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Finger Millet System Productivity as Influenced by Liquid Biofertilizer Consortium

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Abstract: Field experiment was conducted at University of Agricultural Sciences, Bangalore to study the significance of liquid bio fertilizer consortium and modes of its application on growth, yield and nutrient uptake by crop and soil fertility of transplanted finger millet. The treatments included 100, 85 and 70 per cent of recommended dose of fertilizers with liquid bio fertilizer consortium through different methods of application *viz.,* seed treatment, soil application and seedling root dip. Application of 100 per cent RDF + combined methods of application with liquid bio fertilizer consortium (seed treatment, soil application and seedling root dip) numbered as the best technology by having obtained having higher plant height at harvest(102.9 cm), tillers per plant (4.2), dry matter accumulation at harvest (52.12 g/plant), grain and straw yield (4080 and 7810 kg/ha, respectively), nutrient uptake (76.57, 36.40 and 76.53 kg nitrogen, phosphorous and potassium/ha, respectively) with slightly higher post-harvest available nutrients in soil (244, 86 and 210 kg N, P_2O_5 and K_2O/ha, respectively) and higher soil microbial count at 50% flowering (52.3 , 38.6 cfu/g× 10^6 and 16.6 cfu/g× 10^3 bacteria, fungi and actinomycetes, respectively). However, this treatment par with 100% RDF + soil application for all the parameters and emerged as most feasible treatment from the perspective of higher profitability and practical feasibility.

Keywords: Finger millet, Liquid bio fertilizer, Consortium, Application, Yield, Microbes, Nutrients

The agriculture sector is considered as one of the economy pillars in many developing nations. However, continuous use of agrochemicals such as chemical fertilizers and pesticides in this sector is detrimental to fertility status of soil. The frequent usage of chemical fertilizer will also cause soil compaction which negatively affects the crop roots, making them unable to acquire nutrients. Damage caused by chemical fertilizers is often long-term and cumulative, hence there is need to consider alternative and sustainable methods and soil application of liquid bio fertilizer can play vital role. Application of liquid bio fertilizer consortium along with inorganic fertilizers have received a considerable amount of attention as the microbes in consortium are effective in promoting plant growth by secreting phyto hormones, metabolites and plays vital role in enhancing yield, uptake of nutrients by crop and fertility status of soil. Liquid bio fertilizer consortium contains *Azospirillum lipoferum* (nitrogen fixer), *Bacillus megaterium* (phosphorous solubilising bacteria) and *Frateuria aurantia* (potassium solubilising bacteria). *Azospirillum* enhance non-legume plant growth by directly affecting plant metabolism. Phosphorus is abundant in soil but present in complex unavailable forms hence it is exploited by application of phosphate solubilising microbes. The potassium is made available to plants when the minerals are slowly solubilised by potassium solubilising microbes. In India, Finger millet is grown in an area of 12.18 lakh ha with a production of 17.10 lakh tons and a productivity of 1396 kg ha^{-1}. Karnataka is the largest producer of finger millet in India and grown in 8.46 lakh ha with an annual output of 11.26 lakh tons and a productivity of 1332 kg ha^{-1} (Indostat 2022). Because of continuous cropping, inadequate crop residue recycling, and low rates of organic matter application, most soils in semi-arid tropics where finger millet is grown are deficient in macro and micronutrients, which can limit its yield potential (Rao et al 2012 and Sukanya et al 2022, 2023). The integrated nutrient management is an important approach for increasing productivity. Despite the fact that farmers regard finger millet as a low-fertilizer demanding crop, but crop also responds well to fertilizer application Rurinda et al (2014) and Lavanya et al *(*2018). Thus, the present investigation is carried out to assess effect of liquid bio fertilizer consortium on growth, yield, nutrient uptake and fertility status of soil.

