

**STUDIES ON BIO-ENRICHED FARM YARD
MANURE (FYM) ON SOIL PROPERTIES AND
PRODUCTIVITY OF FINGER MILLET
(*Eleusine coracana* (L.) Gaertn) UNDER DRYLAND
CONDITION**

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PALB 8357

**DEPARTMENT OF SOIL SCIENCE AND
AGRICULTURAL CHEMISTRY
UNIVERSITY OF AGRICULTURAL SCIENCES
BANGALORE**

2020

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*Thesis submitted to the
UNIVERSITY OF AGRICULTURAL SCIENCES, BANGALORE
in partial fulfilment of the requirements
for the award of the Degree of*

**MASTER OF SCIENCE (Agriculture)
in
SOIL SCIENCE AND AGRICULTURAL CHEMISTRY**

BENGALURU

NOVEMBER, 2020




***Affectionately
Dedicated to
My Beloved Family
My Chair Person
and
The entire Farming
Community***

**DEPARTMENT OF SOIL SCIENCE AND
AGRICULTURAL CHEMISTRY
UNIVERSITY OF AGRICULTURAL SCIENCES
BANGALORE – 560065**

CERTIFICATE

This is to certify that the thesis entitled “STUDIES ON BIO-ENRICHED FARM YARD MANURE (FYM) ON SOIL PROPERTIES AND PRODUCTIVITY OF FINGER MILLET (*Eleusine coracana* (L.) Gaertn) UNDER DRYLAND CONDITION” submitted by Ms. SHAFNAS, I., ID No. PALB 8357 for the degree of MASTER OF SCIENCE (Agriculture) in SOIL SCIENCE AND AGRICULTURAL CHEMISTRY to the University of Agricultural Sciences, Bangalore, is a record of *bona-fide* research work carried out by her during the period of her study in this university, under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

Bengaluru
November, 2020


B. G. VASANTHI
MAJOR ADVISOR 18/11/20

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(R. MUTHURAJU)

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Bengaluru

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(SHAFNAS, I.)

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SOIL PROPERTIES AND PRODUCTIVITY OF FINGER MILLET
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SHAFNAS, I.

ABSTRACT

A field experiment was conducted during *Kharif*-2019 at AICRP for Dryland Agriculture to study the effect of bio-enriched FYM *viz.*, nitrogen fixers, phosphorus solubilizers, potassium solubilizers, PGPR and microbial consortia with two levels of RDF *viz.*, 60 and 80 % on soil properties and productivity of finger millet, replicated thrice in f-RCBD comprising ten treatments. The growth and yield attributes showed an increasing trend with application of microbial consortia bio-enriched FYM + 80 % RDF with significantly higher grain yield (2999 kg ha⁻¹) and straw yield (4274 kg ha⁻¹) and higher B:C ratio (2.30). The combination of microbial consortia bio-enriched FYM + 80 % RDF proved to be the best treatment in terms of uptake of nitrogen (6.33, 21.68, 45.39 and 70.58 kg ha⁻¹), phosphorus (0.87, 3.95, 9.85 and 21.40 kg ha⁻¹) and potassium (4.28, 18.58, 41.98 and 59.84 kg ha⁻¹) at 30, 60, 90 DAS and at harvest, respectively. Similar was the trend with respect to secondary and micronutrient uptake. No significant variation was recorded in terms of soil physical parameters. However significant increase in major nutrient status of soil was recorded resulting in 4.35, 1.14 and 5.24 % higher available NPK content of soil over its initial value. Soil microbial biomass carbon, nitrogen, phosphorus and dehydrogenase activity was significantly higher in bio-enriched FYM + 80 % RDF. Thus, combined application of inorganic fertilizers and microbial consortia bio-enriched FYM was found to be the suitable nutrient management strategy for yield enhancement and soil health maintenance under dry land condition.

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**ಮಿಷ್ಕಿ ಬೇಸಾಯದಲ್ಲಿ ಸೂಕ್ಷ್ಮಾಣು ಜೀವಿಗಳಿಂದ ವೃದ್ಧೀಕರಿಸಿದ ಕೊಟ್ಟಿಗೆ ಗೊಬ್ಬರದ ಬಳಕೆಯಿಂದ
ಮಣ್ಣಿನ ಗುಣಲಕ್ಷಣ ಮತ್ತು ರಾಗಿ ಇಳುವರಿಯ ಅಧ್ಯಯನ**

ಶಫ್ಟಾಸ್ ಐ.

