Original Research Article

SOIL FERTILITY AND YIELD OF FINGER MILLET (*Eleusinecoracana* L.)AS INFLUENCED BY PHOSPHORUS MANAGEMENT PRACTICES IN SANDY LOAM SOILS

ABSTRACT

Finger millet (*Eleusinecoracana*L.) is an important small millet crop grown in India and has the pride of place in having highest productivity among millets.However, the productivity comes down in low available soil phosphorus areas where finger millet is grown.A field experiment was carried out at Agricultural Research Station, Perumalapalle, Tirupati, Acharya N. G. Ranga Agricultural University, Andhra Pradesh, India during *kharif*,2018 on sandy loam soil to study the effectof phosphorus fertilizer, PSB and VAM on soil fertility status and yield of finger millet.The experiment was laid out in randomized block design with nine treatments consists of combination of phosphorus fertilizer, PSB and VAM and replicated thrice. Soil samples were collected at initial and after harvest and analyzed for physico-chemical, chemical properties and grain yield was recorded after harvest. The results revealed that application of PSB, VAM along with phosphorus fertilizer exerted significant effect on available N, P_2O_5, K_2O, S and DTPA extractablemicronutrients. Significantly the highest available N(150 kg ha^{-1}), P_2O_5(42.34 kg ha^{-1}), K_2O (227 kg ha^{-1}), S (9.57 mg kg^{-1}), DTPA extractableManganese (38.67 mg kg^{-1})and grain yield (4328 kg ha^{-1})was registered with application of 100 % RDP + PSB @ 750 ml ha^{-1} + VAM@ 12.5 kg ha^{-1} (T_6).). Physico-chemical properties (pH, EC and OC) was non-significant with phosphorus management practices.

Keywords: Phosphorus fertilizer, PSB, VAM, soil fertility, grain yield and finger millet.

INTRODUCTION

Finger millet is known as a low fertilizer input crop by the small farmers who live onsubsistencefarming. Under low nutrient input conditions, thecrop expresses poor yields. In India, it is mostly cultivated in resource poor soils of tropics and sub-tropics. In some nutritional components, finger millet is a superior crop compared to some major cereal crops especially polished rice. Among the millets, finger millet has a high amount of calcium (0.38%), fiber

(18%), phenolic compounds (0.3–3%) and sulphurcontaining amino acids. It provides food security for poor farmers, although finger millet plays a very important role especially in the diet of rural people.

One of the main problem faced by the farmers is inherent low soil phosphorus in areas where finger millet is commonly grown. Phosphorus has distinct role in yield improvement of finger millet. Application of biofertilizersare solubilized the insoluble phosphates in soil and thus improves nutrient availability. Since fertile soil is the fundamental resource for higher production, its maintenance is a prerequisite for long term sustainable crop production which cannot be maintained by using chemical fertilizers alone. Mycorrhiza fungi which constitute a group of important soil micro-organisms are ubiquitous throughout the world are known to improve the plant growth through better uptake of nutrients especially phosphorus.Keeping this in view, an investigation was planned to study comprehensively the role of phosphatic fertilizer and biofertilizers (PSB and VAM) in improving soil propertiesand yield of finger millet.

(References to be added wherever necessary in the introduction portion)

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MATERIAL AND METHODS

An experiment was conducted during *kharif*, 2018 at Agricultural Research Station, Perumallapalli, Tirupati, Acharya N.G. Ranga Agricultural University, Andhra Pradesh, India, which is geographically situated at 13° 36'761''N latitude and 79° 20' 704''E longitude with an altitude of 182.9 m above the mean sea level, which falls under Southern Agro Climatic Zone of Andhra Pradesh. During the crop growth period the weekly maximum temperatures ranged from 32.0 to 37.2°C with an average of 34.6°C, while the weekly minimum temperatures ranged from 22.2 to 27.1°C with an average of 24.6°C. The total sunshine hourswere 66 hours with an average of 3.9 h day^{-1}. The total rainfall received during the crop growth period was 272.7 mm during*kharif*, 2018. The experiment was laid out in a randomized block design and replicated thrice with nine (9) treatments.

