Impact of P enriched compost on growth and yield attributes of barnyard millet in red and black soils of Madurai district

ABSTRACT

A field study was conducted during the summer (*kharif*) season of 2022 at the Lalapuram village, Thirumangalam block of Madurai district, to assess the influence of phosphorus-enriched compost on the growth and yield parameters of barnyard millet in both red and black soils. The recommend dose of barnyard millet was 40: 20: 0 kg ha $^{-1}$of NPK in which the recommended dose of P (20 kg ha $^{-1}$) was given in form of enriched compost and the enrichment was done at 1 : 10 ratio of P source and compost. Three different types of compost such as farmyard manure compost, municipal solid waste compost and vermicompost were enriched with two different P sources such as single super phosphate @ 100 kg / t of compost and rock phosphate @ 100 kg / t of comopst. Azophos, a plant growth promoting rhizobacteria based microbial consortium was added to the P enriched compost @ 80 kg / ton of compost. Among the different combinations, application of SSP enriched vermicompost @ 750 kg ha $^{-1}$ along with microbial consortium performed better in both the soils. The growth and yield attributes of barnyard millet in black soil was better compared to that of red soil. SSP enriched vermicompost @ 750 kg ha $^{-1}$ along with microbial consortium recorded the highest growth parameters in terms of no. of tillers per plant (8.71), Leaf area index (2.98), root length (20.7 cm) and dry matter production (5260.1 kg ha $^{-1}$) at 60 DAS and yield parameters in terms of no of productive tillers (6.81), panicle length (21.4 cm), panicle weight (14.65 g), 1000 grain weight (3.24 g), grain yield (2250 kg ha $^{-1}$) and stover yield (4420 kg ha $^{-1}$). Hence, it was found that the application of SSP-enriched vermicompost coupled with azophos at 30 and 60 DAS of the crop growth stages, can curtail N and P fertilizer consumption by 50 and 100 percent respectively while fostering sustainable plant growth and enhancement of yield.

Keywords : *Barnyard Millet, FYM, Vermicompost, MSWC*

1. INTRODUCTION

Rapidly increasing population coupled with depleting resources and nutritional insecurity has necessitated the ecological sustainable increase in the overall grain production of the country. According to the recent estimates by the Food and Agricultural Organization of the United Nations (FAO) in order to feed people on large scale, food production has to be increased by 60% by the year 2050 (FAO, 2012) [1]. Agricultural intensification linked with best nutrient management system can help achieve this goal (Heffer *et al.,* 2016) [2]. Improving the nutrient use efficiency of the crop is a prerequisite which can be improved by certain best management practices. Poor fertilizer management practices lower the yield and productivity of crops. In order to attain optimal crop productivity, it is essential to effectively manage nutrients through judicious utilization of bio-fertilizers, organic and inorganic sources. (Ghaffari *et al.,* 2011) [3]

Recognizing the importance of the international year of millets 2023 and realizing the need for conserving the valuable soil resource, this research study was taken up targeting millet as test crop. Millets are the crops that have a high nutritional value and can be produced under marginal soil conditions. They are rich in vitamins and minerals which act as a source of livelihood for many people (Gowri and Shivakumar, 2020) [4]. Cultivation of millets among Indian farmers has declined during the past few decades. The low level of productivity and low economic returns of millets (Bana *et al.,* 2013) [5] are attributed to poor soil nutrient status and moisture stress. (Bana *et al.* 2018 [6]; Mubeena *et al.,* 2019 [7]). Hence one of the important approaches in achieving higher millet yields in rainfed areas are efficient nutrient management techniques (Bamboriya *et al.,* 2017 [8]; Bana *et al.,* 2016 [9]) and there is no systematic information available on nutrient management for various millet crops.