ಪ್ರಬಂಧದ ಸಾರಾಂಶ

ಸಾರಜನಕ ಸ್ಥಿರೀಕರಿಸುವ, ರಂಜಕ ಕರಗಿಸುವ, ಪೊಟ್ಯಾಷ್ ಕರಗಿಸುವ ಸೂಕ್ಷ್ಮಾಣುಜೀವಿಗಳು, ಪಿ. ಜಿ. ಪಿ. ಆರ್. ಹಾಗೂ ಸೂಕ್ಷ್ಮಾಣುಜೀವಿಗಳ ಮಿಶ್ರಣದಿಂದ ವೃದ್ಧೀಕರಿಸಿದ ಕೊಟ್ಟಿಗೆ ಗೊಬ್ಬರದೊಂದಿಗೆ ಶಿಫಾರಿತ ರಾಸಾಯನಿಕ ಗೊಬ್ಬರ, ಪ್ರತಿಶತ 60 ಮತ್ತು 80 ಬಳಕೆಯಿಂದ ಮಿಷ್ಕಿ ಬೇಸಾಯದಲ್ಲಿ ಮಣ್ಣಿನ ಗುಣಲಕ್ಷಣ ಹಾಗೂ ರಾಗಿ ಉತ್ಪಾದಕತೆ ಮೇಲಾಗುವ ಪರಿಣಾಮದ ಅಧ್ಯಯನವನ್ನು 2019 ರ ಮುಂಗಾರಿನಲ್ಲಿ ಮಿಷ್ಕಿ ಬೇಸಾಯ ಪ್ರಾಯೋಜನೆ, ಕೃಷಿ ವಿಶ್ವವಿದ್ಯಾಲಯ ಬೆಂಗಳೂರಿನಲ್ಲಿ ಕೈಗೊಳ್ಳಲಾಯಿತು. ಈ ಪ್ರಯೋಗವನ್ನು ಯಾದೃಚ್ಛಿತ ಸಂಪೂರ್ಣ ವಿನ್ಯಾಸ ಮಾದರಿಯಲ್ಲಿ ಹತ್ತು ಉಪಚಾರಗಳನ್ನು ಮೂರು ಬಾರಿ ಪುನರಾವರ್ತಿತಲಾಯಿತು. ರಾಗಿಯ ಬೆಳವಣಿಗೆ ಮತ್ತು ಇಳುವರಿ ನಿಯತಾಂಕವು ಸೂಕ್ಷ್ಮಾಣುಜೀವಿಗಳ ಮಿಶ್ರಣದೊಂದಿಗೆ ವೃದ್ಧಿಸಿದ ಕೊಟ್ಟಿಗೆ ಗೊಬ್ಬರ + 80 ಪ್ರತಿಶತ ಶಿಫಾರಿಸ್ಥಿತ ರಸಗೊಬ್ಬರ ಬಳಕೆಯಿಂದ ಹೆಚ್ಚಾಗಿದ್ದು, ಧಾನ್ಯದ ಉತ್ಪಾದನೆ (2999 ಕೆ. ಜಿ. ಪ್ರತಿ ಹೆ.), ಹುಲ್ಲಿನ ಉತ್ಪಾದನೆ (4274 ಕೆ. ಜಿ. ಪ್ರತಿ ಹೆ.) ಹಾಗೂ ಲಾಭ: ವೆಚ್ಚದ ಅನುಪಾತವು (2.30) ಉತ್ತಮವೆಂದು ಕಂಡುಬಂದಿದೆ. ಸೂಕ್ಷ್ಮಾಣುಜೀವಿಗಳ ಮಿಶ್ರಣದಿಂದ ವೃದ್ಧೀಕರಿಸಿದ ಕೊಟ್ಟಿಗೆ ಗೊಬ್ಬರದ ಜೊತೆಗೆ 80 ಪ್ರತಿಶತ ಶಿಫಾರಿಸ್ಥಿತ ರಸಗೊಬ್ಬರ ಬಳಕೆಯಿಂದ ಪ್ರಧಾನ ಪೋಷಕಾಂಶಗಳಾದ ಸಾರಜನಕ (6.33, 21.68, 45.39 ಮತ್ತು 70.58 ಕೆ. ಜಿ. ಪ್ರತಿ ಹೆ.) ರಂಜಕ (0.87, 3.95, 9.85 ಮತ್ತು 21.40 ಕೆ. ಜಿ. ಪ್ರತಿ ಹೆ.) ಮತ್ತು ಪೊಟ್ಯಾಷ್ (4.28, 18.58, 41.98 ಮತ್ತು 59.84 ಕೆ. ಜಿ. ಪ್ರತಿ ಹೆ.) ಹೀರುವಿಕೆಯ ಪ್ರಮಾಣವು 30, 60, 90 ಬಿತ್ತನೆ ದಿನಗಳ ನಂತರ ಮತ್ತು ಕೊಯ್ಲಿನ ನಂತರ ಗಮನಾರ್ಹವಾಗಿ ಹೆಚ್ಚಾಗಿದ್ದು ಕಂಡುಬಂದಿದೆ. ಹಾಗೆಯೇ, ದ್ವಿತೀಯ ಪೋಷಕಾಂಶಗಳು ಮತ್ತು ಸೂಕ್ಷ್ಮ ಪೋಷಕಾಂಶಗಳ ಹೀರಿಕೆಯಲ್ಲಿ ಅದೇ ರೀತಿಯ ಪ್ರವೃತ್ತಿಯು ಕಂಡುಬಂದಿದೆ. ಮಣ್ಣಿನ ಭೌತಿಕ ಗುಣಲಕ್ಷಣಗಳ ಮೇಲೆ ಸೂಕ್ಷ್ಮಾಣುಜೀವಿಗಳಿಂದ ವೃದ್ಧೀಕರಿಸಿದ ಕೊಟ್ಟಿಗೆ ಗೊಬ್ಬರದ ಬಳಕೆಯಿಂದ ಯಾವುದೇ ಗಮನಾರ್ಹ ಬದಲಾವಣೆ ಕಂಡುಬಂದಿಲ್ಲ. ಸೂಕ್ಷ್ಮಾಣುಜೀವಿಗಳ ಮಿಶ್ರಣದೊಂದಿಗೆ ವೃದ್ಧೀಕರಿಸಿದ ಕೊಟ್ಟಿಗೆ ಗೊಬ್ಬರ ಹಾಗೂ 80 ಪ್ರತಿಶತ ಶಿಫಾರಿಸ್ಥಿತ ರಸಗೊಬ್ಬರ ಬಳಕೆಯಿಂದ ಮಣ್ಣಿನಲ್ಲಿ ಪ್ರಧಾನ ಪೋಷಕಾಂಶಗಳಾದ ಸಾರಜನಕ, ರಂಜಕ ಮತ್ತು ಪೊಟ್ಯಾಷ್ ಲಭ್ಯತೆ ಪ್ರಮಾಣವು ಕ್ರಮವಾಗಿ ಶೇ. 4.35, 1.14 ಮತ್ತು 5.24 ರಷ್ಟು ಹೆಚ್ಚು ದಾಖಲಾಗಿದೆ. ಮಣ್ಣಿನ ಜೈವಿಕ ಗುಣಲಕ್ಷಣಗಳಾದ ಸೂಕ್ಷ್ಮಾಣುಜೀವರಾಶಿ ಇಂಗಾಲ, ಸಾರಜನಕ, ರಂಜಕ ಮತ್ತು ಮಣ್ಣಿನ ಕಿಣ್ವಗಳಾದ ಡಿಹೈಡ್ರೋಜಿನೇಸ್ ಚಟುವಟಿಕೆಯು ಗಮನಾರ್ಹವಾಗಿ ಸೂಕ್ಷ್ಮಾಣುಜೀವಿಗಳ ಮಿಶ್ರಣದೊಂದಿಗೆ ವೃದ್ಧಿಸಿದ ಕೊಟ್ಟಿಗೆ ಗೊಬ್ಬರ + 80 ಪ್ರತಿಶತ ಶಿಫಾರಿಸ್ಥಿತ ರಸಗೊಬ್ಬರ ಬಳಕೆಯಿಂದ ಹೆಚ್ಚಾಗಿದೆ. ಒಟ್ಟಾರೆ, ಸೂಕ್ಷ್ಮಾಣುಜೀವಿಗಳ ಮಿಶ್ರಣದಿಂದ ವೃದ್ಧೀಕರಿಸಿದ ಕೊಟ್ಟಿಗೆ ಗೊಬ್ಬರದ ಜೊತೆಗೆ 80 ಪ್ರತಿಶತ ಶಿಫಾರಿಸ್ಥಿತ ರಸಗೊಬ್ಬರ ಬಳಸುವುದರಿಂದ ಮಣ್ಣಿನ ಆರೋಗ್ಯ ಹೆಚ್ಚಿಸಿ ಆಧಿಕ ಇಳುವರಿ ಗಳಿಸುವುದರಲ್ಲಿ ಸಹಕಾರಿಯಾಗಿರುತ್ತದೆ.

ನವಂಬರ್, 2020

ಮಣ್ಣು ವಿಜ್ಞಾನ ಮತ್ತು ಕೃಷಿ ರಸಾಯನ ಶಾಸ್ತ್ರ ವಿಭಾಗ
ಕೃಷಿ ವಿಶ್ವವಿದ್ಯಾಲಯ, ಜಿಕೆವಿಕೆ, ಬೆಂಗಳೂರು

ಬಿ. ಜಿ. ವಾಸಂತಿ
ಪ್ರಮುಖ ಸಲಹೆಗಾರರು

Studies on bio-enriched farm yard manure (FYM) on available major nutrients, uptake and productivity of finger millet (*Eleusine coracana* (L.) Gaertn) under dryland condition



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Introduction

- Finger millet is a staple food crop grown by subsistence farmers and highly valued by traditional farmers as it is nutritious, drought tolerant and require low inputs.
- Nutrient deficiencies observed in soil and plants is due to poor soil quality not being conducive to nutrient uptake.
- About 85 to 90 per cent of the plant nutrient acquisition is microbially mediated. Hence, application of biofertilizer is an excellent alternative to chemical fertilizer which provide nutrient through nitrogen fixation, solubilization and trigger plant growth promoting essence. In this view, role of biofertilizers in soil fertility maintenance is becoming increasingly important in both organic farming and conventional method.

