiency. Similar findings were reported by Narayan (2018), Aliveni (2021), and Rajan (2022) [1, 27, 34]. Nutrient levels significantly influenced NAR during 30-60 DAT and 60-90 DAT. N₁ (100% RDN) recorded the highest NAR, whereas N₄ (Control) recorded the lowest during both years and in the pooled analysis. During 90 DAT to harvest, N₃ (50% RDN) exhibited the highest negative NAR, while N₄ (Control) recorded the lowest negative value. The higher NAR under N₁ may be attributed to balanced nutrient availability, which enhanced chlorophyll synthesis, photosynthetic activity, and assimilate production. These findings are in agreement with Varalakshmi (2005), Shekara (2010), and Harika (2019) [16, 45, 53]. Foliar application of cow urine did not significantly influence NAR during either experimental year, although F₁ (20% cow urine spray) recorded numerically higher NAR than F₂ (10% cow urine spray) and F₃ (No spray). On the pooled basis, its effect was significant during both growth periods. The improvement may be attributed to the supply of readily available nutrients and natural growth-promoting substances that enhanced photosynthetic efficiency and dry matter production. Similar observations were reported by Sutar (2008) and Devakumar (2014) [11, 49]. The negative NAR observed during 90 DAT to harvest is a normal physiological phenomenon associated with crop maturity. At this stage, photosynthetic activity declines due to leaf senescence, while stored assimilates are remobilized from vegetative tissues to developing grains, resulting in negative NAR values. Similar trends have been reported by Radford (1967) and Hunt (1990) [17, 33].

Conclusion

The present investigation demonstrated that growth of finger millet under an organic production system was markedly influenced by crop establishment methods and nutrient levels, whereas the effect of foliar application of cow urine was comparatively limited. Among the crop establishment methods, square transplanting (M₁) consistently produced superior growth by recording higher plant height, dry matter accumulation, Leaf Area Index (LAI), Crop Growth Rate (CGR), Relative Growth Rate (RGR), and Net Assimilation Rate (NAR). It also resulted in greater tiller production at the later growth stages, indicating the advantage of optimum crop geometry for efficient utilization of light, moisture, and nutrients. Among the nutrient levels, application of 100% recommended dose of nutrients (N₁) through organic

sources significantly enhanced all growth parameters throughout the crop growth period. Adequate nutrient availability under this treatment promoted vigorous vegetative growth, improved canopy development, higher biomass accumulation, and superior physiological efficiency compared with reduced nutrient levels and the control. Foliar application of 20% cow urine (F₁) improved plant height, dry matter accumulation, and leaf area index over the no-spray treatment, although its influence on crop growth rate, relative growth rate, and net assimilation rate was generally non-significant. This indicates that cow urine acted as a supplementary organic input that enhanced vegetative growth but had a comparatively smaller effect than crop establishment method and nutrient management. The interaction between square transplanting and 100% RDN (M₁ × N₁) consistently recorded the highest values for plant height, tiller production, dry matter accumulation, and leaf area index, demonstrating the synergistic effect of optimum crop geometry and adequate nutrient supply under organic cultivation. Overall, the study concludes that square transplanting combined with 100% recommended dose of nutrients under an organic production system is the most effective management practice for promoting vigorous growth of finger millet under the Bastar Plateau conditions of Chhattisgarh. Foliar application of 20% cow urine may be recommended as a complementary practice to improve vegetative growth and support sustainable organic finger millet production.

References

- Aliveni V, Reddy MD, Kumar P. Effect of organic nutrient management and crop establishment methods on growth and productivity of finger millet (*Eleusine coracana* L.). *Pharma Innov J*. 2021;10(9):1552-1557.
- Anonymous. Agricultural Statistics at a Glance 2024. New Delhi: Directorate of Economics and Statistics, Department of Agriculture and Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Government of India; 2024.
- Association of Official Analytical Chemists (AOAC). Official Methods of Analysis. 21st ed. Gaithersburg (MD): AOAC International; 2019.
- Ashoka P, Sharanappa, Ramesh YM. Influence of planting methods and nutrient management on growth and yield of finger millet under organic farming. *Biol Forum Int J*. 2021;13(4):769-774.
- Babu S, Yadav GS, Singh R, Avasthe RK, Das A, Mohapatra KP, *et al*. Organic nutrient management in cereals: A review. *Int J Curr Microbiol Appl Sci*. 2020;9(Special Issue):2846-2862.
- Balasubramanian A, Sekayange L. Finger millet (*Eleusine coracana* L.): A climate-resilient crop for food and nutritional security. *Int J Agric Sci*. 2021;13(2):114-121.
- Bhat S, Nandini C, Ravishankar GA. Nutritional and therapeutic potential of finger millet (*Eleusine coracana*): A review. *Food Sci Hum Wellness*. 2018;7(3):181-188.
- Chandra R, Singh AK, Yadav RS. Effect of crop establishment methods and nutrient management on growth and productivity of finger millet (*Eleusine coracana* L.). *Pharma Innov J*. 2021;10(9):1128-1133.