Barnyard Millet (*Echinochloa species*) is one of the small millets crop whose high nutrient content coupled with antioxidant effects make it a suitable functional food crop. It has the potential to offer both food and nutritional security, especially in regions with a high prevalence of nutritional deficiency. Recently, the demand of the crop has increased due to its high nutritional value. Despite its enormous potential, the crop has not gained popularity. (Sood *et al* ., 2015) [10]

Nitrogen (N), phosphorus (P) and potassium (K) are the three important nutrients required by plant for healthy growth. Among these, P is the second limiting nutrient next to nitrogen. Though different forms of P are abundantly present in soil, it is relatively unavailable or not readily available to the plants (Kishore *et al.,* 2015)[11]. P fixation is usually found in both acid and alkaline soil (Hamid *et al.,* 2012) [12]. This deficiency is usually compensated by adding chemical fertilizers. However, the chemical fertilizers are expensive and are not eco-friendly. Irregular usage of chemical fertilizers for a long time decreases soil activity and soil microflora. Usage of microorganisms to augment the P availability is the best alternative. (Kishore *et al.,* 2015)[11].

Addressing the nutritional need of the crop with efficient nutrient management practices is one of the best strategies to improve the availability of nutrients like phosphorous and to enhance the use efficiency of the plant nutrient. Hence barnyard millet being an important nutricereal, is chosen as a test crop and supplied with nutrients through various organic compost inoculated with cheaper microbial sources to enhance the growth, uptake and yield thus ensuring better income for the millet growers and marginal farmers to improve their livelihoods. With this background in a view, an experiment was conducted to evaluate, optimize and standardize the application of P enriched compost along with microbial consortium on the growth and yield of barnyard millet.

2. MATERIALS AND METHODS

A field experiment was conducted during the summer (*kharif*) season of 2023 in the farmers field of Lalapuram village, Thirumanaglam block of Madurai district, Tamil Nadu, India, located at 9° 55.61328' N latitude and 78° 7.82442' E longitude at an altitude of 109 m above sea level to assess the impact of P enriched compost on growth and yield attributes of barnyard millet (*Echinochloa frumentacea*) in red and black soils of Madurai district. The field trial was laid in randomized block design (RBD) with three replications with an individual plot size of 5 × 4 m^2. The black soil of the experimental site was sandy clay loam in texture, with pH 7.9, E C 0.36 dSm^{-1} low in available nitrogen (230 kg ha^{-1}), low in available phosphorus (9.8 kg ha^{-1}) and high in available potassium (280 kg ha^{-1}) whereas the experimental red soil was sandy loam in texture, pH 7.2 , E C 0.30 dSm^{-1} , low in available nitrogen (195 kg ha^{-1}), low in available phosphorus (11.6 kg ha^{-1}) and medium in available potassium (249 kg ha^{-1}). The test crop variety used was MDU - 1. The seeds were sown at a depth of 3-5 cm with the spacing of 22.5 x 10 cm. Different composts namely farmyard manure compost, vermicompost and municipal solid waste compost, enriched with rock phosphate and single super phosphate along with azophos (microbial consortium) were adopted in fourteen different treatmental combinations such as T_1 - Absolute control, T_2 - RDF of 40 :20:0 kg ha^{-1}, T_3 - RP enriched FYM @ 750 kg ha^{-1} with microbial consortium, T_4 - SSP enriched FYM @ 750 kg ha^{-1} with microbial consortium, T_5 - RP enriched FYM @ 750 kg ha^{-1} without microbial consortium,T_6 - SSP enriched FYM @ 750 kg ha^{-1} without microbial consortium, T_7 - RP enriched vermicompost @ 750 kg ha^{-1} with microbial consortium, T_8 - SSP enriched vermicompost @ 750 kg ha^{-1} with microbial consortium, T_9 - RP enriched vermicompost @ 750 kg ha^{-1} without microbial consortium, T_{10} - SSP enriched vermicompost @ 750 kg ha^{-1} without microbial consortium, T_{11} - RP enriched Municipal solid waste compost (MSWC) @ 750 kg ha^{-1} with microbial consortium, T_{12} - SSP enriched Municipal solid waste compost (MSWC) @ 750 kg ha^{-1} with microbial consortium, T_{13} - RP enriched Municipal solid waste compost (MSWC) @ 750 kg ha^{-1} without microbial consortium, T_{14} - SSP enriched Municipal solid waste compost (MSWC) @ 750 kg ha^{-1} without microbial consortium. Same set of treatment combinations were adopted in both red and black soils. In control, recommended N and P fertilizers were applied basally at 86 and 125 kg ha^{-1} as urea and as single super phosphate (SSP) respectively. In all the other treatments only 50 % recommended N (43 kg ha^{-1}) was applied as urea.