Objective

- Effect of bio-enriched farm yard manure on soil nutrient status, nutrient uptake and productivity of finger millet (*Eleusine coracana* (L.) Gaertn) under dryland condition

Material And Methods

- Field experiment was conducted with finger millet (GPU-28) at AICRP for Dryland agriculture, UAS, GKVK during kharif 2019.
- The experimental soil was *Alfisols* with sandy loam texture with pH of 6.06 and EC of 0.040 dS m⁻¹.
- Soil was low in available nitrogen and potassium and high in phosphorus.
- The experiment laid out was RCBD replicated three with ten treatments.
- FYM was enriched with nitrogen fixers (*Azotobacter chroococcum*), PSB (*Bacillus megaterium*), KSB (*Fraterucia aurantia*) and PGPR (*Pseudomonas fluorescens*).



Control Microbial consortia + 80 % RDF

Treatment details

- T₁: Absolute control
- T₂: 7.5 t ha⁻¹ FYM + 100 % RDF
- T₃: 7.5 t ha⁻¹ enriched FYM (nitrogen fixers + PGPR) + 60 % RDF
- T₄: 7.5 t ha⁻¹ enriched FYM (nitrogen fixers + PGPR) + 80 % RDF
- T₅: 7.5 t ha⁻¹ enriched FYM (phosphate solubilizer + PGPR) + 60 % RDF
- T₆: 7.5 t ha⁻¹ enriched FYM (phosphate solubilizer + PGPR) + 80 % RDF
- T₇: 7.5 t ha⁻¹ enriched FYM (potassium solubilizer + PGPR) + 60 % RDF
- T₈: 7.5 t ha⁻¹ enriched FYM (potassium solubilizer + PGPR) + 80 % RDF
- T₉: 7.5 t ha⁻¹ enriched FYM (microbial consortia) + 60 % RDF
- T₁₀: 7.5 t ha⁻¹ enriched FYM (microbial consortia) + 80 % RDF

Results

Significantly higher grain yield (2952 kg ha⁻¹) and straw yield (4167 kg ha⁻¹) was with application of microbial consortia + 80 per cent RDF recorded compared to control (1132 and 1528 kg ha⁻¹, respectively).

Available nitrogen (152.95 kg ha⁻¹), phosphorus (118.80 kg ha⁻¹) and potassium (116.13 kg ha⁻¹) was significantly higher with application microbial consortia. Similarly, increased level of fertilizer i.e., 80 per cent RDF recorded significantly higher available nitrogen, phosphorus and potassium (148.95, 116.10 & 113.81 kg ha⁻¹, respectively).

Over all conjugative use of microbial consortia along with 80 per cent RDF recorded significantly higher available nitrogen (155.07 kg ha⁻¹), phosphorus (119.76 kg ha⁻¹) and potassium (117.80 kg ha⁻¹) compared to control. There was 4.35, 1.14 and 5.24 per cent increase in available NPK content of soil over its initial value.

Application of microbial consortia + 80 per cent RDF recorded significantly higher uptake of nitrogen (70.58 kg ha⁻¹), phosphorus (21.4 kg ha⁻¹) and potassium (59.84 kg ha⁻¹) over absolute control (18.63, 4.25 and 16.28 kg ha⁻¹, respectively).



General view of experimental plot

Table:1 Effect of different biofertilizer treatments and levels of fertilizers on soil available nutrient at harvest

	N	P ₂ O ₅	K ₂ O
	kg ha ⁻¹		
Initial	148.60	118.40	111.93
Biofertilizers enrichment			
B ₁ : NFB+ PGPR	149.39	108.11	106.60
B ₂ : PSB + PGRP	140.72	115.80	109.13
B ₃ : KSB + PGPR	141.93	110.93	113.98
B ₄ : Microbial consortia	152.95	118.80	116.13
S. Em. ±	2.51	2.13	2.04
CD (p=0.05)	7.62	6.47	6.19
Levels of RDF			
L ₁ : 60 % RDF	143.55	110.72	109.12
L ₂ : 80 % RDF	148.95	116.10	113.81
S. Em. ±	1.78	1.51	1.44
CD (p=0.05)	5.38	4.57	4.37
Interactions			
S. Em. ±	3.55	3.02	2.88
CD (p=0.05)	NS	NS	NS
Treatments			
T ₁ -Control	123.86	90.65	88.83
T ₂ -100 % RDF	135.15	102.29	101.27
T ₃ -B ₁ L ₁	146.27	104.76	103.60
T ₄ -B ₁ L ₂	152.50	111.45	109.60
T ₅ -B ₂ L ₁	137.73	113.04	106.13
T ₆ -B ₂ L ₂	143.71	118.55	112.13
T ₇ -B ₃ L ₁	139.35	107.23	112.27
T ₈ -B ₃ L ₂	144.51	114.63	115.70
T ₉ -B ₄ L ₁	150.83	117.84	114.47
T ₁₀ -B ₄ L ₂	155.07	119.76	117.80
S. Em. ±	5.35	5.14	4.57
CD (p=0.05)	15.54	15.27	13.57

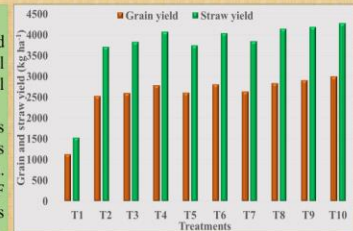


Fig. 1: Effect of bio- enriched FYM and different levels of NPK on grain and straw yield (kg ha⁻¹) of finger millet at harvest.

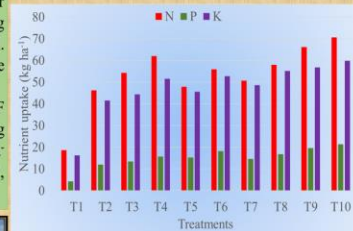


Fig. 2: Effect of bio- enriched FYM and different levels of fertilizers on total nutrient uptake of finger millet at harvest.

Summary

- ❖ Yield increased in all treatments compared to control.
- ❖ Among different biofertilizers, microbial consortia resulted in higher uptake and availability of nutrients.
- ❖ Similar was the trend with application of 80 per cent RDF.
- ❖ Conjugative use of MC+ 80 per cent RDF was found significant on uptake and build up of soil nutrient status.

Conclusion

Application of microbial consortia along with inorganic fertilizers helped in improving soil fertility status and productivity compared to single strain biofertilizers.

References

- RANGESH KUMAR, PATTANAYAK, S. K., JAGTARAN AND PILESHWAR, S. R., 2018, Studying the influence of long term INM practices on yield and quality of Ragi crop. *J. Pharmacogn. Phytochem.*, 7(1): 2175-2177.
- PALLAVI, C., JOSEPH, B., KHAN, M. A., AND HEMALATHA, S., 2016, Effect of integrated nutrient management on nutrient uptake, soil available nutrients and productivity of rainfed finger millet. *Int. J. Sci., Environ. Technol.*, 5(5): 2798-2813.

