PLANT SCIENCE TODAY
ISSN 2348-1900 (online)
Vol x(x): xx–xx
https://doi.org/10.14719/pst.4763

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RESEARCH ARTICLE

Growth, productivity, quality and profitability of organic finger millet under cultivar and nutrient management options

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OPEN ACCESS

ARTICLE HISTORY
Received: 21 August 2024
Accepted: 19 October 2024
Available online
Version 1.0 : 24 January 2025

Check for updates

Additional information
Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

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Indexing: Plant Science Today, published by Horizon e-Publishing Group, is covered by Scopus, Web of Science, BIOSIS Previews, Clarivate Analytics, NAAS, UGC Care, etc See https://horizonepublishing.com/journals/index.php/PST/indexing_abstracting

CITE THIS ARTICLE
Sahoo RK, Behera SD, Behera B, Jena J, Mishra G, Dash S, Mahapatra SS. Growth, productivity, quality and profitability of organic finger millet under cultivar and nutrient management options. Plant Science Today (Early Access). https://doi.org/10.14719/pst.4763

Abstract

Cultivars and nutrient management determine productivity and quality of the organic finger millet. A field trial was carried out during the *kharif* season 2022 at Binjhagiri, Bhubaneswar, Odisha comprising the four cultivars of finger millet and four nutrient management practices through organic manure combinations with split plot design replicated thrice. The four cultivars namely, C_1- 'Arjuna', C_2- 'Bhairabi', C_3- 'Chilika' and C_4- 'Kalua' were assigned to the main plots. Recommended dose of nitrogen (RDN) of 50 kg ha^{-1} was supplied through varying percentage of organic manures namely, farmyard manure (FYM), neem oilcake (NOC) and vermicompost (VC). Four nutrient management practices such as N_1- FYM (RDN_{100}), N_2- FYM (RDN_{40}) + NOC (RDN_{30}) + VC (RDN_{30}), N_3- FYM (RDN_{50}) + NOC (RDN_{25}) + VC (RDN_{25}), N_4- FYM (RDN_{60}) + NOC (RDN_{20}) + VC (RDN_{20}) were assigned to the sub-plots. Combination of the treatments viz., C_3N_2, C_4N_2, C_3N_3 and C_4N_3 excelled over the others for grain and protein yields and profitability, but treatment combination C_4N_2 was the most promising considering the parameters like grain yield (2.10 tha^{-1}), net return (Rs. 36940 ha^{-1}), protein yield (165.75 kg ha^{-1}), calcium yield (7.34 kg ha^{-1}) and iron yield (0.137 kg ha^{-1}). There was significant positive correlation of grain yield with all growth-yield parameters, except test weight, whereas regression analysis indicated 70.86, 85.21 and 73.45% contribution of tillers hill^{-1}, dry matter production and leaf area index at harvest, respectively, to variations in grain yield. The organic finger millet growers should cultivate cv. 'Kalua' with application of FYM+NOC+VC @ 4.35+0.34+0.6 t ha^{-1} for achieving maximum yield and grain quality.

Keywords

calcium; iron; neem oilcake; net return; protein; vermicompost

Introduction

Millets are well known as nutri-cereals on account of the presence of minerals and vegetable fiber. These are also rich in health promoting phytochemicals and can be used as functional foods. Millets with C_4 photosynthetic pathway, are climate change acquiescent crops. These crops sequester carbon and thereby reduce the burden of greenhouse gases. India ranks first in terms of millet production all over the world. India produced total food grain amounting to 308.65 mt from an area of 129.34 mha in 2020-21, out of which nutri-cereals accounted for 51.15 mt from an area of 23.83 mha (1). Among the nutri-cereals, finger millet (*Eleusine coracana* L.) plays a crucial role of producing quality nutrition for humans. Finger millet protein has a high biological value, which is essential for the sustenance of nitrogen equilibrium in the body. Finger millet has about protein (5–8%), carbohydrates (65–75%), minerals (2.5–3.5%), ether extractives (1–2%), and dietary fiber (15–20%) (2). Grain of finger millet has calcium content of 344 mg per 100 g which is the highest among all cereals (3). Finger millet as a diet is very important for pregnant women, young children and aged population in marginalized and indigent regions of the society, who are at highest probability of Ca malnutrition (4).

In Odisha, finger millet, jowar, bajra and other small millets are cultivated in area of 124.47, 5.50, 1.27 and 35.25 thousand hectares with production of 137.49, 3.47, 0.79 and 18.01 thousand metric tonnes and productivity of 1105, 631, 622 and 511 kg ha^{-1}, respectively (5). Finger millet is the principal crop of tribal and rainfed farmers due to low water requirement and drought tolerance behavior. The Government of Odisha launched Odisha Millet Mission in 2017 with a major focus on finger millet.

Farmers in Odisha grow traditional cultivars of finger millet with low yield potential. The breeders have developed high yielding cultivars with good grain quality. There is a need to evaluate the performance of those cultivars and recommend the promising ones to the millet farmers. Worldwide, food trends are changing with a marked health orientation. The demand for organic food would steadily increase in the coming years. The demand for organic finger millet is increasing not only in domestic but also in international market on account of rise in income level and health consciousness of consumers. Hence there is a need to produce finger millet under organic management.

In organic production systems, nutrient management is very important. Locally available organic manures play a major role as source of several nutrients with capability to buildup soil characteristics and to control insects, weeds and other pests. Farmers generally use FYM as a source of nutrient for organic crops. Other sources of manuring like neem oilcake and vermicompost act as nutrient source and improve crop health through their effect on disease control and insect pest management. Neem oilcake acts as a nitrification inhibitor and helps in steady supply of nitrogen to the crop. Slow mineralization of N has been observed in neem oilcake than in the inorganic sources of plant nutrient (6). It is reported that neem materials inhibit nitrification by 40% in compost amended soils (7). Vermicompost minimizes water need, reduces pest infestation, decreases termite infestation, suppresses weed germination; promotes seed and seedling growth and enhanced grains ear^{-1} in cereal crops (8). Combination of different organic sources viz., farmyard manure and vermicompost increased yield and yield parameters of finger millet (9). Due to specific advantages of various organic sources, it is necessary to deduce a manure combination encompassing diverse organic sources for attainment of the nutrient demand of finger millet and with concomitant decrease in cost of input for easy adoption by the small holder farmers. It is hypothesized that choice of appropriate cultivar with manure combinations would give higher productivity and better-quality grains than use of farmyard manure alone as source of nutrient.