The treatmentsconsists of;

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T_1: No Phosphorus

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~~,~~ T_2: 100 % Recommended dose of phosphorus (RDP)

~~,~~ T_3: 125 % RDP

~~, T_4 :~~ T_4:100 % RDP + Phosphorus Solubilizing Bacteria @ 750 ml ha^{-1}(PSB)

~~, T_5 :~~ T_5:100 % RDP + Vesicular ArbuscularMycorrhizae @ 12.5 kg ha^{-1}(VAM)

~~, T_6 :~~ T_6:100 % RDP + PSB + VAM

~~, T_7 :~~ T_7:75 % RDP + PSB

~~, T_8 :~~ T_8:75 % RDP + VAM

~~, T_9 :~~ T_9:75 % RDP + PSB + VAM

~~.~~The recommended dose of nitrogen and potassium were applied in the form of urea and muriate of potash as basal. Phosphorus was applied in the form of single super phosphate as per treatments. PSB and VAM were ~~throughly~~thoroughlymixed with 100 kg FYM and applied as per treatments at the time of sowing.

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The soil samples were collected randomly from 0 to 15 cm depth at initial and after harvest. The soil samples were shade dried, pounded and sieved through 2 mm sieve (0.5 mm sieve for organic carbon)and analysed for its physico-chemical and chemical properties by using standard procedures. The pH of the soil was determined in 1:2.5 (soil:water) suspension by using a digital pH meter (Jackson 1973). The electrical conductivity of the soil saturation extract was determined with the help of a Wheatstone conductivity bridge (Jackson 1973). Organic carbon in soil was determined by methods described by Walkley and Black (1934). The available nitrogen was estimated by the alkaline permanganate method by Subbiah andAsija(1956). The available phosphorusin soil was describe by Olsen *et al*. (1954).The available potassium of the soil samples was extracted with neutral normal ammonium acetate solution. Exchangeable calcium and magnesium was extracted with neutral ammonium acetate and determined by titrating with 0.01 *N* EDTA as per procedure out lined by Jackson (1973). Available sulphur in soil samples was extracted with 0.15 per cent $CaCl_2.2H_2O$ (Williams and Steinberg's, 1959). DTPA extractable micronutrients were determined by using atomic absorption spectrophotometer

(Varian AA 240 FS). Crop was harvested after attained physiological maturity and grain yield was recorded and expressed in kg ha^{-1}.

Initial experimental soil was sandy loam in texture, slightly alkaline in reaction, low in organic carbon and nitrogen, non saline nature, medium in available phosphorus and potassium, sufficient in DTPA extractable micronutrients. Initial soil properties of experimental field was presented in table 1.

STATISTICAL DATA ANALYSIS

The data on various soil properties and yield were subjected to statistical scrutiny by following the analysis of variance for randomized block design as outlined by Panse and Sukhatme (1985). Statistical significance was tested with ‘F’ test at 5 percent and 1 per cent level of probability. Further multiple comparision tests have been done using duncan’s multiple range test (DMRT) to identify the homogenous groups of treatments using SPSS-20.

RESULTS AND DISCUSSION

Physico-Chemical properties

Data pertaining to physico-chemical properties of soil after harvest was presented in table 2.

Application of phosphatic fertilizer, PSB and ~~VAM exerted~~VAM exerted~~non significant~~non-significant effect on soil physico-chemical properties *viz*.~~, pH~~, pH, EC and OC. The maximum soil pH (7.77) was noticed with 75 % RDP + PSB @ 750 ml ha^{-1} (T_7) while, the lowestpH (7.55) was recorded with no phosphorus (T_1). The EC range varied from 0.409 dS m^{-1} with no phosphorus (T_1) to 0.477 dS m^{-1} due to application of 75 % RDP + VAM @ 12.5 kg ha^{-1} (T_8). Higher soil OC (0.39 %) was registered with 100 % RDP + PSB @ 750 ml ha^{-1} + VAM @ 12.5 kg ha^{-1} (T_6) ~~where as~~whereas, the lowest (0.36%) was observed with no phosphorus (T_1) and 100 % RDP (T_2).

Chemical properties

Chemical properties *viz.*, available nitrogen, phosphorus and potassium were significantly influenced by phosphorus management practices at harvest was presented in table 2.