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LIST OF ABBREVIATIONS

Abbreviation	Full form	Abbreviation	Full form
%	Per cent	DTPA	Diethylenetriamine Penta acetic acid
@	At the rate of	EBT	Erichrome black - T
$\mu\text{g g}^{-1}$	Microgram per gram	E	East
AAS	Atomic absorption spectrophotometer	EC	Electrical conductivity
AgSO_4	Silver sulphate	EDTA	Ehtylene diamine tetra acetic acid
AICRP	All India Coordinated Research Project	<i>et al.</i> ,	and other people
AMF	Arbuscular mycorrhizal fungi	<i>etc.</i> ,	and so on
ANOVA	Analysis of variance	FAO	Food and Agriculture organisation
AZT	Azotobacter	FAS	Ferrous ammonium sulphate
B : C ratio	Benefit cost ratio	Fe	Iron
BD	Bulk Density	Fig.	Figure
Ca	Calcium	FYM	Farm yard manure
CaCl_2	Calcium chloride	g	Gram
CaCO_3	Calcium carbonate	GPU-28	Germ plasm unit
CD	Critical difference/ cow dung	H_2SO_4	Sulphuric acid
CFU g^{-1}	Colony forming unit per gram	H_3BO_3	Boric acid
cm	Centimetre	HCl	Hydrochloric acid
$\text{C mol (p+) kg}^{-1}$	Centimole per kilogram	HClO_4	Perchloric acid
Cu	Copper	HNO_3	Nitric acid
CuSO_4	Copper sulphate	INM	Integrated nutrient management
DAG	Days after germination	$\text{K}_2\text{Cr}_2\text{O}_7$	Potassium dichromate
DAP	Diammonium phosphate	K	Potassium
DAS	Days after sowing	K_2O	Potassium oxide
DAT	Day after transplanting	K_2SO_4	Potassium sulphate
dS m^{-1}	Decisiemen per meter	KCl	Potassium chloride

Abbreviation	Full form	Abbreviation	Full form
kg ha ⁻¹	Kilogram per hectare	P ₂ O ₅	Phosphorus pentoxide
KH ₂ PO ₄	Potassium dihydrogen phosphate	PD	Particle density
KRB	Potassium Releasing Bacteria	PGPR	Plant growth promoting rhizobacteria
KSB	Potassium solubilizing bacteria	PM	poultry manure
L. Gaertn.	Linnaeus and Gaertner	PMC	Press Mud cake
M	Molar	PNP g ⁻¹	para nitrophenol per gram
MBC	Microbial biomass carbon	POP	Package of practice
MBN	Microbial biomass nitrogen	ppm	Parts per million
MBP	Microbial biomass phosphorus	PSB	Phosphate solubilizing bacteria
MC	Microbial consortia	q ha ⁻¹	Quintal per hectare
Mg	Magnesium	RD	Recommended dose
mg kg ⁻¹	Milligram per kilogram	RDF	Recommended dose of fertilizer
Mg m ⁻³	Mega gram per cubic meter	Rs.	Rupees
mm	millimetre	S	Sulphur
Mn	Manganese	SOC	Soil organic carbon
MSL	Mean sea level	t ha ⁻¹	Tonnes per hectare
MUB	Modified Universal buffer	THAM	Tris-hydroxymethyl amino methane
MUB	Modified Universal buffer	TPF	Triphenyl formazon
nm	nanometre	TTC	Triphenyl tetrazolium chloride
NPK	Nitrogen, phosphorus and potassium	VAM	Vesicular Arbuscular mycorrhiza
NS	Non-significant	Var.	Variety
OC	Organic carbon	vs.	Versus
°C	Degree Celsius	ZnSO ₄	Zinc sulphate
P	Phosphorus	Zn	Zinc

I INTRODUCTION

Millets play an important role in farming and food culture in semi-arid zones of the world for millions of people in Africa and Asia. It has the ability to withstand varied conditions of heat, drought, humidity and tropical weathers. In India, finger millet (*Eleusine coracana* (L.) Gaertn) is mostly grown and consumed in Karnataka and to limited extent in Andhra Pradesh, Tamil Nadu, Odisha, Maharashtra, Goa and Uttarakhand. Alfisol form major soil order in Karnataka for finger millet and crop serve as staple food. In Karnataka, it covers an area of 598 lakh hectare with a production of 858.97 lakh tonne and productivity of 1436 kg per hectare during 2016-17 (Anon., 2017). With regard to nutrient content, finger millet grains are rich in carbohydrates (81.5 %), proteins (9.8 %), crude fibre (4.3 %), minerals (2.7 %) and fat (1-2 %) and also calcium (0.38 %), iron (3-20 %) and some of the vitamins like vitamin B, especially niacin, pyridoxine and folic acid (Gull *et al.*, 2014).

In a country like India, where 44 per cent of the total food production is being supported by dryland and there by playing a critical role in national's food security. In dry land situations, the major problems accounting with the soil are nutrient deficiency, low organic matter, less water holding capacity, poor soil structure due to poor aggregation, low soil pH, low cation exchange capacity (CEC), less moisture retentivity, higher infiltration rate, susceptible for causing erosion and runoff and starved crop conditions caused by aberrant weather all these bring down the productivity of rainfed crops. Therefore, it is important to recognize the untapped potentials of the dry land regions and design strategies for stimulating sustainable development in these regions.

Dry land soils need addition of organic matter along with chemical fertilizer to maintain productivity and soil health, but the availability of quality organic manure is of great concern. In crop production, nutrient management is an important practice to attain higher yield. Now a days, farmers are exuberantly using chemical fertilizers and this is considered as one of the main causes for environmental pollution and also deteriorates soil health (Rekha *et al.*, 2018). Most of the deficiencies observed in plants, animal and people are due to soil condition not being conducive to nutrient uptake. The minerals are present

in excess but simply not available to plant. Adding inorganic elements to correct these deficiencies is an inefficient practice.

Availability of nutrients in sufficient and balanced quantities throughout the plant growth period is very important to maintain productivity. The most important constraint faced by developing country and especially among resource-poor farmers, is poor soil fertility. It can be restored efficiently by adaptation of integrated nutrient management encompassing nutrient management strategy to enhance input use efficiency, application of biofertilizers and natural resource conservation. Balanced application of fertilizer is the basis of plant health. Application of chemical fertilizers cannot be avoided completely, since they are the potential source for nutrients in easily available form. However, the increasing fertilizer costs on one hand and the use of inorganic fertilizers alone without proper understanding of balanced application has led to decline in the finger millet productivity in many areas of southern Karnataka. Hence, there is an urgent need for finding an alternate source of chemical fertilizers.

There are abundant microorganisms thriving in soil, especially in the rhizosphere of plants. It is well known that a considerable number of bacteria and fungi species possess a functional relationship and constitute a holistic system with plants (Wu *et al.*, 2005). About 85 to 90 per cent of plant nutrient acquisition is microbially mediated. The soil's ability to support nutrient requires the presence of diverse array of soil microbes from a range of functional groups, which can be made available through addition of organic manure. The majority of microbes involved in nutrient acquisition are plant dependent, that is they respond to carbon compound exuded by the roots of actively growing green plants. In this regard, the role of biofertilizers in soil fertility maintenance is becoming increasingly important in both organic farming and conventional agriculture. Application of enriched organic manure with biofertilizers improves physical, chemical and biological condition of soils.

Biofertilizers are living cells of different microorganisms which has ability to convert nutritionally important elements from unavailable to plant useable form through various biological processes. In recent years, biofertilizers has emerged as an important

component of integrated nutrient supply system and their use is focused for enhancing productivity and supplementing chemical fertilizers. Where in, their application can improve soil, quality of yield and reduce chemical fertilizer demand upto 30 per cent. However, application of microbial fertilizers in practice somehow has not achieved constant effect. The mode of action and interactions among these microbes still are not well understood, especially in real time application. A biofertilizers consisting of nitrogen fixers (*Azotobacter chroococcum*), P solubilizer (*Baccillus megaterium*), K solubilizer (*Frateuria aurantia*) and PGPR (Plant growth promoting rhizobacteria) (*Pseudomonas fluorescens*) which play a important role in biological control of plant pathogens, nutrient cycling and seedling establishment, deserves particular attention for maintaining soil fertility and enhancing productivity in rainfed ecosystem. Inoculation of PGPR along with nitrogen fixers, *Azotobacter* may derive beneficial effect both from its nitrogen fixation and stimulating effect on root development. P and K solubilizing bacteria may enhance mineral uptake by plants through solubilizing insoluble *phosphorus* and releasing potassium from the silicate in soil.