2.1 Preparation of Enriched Compost

The composts namely farmyard manure compost, vermicompost and MSWC were enriched with single super phosphate (16 % P_2O_5) and rock phosphate (17.5 % P_2O_5) at 1 :10 ratio i.e 1 t compost was enriched with 100 kg single super phosphate and 100 kg rock phosphate along with 80 kg azophos as per treatment schedule. Finally, each compost heap was plastered with mud and left for a period of 45 days. Before and after the enrichment process, the compost samples were collected and analyzed for total nitrogen content by macro-kjeldhal method as described by Bremner and Mulvaney (1983) [13], total phosphorous content and total potassium content by vanadophosphomolybdate yellow colour method and by flame photometer method (Triacid extract) respectively as mentioned by Jackson (1973) [14]. The enriched composts were applied basally at the rate of 750 kg ha^{-1} as a basal application by mixing 1 kg of compost along with 5 kg of soil in proportion to the plot size of the field trial.

2.2 Crop Observations

Five randomly selected plants were tagged to record the biometric observations. Biometeric observations in terms of plant height, no of tillers / plant, dry matter production, leaf area index and root length were assessed at 30 and 60 DAS in both red and black soils and yield attributes such as number of productive tillers per plant, panicle length, panicle weight, 1000 grain weight, grain yield and stover yield were recorded at maturity stages of crop in both red and black soils.

2.3 Statistical Analysis

The recorded data were statistically analyzed using R software. The subjected data was worked out for standard error of mean (SEm +) and critical difference (CD) to compare the differences between the treatment means.

3. RESULT AND DISCUSSION

3.1 Composition Of Enriched Compost

The data presented in Table 1 demonstrates the changes in the overall NPK (%) content of the enriched compost after the incubation period. The initial NPK (%) contents in farmyard manure compost were 0.62, 0.28 and 0.54 respectively. These values notably increased to 0.94, 1.08, and 0.83 percent, respectively when enriched with single super phosphate (SSP) containing 16% P_2O_5 accompanied by azophos. The incubation of rock phosphate (RP) containing 17.5% P_2O_5 along with azophos in FYM compost resulted in NPK content of 0.87, 0.97, and 0.72 percent. Upon enrichment with SSP and azophos, the NPK contents in vermicompost exhibited an improvement from 0.83, 0.41, and 0.75 to 1.25, 1.32, and 1.03, whereas in the case of RP enriched with azophos, the NPK contents transitioned to 1.08,1.25 and 0.93 percent. Municipal solid waste compost (MSWC) enriched with SSP along with azophos showed a gradual increase from 0.56, 0.35, and 0.42 to 0.81, 0.96, and 0.64 and enrichment with RP along with azophos recorded higher NPK contents of 0.75, 0.86 and 0.59 percent. This gradual surge in nitrogen content after enrichment was attributed to the introduction of azophos, which facilitates biological nitrogen fixation and enhances nutrient availability. The increase in phosphorus content is attributed to the inclusion of SSP and RP. The application of SSP has amplified phosphorus bioavailability due to its inherently soluble nature and organic acids generated by bacterial activity contributed to the solubilization of rock phosphate, thereby increasing the phosphorus content of the enriched compost.

Table 1. NPK content (%) in compost before and after enrichment

Source of enrichment : Single super phosphate (SSP), Rock phosphate (RP) along with Azophos

Organic sources	Before enrichment			After enrichment with SSP and azophos			After enrichment with RP and azophos		
	N	P	K	N	P	K	N	P	K
FYM	0.62	0.28	0.54	0.94	1.08	0.83	0.87	0.97	0.72
Vermicompost	0.83	0.41	0.75	1.25	1.32	1.03	1.08	1.25	0.93

MSWC	0.56	0.35	0.42	0.81	0.96	0.64	0.75	0.86	0.59

3.2 Effect Of P Enriched compost on crop growth parameters

Table 2 illustrates the substantial impact of different nutrient management practices on various growth parameters such as plant height, no of tillers / plant, dry matter production, leaf area index and root length. Significantly T_8 - SSP enriched vermicompost @ 750 kg ha $^{-1}$ with microbial consortium, exhibited the highest values for various growth parameters of the crop. This includes maximum number of tillers per plant 8.71 and 8.53, leaf area index of 2.98 and 2.17, dry matter production of 5260.1 and 5055.1 kg ha $^{-1}$ and root length 20.7 and 13.2 cm at 60 DAS in black and red soils.