MATERIAL AND METHODS

Field experiment on Effect of liquid bio fertilizer consortium on growth, yield, nutrient uptake and soil fertility of transplanted finger millet was conducted during summer 2020 and 2021 at Zonal Agriculture Research Station (ZARS), University of Agricultural Sciences, GKVK, and

Bangalore. Experimental site had red sandy loam, slightly acidic pH, low organic carbon content (0.34%), low available nitrogen (225.9 kg/ha), high phosphorus (66.3 kg/ha) and medium potassium (199.6 kg/ha). The experimental location comes under semi-arid tropical climatic condition, 924 metre above mean sea level, minimum temperature 18.2^{0}C and maximum temperature 29.8^{0}C, minimum relative humidity 50.7% and maximum relative humidity 87.4%, and receives a normal rainfall of 920 mm and the location is falling under Eastern dry zone of Karnataka. Randomized complete block design was adopted in the experiment with three replications. Liquid biofertilizer consortium contained *Azopirillum lipoferum* (nitrogen fixer), *Bacillus megaterium* (phosphorous solubilising bacteria) and *Frateuria aurantia* (potassium solubilizing bacteria) which were procured from the Department of Microbiology, College of Agriculture, GKVK, Bangalore. The liquid bio fertilizer (5 ml) was mixed with equivalent quantity of 10 per cent jaggery solution for one kg of the seed and mixture has been coated uniformly on seed and exposed for drying in shade for 10 minutes before sowing for seed treatment (Trimurtulu and Rao 2014). The 625 ml of liquid bio fertilizer was used for one hectare of main field and was diluted with 25 litres of water and then mixed with 500 kg of powdered farm yard manure incubated overnight. This mixture was applied at the time of transplantation in the furrows below the seed surface (Khandare et al 2020) and for the seedling dip, 500 ml of liquid bio fertilizer mixed with 25 litres of water and the root portion of the seedlings meant for 1 hectare were dipped for 20 minutes just before transplanting (Poorniammal et al 2020). Fertilizers were provided through urea, di-ammonium phosphate and muriate of potash to meet nitrogen, phosphorus and potassium requirement, respectively of the crop as per the treatments. The observations on growth and yield parameters were recorded, nutrient uptake and available soil nutrients were computed. The soil available nitrogen was estimated by following the procedures of alkaline potassium permanganate method (Subbiah and Asija 1965). Available phosphorus in soil was calculated using Bray's method (Jackson 1967) while, the available potassium was using ammonium acetate and calculated using Hange's flame photometer (Jackson 1967). The count of bacteria was assessed using the serial dilution pour plate method (Gerhardt et al 1981) and the actinomycetes count was assessed using the serial dilution pour plate method (Nonomura and Ohara 1969). The number of fungi was counted using the serial dilution pour plate method (Kanwar et al 1997). The recorded data for different characteristics were subjected to statistical analysis adopting the method of analysis of variance.

RESULTS AND DISCUSSION

Plant growth parameter: Significantly higher plant height, tillers per plant and dry matter accumulation at harvest were with the treatment T4:100% RDF + Seed treatment + Soil application + Seedling root dip (103 cm, 4.2 and 52.12 g plant^{-1}, respectively) and was on par to T2:100% RDF + Soil application, T3:100% RDF + Seedling root dip and T8: 85% RDF + Seed treatment + Soil application+ Seedling root dip (Table 1). The higher growth parameter was due to better availability of nutrients which helped the plants to grow profusely. Similarly, rapid initiation of leaves and their expansion ultimately resulted in higher rate of photosynthesis besides higher dry matter accumulation of individual plants. These results are inconformity with the findings of earlier researchers (Meena et al 2013, Panwar et al 2014, Opera et al 2017 and Deepto et al 2022).

Grain and straw yield (kg ha^{-1}): The maximum grain and straw yield (4080 and 7810 kg/ha, respectively) was with 100% RDF + Seed treatment + Soil application + Seedling root dip, which was statistically superior over other treatments but was on par with T2, T3 and T8. However, significantly lesser grain and straw yield was noticed in T14: absolute control (1757 kg/ha and 3710 kg/ha, respectively) and T13:RDF(3245 and 6294 kg/ha, respectively) but T13 was on par with the T10:70% RDF + soil application and T11: 70% RDF + seedling root dip (Table 1). Increased in yield was attained due to overall improvement in crop growth, which further enabled the plants to absorb more nutrients, leading the plants to produce more photosynthates resulted in enhanced yield attributes and finally yield with integration of inorganic fertilizer and consortium. Similar results were obtained with the findings of Opera et al (2017) and Jat et al (2018).