Crop suffers from the slow release of nutrients from organic manures at initial stages, which may cause significant reduction in crop yield and farm income. This can be overcome by enrichment of organic manures with beneficial microbial culture and judicious combination of inorganic fertilizers with such enriched organic manures. The biofertilizer enrichment of organic manures will further contribute to the enhancement of P solubilization, K solubilizer, nitrogen fixers and also in release of nutrients at different periods and controlling the soil borne pathogens. Hence, integration of organic, inorganic and biofertilizers (single strain and consortia) play a pivotal role to enhance crop productivity, sustain soil health and decreases environmental impact. Adoption of appropriate strategies hold a great potential in boosting finger millet yield in effective manner.

To understand tripartite interaction between microbial inoculation, mineral fertilizer and crop species is a prerequisite, more particularly to unravel behaviour responses of beneficial microbes in agro-ecosystem, for higher nutrient release, uptake and tolerance to multiple constrains. Considering the above facts, the present investigation,

entitled “**Studies on bio enriched farm yard manure (FYM) on soil properties and productivity of finger millet (*Eleusine coracana* (L.) Gaertn) under dryland condition**” was carried out at AICRP on Dry Land Agriculture, UAS GKVK with the following objectives-

- 1) To study the effect of enriched farm yard manure (FYM) on nutrient availability, uptake and biological properties of soil at different growth stage.
- 2) To study the influence of enriched farm yard manure (FYM) on physico-chemical and biological properties of soil.
- 3) To study the impact of enriched farm yard manure (FYM) on growth, yield, nutrient content and economics of finger millet.

II REVIEW OF LITERATURE

The literature pertaining to “**Studies on bio-enriched farm yard manure (FYM) on soil properties and productivity of finger millet (*Eleusine coracana* (L.) Gaertn) under dryland condition**” has been reviewed and presented under following headings.

- 2.1 Characterization of FYM for its nutrient status
- 2.2 Effect of microbial enrichment of organic manure on its nutrient status
- 2.3 Effect of bio- enriched FYM and inorganic fertilizer on growth and yield of crop
- 2.4 Effect of bio- enriched FYM and inorganic fertilizer on soil physical properties
- 2.5 Effect of bio- enriched FYM and inorganic fertilizer on soil chemical properties
- 2.6 Effect of bio- enriched FYM and inorganic fertilizer on soil biological properties
- 2.7 Effect of bio- enriched FYM and inorganic fertilizer on nutrient content and uptake by crops.
- 2.8 Effect of bio- enriched FYM and inorganic fertilizer on economics.

2.1 Characterization of FYM for its nutrient status

At present, most optimistic estimates show that about 25 –30 per cent of nutrient needs of Indian agriculture can be met by various organic sources. The availability from organic sources are based on total nutrient content but their efficiencies to meet the nutrient requirement of crops is not as assured as such as mineral fertilizers. However, the joint use of chemical fertilizers along with various organic sources is capable of sustaining higher crop productivity, improving soil quality and productivity on long-term basis.

Theunissen *et al.* (2010) analysed FYM and found that FYM contain 0.5, 0.2, 0.5, 0.9 and 0.2 per cent of nitrogen, phosphorus, potassium, calcium and magnesium, respectively. Whereas, iron, copper, manganese and zinc were found to be 146.5, 2.8, 69.0 and 14.5 ppm, respectively.

Nutrient composition of FYM was analysed by Parihar *et al.* (2013) and recorded 0.53 per cent of nitrogen, 0.22 per cent phosphorus, 0.59 per cent potassium, 2100 mg kg⁻¹ iron, 61 mg kg⁻¹ zinc and 2.2 mg kg⁻¹ boron on dry weight basis.

FYM was characterized by Veerasha and Gopakkali (2014) and observed pH of 8.1, EC of 0.16 dS m⁻¹ and organic carbon content of 10.71 per cent. Whereas nitrogen, phosphorus and potassium were found to be 0.54, 0.29 and 0.40 per cent, respectively.

Nutrient analysis of FYM recorded 39.53 per cent of organic carbon, 1.21 per cent of nitrogen, 0.58 per cent of phosphorus and 4.26 per cent of potassium. Whereas, among micronutrients zinc 57 mg kg⁻¹, copper 239 mg kg⁻¹, iron 2214 mg kg⁻¹ and manganese 28 mg kg⁻¹ were recorded (Kumar and Narwal, 2016).

The physical and chemical properties characterization of FYM by Lavanya (2019) showed bulk density of 1.12 Mg m⁻³, 48.32 per cent MWHC with neutral pH (7.32) and EC of 2.35 dS m⁻¹. Whereas 0.60 per cent of nitrogen, 0.31 per cent of phosphorus, 0.57 per cent of potassium, 0.78 per cent of calcium, 0.21 per cent of magnesium and 25.60 mg kg⁻¹ of sulphur were found. With respect to micronutrients 973.0 mg kg⁻¹ of iron, 456.0 mg kg⁻¹ of manganese, 164.0 mg kg⁻¹ of zinc, 66.80 mg kg⁻¹ of copper and 0.13 mg kg⁻¹ of nickel were recorded.

2.2 Effect of microbial enrichment of FYM on nutrient status of organic manure

Kumar and Singh (2001) conducted a work on effect of inoculation of vermicompost with nitrogen fixing biofertilizer (*Azotobacter chroococcum*) and P solubilizer (*Pseudomonas striata*) on N and P content of vermicompost and noticed that application of *Azotobacter chroococcum* (2.73 and 1.45 %) and *Pseudomonas striata* (1.68 and 1.52 %) increased N and P content, respectively at 75 days after inoculation compared to initial N (1.40 %) and P (1.10 %) content.

Mahanta *et al.* (2012) evaluated the microbial enriched vermicompost and their effect on nutrient availability and microbial population in vermicompost. The results revealed that eight weeks of incubation after inoculating with *Azotobacter chroococcum*,

Azospirillum brasilense, and *Pseudomonas fluorescens*, either alone or in combination there was increase in microbial composition and nutrient status. The highest increase of nitrogen concentration was observed with vermicompost (mixed biomass) enriched with *A. chroococcum* (2.35 %) followed by *A. brasilense* (2.26 %) and least in control (2.00 %).

Enrichment of compost with lignite based biofertilizer viz., nitrogen fixers (*Azospirillum* sp.) and P solubilizers (*Pseudomonas striata*) recorded higher nitrogen (1.45 %), phosphorus (0.75 %), potassium (0.80 %), iron (245.60 ppm), copper (26.80 ppm), zinc (156.21 ppm) and manganese (256.9 ppm) compared to unenriched compost (1.08 %, 0.42 %, 0.35 %, 241.8 ppm, 24.05 ppm, 152.0 ppm and 256.9 ppm, respectively). Similarly, higher microbial population of bacteria (154.2×10^5 CFU g⁻¹), fungi (115×10^3 CFU g⁻¹), actinomycetes (35×10^2 CFU g⁻¹), PSB (30.8×10^3 CFU g⁻¹) and nitrogen fixers (40.3×10^3 CFU g⁻¹) were found in enriched FYM compared to unenriched FYM (92.2×10^5 , 87×10^3 , 26×10^2 , 18.3×10^3 and 26.2×10^3 CFU g⁻¹, respectively) (Rao *et al.*, 2012).

