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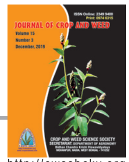

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Performance of finger millet [*Eleusine coracana* (L.) Gaertn.] under integrated nutrient management in the Southern Laterites of Kerala

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ABSTRACT

A field study was undertaken in the sandy clay loam soils of the Southern Laterites in Kerala, India, during the summer season of 2020-2021, to assess the effect of integrated nutrient management on the growth and yield of finger millet (Eleusine coracana (L) Gaertn.).*The treatments comprised 10 combinations of five levels of nutrient substitution, with and without plant growth promoting rhizobacteria Mix I. Plant height and tiller count recorded with 100 per cent recommended dose of fertilizers (RDF) as inorganic and 75 per cent as inorganic + 25 per cent as vermicompost were comparable. The number of days taken by the crop to reach 50 per cent flowering stage was significantly more when the entire recommended dose of fertilizers was applied as organic. However, this was not reflected in the yield. Total dry matter was significantly higher when 75 per cent of RDF was applied as vermicompost along with the application of PGPR Mix I. Substituting 25 per cent of RDF with vermicompost in combination with plant growth promoting rhizobacteria Mix I resulted in significantly higher grain yield (1504 kg ha^{-1}) in finger millet.*

Keywords: Finger millet, integrated nutrient management,plant growth promoting rhizobacteria

Among millets, finger millet (*Eleusine coracana* (L.) Gaertn.), commonly known as *Ragi* ranks fourth in significance following sorghum, pearl millet and fox tail millet (Upadhyaya *et al*., 2007). In finger millet, the yield gap has been reported to be more than 40 per cent between the low and the best performers (Sakamma *et al*., 2018) and they had identified lack of proper and balanced nutrition as one of major reasons for the low productivity of finger millet. Therefore, integrated nutrient management (INM) can provide proper nutrition ensuring balanced nutrient availability to the crop and sustain both crop productivity as well as soil health. INM practices play a greater role in boosting yield of finger millet with improvement of soil health (Maitra *et al*., 2020). Being a low-input requiring crop, finger millet has been reported to respond well to nutrient application and organic nutrition (Ullasa *et al*., 2017) and it can also be raised purely as organic (Gull *et al*., 2014). Plant growth promoting rhizobacteria (PGPR) have been identified to possess positive impact on the growth, yield and nutrient uptake of crops through various mechanisms. They also help crops like millets to overcome moisture stress under rainfed conditions. Compared to the other important cereal crops, information on INM strategies utilizing indigenous resources and plant growth promoting rhizobacteria (PGPR) as biofertilizer are scarce in finger millet. Given this background, the present investigation was undertaken to identify the response of finger millet to various combinations of organic and inorganic nutrition, supplemented with PGPR in terms of growth and yield.

The experiment was conducted at the Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram, Kerala, India, in summer season (January - April) of 2020-'21. The soil of the experimental site was sandy clay loam (45.83% coarse sand, 9.75% fine sand, 8.42% silt, 34.12% clay) in texture, moderately acidic (pH 5.65), medium in organic carbon (1.11%), low in available nitrogen (248.74 kg ha^{-1}), high in available phosphorus (290.86 kg ha^{-1}) and medium in available potassium status (222.24 kg ha^{-1}). Finger millet, variety PPR 2700 (Vakula) from Acharya N.G. Ranga Agricultural University, Andhra Pradesh, was chosen for the study.Vakula is a short duration (100 to 105 days) medium-tall variety with large, compact ear head, tolerance to terminal drought and blast disease and resistance to pink stem borer. The investigation was laid out in factorial randomized block design with 10 treatments, replicated thrice. The treatments comprised of combinations of five levels of nutrient substitution *i.e*., S_1(100 % recommended dose of fertilisers (RDF) as inorganic), S_2 (75% recommended dose of nitrogen (RDN) as inorganic + 25% RDN as vermicompost), S_3 (50% RDN as inorganic + 50% RDN as vermicompost), S_4 (25% RDN through inorganic + 75% RDN as vermicompost) and S_5(100 % RDF as organic manures, half as farm yard manure (FYM) and rest half as vermicompost on nitrogen equivalent basis) and two levels of biofertilizer *i.e*., B_0(without PGPR Mix I) and B_1 (with PGPR Mix I). PGPR Mix I is a microbial consortium containing 10^8 colony forming units (cfu) each of *Azospirillum lipoferum*, *Azotobacter chroococcum*, *Bacillus megaterium* and *Bacillus sporothermodurans*, developed and commercialised by the Department of Agricultural Microbiology, College of Agriculture, Vellayani.The crop was direct sown