Available nitrogen: The available N in soil varied significantly with treatments. Significantly the highest available N (150 kg ha^{-1}) was recorded with 100 % RDP + PSB @ 750 ml ha^{-1} + VAM @ 12.5 kg ha^{-1} (T_6) followed by 100 % RDP + PSB @ 750 ml ha^{-1} (T_4) which was on par with 75 % RDP + PSB @ 750 ml ha^{-1} + VAM @ 12.5 kg ha^{-1} (T_9). The lowest (117 kg ha^{-1}) was observed with no phosphorus (T_1).Significantly the highest available N was recorded with application of 100 % RDP + PSB @ 750 ml ha^{-1} + VAM @ 12.5 kg ha^{-1} might be due to phosphorus application favourably responded to buildup N, P and K status of the soil. Increased buildup of N, P and K status was noted with increase in level of phosphorus. Further, the release of organic acids and hormones due to phosphorus bacterial activity might have helped in not only solubilize and mineralize P from insoluble compounds but also release other nutrients like available N in rhizosphere soil. VAM also increased nitrogen status in the mycorrhizosphere by decomposing organic matter. The results are in agreement with those ofRamakrishnaiah and Vijaya (2013) and Venkatarao*et al*. (2017)**.**

Available phosphorus: Phosphorus management practices exerts significant effect on available P_2O_5 after harvest. The highest available P_2O_5 (42.74 kg ha^{-1}) was observed with 100 % RDP + PSB @ 750 ml ha^{-1} + VAM @ 12.5 kg ha^{-1} (T_6) which was on par with 100 % RDP + PSB @ 750 ml ha^{-1} (T_4), 100 % RDP [1] + VAM @ 12.5 kg ha^{-1} (T_5) and 75 % RDP + PSB @ 750 ml ha^{-1} (T_7). The lowest (33.95 kg ha^{-1}) was observed with no phosphorus (T_1).The increase in available P_2O_5 content in soil with combined application of P fertilizer, PSB and VAM may be attributed to direct addition of P as well as solubilization of native P through release of various organic acids during microbial processes which solubilizes the tricalcium phosphate into monocalcium phosphate makes plant available form(Kamble*et al*., 2018)

Available potassium: Application ofphosphorus fertilizer, PSB and VAM exerted significant influence on available K_2O status in the soil after harvest. The highest available K_2O (227 kg ha^{-1}) was obtained with 75 % RDP + PSB @ 750 ml ha^{-1} + VAM @ 12.5 kg ha^{-1} (T_9) which was on par with 75 % RDP + PSB @ 750 ml ha^{-1} (T_7), 125 % RDP (T_3), 75 % RDP + VAM @ 12.5 kg ha^{-1} (T_8) and 100 % RDP + PSB @ 750 ml ha^{-1} + VAM @ 12.5 kg ha^{-1} (T_6). The treatment no phosphorus (T_1) which received the lowest (196 kg ha^{-1}) available K_2O.The highest available K_2O due to application of 75 % RDP + PSB @ 750 ml ha^{-1} + VAM @ 12.5 kg ha^{-1} may be attributed to direct addition of K to available pool of soil K. The beneficial effect of PSB and VAM on available K_2O might also attributed to the organic acids released due to microbial activity which might have mobilized the native or non-exchangable form of K and charge the soil solution with K ions, so that it may be readily available. Similar results are perceived by Sharma *et al*. (2003) and also these results were agreement with finding of vajanthaand subbarao (2017).

Secondary nutrients

Exchangeable Ca and Mg in soil was not significantly influenced by phosphaticfertilizer and biofertilizers. Maximum exchangeable Ca and Mg (3.00and 1.93 meq 100 g^{-1}) was obtained with 100 % RDP + PSB @ 750 ml ha^{-1} + VAM @ 12.5 kg ha^{-1} (T_6) while the lowest (2.55 and 1.60 meq 100 g^{-1}) was noticed with no phosphorus (T_1).