Nutrient uptake: The significantly higher uptake of nitrogen (76.57 kg/ha), phosphorus (36.40 kg/ha) and potassium (76.53 kg/ha) by finger millet was with 100% RDF + Seed treatment + Soil application + Seedling root dip (Table 1) but was with T2, T3 and T8). Significantly the lowest uptake of nitrogen, phosphorous and potassium (32.15, 18.15 and 56.73 kg/ha, respectively) was with absolute control (T14). T4 and T2 registered significant increases in N uptake by grain of 18.56 and 14.86 per cent and straw of 17.96 and 15.35 per cent; P by grain of 15.49 and 14.14 per cent and straw of 22.15 and 17.77 per cent and K by grain of 17.96 and 15.89 per cent and straw of 12.77 and 8.85 per cent, respectively over RDF. Higher nutrients uptake upon application of liquid bio fertilizer is mainly due to co-inoculation of associative nitrogen fixer (*Azospirillum lipoferum*), which fixes atmospheric nitrogen by association with roots whereas phosphorus solubilising bacteria(*Bacillus* *megaterium*) and potassium solubilising bacteria(*Frateuria aurantia*) which can synergistically solubilised P and K in soil and make them ample available for the uptake by plant root and leading to plant growth (Sheng 2005) and also the impact of liquid bio fertilizer is that they are able to grow beyond the depletion zones around the plant roots and increase the uptake of immobile nutrients such as P and K and this result is in accordance with Chelvi (2017) and Deleep and Ravinder (2006) (Table 2).

Soil properties after harvest: Physico-chemical properties of soil *viz.,* pH, electrical conductivity and organic carbon after the harvest of finger millet was not influenced significantly due to various treatments (Table 2). The highest soil available nitrogen, phosphorus and potassium was recorded with application of 100% RDF + combined methods of application (seed treatment, soil application and seedling root dip) (244, 86 and 210 kg/ha, respectively) and followed by T2 and T3 (Table 2). Higher availability of nutrients when compared to RDF and absolute control might be due to microbes in consortia like *Azospirillum lipoferum* (Nitrogen fixer) which fixes atmospheric nitrogen in biological nitrogen fixation process. *Bacillus megaterium* (Phosphorous solubilising bacteria) which solubilizes native fixed P through release of various organic acids during microbial processes and *Frateuria aurantia* which help in solubilizing and mobilizing the native or non-exchangeable form of K and charge the soil solution with K ions, so that it may be readily available in the soil. Similar results are perceived by Sharma et al (2003). This result was also confirmed by the findings of Kamble et al (2018).

Soil Microbial Count at 50% Flowering

Bacterial count: Initial soil bacteria count before transplanting of finger millet was 10.60×10^{6} cfu/g soil and which increased at 50% flowering and observed highest in T4 (52.30×10^{6}cfu/g) which was statistically significantly superior than other treatments (Table 4) and followed by T13 RDF recorded lower bacterial population (26.40×10^{6} cfu/g) than all other treatments except 70% RDF + seed treatment and absolute control. Increased bacterial population was the result of production of root exudates due to the luxuriant growth of crop as reflected by higher dry matter production and finally resulted in higher microbial population and interaction of roots of a plant with its neighbouring plant might have increased the bacterial population with closer density. This result agrees with Badri and Vivanco (2009).