9. Chandrasekara A, Shahidi F. Bioactivities and health-promoting properties of millet grains and their products: A review. *J Funct Foods*. 2011;3(3):144-158.
10. Das A, Patel DP, Kumar M, Ramkrushna GI, Layek J, Ngachan SV, *et al*. Impact of organic sources of nutrients on productivity, soil quality and energy budgeting of rice-based cropping systems. *Exp Agric*. 2014;50(1):88-104.
11. Devakumar N, Rao GGE, Shubha S, Imrankhan, Nagaraj, Gowda SB. Activities of Organic Farming Research Centre on Scientific Validation of Indigenous Technical Knowledge (Panchagavya, Jeevamrutha and Beejamrutha). Bengaluru: University of Agricultural Sciences; 2014. p. 1-16.
12. Food and Agriculture Organization of the United Nations (FAO). The State of Food and Agriculture 2023. Rome: FAO; 2023.
13. Ghosh D, Bera S, Mahapatra P. Effect of crop establishment methods and nutrient management on growth and productivity of finger millet (*Eleusine coracana* L.). *Int J Chem Stud*. 2020;8(4):2745-2749.
14. Gopalan C, Rama Sastri BV, Balasubramanian SC. Nutritive Value of Indian Foods. Revised ed. Hyderabad: National Institute of Nutrition; 2019.
15. Gottimukkala KS, Reddy GP, Kumar A. Effect of organic liquid formulations on physiological growth parameters and productivity of millets under organic farming. *Int J Curr Microbiol Appl Sci*. 2019;8(11):1758-1765.
16. Harika M, Reddy MD, Kumar P. Influence of integrated nutrient management on growth and yield of finger millet (*Eleusine coracana* L.). *Int J Curr Microbiol Appl Sci*. 2019;8(6):2192-2200.
17. Hunt R. Basic Growth Analysis: Plant Growth Analysis for Beginners. London: Unwin Hyman Ltd.; 1990.
18. ICAR-Indian Institute of Millets Research (IIMR). Millets: Production Technology and Nutritional Benefits. Hyderabad: ICAR-Indian Institute of Millets Research; 2023.
19. Jain A, Sharma SK, Meena RK. Effect of cow urine foliar application on growth and yield of organically grown cereal crops. *Pharma Innov J*. 2021;10(8):987-991.
20. Kumar B. Effect of crop geometry and nutrient management on growth and productivity of finger millet (*Eleusine coracana* L.). *Int J Chem Stud*. 2018;6(5):2754-2758.
21. Kumar R, Rana MC. Organic nutrient management for enhancing growth and productivity of finger millet. *J Pharmacogn Phytochem*. 2019;8(5):1819-1823.
22. Kumar R, Singh AK, Patel S. Response of finger millet to organic nutrient management under different crop establishment methods. *Pharma Innov J*. 2022;11(5):1648-1653.
23. Kumar R, Singh AK, Yadav RA. Organic nutrient management for sustainable crop production: A review. *J Pharmacogn Phytochem*. 2021;10(1):1436-1443.
24. Kumar S, Meena BP, Singh R. Response of finger millet to integrated nutrient management under different establishment methods. *Int J Agric Sci*. 2017;13(2):237-241.
25. Malleshi NG. Nutritional and health benefits of millets. In: Henry RJ, editor. *Millets and Sorghum: Biology and Genetic Improvement*. Cambridge: Woodhead Publishing; 2017. p. 3-18.
26. Meena RK, Yadav GS, Singh VK. Organic nutrient management and planting methods influence growth and yield of finger millet under rainfed conditions. *Indian J Agric Res*. 2020;54(6):741-746.
27. Narayan P, Reddy MD, Kumar V. Effect of planting methods and nutrient management on growth and yield of finger millet (*Eleusine coracana* L.). *J Pharmacogn Phytochem*. 2018;7(6):1128-1132.
28. Natarajan K. Panchagavya: A Manual. Goa: Other India Press; 2002.
29. Palekar S. Text Book on Shoonya Bandovalada Naisargika Krushi. Amravati: Swamy Anand; 2006.
30. Panse VG, Patil DV, More SM. Effect of cow urine and organic nutrient management on growth and yield of finger millet under organic farming. *Int J Chem Stud*. 2017;5(6):1425-1429.
31. Panse VG, Patil DV, More SM. Effect of cow urine and organic nutrient management on growth and yield of finger millet under organic farming. *Int J Chem Stud*. 2017;5(6):1425-1429.
32. Pradhan A, Panda D, Mishra P. Effect of organic nutrient management on growth and productivity of finger millet (*Eleusine coracana* L.). *Pharma Innov J*. 2022;11(7):2187-2191.
33. Radford PJ. Growth analysis formulae: Their use and abuse. *Crop Sci*. 1967;7(3):171-175.
34. Rajan Kumar K, Prasad TV, Kumar M. Influence of establishment methods and nutrient management on growth analysis and productivity of finger millet (*Eleusine coracana* L.). *Biol Forum Int J*. 2022;14(2):884-889.
35. Rajan K, Prasad TV, Kumar M. Influence of establishment methods and nutrient management on growth analysis and productivity of finger millet (*Eleusine coracana* L.). *Biol Forum Int J*. 2022;14(2):884-889.
36. Ramesh P, Singh M, Rao AS. Organic farming: Its relevance to the Indian context. *Curr Sci*. 2005;88(4):561-568.
37. Rana MC, Sharma A, Sharma RP. Effect of organic manures and biofertilizers on growth and yield of finger millet under rainfed conditions. *Int J Chem Stud*. 2018;6(5):2422-2426.
38. Rao SS. Effect of crop establishment methods and integrated nutrient management on physiological growth parameters of finger millet. *J Pharmacogn Phytochem*. 2019;8(4):2350-2354.
39. Rao SS, Reddy YV, Prasad PR. Effect of crop establishment techniques and nutrient management on growth and yield of finger millet (*Eleusine coracana* L.). *J Millets Res*. 2014;9(2):74-79.
40. Ravindra B, Reddy MD, Reddy SN. Influence of planting methods and spacing on growth and yield of finger millet. *Madras Agric J*. 2012;99(7-9):481-484.
41. Reddy BVS, Upadhyaya HD, Gowda CLL, Singh S. Finger millet: A climate-resilient crop for nutritional security. *SAT eJournal*. 2013;11:1-5.
42. Sahu P, Netam CR, Singh DP. Organic farming and indigenous technical knowledge for sustainable agriculture in Chhattisgarh. *J Soils Crops*. 2021;31(2):215-222.