Available S significantly influenced by phosphatic fertilizer and biofertilizers. Significantly the highest available S (9.57 mg kg^{-1}) was recorded with 100 % RDP + PSB @ 750 ml ha^{-1} + VAM @ 12.5 kg ha^{-1} (T_6) followed by 125 % RDP (T_3), 75 % RDP + VAM @ 12.5 kg ha^{-1} (T_8) and 75 % RDP + PSB @ 750 ml ha^{-1} (T_7). The lowest (7.69 mg kg^{-1}) was observed with no phosphorus (T_1).Significantly the highest available S after harvest was registered with combined application of 100 % RDP + PSB @ 750 ml ha^{-1} and VAM @ 12.5 kg ha^{-1} may be due to S is added through SSP which is source of phosphatic fertilizer and VAM fungi provides significant amount of sulphur by making their widely extended hyphal network on the upper or lower side of the soil layer. The present findings are in accordance with findings ofPramanik and Bera (2013).

DTPA extractable micronutrients

Data pertaining to DTPA extractable micronutrientsin soil after harvest of finger millet was presented in Table 3.

All DTPA extractable cationic micronutrients *viz*., Fe, Zn and Cu were not significantly influenced by application of phosphorus fertilizer and biofertilizers except Mn. The higher DTPA extractableFe, Zn and Cu (6.38, 1.15 and 1.63 mg kg^{-1}, respectively) was recorded with combined application of with 100 % RDP + PSB @ 750 ml ha^{-1} + VAM @ 12.5 kg ha^{-1} (T_6) while the lowest was (4.67, 0.95 and 1.46mg kg^{-1}, respectively)noticed with no phosphorus (T_1). The DTPA extractable Mnvaried significantly with treatments. Significantly the highest DTPA extractable Mn (38.67 mg kg^{-1}) obtained from 100 % RDP + PSB @ 750 ml ha^{-1} + VAM @ 12.5 kg ha^{-1} (T_6). The lowest (31.32 mg kg^{-1}) was registered with no phosphorus (T_1).Maximum post harvestDTPA extractableMn was obtained with 100 % RDP + PSB @ 750 ml ha^{-1} + VAM @ 12.5 kg ha^{-1} may be due to application of biofertilizers affected the plant nutrient dynamics in soil, especially less mobile nutrients in soil solution with their hyphae, which explore the soil for nutrients. (Sharma *et al*., 2003).

Grain Yield

Data presented in Table 4 on grain yield revealed that phosphorus management practices showed a greater impact on grain yield of finger millet.

Grain yield of finger millet was significantly influenced by phosphatic fertilizer and biofertilizers. Significantly the highest grain yield (4328 kg ha^{-1}) was recorded with application of 100 % RDP + PSB @ 750 ml ha^{-1} + VAM @ 12.5 kg ha^{-1} (T_6) followed by 75 % RDP + PSB @ 750 ml ha^{-1} + VAM @ 12.5 kg ha^{-1} (T_9). The lowest grain yield (3692 kg ha^{-1}) was recorded with no phosphorus (T_1).

The highest grain yield was recorded with application of 100 % RDP + PSB @ 750 ml ha^{-1} + VAM @ 12.5 kg ha^{-1} might be attributed to better supply of nutrients along with conducive physical environment leading to better root activity and higher nutrient absorption, which resulted in more plant growth and superior yield attributes responsible for higher yield. The application of biofertilizers (PSB and VAM) increased the efficiency of chemical fertilizers due to control release of nutrients in the soil through microbial activity which might have facilitated better crop growth. The present findings are in accordance with findings ofAbbasi and Yousra (2012), Acharya *et al*. (2012) and Kejiya*et al*. (2019).

Conclusion

Combined application of 100 % RDP + PSB @ 750 ml ha^{-1} + VAM @ 12.5 kg ha^{-1} is the most efficient phosphorus management practice for sustainable grain yield and soil fertility followed by 75 % RDP + PSB @ 750 ml ha^{-1} + VAM @ 12.5 kg ha^{-1}.