Fungi count: The fungi population was low initially (7.60×10^{4} cfu/g soil) and subsequently increased during stage of 50% flowering in all treatments but the increase was relatively higher in liquid bio fertilizer treatments than absolute control. Application of 100% RDF+ Seed treatment + Soil application + Seedling root dip (T4) recorded higher fungi count (38.60×10^{4}cfu/g soil) which is significantly

Table 1. Influence of liquid biofertilizer consortium and its methods of application on Growth, Yield and Economics of finger millet (Pooled data of 2020 and 2021)

Treatments	Plant height at harvest (cm)	Tillers per plant	Dry matter accumulation (g/plant)	Grain yield (kg/ha)	Straw yield (kg/ha)	Net returns (Rs./ha)	B:C
T_1:100%RDF+Seed treatment	91.6	3.7	45.42	3625	7032	74178	2.96
T_2:100%RDF + Soil application	99.2	4.0	50.78	4025	7718	84668	3.14
T3:100% RDF + Seedling root dip	97.1	3.7	49.35	3938	7560	82520	3.11
T4:100% RDF + Seed treatment + Soil application+ Seedling root dip	102.9	4.2	52.12	4080	7810	84565	3.04
T5: 85 % RDF+ Seed treatment	83.9	3.3	40.78	3178	6260	61206	2.65
T6:85%RDF + Soil application	91.0	3.6	46.14	3590	7016	72137	2.85
T7:85 % RDF + Seedling root dip	89.5	3.5	44.71	3498	6885	69890	2.82
T8: 85% RDF + Seed treatment + Soil application+ Seedling root dip	95.2	3.8	47.48	3648	7038	72013	2.77
T_9:70%RDF+Seedtreatment	76.4	3.8	36.14	2735	5458	48301	2.32
T_{10}:70%RDF+Soilapplication	83.7	3.2	41.50	3148	6191	59226	2.55
T_{11}:70%RDF+Seedlingrootdip	81.9	3.0	40.07	3085	6035	57753	2.53
T_{12}: 85%RDF + Seed treatment+ Soil application+ Seedling root dip	87.6	3.3	42.84	3200	6208	58926	2.47
T_{13}:RDF (100:50:50 N,P_2O_5, K_2O kg ha^{-1}+ 375gazospirillum)	88.5	3.4	43.78	3245	6294	62400	2.65
T_{14}: Absolute control	65.1	2.4	29.27	1757	3710	29771	2.19
CD (p=0.05)	11.2	0.5	6.52	450	855	-	-

superior over other treatments but was at par with T2, T3 and T8. However, RDF) and absolute control treatment recorded lower fungi count than T4, T2, T3 and T8. Increased fungi population was due to root exudation which is positively correlated with root growth, which means actively growing root systems secrete more exudates that mediate positive interactions which include symbiotic associations with beneficial microbes, such as mycorrhizae, rhizobia and plant growth-promoting rhizobacteria (PGPR), thereby increasing fungi population. This result agrees with the studies of Garcia

Table 2. Nutrient uptake of finger millet as influenced by liquid biofertilizer consortium and its methods of application (Pooled data of 2020 and 2021)

Treatments	Nitrogen (kg/ha)			Phosphorous (kg/ha)			Potassium (kg/ha)		
	Grain	Straw	Total	Grain	Straw	Total	Grain	Straw	Total
T_1	45.46	22.86	68.32	16.65	15.45	32.1	46.65	22.25	68.9
T_2	49.48	24.95	74.43	18.56	16.95	35.51	48.95	24.75	73.70
T_3	48.12	23.92	72.04	17.95	16.16	34.11	48.25	23.56	71.81
T_4	50.71	25.86	76.57	19.25	17.15	36.4	51.25	25.28	76.53
T_5	40.62	20.36	60.98	14.85	14.25	29.1	42.35	19.28	61.63
T_6	44.68	22.35	67.03	16.76	15.75	32.51	46.35	22.08	68.43
T_7	43.32	21.42	64.74	16.15	14.96	31.11	43.95	21.06	65.01
T_8	45.91	23.15	69.06	17.18	15.95	33.13	47.86	22.78	70.64
T_9	35.82	17.86	53.68	13.05	13.05	26.1	38.05	16.78	54.83
T_{10}	39.88	19.85	59.73	14.96	14.55	29.51	41.35	19.75	61.1
T_{11}	38.52	18.92	57.44	14.35	13.76	28.11	39.65	18.56	58.21
T_{12}	41.11	20.65	61.76	15.38	14.75	30.13	43.56	20.28	63.84
T_{13}	42.23	21.03	63.26	15.76	14.85	30.61	43.75	20.67	64.42
T_{14}	20.15	12	32.15	9.85	8.3	18.15	43.25	13.48	56.73
CD (p=0.05)	6.25	3.95	7.55	2.50	1.60	3.50	5.50	3.25	7.25