43. Sarawale PP, Chavan AP, Jadhav JD. Effect of crop establishment methods on growth and yield of finger millet (*Eleusine coracana* L.). *Int J Agric Sci.* 2017;13(1):86-89.
44. Sharma R, Singh V, Kumar A. Effect of foliar application of cow urine on growth, yield and economics of organically grown crops. *Int J Curr Microbiol Appl Sci.* 2019;8(10):2363-2370.
45. Shekara BG, Sharanappa, Krishnamurthy N. Response of finger millet to organic nutrient management under rainfed conditions. *Karnataka J Agric Sci.* 2010;23(2):231-234.
46. Singh R, Das A, Patel DP, Kumar M, Ramkrushna GI. Organic farming for sustainable agriculture and improved soil health: A review. *Indian J Agric Sci.* 2018;88(8):1155-1163.
47. Somashekara BG, Sharanappa, Krishnamurthy N. Influence of organic nutrient management on growth, tillering and productivity of finger millet under rainfed conditions. *Karnataka J Agric Sci.* 2015;28(2):248-252.
48. Subbaiah G, Reddy MD, Reddy SN. Effect of planting geometry and nutrient management on growth and yield of finger millet. *Andhra Agric J.* 2005;52(3-4):338-341.
49. Sutar RM, Supe VS, Jadhav AS. Effect of foliar application of cow urine on growth and yield of cereal crops under organic farming. *Asian J Soil Sci.* 2008;3(2):287-290.
50. Thilakarathna MS, Raizada MN. A review of nutrient management studies involving finger millet (*Eleusine coracana* L.): Crop productivity, nutrient uptake and soil fertility. *Front Plant Sci.* 2015;6:1-16.
51. Upadhyaya HD, Vetriventhan M, Dwivedi SL. Finger millet: A resilient crop for nutritional security. *Adv Agron.* 2016;136:1-55.
52. Vanukuri K, Reddy MD, Kumar P. Effect of organic nutrient management on crop establishment and growth of finger millet under organic farming. *Pharma Innov J.* 2022;11(9):1970-1975.
53. Varalakshmi LR. Effect of integrated nutrient management on growth and yield of finger millet (*Eleusine coracana* L.). *Karnataka J Agric Sci.* 2005;18(2):446-448.