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Table 1. Initial soil properties of the experimental field

Particulars	Value
A. Physical characteristics	
Sand (%)	68.26
Silt (%)	20.50
Clay (%)	11.24
Textural class	Sandy loam
B. Physico-chemicalcharacteristics	
Soil pH (1:2.5 Soil water suspension)	7.62
EC (dS m^{-1}) at 25^{O} C	0.40
C. Chemical characteristics	
Organic carbon (%)	0.33
Available N (kg ha^{-1})	120
Available P_2O_5 (kg ha^{-1})	43.8
Available K_2O (kg ha^{-1})	218
Exchangeable Ca (meq 100 g^{-1})	2.53

Exchangeable Mg (meq 100 g^{-1})	1.63
Available S (ppm)	7.31
DTPA extractable Fe (mg kg^{-1})	1.50
DTPA extractable Mn (mg kg^{-1})	33.84
DTPA extractable Zn (mg kg^{-1})	5.05
DTPA extractable Cu (mg kg^{-1})	1.05

Table 2. Physico-chemical and chemical properties of soil after harvest of finger millet as influenced by phosphatic fertilizer and biofertilizers

Treatments	pH	EC (dS m^{-1})	OC (%)	Available nitrogen (kg ha^{-1})	Available P_2O_5 (kg ha^{-1})	Available K_2O (kg ha^{-1})
T_1	7.55	0.409	0.36	117^{b}	33.95^{c}	196^{c}
T_2	7.58	0.460	0.36	121^{ab}	35.75^{bc}	201^{bc}
T_3	7.72	0.448	0.37	125^{ab}	40.65^{ab}	226^{a}
T_4	7.66	0.447	0.37	142^{ab}	42.34^{a}	213^{abc}
T_5	7.73	0.410	0.38	125^{ab}	41.77^{a}	219^{ab}
T_6	7.66	0.452	0.39	150^{a}	42.74^{a}	222^{a}
T_7	7.77	0.428	0.38	134^{ab}	41.72^{a}	226^{a}
T_8	7.73	0.477	0.37	129^{ab}	40.63^{ab}	224^{a}
T_9	7.61	0.418	0.38	138^{ab}	38.88^{ab}	227^{a}
F value	1.13	0.26	0.40	1.94*	3.85*	3.68*

p-value	0.393	0.969	0.903	0.023	0.010	0.013

* Significant at p=0.05 level ** Significant at p=0.01 level

Note : Same set of alphabets indicates no significant difference or at par with each other (DMRT)

Table 3. Secondary nutrients and DTPA extractable micronutrients in soil as influenced by phosphatic fertilizer and biofertilizers in finger millet

Treatments	Exchangeable calcium (meq 100 g^{-1})	Exchangeable magnesium (meq 100 g^{-1})	Available sulphur (mg kg^{-1})	DTPA extractable Micronutrients (mg kg^{-1})			
				Iron	Manganese	Zinc	Copper
T_1	2.55	1.60	7.69^{c}	4.67	31.32^{c}	0.95	1.46
T_2	2.70	1.73	8.07^{bc}	4.70	34.07^{bc}	0.97	1.50
T_3	2.83	1.78	9.39^{ab}	5.84	34.41^{bc}	0.98	1.51
T_4	2.60	1.77	8.85^{abc}	6.07	34.50^{bc}	1.04	1.56
T_5	2.65	1.85	8.64^{abc}	6.16	35.96^{ab}	1.02	1.52
T_6	3.00	1.93	9.57^{a}	6.38	38.67^{a}	1.15	1.63
T_7	2.64	1.62	9.24^{ab}	5.88	35.95^{ab}	1.03	1.55
T_8	2.73	1.83	9.37^{ab}	5.13	34.73^{abc}	0.99	1.52

T_9	2.80	1.89	8.75^{abc}	6.20	37.15^{ab}	1.10	1.61
F value	2.39	0.92	1.79*	2.57	2.87*	2.41	1.52
p-value	0.065	0.521	0.025	0.061	0.034	0.064	0.256
* Significant at p=0.05 level ** Significant at p=0.01 level Note : Same set of alphabets indicates no significant difference or at par with each other (DMRT)							

Table 4. Grain yield (kg ha^{-1}) of finger millet as influenced by phosphatic fertilizer and biofertilizers

Treatments	Grain yield
T_1	3692^{d}
T_2	3846^{bc}
T_3	4083^{abc}
T_4	3946^{bc}
T_5	3858^{bc}
T_6	4328^{a}
T_7	3783^{cd}
T_8	3942^{bc}
T_9	4157^{ab}
F value	3.54*
p-value	0.015
* Significant at p=0.05 level ** Significant at p=0.01 level Note : Same set of alphabets indicates no significant difference or at par with each other (DMRT)	

(Field / plant photographs should be included as a evidence)

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