The enrichment of FYM using lignite-based cultures such as *Azospirillum* sp., *Pseudomonas striata* and *Trichoderma harzianum* @ one kg per ton of manure showed increase in nitrogen (31.43 %), phosphorus (23.40 %) and potassium (19.59 %) over unenrichment of FYM. The higher microbial population of *Azospirillum* sp. (0.17, 7.90, 7.40 and 6.53×10^3 CFU g⁻¹), PSB (66.40, 78.17, 32.50 and 29.26×10^4 CFU g⁻¹) and *Trichoderma* sp. (4.62, 10.17, 6.00 and 4.22×10^3 CFU g⁻¹) were recorded at 7, 14, 21 and 28th days after enrichment were recorded compared to unenriched FYM with 0.11×10^3 , 32.5×10^4 and 2.50×10^3 CFU g⁻¹, respectively of *Azospirillum* sp., PSB and *Trichoderma* sp. (Nandini and Sreenivasa, 2014).

Application of bio enriched vermicompost (*Azotobacter* + *Pseudomonas*) increased available nitrogen (16.8 %) and phosphorus (10.7 %) compared to initial vermicompost (12.0 and 8.2 %) at 60 days after incubation @ 28°C (Alikhani *et al.*, 2016)

2.3 Effect of bio- enriched FYM and inorganic fertilizer on growth and yield of crop

Mathews *et al.* (2006) conducted a work on effect of nutrient and biofertilizers (*Azospirillum* + *Phosphobacterin*) on yield and yield component of rice and noticed higher

productive tillers per hill (14.6), test weight (26.8 g), grain yield (99.3 q ha⁻¹), straw yield (104.3 q ha⁻¹) and harvesting index (0.48) with application of 150 per cent RDF + biofertilizer compared to application of 150 per cent RDF alone with productive tillers per hill (14.4), test weight (26.6 g), grain yield (97.4 q ha⁻¹), straw yield (101.9 q ha⁻¹) and harvesting index (0.49).

In paddy, application of 75 per cent RDF + biofertilizer increased plant height (62.3, 78.4, 96.8 and 100.4 cm), number of tillers per plant (26.5, 47.0, 50.0 and 47.5), dry matter production (40.70, 86.04, 106.23 and 90.74 q ha⁻¹) at 30, 60, 90 and at harvest, respectively compare to 100 per cent RDF. Similarly, highest grain yield (73.0 vs. 61.4 q ha⁻¹), straw yield (86.3 vs. 72.7 q ha⁻¹), test weight (29.9 vs. 28.2 g) and harvesting index (0.45 vs. 0.46) was recorded in same treatment compared to 100 per cent RDF (Wijebandara *et al.*, 2009).

An experiment conducted to find out the effect of *Azospirillum* and AMF (Arbuscular mycorrhizae fungi) on finger millet by Bama and Ramakrishanan (2010) showed that co-inoculation of *Azospirillum* and AM fungi significantly enhanced number of fingers per plant (7.3), ear head length (8 cm) followed by *Azospirillum* treatment alone. Similarly, it showed increased plant biomass (5.01 and 8.12 g plant⁻¹), shoot length (16.6 and 21.2 cm) and root length (31.6 and 52.6 cm) at 30 and 45 days after sowing, respectively. The grain productivity in co-inoculants recorded 36.8 per cent increased yield over their respective control.

Application of recommended fertilizer + ZnSO₄ + gypsum + *Azotobacter* showed significantly higher number of tillers (8 vs. 4 plant⁻¹), ear head (8 vs. 3 plant⁻¹), number of fingers (43 vs. 25 plant⁻¹) and yield (61 vs. 49 q ha⁻¹) in finger millet under rainfed condition (Sridhara *et al.*, 2010).

A study carried out by Iwuagwu *et al.* (2012) on the effect of biofertilizers on the growth of maize reported that application of *Azotobacter* + *Azospirillum* + PSB showed higher plant height (38.85 cm) followed by application of *Azotobacter* + *Azospirillum* (38.65 cm) 10 days after planting.

Study conducted by Mudalagiriappa *et al.* (2012) on nutrient management practices on growth and yield of *rabi* sorghum revealed that 50 per cent RDF + FYM 2.5 t ha⁻¹ + microbial consortia increased plant height (11.06 %), panicle length (27.94 %), panicle diameter (25.4 %) test weight (10.22 %), grain yield (26.66 %) and straw yield (31.48 %) over 50 per cent RDF + FYM 2.5 t ha⁻¹.

Goutami (2013) conducted an experiment to study the nutrient management in rice – sorghum and revealed that application of 150 kg N ha⁻¹ + FYM + biofertilizers (*Azospirillum*, PSB and PGPR) increased plant height (177 cm), length of ear (24 cm), no. of grain per ear (1271), test weight (31.29 g), grain yield (35.8 q ha⁻¹) and straw yield (69.4 q ha⁻¹) compared to application of 150 kg N ha⁻¹ alone (161 cm, 22.8 cm, 1125, 28.43 g, 29.1 q ha⁻¹ and 61.4 q ha⁻¹, respectively).

Abdullahi *et al.* (2014) conducted a field experiment to study the effect of bio-fertilizer, Arbuscular mycorrhizal fungi (AMF) (*Glomus mosseae*) and *Azospirillum brasilense* alone or in combination with cow dung (CD) or poultry manure (PM) on growth of pearl millet. They found significant increase in plant height (67.4 cm), number of tillers plant⁻¹ (3.0), shoots (5.8 g) and root (2.6 g) dry biomass in treatment which received cow dung + biofertilizers compared to number of tillers plant⁻¹ (2.2), shoot (3.2 g) and root (1.2 g) dry biomass in control.

The effect of levels of phosphorus and potassium on growth, yield, nutrient content of finger millet (*Eleusine coracana* L.) conducted by Shruthi (2014), revealed that plant height at harvest (123.50 vs. 118.80 cm), number of tillers per plant (4.72 vs. 4.38), number of ear head per plant (4.74 vs. 4.41), number of finger per ear head (6.40 vs. 5.83), ear head length (6.92 vs. 6.43 cm), test weight (4.13 vs. 3.64 g), grain yield (3878.5 vs. 3433.0 kg ha⁻¹) and straw yield (4499.5 vs. 4025.6 kg ha⁻¹) of finger millet crop was significantly higher in treatment which received 100 per cent NPK + FYM + P and K solubilizer compared to 100 per cent NPK + FYM alone.

Ram *et al.* (2015) conducted experiment on effect of bio-fertilizers and nitrogen management on yield and soil fertility of pearl millet under rainfed condition and revealed

that inoculation of *Azotobacter* + PSB increased grain and fodder yield (819 and 3197 kg ha⁻¹, respectively), compare to sole inoculation of PSB (879 and 3130 kg ha⁻¹) and *Azotobacter* (853 and 3058 kg ha⁻¹) grain and fodder yield, respectively.

Kumar (2016) recorded that application of 50 per cent P + FYM @ 7.5 kg ha⁻¹ + PSB @ 5.0 kg ha⁻¹ increased grain yield (2200 kg ha⁻¹), straw yield (4550 kg ha⁻¹) and harvesting index (32.5 %) compared to grain yield (9900 kg ha⁻¹), straw yield (2800 kg ha⁻¹) and harvesting index (24.4 %) with 50 per cent P + FYM @ 7.5 kg ha⁻¹ in finger millet.