The values for various favorable growth parameters were significantly low in treatment T_1 - Absolute control, with 5.19 and 5.10 number of tillers per plant, leaf area index of 1.71 and 1.49, dry matter production of 3210.1 and 2080.7 kg ha $^{-1}$ and root length of 9.8 and 8.5 cm were recorded at 60 DAS in black and red soils

Similar results were reported by Bana et al. (2012) [15]. The observed phenomenal growth with enriched compost application was due to the adoption of integrated nutrient management practices. Use of SSP enriched vermicompost which contains essential macronutrients, releases nutrients at a steady state coinciding with the crop growth stages. This steady supply of nutrients has led to an elevation in the availability of nutrients. Enhanced nutrient availability has triggered the activity of meristematic cells, promoting increased cell division and cell elongation. These physiological alterations are reflected in morphological characters ampliflying the growth attributes of the crop (Patel *et al.,* 2020) [16]. In addition, use of azophos must have helped in mobilizing nutrients such as phosphorous and increased the nutrient availability for plant uptake. It also promoted the production of plant growth-promoting hormones such as auxins, cytokinins, and gibberellins. These hormones play pivotal roles in plant growth by encouraging cell division and elongation ultimately promoting plant and root development.

3.3 Effect Of P Enriched Compost On Yield Attributes

The yield and yield attributes of barnyard millet exhibited significant variations across different treatments, as outlined in Table 3. Among the various treatment combinations, the utilization of SSP-enriched vermicompost at a rate of 750 kg ha $^{-1}$in conjunction with azophos (T_8), resulted in the highest yield attributes. Specifically, this treatment yielded 6.81 and 6.42 numbers of productive tillers with panicle lengths measuring 21.45 and 19.84 cm, panicle weights of 14.65 and 12.35 g, 1000 grain weights of 3.24 and 3.17 g, grain yields of 2250 and 2068 kg/ha, and stover yields of 4420 and 4184 kg ha $^{-1}$ at maturity stage in black and red soils respectively. Absolute control showed notable reduction in yield attributes of the crop. This reduction is evident in the form of a decreased number of productive tillers such as 4.07 and 2.10, accompanied by shorter panicle lengths of 10.10 and 9.12 cm and panicle weight of 8.31 and 5.41 g, while the 1000 grain weight were 1.82 and 1.60 g. Consequently, the grain yield reached 1110 and 1005 kg ha $^{-1}$, while the stover yield amounted to 2514 and 2210 kg ha $^{-1}$ in the context of black soil and red soil respectively.

The observed higher yields and improved yield attributes in the treatment involving SSP-enriched vermicompost at 750 kg ha^{-1} along with azophos. The significant improvement is due to the increased nutrient availability in the soil which ultimately increased the uptake in plants and grains and increased panicle length and weight of the panicles. Similar observation has been made by (Pallavi *et al.,* 2016)[17] The improvement in growth characteristics can be attributed to an increased uptake of nitrogen and the efficient movement of assimilates from source to sink within the plant as the treatments included 50 % of recommendation. This phenomenon has led to the enhancement of various yield-related traits of barnyard millet which reflected in higher grain weight. The N_2 fixation mechanism under N poor environment (low available N of the experimental soil) by azophos is the reasons behind increased plant growth and nutrient uptake which produced more grain weight. Islam et al. (2012) [18] recorded similar results highlighting the use of microbial sources that promoted root and shoot growth of cereals.