Materials and Methods

The experiment comprising four finger millet cultivars and four nitrogen management practices was carried out in split plot design replicated thrice at Agricultural Research Station (ARS), Chhatabar, Bhubaneswar, Odisha. The cultivars namely, C_1- 'Arjuna' (105–110d), C_2- 'Bhairabi' (102–108d), C_3- 'Chilika' (110–115d) and C_4- 'Kalua' (110–115d) were assigned to the main-plots. The recommended dose of nitrogen (RDN) amounting to 50 kg ha^{-1} was provided through varying percentage from organic manures such as farmyard manure (FYM), neem oilcake (NOC) and vermicompost (VC). Four nitrogen management practices viz., N_1- FYM (RDN_{100}), N_2- FYM (RDN_{40}) + NOC (RDN_{30}) + VC (RDN_{30}), N_3- FYM (RDN_{50}) + NOC (RDN_{25}) + VC (RDN_{25}), N_4- FYM (RDN_{60}) + NOC (RDN_{20}) + VC (RDN_{20}) were assigned to the sub-plots. The FYM, NOC and VC had nitrogen content of 0.46, 4.4 and 2.5 %, respectively. The soil of the experimental field had a sandy loam texture, an acidic response (pH 5.35), medium in organic carbon (0.51%), available phosphorus (12.5 kg ha^{-1}), available potassium (235.6 kg ha^{-1}) and low in available nitrogen (208.2 kg ha^{-1}).

In the nursery bed, seed was sown on 30^{th} June 2022, followed by covering of seeds with FYM. Straw mulching was done for quick germination. Straw mulch was removed from the beds on 6 July after the emergence of seedlings. Neem oilcake was given as per the treatment a week prior to transplanting to avoid injury to the seedlings. The FYM and vermicompost were applied one day before transplanting. The seedlings were transplanted with spacing of 20 cm × 10 cm on 1^{st} August 2022 after seedling root dip in Beejamrit solution. It was predominantly grown as a rainfed or non-irrigated crop. The organic preparation *Brahmastra* was sprayed on 3 September 2022 as a prophylactic plant protection measure. The crop was harvested from 17 October to 9 November depending on the duration of the variety. The observations on days to the occurrence of phenophases, growth and yield attributes were recorded by using an appropriate sampling method. The grain yield of finger millet was recorded plot wise from the delineated plot and was converted to t ha^{-1}. The protein content of the grain was derived by multiplying grain N content with 6.25 (10). Calcium content was estimated by the Versanate titration method in which ethylene diamine tetra-acetic acid (EDTA) forms a complex with calcium ion (11). The estimation of Fe was done by using an atomic absorption spectrophotometer (12). All the data recorded on various parameters of the crop were analysed as per the method statistically (13). Correlation coefficients in between grain yield and growth-yield parameters were calculated and the significance was tested with 5% and 1% level of significance. Regression analysis was done to test the relationship between various parameters using Microsoft Excel data analysis tool.

Results

Days to phenophases

The finger millet cultivars influenced the days to phenophases viz., 50% flowering and physiological maturity (PM) significantly (Fig. 1). Among the cultivars, cv. 'Kalua' (C_4) and cv. 'Chilika' (C_3) took 90 days to attain 50% flowering stage, whereas cv. 'Arjuna' (C_1) and cv. 'Bhairabi' (C_2) took significantly fewer days to attain 50% flowering stage. Furthermore, among cultivars, cv. 'Chilika' (C_3) took a maximum of 126 days to attain the stage of physiological maturity compared to 120 days by cv. 'Kalua' (C_4). 'Arjuna' (C_1) with 111 days and cv. 'Bhairabi' (C_2) with 112 days were the earliest cultivars.

'Chilika' (C_3) recorded the maximum ears m^{-2} (263), finger earhead^{-1} (4.9) and seeds finger^{-1} (183). 'Kalua' (C_4) with ears m^{-2} of 239, finger ear^{-1} of 4.3 and seeds finger^{-1} of 179 remained at par with cv. 'Chilika' (C_3). 'Arjuna' (C_1) and cv. 'Bhairabi' (C_2) recorded lower values for yield attributes than cv. 'Chilika' (C_3) and cv. 'Kalua' (C_4). The yield attributes under different cultivars exhibited a similar trend to the growth parameters, like dry matter production (g m^{-2}) and LAI. Among organic nutrient management practices, recommended nitrogen applied through FYM (RDN_{40}) + NOC (RDN_{30}) + VC (RDN_{30}) resulted in the maximum ears m^{-2} (267), seeds ear^{-1} (182) and test weight (2.71g 1000 seeds^{-1}). However, application of FYM (RDN_{50}) + NOC (RDN_{25}) + VC (RDN_{25}) recorded statistically similar test weight of 1000 grains (2.63 g).

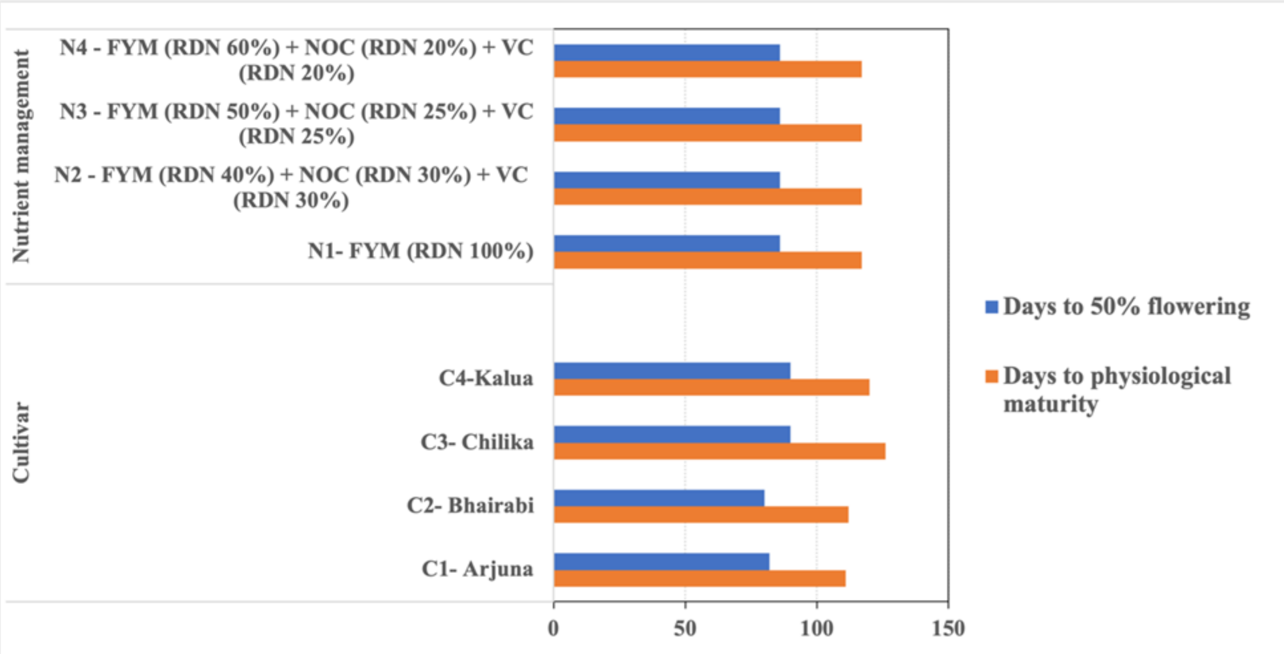

Fig. 1. Effect of cultivar and nutrient management on days to phenophases of organic finger millet.