See Table 1 for treatment details

Table 3. Physicho-chemical properties and nutrient status of soil after harvest of Finger millet as influenced by liquid biofertilizer consortium and its methods of application (Pooled data of 2020 and 2021)

Treatments	pH	EC (dsm^{-1})	Organic carbon (%)	Nitrogen (kg/ha)	Phosphorous (kg/ha)	Potassium (kg/ha)
T_1	5.64	0.26	0.35	236	79	205
T_2	5.58	0.27	0.36	242	83	209
T_3	5.60	0.27	0.36	241	82	208
T_4	5.55	0.27	0.36	244	86	210
T_5	5.72	0.25	0.35	227	66	196
T_6	5.65	0.26	0.35	233	71	199
T_7	5.67	0.26	0.35	232	71	197
T_8	5.62	0.26	0.36	236	74	200
T_9	5.79	0.24	0.34	219	53	187
T_{10}	5.73	0.25	0.34	224	59	191
T_{11}	5.75	0.25	0.34	223	58	188
T_{12}	5.70	0.25	0.34	227	61	194
T_{13}	5.72	0.27	0.35	229	63	195
T_{14}	5.93	0.22	0.33	75	46	138
CD (p=0.05)	NS	NS	NS	31	10	28

NS-Non significant
See Table 1 for treatment details

Table 4. Bacterial, fungi and actinomycetes population as influenced by liquid biofertilizer consortium and its methods of application

Treatments	Bacteria (cfu/gX10^6)	Fungi (cfu/gX 10^4)	Actinomycetes population (cfu/gX10^3)
T_1	34.3	34.6	14.0
T_2	46.6	36.6	15.9
T_3	44.9	35.6	15.0
T_4	52.3	38.6	16.6
T_5	27.6	30.3	12.3
T_6	38.4	34.0	13.6
T_7	36.6	32.6	14.6
T_8	43.3	35.0	9.6
T_9	22.6	26.0	11.6
T_{10}	30.9	29.6	10.3
T_{11}	28.3	27.6	12.6
T_{12}	33.9	32.0	10.7
T_{13}	26.4	27.17	11.2
T_{14}	14.3	20.0	6.0
CD (p=0.05)	5.2	3.8	2.1

See Table 1 for treatment details

et al (2001), Saini et al (2004), Badri and Vivanco (2009).

Actinomycetes count: The T4 has recorded significantly higher actinomycetes count (16.60×10^3 cfu/g soil) than initial population (3.30×10^3 cfu/g soil) and was followed by T2, T3 and T8 which were on par with each other (Table 4). Increased actinomycetes population was owing to application of inorganic fertilizers together with liquid biofertilizers favoured the augmentation of microbial population. These results agree with the results of Arbad et al (2008), Padmaja et al (2012) and Goutami et al (2015).

Economics: The highest net return and benefit cost ratio was recorded with T2 treatment which was due to relatively reduced cost of cultivation, higher grain and straw yield and improved growth and yield attributes (Table 1). The results agree with the findings of Mishra et al (2015), Kishor et al (2017) and Patel et al (2018).

CONCLUSION

Over all, the application of 100% RDF +Seed treatment + Soil application + Seedling root dip exhibited higher growth, yield, nutrient uptake, available nutrient status in soil and more microbial population over RDF alone and absolute control treatments. However, the treatment comprising 100% RDF + soil application of liquid biofertilizer consortium emerged as the best treatment from the economical and practical perspective of the results obtained. Hence from the present investigation, 100% RDF with the soil application of liquid bio fertilizer consortium could be endorsed to augment the overall productivity of the system.

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