Table 2. Effect of enriched composts on growth attributes of barnyard millet at 60 DAS. (Mean of 3 replications)

Treatment	Black soil				Red soil			
	No of tillers / plant	Leaf area index	Dry matter production (Kg ha $^{-1}$)	Root length (cm)	No of tillers / plant	Leaf area index	Dry matter production (Kg ha $^{-1}$)	Root length (cm)
T_1	5.19	1.71	3210.2	9.8	5.10	1.49	2080.7	8.5
T_2	7.01	2.16	3968.6	14.7	6.11	1.66	3872.6	11.9
T_3	7.62	2.49	4751.3	17.6	7.10	1.88	4406.5	14.9
T_4	8.17	2.61	4924.5	18.7	7.41	2.01	4660.8	16.5
T_5	7.14	2.28	4074.9	15.9	6.42	1.72	3996.4	12.5
T_6	6.63	2.09	3846.4	13.2	5.80	1.61	3674.2	11.3
T_7	8.24	2.70	5031.7	19.1	8.01	2.08	4825.5	17.2
T_8	8.71	2.98	5260.1	20.7	8.53	2.17	5055.1	18.2
T_9	7.25	2.32	4261.2	16.4	6.52	1.75	3970.8	12.9
T_{10}	8.41	2.88	5193.9	19.5	8.24	2.12	4895.4	17.4
T_{11}	7.81	2.52	4873.9	18.1	7.21	1.91	4552.1	15.9
T_{12}	7.38	2.39	4437.6	16.6	6.61	1.79	4131.3	13.3
T_{13}	6.38	1.96	3761.5	12.6	5.51	1.54	2560.5	10.7
T_{14}	7.54	2.45	4589.4	17.1	6.92	1.84	4314.5	13.9
sEd	0.112	0.044	28.17	0.186	0.14	0.026	74.95	0.29
CD(P=0.05)	0.24	0.091	60.33	0.42	0.29	0.054	160.01	0.61

T_1 - Absolute control,
T_2 - RDF of 40 :20:0 kg ha $^{-1}$,
T_3 - RP enriched FYM @ 750 kg ha $^{-1}$ with microbial consortium
T_4 - SSP enriched FYM @ 750 kg ha $^{-1}$ with microbial consortium
T_5 - RP enriched FYM @ 750 kg ha $^{-1}$ without microbial consortium
T_6 - SSP enriched FYM @ 750 kg ha $^{-1}$ without microbial consortium
T_7 - RP enriched vermicompost @ 750 kg ha $^{-1}$ with microbial consortium
T_8 - SSP enriched vermicompost @ 750 kg ha $^{-1}$ with microbial consortium
T_9 - RP enriched vermicompost @ 750 kg ha $^{-1}$ without microbial consortium
T_{10} - SSP enriched vermicompost @ 750 kg ha $^{-1}$ without microbial consortium
T_{11} - RP enriched Municipal solid waste compost (MSWC) @ 750 kg ha $^{-1}$ with microbial consortium
T_{12} - SSP enriched Municipal solid waste compost (MSWC) @ 750 kg ha $^{-1}$ with microbial consortium
T_{13} - RP enriched Municipal solid waste compost (MSWC) @ 750 kg ha $^{-1}$ without microbial consortium
T_{14} - SSP enriched Municipal solid waste compost (MSWC) @ 750 kg ha $^{-1}$ without microbial consortium

Table 3. Effect of enriched compost application on yield attributes of barnyard millet in black soil

Treatments	No. of productive tillers per plant	Earhead length (cm)	Earhead weight (g)	1000 grain weight(g)	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})
T_1	4.07	10.10	8.31	1.82	1110	2514
T_2	4.41	14.92	10.58	2.25	1520	3070
T_3	5.53	17.88	11.92	2.75	1780	3760
T_4	6.01	19.16	12.81	2.97	1995	4074
T_5	4.61	15.96	10.98	2.39	1590	3220
T_6	4.20	13.26	10.18	2.12	1430	2815
T_7	6.34	20.75	13.21	3.08	2140	4224
T_8	6.81	21.45	14.65	3.24	2250	4420
T_9	4.82	16.53	11.20	2.48	1650	3290
T_{10}	6.63	20.82	14.14	3.11	2180	4260
T_{11}	5.72	18.12	12.38	2.85	1910	3980
T_{12}	5.06	16.88	11.28	2.51	1701	3460
T_{13}	4.23	12.22	9.64	2.01	1360	2660
T_{14}	5.34	17.25	11.74	2.64	1773	3620
sEd	0.08	0.48	0.22	0.072	38.39	71.12
CD(P=0.05)	0.29	0.84	0.46	0.14	70.25	152.2