Growth parameters

Among the cultivars, cv. 'Kalua' (C_4) was the tallest, with plant height of 83.5 cm, and cv. 'Chilika' (C_3) had the maximum LAI (Table 1). 'Chilika' (C_3) had the maximum tiller density with 263 tillers m^{-2} and the maximum dry matter production (DMP) of 654.9 g m^{-2}, keeping cv. 'Kalua' (C_4) at par. Among the nutrient management practices, recommended nitrogen of 50 kg ha^{-1} applied through FYM (RDN_{40}) + NOC (RDN_{30}) + VC (RDN_{30}) resulted in the highest values of growth parameters viz., plant height (77.3 cm), tiller density (258 m^{-2}), LAI (4.05), and dry matter production (562.7 g m^{-2}), keeping FYM (RDN_{50}) + NOC (RDN_{25}) + VC (RDN_{25}) at par for LAI (4.02) and dry matter production (540.7 g m^{-2}) and FYM (RDN_{60}) + NOC (RDN_{20}) + VC (RDN_{20}) for tillers m^{-2} (243). Recommended nitrogen applied through FYM alone recorded the minimum values of all growth parameters.

Yield attributes

The finger millet cultivars influenced ears m^{-2}, fingers earhead^{-1} and seeds finger^{-1} significantly (Table 2). All the four cultivars failed to exert a significant influence on the test weight of 1000 seeds. Among the cultivars, cv.

Grain yield

Both the cultivars of finger millet and organic nutrient management practices exerted a significant influence on grain yield (Table 3). Among the cultivars, cv. 'Chilika' (C_3) produced the highest grain yield of 1.89 t ha^{-1}. 'Kalua' (C_4), with a yield of 1.82 t ha^{-1} remained statistically at par with it. 'Arjuna' (C_1) and 'Bhairabi' (C_2) recorded significantly less grain yield than 'Chilika' (C_3) and 'Kalua' (C_4). Among the nutrient management practices, the recommend dose of nitrogen applied through FYM (RDN_{40}) + NOC (RDN_{30}) + VC (RDN_{30}) resulted in the significantly highest grain yield of 1.82 t ha^{-1}. Recommended N applied through FYM (RDN_{50}) + NOC (RDN_{25}) + VC (RDN_{25}) recorded a statistically similar yield. The application of FYM (N_{100}) recorded the minimum grain yield. The interaction effects of cultivar and organic nutrient management on finger millet yield were significant. The finger millet 'Chilika' (C_3) with recommended N applied through FYM (RDN_{40}) + NOC (RDN_{30}) + VC (RDN_{30}) produced higher grain yield of 2.12 t ha^{-1}, keeping the treatment combination cv. 'Kalua' (C_3) with recommended N applied through FYM (RDN_{40}) + NOC (RDN_{30}) + VC (RDN_{30}) and cv. 'Chilika' (C_3) and cv.

Table 1. Effect of cultivar and nutrient management on growth of organic finger millet

Treatment	Growth parameters			
	Plant height at PM (cm)	Tillers m^{-2} at harvest	LAI at 60 DAT	DMP at harvest ($g\ m^{-2}$)
Cultivar				
C_1- Arjuna	61.9	223	3.43	431.6
C_2- Bhairabi	65.1	226	3.56	453
C_3- Chilika	78.5	263	4.18	654.9
C_4- Kalua	83.5	244	3.73	613.4
SEm±	1.3	7	0.09	13.2
CD (P=0.05)	4.7	23	0.32	45.8
Nutrient management (% of RDN from sources)				
N_1- FYM (RDN_{100})	68.8	224	3.4	518.5
N_2- FYM (RDN_{40}) + NOC (RDN_{30}) + VC (RDN_{30})	77.3	258	4.05	562.7
N_3- FYM (RDN_{50}) + NOC (RDN_{25}) + VC (RDN_{25})	70.4	230	4.02	540.7
N_4- FYM (RDN_{60}) + NOC (RDN_{20}) + VC (RDN_{20})	72.5	243	3.43	531
SEm±	1.3	6	0.09	9.6
CD (P=0.05)	3.8	18	0.26	28.2

RDN- Recommended dose of nitrogen (50kg ha^{-1}), LAI- Leaf area index, DMP- Dry matter production, SEm±- Standard error of mean, CD- Critical difference, FYM - Farmyard manure, NOC - Neem oilcake, VC- Vermicompost

Table 2. Effect of cultivar and nutrient management on yield parameters of organic finger millet

Treatment	Ears m^{-2}	Fingers ear^{-1}	Seeds $finger^{-1}$	Test weight (g)
Cultivar				
C_1- Arjuna	213	4.1	151	2.60
C_2- Bhairabi	221	4.1	168	2.55
C_3- Chilika	263	4.9	183	2.72
C_4- Kalua	239	4.3	179	2.68
SEm±	8	0.1	7	0.04
CD (P=0.05)	27	0.5	23	NS
Nutrient management (% of RDN from sources)				
N_1- FYM (RDN_{100})	210	4.2	165	260
N_2- FYM (RDN_{40}) + NOC (RDN_{30}) + VC (RDN_{30})	267	4.4	182	2.71
N_3- FYM (RDN_{50}) + NOC (RDN_{25}) + VC (RDN_{25})	230	4.5	169	2.63
N_4- FYM (RDN_{60}) + NOC (RDN_{20}) + VC (RDN_{20})	229	4.3	165	2.60
SEm±	10	0.2	4	0.03
CD (P=0.05)	30	NS	12	0.09

RDN- Recommended dose of nitrogen (50kg ha^{-1}), FYM- Farmyard manure, NOC- Neem oilcake, VC- Vermicompost, SEm± - Standard error of mean, CD- Critical difference, NS- Non-significant

Table 3. Effect of cultivar and nutrient management on grain yield (t ha^{-1}) of organic finger millet

Treatment	N_1	N_2	N_3	N_4	Mean
C_1- Arjuna	1.35	1.42	1.64	1.48	1.47
C_2- Bhairabi	1.58	1.63	1.57	1.37	1.54
C_3- Chilika	1.59	2.12	1.98	1.87	1.89
C_4- Kalua	1.71	2.10	1.96	1.52	1.82
Mean	1.56	1.82	1.79	1.56	1.68
Mainor interaction	**Cultivar (C)**	**Nutrient (N)**	**CxN**	**NxC**	
SEm±	0.04	0.03	0.07	0.06	
CD (P=0.05)	0.15	0.09	0.22	0.19	

N_1- FYM (RDN_{100}), N_2- FYM (RDN_{40}) + NOC (RDN_{30}) + VC(RDN_{30}), N_3- FYM (RDN_{50}) + NOC (RDN_{25}) + VC (RDN_{25}), N_4- FYM (RDN_{60}) + NOC (RDN_{20}) + VC (RDN_{20}), CxN- Cultivar in same or different levels of nutrient, NxC- Nutrient in same level of cultivar, SEm±- Standard error of mean, CD- Critical difference

'Kalua' (C_4) with FYM (RDN_{50}) + NOC (RDN_{25}) + VC (RDN_{25}) at par with it.