Short Communication

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Table 1: Effect of integrated nutrient management on the growth attributes of finger millet

Treatment	Plant height			Tillers plant^{-1}			Days taken		Total dry matter production (aerial) (kg ha^{-1})	Leaf area index		
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest	50 % flowering	50% Maturity		30 DAS	60 DAS	At harvest
Levels of nutrient substitution (S)												
S_1	58.03	87.33	97.73	2.13	3.12	4.67	56.33	93.33	3588	0.542	3.187	4.087
S_2	56.13	85.67	96.80	2.10	2.90	4.35	58.17	96.50	4048	0.513	2.907	3.940
S_3	52.37	84.23	91.40	1.83	2.73	4.14	59.32	94.00	3679	0.505	2.533	3.533
S_4	52.03	83.03	86.98	1.73	2.57	4.15	58.31	99.33	4270	0.482	2.330	3.373
S_5	50.30	81.90	80.93	1.60	2.67	3.87	60.33	96.64	3771	0.465	2.065	3.003
SE m (±)	**0.75**	**0.54**	**0.66**	**0.07**	**0.08**	**0.07**	**0.74**	**1.88**	**105**	**0.008**	**0.055**	**0.045**
LSD (0.05)	**2.251**	**0.768**	**1.968**	**0.221**	**0.243**	**0.213**	**2.209**	**NS**	**313.6**	**0.0231**	**0.1642**	**0.1330**
Biofertilizer (B)												
B_0	52.77	82.84	88.29	1.60	2.28	3.98	58.47	95.40	3768	0.487	2.169	3.189
B_1	54.68	86.03	93.25	2.16	3.31	4.49	58.53	96.53	3975	0.515	3.039	3.986
SE m (±)	**0.48**	**0.34**	**0.42**	**0.05**	**0.05**	**0.05**	**0.47**	**1.19**	**66**	**0.005**	**0.035**	**0.028**
LSD (0.05)	**1.424**	**0.486**	**1.245**	**0.140**	**0.153**	**0.135**	**NS**	**NS**	**198.4**	**0.0141**	**0.1040**	**0.0840**
Levels of nutrient substitution (S) x Biofertilizer (B)												
S_1B_0	57.20	85.67	94.60	2.00	2.67	4.43	56.34	91.00	3694	0.517	2.767	3.847
S_1B_1	58.87	89.00	100.87	2.28	3.54	4.91	56.32	95.68	3482	0.567	3.607	4.327
S_2B_0	54.73	84.07	94.27	1.66	2.48	4.10	58.00	97.34	4013	0.500	2.540	3.643
S_2B_1	57.53	87.27	99.34	2.54	3.33	4.62	58.33	95.67	4082	0.527	3.273	4.237
S_3B_0	51.53	82.60	89.93	1.53	2.28	3.93	59.00	94.02	3342	0.487	1.897	2.893
S_3B_1	53.20	85.87	92.87	2.12	3.20	4.33	59.68	94.04	4016	0.523	3.170	4.173
S_4B_0	51.40	81.80	84.76	1.47	2.06	3.83	59.00	97.00	4215	0.467	1.807	2.833
S_4B_1	52.67	84.27	89.20	2.00	3.07	4.48	57.67	101.64	4326	0.497	2.853	3.913
S_5B_0	49.00	80.07	77.88	1.33	1.93	3.60	60.00	97.67	3575	0.467	1.837	2.727
S_5B_1	51.60	83.73	84.00	1.87	3.40	4.12	60.67	95.68	3966	0.463	2.293	3.280
SE m (±)	**1.06**	**0.76**	**0.93**	**0.10**	**0.12**	**0.10**	**1.04**	**2.66**	**148**	**0.011**	**0.076**	**0.063**
LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**0.2321**	**0.1880**