The study on effect of NPK with biofertilizers on growth, yield and nutrient uptake of wheat by Singh *et al.* (2016) showed increase in growth and yield with increase in the NPK fertilizer levels. Significantly highest grain yield (54.10 q ha⁻¹) and straw yield (79.69 q ha⁻¹) was found in treatment which received 125 per cent RDF along with biofertilizers over control.

Recommended NPK + FYM 7.5 t ha⁻¹ + PGPR @ 2 kg ha⁻¹ increased plant height (140.47 cm), number of tillers per plant (3.40), total dry weight (49.40 g), number of ear heads per plant (2.40), test weight (3.57 g), grain yield (50.73 q ha⁻¹), straw yield (73.70 q ha⁻¹) and harvesting index (0.33) compared to plant height (139.60 cm), number of tillers per plant (3.13), total dry weight (45.77 g), number of ear heads per plant (2.00), test weight (3.27 g), grain yield (44.74 q ha⁻¹), straw yield (69.03 q ha⁻¹) and harvesting index (0.33) in treatment which received NPK + FYM 7.5 t ha⁻¹ (Thimmaiah *et al.*, 2016).

Effect of biofertilizers and inorganic fertilizers on soil health, growth and yield of rice (*Oryza sativa* L.) crop was conducted by Yuvaraj (2016) and found significantly higher grain (64.92 q ha⁻¹) and straw yield (79.68 q ha⁻¹) in the treatment receiving inorganic fertilizers along with consortium biofertilizers (RD N and P + *Azospirillum* + PSB + PGPR). While, least was in treatment which received 75 per cent of N and P (59.44 and 73.62 q ha⁻¹, respectively).

Finger millet grown under three-year-old *Melia azedarach* in red sandy loam soil with different management study revealed that application of 75 per cent RD N +

Azospirillum + PSB increased plant height by 8.17, 11.89 and 8.09 per cent over 75 per cent RD N + 25 per cent N FYM at 30, 60 DAS and at harvest, respectively. Similarly, application of 75 per cent RD N + *Azospirillum* + PSB significantly increased fingers per ear head (6.90 vs. 6.63), finger length (8.67 vs. 6.63 cm), ear head weight (4.27 vs. 3.56 g), test weight (3.26 vs. 2.56 g), grain yield (2681 vs. 1828 kg ha⁻¹) and straw yield (5063 vs. 3745 kg ha⁻¹) over application of 75 per cent N + 25 per cent N FYM alone. (Pallavi *et al.*, 2017).

Performance of finger millet (*Eleusine coracana* L. Gaertn.) under integrated nutrient management practices studied by Ashok Kumar Roy (2018) found that application of FYM (10 t ha⁻¹) + biofertilizer (*Azospirillum brasilense* + *Bacillus* spp. + *Psuedomonas fluorescens* @ 20 g kg⁻¹ seed each) + ZnSO₄ (12.5 kg ha⁻¹) + Borax (5 kg ha⁻¹) + 100 per cent RDF increased plant height by 53.12, 131.70, 99.67 and 96.59 per cent at 30, 60, 90 DAS and at harvest respectively over absolute control.

Gupta (2018) worked on effect of Integrated use of fertilizers and biofertilizers on performance of maize and soil properties in a *Vertisol* and found that application of RDF + *Azotobacter* + *Azospirillum* + PSB + VAM increase grain yield (3329 kg ha⁻¹), straw yield (10984 kg ha⁻¹) and harvesting index (23.26 %) compared to RDF + *Azotobacter* (3121 kg ha⁻¹, 10587 kg ha⁻¹ and 22.77 %), RDF + PSB (2763 kg ha⁻¹, 9711 kg ha⁻¹ and 22.15 %) and RDF (2547 kg ha⁻¹, 9123 kg ha⁻¹ and 21.83 %).

Study on yield and nutrient uptake of finger millet as influenced by organics and liquid biofertilizer consortium was conducted by Lavanya *et al.* (2018) reported increase in grain yield (1029 kg ha⁻¹) with application of RDF + liquid microbial consortia (phosphorus solubilising bacteria (PSB) + *Azospirillum* + Potash releasing bacteria (PRB) @ 3.75 l ha⁻¹ + vesicular Arbuscular Mycorrhizae @ 12.5 kg ha⁻¹) compared to RDF alone (942 kg ha⁻¹).

Rangesh Kumar *et al.* (2018) compiled the long-term experiment (6 years) on upland irrigated system with 10 different treatments in finger millet. Among those treatments 100 per cent NPK (52:15:32 kg ha⁻¹) + FYM (5 kg ha⁻¹) + Lime + Bio fertilizer

(*Azotobacter* and PSB @ 4 kg each ha⁻¹) showed significantly higher grain yield (2.72 t ha⁻¹) and straw yield (4 t ha⁻¹) as compared to absolute control (1.14 t ha⁻¹ and 2.92 t ha⁻¹, respectively).

Singh *et al.* (2018) cited that application of biofertilizer (*Pseudomonas fluorescens*, *Azotobacter chroococcum*, *Azospirillum lipoferum*, *Acetobacter diazotrophicus* and one fungi- *Trichoderma viride* @ 10-25 g kg⁻¹) in combined treatment with all the bioinoculants enhanced the grain (30.1q ha⁻¹) and straw (107.7 q ha⁻¹) yield compared to control (16.8 and 87.4 q ha⁻¹, respectively) in pearl millet.

Growth, yield and quality of finger Millet (*Eleusine coracana* L. Gaertn) as influenced by Integrated Nutrient Management was the work done by Harika *et al.* (2019) and reported that application of 75 per cent RDF +FYM 2 t ha⁻¹+ *Azospirillum* increased grain (1191 kg ha⁻¹) and straw (3882 kg ha⁻¹) yield over 75 per cent RDF +FYM 2 t ha⁻¹ (1176 and 3951 kg ha⁻¹, respectively).

Kejiya *et al.* (2019) studied the effect of phosphatic fertilizers on yield and quality of finger millet (*Eleusine coracana* L.) and reported that application of 75 per cent RDF + PSB + VAM increased grain (4157 kg ha⁻¹) and straw (8387 kg ha⁻¹) yield compared to 100 per cent RDF (3846 and 8382 kg ha⁻¹, respectively) application in finger millet.

A field experiment was conducted to evaluate the effect of Integrated Nutrient Management (INM) on growth and yield of foxtail millet in Madurai district showed significantly higher grain (1680 kg ha⁻¹) and straw (3552 kg ha⁻¹) yield with application of 75 per cent RDF+ 25 per cent Azophos compared to 100 per cent RDF (1543 and 3245 kg ha⁻¹, respectively) (Monisha *et al.*, 2019).

Rani *et al.* (2019) reported the effect of liquid biofertilizers on growth and yield of *rabi* sorghum (*Sorghum bicolor* L.) and found that seed treatment with *Azospirillum* @ 4ml + PSB @ 4 ml kg⁻¹ seed increased grain yield (2.33 t ha⁻¹), straw yield (5.43 t ha⁻¹) and harvesting index (28.7 %) compared to control (1.35 t ha⁻¹ of grain yield, 4.75 t ha⁻¹ of straw yield and 24.4 % of harvesting index).

Gangaraddi *et al.* (2020) worked on biofertilizer effect on finger millet crop revealed that application of microbial consortia (*Azotobacter chroococcum*., *Bacillus megaterium* and *Pseudomonas fluorescens*) recorded increase in plant height (20.78 cm) followed by *A. chroococcum* + *B. megaterium* (19.57 cm) at 30 days after transplanting (DAT). While, at 60 days height was highest (37.46 cm) in treatment which received *A. chroococcum* + *B. megaterium* + *P. fluorescens* followed by *A. chroococcum* + *P. fluorescens* (34.16 cm).