Protein and minerals content in grain

The cultivars failed to cause a significant difference in protein content (Table 4). However, among the cultivars, 'Bhairabi' (C_2) had the maximum protein content of 7.89% closely followed by 'Arjuna' (C_1) with protein content of 7.81%. 'Chilika' (C_3) which was the maximum yielding cultivar, had the moderate protein content of 7.65%. 'Kalua' (C_4) had the minimum protein content of 7.28%. Among the nutrient management practices, the maximum protein content of 8.08% was recorded with recommended N applied through FYM (RDN_{40}) + NOC (RDN_{30}) + VC (RDN_{30}). The application of FYM (RDN_{50}) + NOC (RDN_{25}) + VC (RDN_{25}) recorded statistically similar protein content (7.91%).

Table 4. Effect of cultivar and nutrient management on calcium and iron content of organic finger millet

Treatment	Protein content (%)	Ca content (mg $100g^{-1}$)	Fe content (mg $100g^{-1}$)
Cultivar			
C_1- Arjuna	7.81	326	4.72
C_2- Bhairabi	7.89	341	4.86
C_3- Chilika	7.65	310	4.88
C_4- Kalua	7.28	328	5.64
SEm±	0.21	6	0.10
CD (P=0.05)	NS	20	0.34
Nutrient management (% of RDN from sources)			
N_1- FYM (RDN_{100})	7.26	323	4.7
N_2- FYM (RDN_{40}) + NOC (RDN_{30}) + VC (RDN_{30})	8.08	333	5.39
N_3- FYM (RDN_{50}) + NOC (RDN_{25}) + VC (RDN_{25})	7.91	315	6.11
N_4- FYM (RDN_{60}) + NOC (RDN_{20}) + VC (RDN_{20})	7.39	334	4.89
SEm±	0.08	3	0.05
CD (P=0.05)	0.24	9	0.16

RDN- Recommended dose of nitrogen (50kg ha^{-1}), FYM- Farmyard manure, NOC- Neem oilcake, VC- Vermicompost, SEm±- Standard error of mean, CD- Critical difference, NS- Non-significant

Both the cultivars and nutrient management exerted a significant influence on calcium content of grain. Among the cultivars, 'Bhairabi' (C_2) had the maximum calcium content of 341 mg $100g^{-1}$ (0.34%). The cultivars *viz.,* 'Kalua' (C_4) with 328 mg $100g^{-1}$ and 'Arjuna' (C_1) with 326 mg $100g^{-1}$ recorded a statistically similar Ca content. 'Chilika' (C_3) had the minimum Ca content of 310 mg $100g^{-1}$ (0.31%). Among the nutrient management practices, recommended N applied through FYM (RDN_{60}) + NOC (RDN_{20}) + VC (RDN_{20}) (334 mg 100 g^{-1}) and FYM (RDN_{40}) + NOC (RDN_{30}) + VC (RDN_{30}) recorded higher calcium content (333 mg 100 g^{-1}) than FYM (RDN_{100}) of 323 mg 100 g^{-1} and FYM (RDN_{50}) + NOC (RDN_{25}) + VC (RDN_{25}) of 315 mg 100 g^{-1}.

Both the cultivars and the nutrient management practices influenced iron content significantly. Among the cultivars 'Kalua' (C_4) had a maximum iron content of 5.64 mg 100 g^{-1}. Other cultivars had significantly less iron content. Among nutrient management practices, significantly maximum iron content of 6.11 mg 100 g^{-1} was recorded in recommended N applied through FYM (RDN_{50}) + NOC (RDN_{25}) + VC (RDN_{25}) and proved superior over other management practices.

Yield of protein and minerals

'Kalua' (C_4) and 'Chilika' (C_3) recorded a significantly higher protein and calcium yield than 'Arjuna' (C_1) and 'Bhairabi' (C_2) (Table 5). 'Kalua' (C_4) recorded a significantly higher iron yield than the other three cultivars. Among the nutrient management practices, recommended N applied through FYM (RDN_{40}) + NOC (RDN_{30}) + VC (RDN_{30}) and FYM (RDN_{50}) + NOC (RDN_{25}) + VC (RDN_{25}) recorded higher protein and calcium yield than FYM (RDN_{100}) and FYM (RDN_{60}) + NOC (RDN_{20}) + VC (RDN_{20}). The significantly maximum iron yield was observed in recommended N applied through FYM (RDN_{40}) + NOC (RDN_{30}) + VC (RDN_{30}) and proved superior over others. Among the treatment combinations, 'Kalua' (C_4) with FYM (RDN_{40}) + NOC (RDN_{30}) + VC (RDN_{30}) proved the best for protein and minerals yield of finger millet with protein yield (165.75 kg ha^{-1}), calcium yield (7.34 kg ha^{-1}) and iron yield (0.137 kg ha^{-1}).

Economics

Both the cultivars and the organic nutrient management practices significantly influenced gross return (GR), net return (NR) and return per rupee investment (Table 6). Among cultivars, 'Chilika' (C_3) gave the maximum gross return of Rs. 81380 ha^{-1} and net return of Rs. 29840 ha^{-1}. 'Kalua' (C_4) gave a statistically similar gross and net return while other cultivars recorded significantly less gross and net return. Among the nutrient management practices, recommended N applied through FYM (RDN_{40}) + NOC (RDN_{30}) + VC (RDN_{30}) accrued the significant maximum gross return (Rs. 77630 ha^{-1}) and net return (Rs. 24190 ha^{-1}). Recommended N applied through FYM (RDN_{50}) + NOC (RDN_{25}) + VC (RDN_{25}) accrued statistically similar gross and net returns. The application of a combination of manure sources i.e., FYM (RDN_{40}) + NOC (RDN_{30}) + VC (RDN_{30}) and FYM (RDN_{50}) + NOC (RDN_{25}) + VC (RDN_{25}) incurred a higher

Table 5. Effect of cultivar and nutrient management on protein and mineral yields of organic finger millet