Table 2 : Effect of integrated nutrient management on yield attributes and yield of finger millet

Treatment	Productive tillers $plant^{-1}$	Fingers ear^{-1}	Grain yield per plant (g)	1000 grain weight (g)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harves tindex
Levels of nutrient substitution (S)							
S_1	1.82	7.88	5.84	3.43	1291	2930	0.31
S_2	2.22	8.73	6.18	3.47	1381	3382	0.29
S_3	1.77	8.11	5.65	3.75	1240	3089	0.29
S_4	1.90	7.67	5.99	3.70	1332	3693	0.27
S_5	1.93	7.02	5.11	3.46	1185	3251	0.27
SE m (±)	**0.10**	**0.36**	**0.14**	**0.19**	**18**	**120**	**0.08**
LSD (0.05)	**0.302**	**1.073**	**0.431**	**NS**	**54.9**	**359.4**	**0.025**
Biofertilizer (B)							
B_0	1.75	7.29	5.43	3.65	1182	3251	0.29
B_1	2.11	8.47	6.08	3.48	1389	3287	0.30
SE m (±)	**0.06**	**0.23**	**0.09**	**0.12**	**12**	**76**	**0.01**
LSD (0.05)	**0.191**	**0.679**	**0.273**	**NS**	**34.8**	**NS**	**0.016**
Levels of nutrient substitution (S) x Biofertilizer (B)							
S_1B_0	1.75	7.46	5.66	3.40	1244	3102	0.29
S_1B_1	1.90	8.28	6.02	3.48	1338	2759	0.33
S_2B_0	1.82	8.60	5.71	3.60	1257	3464	0.27
S_2B_1	2.63	8.86	6.64	3.33	1504	3299	0.32
S_3B_0	1.53	7.40	5.02	3.62	1072	2859	0.27
S_3B_1	2.00	8.82	6.27	3.87	1407	3318	0.29
S_4B_0	1.74	6.67	5.71	4.00	1257	3702	0.25
S_4B_1	2.07	8.68	6.27	3.40	1406	3683	0.28
S_5B_0	1.93	6.33	5.05	3.60	1080	3126	0.26
S_5B_1	1.98	7.70	5.17	3.34	1291	3376	0.28
SE m (±)	**0.14**	**0.51**	**0.20**	**0.27**	**26**	**170**	**0.12**
LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**77.7**	**NS**	**NS**

(solid row planting) at a seed rate of 5 kg ha^{-1}, maintaining a row-to-row distance of 25 cm. Thinning was done at two-leaf stage of seedlings, so as to provide an intra-row spacing of 15 cm. A fertilizer recommendation of 45: 22.5: 22.5 kg NPK ha^{-1} was followed (KAU, 2016).Urea (46% N), Rajphos (20% P_2O_5) and Muriate of Potash (60% K_2O) were used as the inorganic sources. Nutrient substitution was done on nitrogen equivalent basis of the organic sources *viz*., farm yard manure (0.52% N, 0.20% P_2O_5, 0.43% K_2O) and vermicompost (1.46% N, 0.32% P_2O_5, 0.68% K_2O). PGPR Mix I was mixed with dried and powdered FYM at 2 per cent (w/w) and applied at the time of sowing. All other cultural operations were done as per the package of practices recommended by Kerala Agricultural University (KAU, 2016).

Data on growth, yield attributes and yield were recorded from the net plot area of each plot, leaving two outer rows as border rows. The gross plot and net plot sizes were 5.0m x 4.5m and 4.0m x 3.9m respectively. Harvest index (HI) was calculated as the ratio of economic yield (grain yield) and biological yield (sum of grain and straw yields) by the formula suggested by Donald and Hamblin (1976).The data generated were statistically analyzed using analysis of variance technique (ANOVA) as applied to randomized block design (Panse and Sukhatme, 1985).