Table 4. Effect of enriched compost application on yield attributes of barnyard millet in red soil

Treatments	No. of productive tillers per plant	Earhead length (cm)	Earhead weight (g)	1000 grain weight (g)	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})
T_1	2.10	9.12	5.41	1.60	1005	2210
T_2	3.05	12.92	7.28	2.04	1312	2845
T_3	4.28	14.54	9.86	2.62	1671	3474
T_4	5.05	16.76	10.94	2.80	1861	3794
T_5	3.42	13.19	7.83	2.20	1405	3015
T_6	2.68	11.12	6.57	1.91	1210	2681
T_7	5.42	17.87	11.42	2.91	1956	3954
T_8	6.42	19.84	12.35	3.17	2068	4184
T_9	3.54	13.64	8.16	2.36	1480	3163
T_{10}	6.05	18.77	11.81	3.06	1985	4024
T_{11}	4.65	15.75	10.54	2.77	1761	3631
T_{12}	3.61	13.86	8.62	2.41	1520	3242
T_{13}	2.30	10.27	5.93	1.75	1110	2520
T_{14}	3.98	14.23	9.32	2.50	1620	3405
sEd	0.17	0.42	0.25	0.05	46.47	74.76
CD(P=0.05)	0.37	0.90	0.55	0.10	92.45	160.25

T_1 - Absolute control,
T_2 - RDF of 40 :20:0 kg ha^{-1},
T_3 - RP enriched FYM @ 750 kg ha^{-1} with microbial consortium
T_4 - SSP enriched FYM @ 750 kg ha^{-1} with microbial consortium
T_5 - RP enriched FYM @ 750 kg ha^{-1} without microbial consortium
T_6 - SSP enriched FYM @ 750 kg ha^{-1} without microbial consortium
T_7 - RP enriched vermicompost @ 750 kg ha^{-1} with microbial consortium
T_8 - SSP enriched vermicompost @ 750 kg ha^{-1} with microbial consortium
T_9 - RP enriched vermicompost @ 750 kg ha^{-1} without microbial consortium
T_{10} - SSP enriched vermicompost @ 750 kg ha^{-1} without microbial consortium
T_{11} - RP enriched Municipal solid waste compost (MSWC) @ 750 kg ha^{-1} with microbial consortium
T_{12} - SSP enriched Municipal solid waste compost (MSWC) @ 750 kg ha^{-1} with microbial consortium
T_{13} - RP enriched Municipal solid waste compost (MSWC) @ 750 kg ha^{-1} without microbial consortium
T_{14} - SSP enriched Municipal solid waste compost (MSWC) @ 750 kg ha^{-1} without microbial consortium

4.CONCLUSION

The findings of the experiments indicates that the application of enriched composts contributed higher crop growth and yield. Combined use of biofertilizer along with enriched compost serves as a valuable reservoir of nutrient-rich soil amendment which helps cut the fertilizer and effectively meets the crop's nutritional needs over a prolonged period, acting as a viable substitute for chemical fertilizers. By incorporating compost and biofertilizers into agricultural or gardening practices, the overall nutrient content and health of the soil can be improved. This, in turn, leads to reduced fertilizer requirements for achieving desired plant growth and yields. However, it's important to note that the effectiveness of these methods can depend on various factors, including soil type, crop type, and local conditions. Therefore, their application should be tailored to specific contexts for optimal results. The incorporation of azophos further contributes to the preservation of soil biological well-being by promoting key soil biological processes such as immobilization, nutrient mobilization, organic matter mineralization, and the production of growth-promoting substances like siderophores. Encouraging the adoption of organic sources alongside bio fertilizers emerges as a strategic approach to achieving higher growth and yield in an ecologically sustainable manner. Future endeavors are encouraged to center on assessing efficient nutrient management strategies to harness the inherent potential of organic sources, thereby enhancing the growth and yield of barnyard millet.

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