Treatment	N_1	N_2	N_3	N_4	Mean
		Protein yield (kg ha^{-1})			
C_1- Arjuna	95.76	116.35	132.44	117.84	115.60
C_2- Bhairabi	117.47	135.36	126.18	107.44	121.61
C_3- Chilika	116.97	166.62	153.48	142.47	144.89
C_4- Kalua	123.01	165.75	153.85	94.47	134.27
Mean	113.30	146.02	141.49	115.56	129.09
Mainor interaction	**Cultivar (C)**	**Nutrient (N)**	**CxN**	**NxC**	
SEm±	5.31	2.85	7.25	5.71	
CD (P=0.05)	18.36	8.33	23.27	16.66	
		Calcium yield (kg ha^{-1})			
C_1- Arjuna	4.47	4.82	4.76	5.08	4.78
C_2- Bhairabi	5.22	5.22	5.36	5.12	5.23
C_3- Chilika	4.75	6.78	6.15	5.79	5.87
C_4- Kalua	5.65	7.34	6.28	4.71	6.00
Mean	5.02	6.04	5.64	5.18	5.47
Main or interaction	**Cultivar (C)**	**Nutrient (N)**	**CxN**	**NxC**	
SEm±	0.18	0.12	0.28	0.24	
CD (P=0.05)	0.62	0.35	0.87	0.70	
		Iron yield (kg ha^{-1})			
C_1- Arjuna	0.060	0.077	0.083	0.063	0.071
C_2- Bhairabi	0.067	0.083	0.080	0.067	0.074
C_3- Chilika	0.077	0.103	0.103	0.093	0.094
C_4- Kalua	0.090	0.137	0.107	0.080	0.103
Mean	0.073	0.100	0.093	0.076	0.086
Main or interaction	**Cultivar (C)**	**Nutrient (N)**	**CxN**	**NxC**	
SEm±	0.002	0.002	0.004	0.004	
CD (P=0.05)	0.008	0.005	0.012	0.011	

N_1- FYM (RDN_{100}), N_2- FYM (RDN_{40}) + NOC (RDN_{30}) + VC (RDN_{30}), N_3- FYM (RDN_{50}) + NOC (RDN_{25}) + VC (RDN_{25}), N_4- FYM (RDN_{60}) + NOC (RDN_{20}) + VC (RDN_{20}), CxN- Cultivar in same or different levels of nutrient, NxC- Nutrient in same level of cultivar, SEm±- Standard error of mean, CD- Critical difference

Table 6. Effect of cultivar and nutrient management on economics of organic finger millet

Treatment	N_1	N_2	N_3	N_4	Mean
		Gross return (x10^3 Rs. ha^{-1})			
C_1- Arjuna	57.21	60.12	68.57	61.98	61.97
C_2- Bhairabi	66.73	68.52	65.21	58.39	64.71
C_3- Chilika	69.33	91.51	85.45	79.24	81.38
C_4- Kalua	72.62	90.38	83.52	66.90	78.35
Mean	66.47	77.63	75.69	66.63	71.60
Main or interaction	**Cultivar (C)**	**Nutrient (N)**	**CxN**	**NxC**	
SEm±	1.65	1.23	2.70	2.46	
CD (P=0.05)	5.71	3.59	8.41	7.18	
		Net return (x10^3 Rs. ha^{-1})			
C_1- Arjuna	8.82	6.68	15.98	10.23	10.43
C_2- Bhairabi	18.34	15.09	12.62	6.65	13.17
C_3- Chilika	20.93	38.07	32.85	27.49	29.84
C_4- Kalua	24.23	36.94	30.93	15.15	26.81
Mean	18.08	24.19	23.09	14.88	20.06
Main or interaction	**Cultivar (C)**	**Nutrient (N)**	**CxN**	**NxC**	
SEm±	1.65	1.23	2.70	2.46	
CD (P=0.05)	5.71	3.59	8.41	7.18	
		Return per rupee investment			
C_1- Arjuna	1.18	1.12	1.30	1.20	1.20
C_2- Bhairabi	1.38	1.28	1.24	1.13	1.26
C_3- Chilika	1.43	1.71	1.63	1.53	1.58
C_4- Kalua	1.50	1.69	1.59	1.29	1.52
Mean	1.37	1.45	1.44	1.29	1.39
Main or interaction	**Cultivar (C)**	**Nutrient (N)**	**CxN**	**NxC**	
SEm±	0.03	0.02	0.05	0.05	
CD (P=0.05)	0.11	0.07	0.16	0.14	

N_1- FYM (RDN_{100}), N_2- FYM (RDN_{40}) + NOC (RDN_{30}) + VC (RDN_{30}), N_3- FYM (RDN_{50}) + NOC (RDN_{25}) + VC (RDN_{25}), N_4- FYM (RDN_{60}) + NOC (RDN_{20}) + VC (RDN_{20}), CxN- Cultivar in same or different levels of nutrient, NxC- Nutrient in same level of cultivar, SEm±- Standard error of mean, CD- Critical difference cost of cultivation than the application of FYM (RDN_{100}), but net return under a combination of manures was higher than FYM alone. The interaction effects of cultivar and nutrient management on both gross and net return were found to be significant. 'Chilika' (C_3) with recommended N applied through FYM (RDN_{40}) + NOC (RDN_{30}) + VC (RDN_{30}) accrued the significantly maximum gross return (Rs. 91510 ha^{-1}) and net return (Rs. 38070 ha^{-1}). The treatment combinations 'Chilika' (C_3) with FYM (RDN_{50}) + NOC (RDN_{25}) + VC (RDN_{25}), cv. 'Kalua' (C_4) with FYM (RDN_{40}) + NOC (RDN_{30}) + VC (RDN_{30}) and 'Kalua' (C_4) with FYM (RDN_{50}) + NOC (RDN_{25}) + VC (RDN_{25}) accrued statistically similar gross and net return. On average, organic finger millet gave net returns of Rs. 20060 ha^{-1}.

Among the cultivars, 'Chilika' (C_3) gave the maximum return per rupee investment of 1.58, and 'Kalua' (C_4) with return per rupee investment of 1.52 was at par. Both 'Arjuna' (C_1) and 'Bhairabi' (C_2) gave a significantly less return per rupee investment. Among the nutrient management practices, recommended N applied through FYM (RDN_{40}) + NOC (RDN_{30}) + VC (RDN_{30}) gave the maximum return per rupee investment (1.45) and FYM (RDN_{50}) + NOC (RDN_{25}) + VC (RDN_{25}) gave a statistically similar value. 'Chilika' (C_3) with recommended N applied through FYM (RDN_{40}) + NOC (RDN_{30}) + VC (RDN_{30}) gave the significantly higher return per rupee investment (1.71). 'Chilika' (C_3) with FYM (RDN_{50}) + NOC (RDN_{25}) + VC (RDN_{25}) and cv. 'Kalua' (C_4) with FYM (RDN_{40}) + NOC (RDN_{30}) + VC (RDN_{30}) and FYM (RDN_{50}) + NOC (RDN_{25}) + VC (RDN_{25}) gave similar value. Among treatment combinations, cv. 'Chilika' (C_3) with recommended N applied through FYM (RDN_{40}) + NOC (RDN_{30}) + VC (RDN_{30}), 'Kalua' (C_4) with FYM (RDN_{40}) + NOC (RDN_{30}) + VC (RDN_{30}), cv. 'Chilika' (C_3) with FYM (RDN_{50}) + NOC (RDN_{25}) + VC (RDN_{25}) and 'Kalua' (C_4) with FYM (RDN_{50}) + NOC (RDN_{25}) + VC (RDN_{25}) were the most productive and remunerative than other treatment combinations.