The findings revealed that S_1(100% RDF as chemical fertilizers) resulted in the tallest plants with more number of tillers and LAI at 30 DAS (58.03 cm, 2.13 nos, 0.542), 60 DAS (87.33 cm, 3.12 nos, 3.187) and at harvest (97.73 cm, 4.67 nos, 4.087). At 30 DAS and 60 DAS, the treatment S_1 remained at par with $S_2$with respect to plant height.The crop took significantly more number of days to reach 50 per cent flowering (60.33 days) when the entire dose of RDF was applied as organic (S_5) and the least (56.33 days) with S_1. The treatment, S_4(25% RDN as inorganic + 75% as vermicompost) resulted in the highest total dry matter production (4270 kg ha^{-1}). Biofertilizer application (B_1) had profound effect on plant height, tiller production, LAI and total dry matter production (aerial). Application of PGPR Mix I (B_1) resulted in significantly taller plants with more number of tillers and LAI at 30 DAS (54.68 cm, 2.16 nos, 0.515), 60 DAS (86.03 cm, 3.31 nos, 3.039) and at harvest (93.25 cm, 4.49 nos, 3.936) than without biofertilizer (B_0). The treatment combination, S_1B_1 recorded superior LAI at 60 DAS (3.607) and at harvest (4.327). While at harvest, S_2B_1 was found to be comparable with S_1B_1.

The productive tiller count (2.22 per plant), fingers per ear (8.73 nos.), grain yield per plant (6.18g) and grain yield (1381 kg ha^{-1}) were superior with S_2(75% RDN as inorganic + 25% as vermicompost) The treatment S_4, resulted in significantly higher straw yield (3693 kg ha^{-1}) and it was comparable with S_2 (3382 kg ha^{-1}). Harvest index was significantly higher in S_1 (0.31) and remained comparable with S_2 and S_3. As with the case of growth, yield attributes, yield and harvest index of finger millet increased significantly with the application of PGPR Mix I (B_1). Among the interactions, the treatment combination, S_2B_1 recorded significantly higher grain yield (1504 kg ha^{-1}).

The effect of inorganic fertilizers could be attributed to the increase in the nutrient ion concentration in the soil solution and higher availability of nutrients resulting in better nutrient uptake. Similar observation was made by Nigade and More (2013). However, INM resulted in higher yield and total dry matter production. Integrating inorganics and organics might have resulted in a balanced nutrient supply, improved the soil moisture retention capacity and in turn alleviated the moisture stress in the plants, leading to optimum photosynthetic activity and greater accumulation of photosynthates (Basavaraju and Purushotham, 2009; Choudhary and Suri, 2014). Further, the increased nitrogen availability through mineralization of organic sources might have also resulted in better root : shoot ratio supporting the uptake of other nutrients also. Higher yield on account of INM could also be attributed to the rhizospheric modulation leading to enhanced microbial activity, sustained nutrient availability and better assimilation of the applied nutrients, as suggested by Chaudhari *et al.* (2011).The nitrogen fixing and phosphorus solubilising effects of the microorganisms in the PGPR consortium might have conferred the crop with a well developed root system. This coupled with better availability of nutrients might have improved the growth of finger millet. PGPR Mix I might have also affected the growth of finger millet through the production of plant growth promoting hormones like IAA, giberellic acids and cytokinins. Similar effect of biofertilizer has been reported by Gautam (2000).

Application of 75 per cent of the recommended dose of fertilizers (45:22.5:22.5 kg NPK ha^{-1}) as inorganic along with 25 per cent as vermicompost on nitrogen equivalent basis, supplemented with the biofertilizer consortium PGPR Mix I was found to improve the growth and yield of finger millet in the sandy clay loam soil of the Southern Laterites of Kerala.

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