Correlation and regression studies

The grain yield of finger millet (t ha^{-1}) exhibited a significant positive correlation (Fig. 2) with plant height at physiological maturity (r = 0.883), tillers m^{-2} at harvest (r = 0.842), leaf area index at 60 DAT (r = 0.857), dry matter production at harvest (r = 0.923), ears m^{-2} (0.860), fingers ear^{-1} (r = 0.828), seeds $finger^{-1}$ (r = 0.883) at 1% level of significance. The correlation between grain yield and test weight of 1000 grains was non-significant. All the growth parameters and yield attributes except test weight (1000 grains), expressed a significant positive correlation with each other.

Regression study (Fig. 3) revealed that grain yield of finger millet increased linearly with increase in tillers m^{-2} at harvest (Y = 84.057x + 96.294), LAI (1.7402x + 0.7732) and DMP at harvest (Y= 440.02x + 208.17). The values of R^2 revealed that tillers $hill^{-1}$, LAI and DMP at harvest explained 70.86, 73.45 and 85.21% variation in yield of finger millet, respectively.

Discussion

Days to phenophases

The occurrence of phenophases is decided predominately by genetic makeup and modified to some extent by environmental factors (temperature and photoperiod), as well as edaphic and management factors. Varietal variation in finger millet for cv. 'RAU 8' has been reported for days to 50% flowering (81 days) and physiological maturity (110 days) (14). Similar variation in cv. 'Boneya' (88 days) and cv. 'Tesema' (84 days), and cv. 'VL 352' (45 days) and cv. 'GPU 45' (61 days) for days to 50% flowering has been noted in the present investigation (15, 16).

Growth parameters

The variation in growth parameters among cultivars can

	Plant height at PM (cm)	Tillers m^{-2} at harvest	LAI at 60 DAT	DMP at harvest ($g\ m^{-2}$)	Ears m^{-2}	Fingers ear^{-1}	Seeds $finger^{-1}$	1000 grain weight (g)	Yield (t ha^{-1})
Plant height at PM (cm)	1.000								
Tillers m^{-2} at harvest	0.798	1.000							
LAI at 60 DAT	0.578	0.720	1.000						
DMP at harvest ($g\ m^{-2}$)	0.922	0.821	0.701	1.000					
Ears m^{-2}	0.746	0.956	0.852	0.756	1.000				
Fingers ear^{-1}	0.584	0.763	0.840	0.829	0.745	1.000			
Seeds $finger^{-1}$	0.868	0.833	0.778	0.858	0.867	0.680	1.000		
1000 grain weight (g)	-0.193	-0.384	-0.413	-0.106	-0.454	-0.231	-0.197	1.000	
Yield (t ha^{-1})	0.883	0.842	0.857	0.923	0.860	0.828	0.883	-0.351	1.000

Fig. 2. Correlation studies between growth, yield parameters and yield of organic finger millet. PM- Physiological maturity, LAI- Leaf Area Index, DAT- Days after transplanting, DMP- Dry matter production.

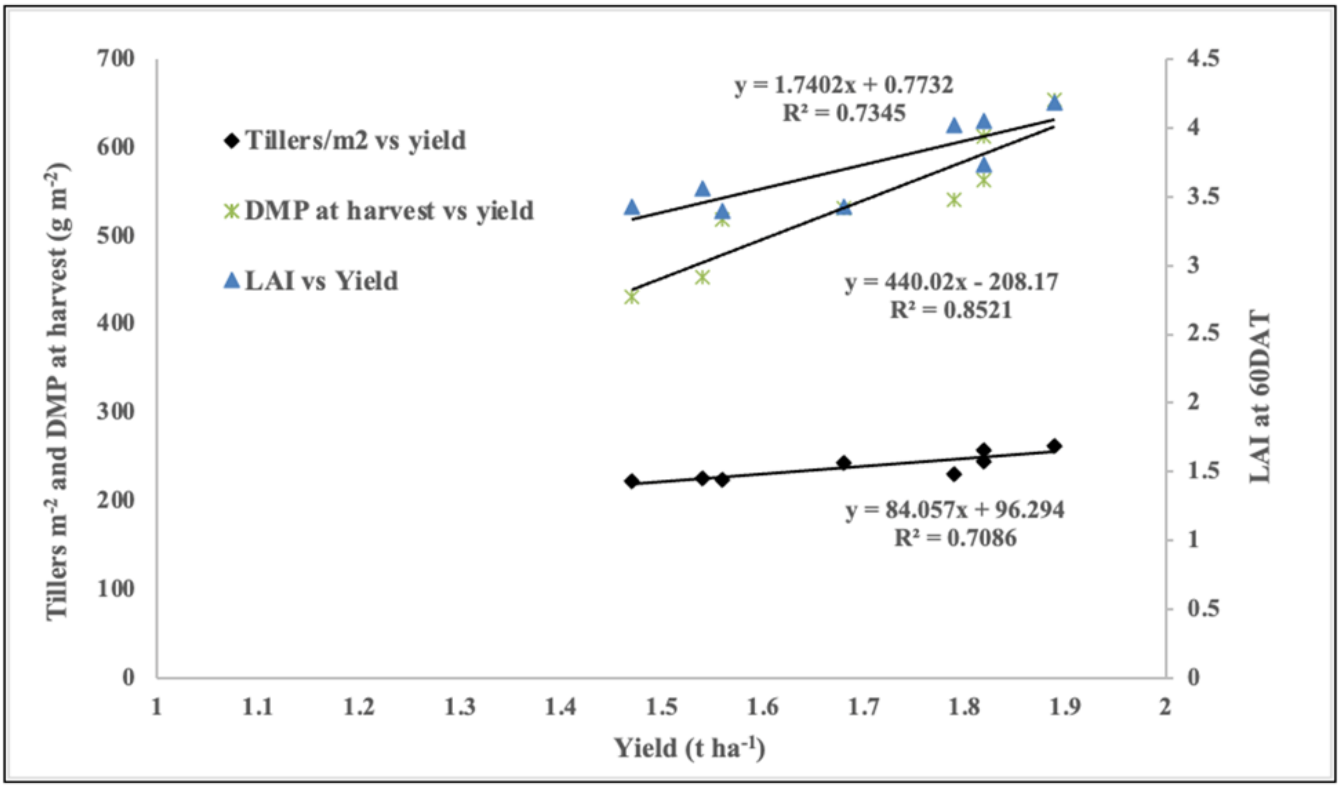

Fig. 3. Regression equations between tillers m^{-2}, dry matter production at harvest and leaf area index vs yield of organic finger millet.

be attributed to their genetic makeup. The manuring practices with excess quantities of neem oilcake and vermicompost recorded maximum values of growth parameters (Table 1). Similar findings have been reported, indicating that the application of FYM @ 2.5 t ha^{-1} + VC @ 1 t ha^{-1} resulted in higher growth parameters values compared to the application of FYM alone in organic finger millet (17). Since crop growth is predominantly influenced by nitrogen, the application of an optimal quantity of nitrogen enhanced N metabolism, cell division, cell elongation and dry matter production (18). The microbial diversity in vermicompost enhanced enzymatic activities, facilitated nutrient release, and improved crop health (19). Neem oilcake suppressed the activity of nitrifying bacteria, minimized nitrate leaching in porous soil, and increased nitrogen availability for crop use, thereby further improving crop growth (7).

Yield attributes

The four finger millet cultivars influenced all the yield attributes, namely ears m^{-2}, fingers earhead^{-1} and seeds finger^{-1} significantly, except for 1000-grain weight (Table 2). Yield attributes of finger millet are varietal features, and under a given environment with adequate management practices, the cultivars flourish according to their inherent genetic potential. It has been reported that under rainfed conditions in farmer's field fingers ear^{-1} of 10.8 and 1000-grain weight of 3.19g were observed in cv. 'Arjuna' with a recommended package of practices (20). The cv. 'Arjuna' (C_1) in the present experiment has recorded comparatively less fingers ear^{-1} and test weight due to raising of the crop under organic environment. Varietal variation in yield attributes in finger millet has been reported earlier by several researchers (14, 16, 21).

The higher values of yield attributes under recommended nitrogen applied through FYM (RDN_{40}) + NOC (RDN_{30}) + VC (RDN_{30}) were attributed to the beneficial effect of applying a higher proportion of NOC and VC. Earlier reports indicated that higher values of yield parameters in finger millet were observed with the combined application of FYM (RDN_{50}) as basal and vermicompost (RDN_{50}) as top-dressing which enabled continuous and steady supply of macro and micronutrients as per the crop demand (9). Nutrients supplied through FYM @ 2.5 t ha^{-1} + VC @ 1 t ha^{-1} could have released adequate nutrients into the soil solution to match the required absorption pattern of the crop resulted in superior growth and yield attributing characters of finger millet (17).

Grain yield

In the case of finger millet, grain yield is a function of number of ears m^{-2}, number of fingers ear^{-1}, grains finger^{-1} and 1000- grain weight. In the present experiment, the cultivars did not differ significantly in the test weight of grains. The cultivars, namely cv. 'Chilika' (C_3) and cv. 'Kalua' (C_4) recorded higher grain yield than cv. 'Arjuna' (C_1) and cv. 'Bhairabi' (C_2) due to higher value of yield attributes like ears m^{-2}, fingers ear^{-1} and grains finger^{-1} which in turn, were the reflection of superior growth parameters. Further, cv. 'Chilika' (C_3) and cv. 'Kalua' (C_4), due to being comparatively longer in duration, accumulated more photosynthates that ultimately resulted in higher grain yield. Similar findings were reported in cv. 'RAU 8' with more growth duration resulted in better yield due to more accumulation of heat units (14). Varietal variation in yield and associated yield attributes among finger millet cultivars were reported earlier by researchers (16, 21).

Application of recommended dose of nitrogen (RDN) i.e., 50 kg ha^{-1} supplied through varying percentage of organic manures viz., farmyard manure (FYM), neem oilcake (NOC) and vermicompost (VC) resulted in higher grain yield than RDN supplied through FYM alone (Table 3). Higher grain yield of organic finger millet was reported with application of FYM (RDN_{50}) as basal + vermicompost (RDN_{50}) as top dressing than FYM (RDN_{100}) at Bhubaneswar, Odisha (9). The increased grain yield under application of FYM @ 2.5 t ha^{-1} + VC @ 1 t ha^{-1} was a result of beneficial effect of both FYM and VC over FYM alone with better growth and yield components in organic finger millet (17).

Protein and minerals in grain

The cultivars failed to significantly influence protein content but exerted significant influence on calcium and iron content of finger millet (Table 4). The varietal variation in protein content aligns with findings showing the protein content ranging from 6.53% in cv. 'WWN-10' to 7.47% in cv. 'GN-4' (22). In another study, protein content of finger millet cultivars varied from 6.26% (local PBL 1) to 10.5% (improved Boneya) (23). Protein content varied between 6.8-7.3% in six cultivars grown in Nepal (24).

Varietal differences in calcium content from 0.90 to 1.40% and in iron content from 46.1 to 105.03 ppm have been reported earlier in finger millet (22). Varietal variation for calcium content ranging from 50.66-319 mg 100 g^{-1} and for iron content ranging between 4.59 to 53.39 mg 100 g^{-1} have also been reported (23).

The higher protein, calcium and iron content was recorded with the recommended N applied through combination of FYM, NOC and VC than FYM alone. Better availability of nitrogen under these combinations resulted in higher protein and mineral contents in finger millet grain. The trend of treatments for protein, calcium and iron yield was more or less similar to treatment trend of grain yield in finger millet as the yield of protein and minerals was computed by multiplying grain yield by the respective nutrient content.

Economics

The experimental findings indicated that both cultivars and organic nutrient management practices significantly influenced various economic parameters of finger millet (Table 6). A higher net return was reported in the cultivars associated with higher yield during the experiment (14). Varietal variation for economic parameters has been reported earlier in cv. 'Arjuna' and cv. 'Bhairabi' with a net return of Rs. 31332 and 21289 ha^{-1} and benefit cost ratio of 2.4 and 1.9, respectively (20). Among nutrient management practices, the application of a combination of manure sources i.e., FYM, NOC and VC incurred higher cost of cultivation than application of FYM alone, although the net return under the combination of manures was higher than FYM alone because extra expenditure for combination increased grain and straw yield. Each additional rupee invested in the combination yielded higher dividends. Such variation in cost of cultivation, gross return and net return with respect to different organic sources of nutrients has been reported due to differences in inputs and their prices (17).

Correlation and regression studies

The significant positive correlation between grain yield and the growth parameters, namely plant height, tillers m^{-2}, LAI, dry matter production, and yield attributes, namely ears m^{-2}, fingers ear^{-1} and seeds finger^{-1} confirmed these parameters as key determinants of grain yield for finger millet. The positive relationship between growth and yield parameters also revealed the importance of creating superior growth parameters to achieve better yield attributes in finger millet.

Conclusion

The experiment aimed to assess the effects of four cultivars and four nutrient management practices on growth, productivity and quality parameters of organic finger millet, and the crop nitrogen demand was met through a single manure source (farmyard manure) or combination of manure sources (farmyard manure, neem oilcake and vermicompost). The cv. 'Chilika' and cv. 'Kalua' were comparable in terms of grain and protein yield and proved to be superior to other cultivars, whereas cv. 'Kalua' was better than other cultivars for calcium and iron yield. The manure combination FYM (RDN_{40}) + NOC (RDN_{30}) + VC (RDN_{30}) excelled in other combinations for yield and quality. The study concludes that farmers should grow cv. 'Kalua' of finger millet with the integrated application of FYM, neem oilcake and vermicompost @ 20, 15 and 15 kg nitrogen ha^{-1}, respectively, for maximizing grain yield, net return and yield of protein, calcium and iron under organic farming conditions of Odisha. The findings provide valuable guidelines on cultivar choice and nutrient management for organic finger millet growers.

Acknowledgements

We express our gratitude to the Faculty of Agricultural Sciences, SOADU for providing financial support to conduct the experiment in the Agricultural Research Station, Binjhagiri and to use their laboratory facilities for chemical analysis.

Authors' Contributions

RKS, SDB and BB conceptualized and designed the research work. RKS, SDB and SSM carried out field/lab experiments and collected data. SD and BB analysed and interpreted the data statistically. SDB, JJ and GM prepared the original manuscript and figures. All authors read and approved the final manuscript.

Compliance with Ethical Standards

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

Ethical issues: None

References

1. Agricultural statistics at a glance. Directorate of Economics and Statistics, Department of Agriculture and Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Government of India; 2021.
2. Chethan S, Malleshi NG. Finger millet polyphenols: Optimization of extraction and the effect of pH on their stability. Food Chem. 2007;105(2):862–70. https://doi.org/10.1016/j.foodchem.2007.02. 012
3. Devi PB, Vijayabharathi R, Sathyabama S, Malleshi NG, Priyadarisini VB. Health benefits of finger millet (*Eleusine coracana* L.) polyphenols and dietary fiber: A review. J Food Sci Technol. 2014;51:1021–40. https://doi.org/10.1007/s13197-011-0584-9
4. Puranik S, Kam J, Sahu PP, Yadav R, Srivastava RK, Ojulong H, et al. Harnessing finger millet to combat calcium deficiency in humans: Challenges and prospects. Front Plant Sci. 2017;8:1311. https://doi.org/10.3389/fpls.2017.01311
5. APEDA. E-catalogue for export of millets and value-added products-Odisha, Ministry of Commerce and Industry, Govt of India; 2023. p. 8.
6. Vel Murugan A, Swarnam TP. Nitrogen release pattern from organic manures applied to an acid soil. J Agric Sci. 2013;5 (6):174–84. https://doi.org/10.5539/jas.v5n6p174
7. Abeka H, Lawson IY, Nartey E, Adjadeh T, Asuming-Brempong S, Bindraban P, et al. Effectiveness of neem materials and biochar as nitrification inhibitors in reducing nitrate leaching in a compost-amended Ferric Luvisol. Front Soil Sci. 2022;2:1023743. https://doi.org/10.3389/fsoil.2022.1023743
8. Olle M. Review: Vermicompost, its importance and benefit in agriculture. J Agric Sci. 2019;2:93–98. https://doi.org/10.15159/jas.19.19
9. Bandita S, Tripathy S, Bastia DK, Jena S, Sahoo SK. Effect of establishment methods and organic nutrient management practices on productivity and profitability of finger millet (*Eleusine coracana* L.) in lateritic soils of Odisha. Int J Plant Soil Sci.2022;34(24):1200–07.https://doi.org/10.9734/ijpss/2022/v34i243126
10. Tsen CC, Martin EE. A note on determining protein contents in various wheat flours and flour streams by the Kjeldahl and by neutron-activation methods. Cereal Chem. 1971;48:721–26.
11. Piper CS. Soil and plant analysis. Scientific Publishers; 2019.
12. Lindsay WL, Norvell WA. Development of a DTPA soil test for zinc, iron, manganese and copper. Soil Sci Soc Am J. 1978;42 (3):421–28. https://doi.org/10.2136/sssaj1978.03615995004200030009x
13. Gomez KA, Gomez AA. Statistical procedure for agricultural research. 2nd ed. John New York: Wiley and Sons; 1984.
14. Singh MK, Kumar V, Prasad S. Evaluation of finger millet varieties under rainfed region of Eastern India: Evaluation of finger millet varieties under rainfed region of South Bihar. J Agri Search. 2017;4(3):179–83. https://doi.org/10.21921/jas.v4i03.9018
15. Alemayehu B, Zeleke L, Jifara G. Adaptation trial of finger millet (*Eleusine coracana* L. Gaertn) varieties in East Hararghe zone, Ethiopia industry. Int J Agric Life Sci. 2023;9(4):423–27. https://doi.org/10.22573/spg.ijals.023.s122000118
16. Triveni U, Nagarjuna D, Rani YS, Anuradha N, Patro TS. Performance of improved short duration finger millet genotypes in red sandy loamy soils of North coastal zone of Andhra Pradesh at graded doses of NPK fertilizers. Int J Chem Stud. 2020;8(4):1130–32. https://doi.org/10.22271/chemi.2020.v8.i4i.9756
17. Das H, Sial P, Dash SR, Dalei BB, Behera TK. Effect of different crop establishment methods and organic sources of nutrients on finger millet in Southeastern Ghat zone of Odisha, India. J Sci Res Reports. 2024;30(5):91–98. https://doi.org/10.9734/jsrr/2024/v30i51925
18. Pramanick B, Choudhary S, Kumar M, Singh SK, Jha RK, Singh SK, et al. Can site-specific nutrient management improve the productivity and resource use efficiency of climate-resilient finger millet in calcareous soils in India? Heliyon. 2024;10:e32774. https://doi.org/10.1016/j.heliyon.2024.e32774
19. Pathma J, Sakthivel N. Microbial diversity of vermicompost bacteria that exhibit useful agricultural traits and waste management potential. Springer Plus. 2012;1:1–9. https://doi.org/10.1186/2193-1801-1-26
20. Dash SR, Mishra PM, Rai AR, Das HD, Rautray BR. A comparative study on yield performance of finger millet varieties under rainfed conditions in Southeastern Ghat zone of Odisha. J Adv Agric Hort Res. 2021;1(1):17–23. https://doi.org/10.55124/jahr.v1i1.63
21. Sarawale PP, Rajemahadik VA, Shendage GB, Mane SV. Effect of different varieties and establishment methods on growth and yield of finger millet [*Eleusine coracana* (L.) Gaertn.] under Konkan condition. J Indian Soc Coastal Agric Res. 2016;34(2):22–26.
22. Patil HE, Patel BK, Pali V. Nutritive evaluation of finger millet [*Eleusine coracana* (L.) Gaertn.] genotypes for quality improvement. Int J Chem Stud. 2019;7:642–46.
23. Admassu S, Teamir M, Alemu D. Chemical composition of local and improved finger millet [*Eleusine corocana* (L.) Gaertn] varieties grown in Ethiopia. Ethiopian J Health Sci. 2009;19(1):1–7.
24. Shrestha K, Karki DB. Evaluation of nutritional composition of Nepalese finger millet (*Eleusine coracana* L.). Acta Sci Nutr Health. 2019;3(1):70–74.