2.5 Effect of bio- enriched FYM and inorganic fertilizer on soil physical properties

Nisha *et al.* (2007) reported that physical structure of the soil was influenced by application of biofertilizer and reported significant decline in bulk density from 1.09 to 1.04 and 1.04 to 1.02 gm cm⁻³ in pearl millet and wheat, respectively. Similarly, application of biofertilizer increased water holding capacity (39.7 to 40.5 and 38.0 to 38.75 %), hydraulic conductivity (0.75 to 0.95 and 1.32 to 2.06 cm h⁻¹) and mean weight diameter (0.38 to 0.65 and 0.45 to 0.64 mm) at the end of both pearl millet and wheat crop.

Saha *et al.* (2010) observed that continuous application of balanced nutrition, lime, FYM and microbial inoculants over a period of five years under maize- mustard cropping sequence in acidic soil induced substantial improvement in soil aggregate size (48.82 %), stability (39.57 %), water holding capacity (54.67 %) and porosity (32.41 %) over the treatment which received only inorganic fertilizer.

Banerjee *et al.* (2011) studied influence of Integrated Nutrient Management on soil properties of old Alluvial soil under mustard cropping system and found significant decrease in bulk density and particle density by 17.75 and 11.21 per cent and increase in porosity and water holding capacity by 14.92 and 22.24 per cent in biofertilizer inoculated plot after harvest of crop compared to before sowing.

Experiment entitled nutrient management in rice – sorghum was conducted by Goutami (2013) found that application of 150 kg N ha⁻¹ + FYM + biofertilizers (*Azospirillum*, PSB and PGPR) reduced bulk density (1.42 Mg m⁻³) and increased particle

density (2.69 Mg m^{-3}) and porosity (48.72 %) compared to absolute control (1.49 Mg m^{-3} , 2.61 Mg m^{-3} and 42.91 %, respectively).

Effect of integrated nutrient management practices on physico chemical properties of soil under different growth stages of finger millet was studied by Chikkaramappa *et al.* (2014) and revealed that application of FYM + 100 per cent RDF + *Azospirillum* recorded higher water holding capacity (32, 32 and 31.66 %) at maximum tillering stage, earhead initiation and harvesting stage, respectively compared to 100 per cent RDF alone (23.3, 23 and 23.66 %, respectively).

The influence of biofertilizer inoculation, *viz.*, *Azotobacter* (AZT) and phosphate solubilising bacteria (PSB) alone and in different combinations with recommended dose of chemical fertilizer (NPK) on cotton crop was tested by Doifode (2016) and recorded that water holding capacity (WHC) was 66.25 per cent. The post-harvest soil analysis showed maximum WHC (69.74 %) in the treatment AZT + PSB followed by 50 per cent RDF + AZT (69.54 %) while minimum (61.54 %) was recorded in 100 per cent RDF.

A field experiment conducted to find out the effect of integrated use of urea, zinc, poultry manure and *Azotobacter* on physico-chemical properties of soil under rice crop (*Oryza sativa* L.) found increase in bulk density in treatment which received 50 per cent N through poultry manure + 50 per cent N through urea + Zn (1.30 , 1.34 and 1.40 Mg m^{-3}) at 30, 60 days after transplanting and at harvest, respectively compared to 50 per cent N through poultry manure + 25 per cent N through urea + *Azotobacter* + Zn (1.27 , 1.31 and 1.36 Mg m^{-3}) (Kumar, 2016).

Experiment comprising four fertility levels (control, 50 % RDF, 75 % RDF, and 100 % RDF) and four biofertilizers levels (control, PSB, Rhizobium and Rhizobium + PSB) on black gram conducted by Chetan *et al.* (2017) found that bulk density, particle density and porosity was not significantly affected by application of biofertilizers but there was slight reduction in bulk density and particle density by 4.41 and 1.14 per cent, respectively and increased porosity by 3.52 per cent was noticed due to application of PSB + Rhizobium over control.

Soil BD was markedly decreased by 4.69 per cent with application of 60 per cent chemical fertilizers + biofertilizers (*B. subtilis* and *B. subtilis*) treatment, compared with 60 per cent chemical fertilizers + organic fertilizers treatment (Li *et al.*, 2017).

2.5 Effect of bio- enriched FYM and inorganic fertilizer on soil chemical properties

Ramalakshmi *et al.* (2008) studied the influence of biofertilizer on soil physico-chemical and biological properties during cotton cropping period and reported that the biofertilizer inoculation resulted in shift in the pH reducing the alkalinity with biofertilizers, while the organic carbon increased slightly in soils inoculated (0.34 – 0.38 %) treatments compared to uninoculated soil (0.30 %). The available nitrogen status of soil was higher (179- 182 kg ha⁻¹) where *Azospirillum* was component, while the treatment with mycorrhiza and Phosphobacteria increased the available soil phosphorus (10.7- 11.1 kg ha⁻¹). Higher soil potassium (456 kg ha⁻¹) was observed with co-inoculation of Azophos and mycorrhiza compared to control (132, 7 and 364 kg ha⁻¹ of NPK, respectively.)

Saha *et al.* (2010) found that application of lime, organic manure and biofertilizer along with graded doses of N, P, and K resulted in the greatest total N content of the soils. The available N content of the soils varied from 246.72 kg ha⁻¹ in the control to 501.82 kg ha⁻¹ with the application of optimum doses of NPK + lime + FYM + biofertilizer. Similarly, the available P (Bray's P) significantly varied from 6.61 kg ha⁻¹ (control) to 32.85 kg ha⁻¹ (100 % NPK + lime + FYM + biofertilizer) and available K content varied from 124.14 kg ha⁻¹ (control) to 243.62 kg ha⁻¹ (100 % NPK + FYM + lime + Biofertilizer).

According to Dass *et al.* (2013) application of 50 per cent RF + 2.5 t ha⁻¹ Gliricidia + 2.5 kg ha⁻¹ each of PSB and *Azotobacter* increased SOC (0.46 vs. 0.41 %), soil available N (278 vs. 240 kg ha⁻¹), available P (14.7 vs. 12.1 kg ha⁻¹), and available K (307 vs. 279 kg ha⁻¹) compared to farmers input (FYM at 2 t ha⁻¹ + 17:12:0 kg N, P₂O₅, K₂O).

Goutami (2013) conducted an experiment on nutrient management in rice – sorghum and reported that application of 150 kg N ha⁻¹ + FYM + biofertilizers (*Azospirillum*, PSB and PGPR) incremented available nitrogen (197 and 176 kg ha⁻¹), phosphorus (44.9 and 42.7 kg ha⁻¹), potassium (974 and 842 kg ha⁻¹), zinc (0.37 and 0.41

mg kg⁻¹), iron (13.20 and 12.00 mg kg⁻¹), copper (4.87 and 3.68 mg kg⁻¹) and manganese (8.54 and 6.98 mg kg⁻¹) over application of 150 kg N ha⁻¹ at flowering and after harvest of sorghum crop, respectively in soil.

Chikkaramappa *et al.* (2014) studied the effect of integrated nutrient management practices on physico chemical properties of soil under different growth stages of finger millet and reported that application of FYM + 100 per cent RDF + *Azospirillum* recorded higher organic carbon (0.62, 0.52 and 0.5 %), EC (0.29, 0.29 and 0.29 dS m⁻¹), available N (448.5, 4459.6 and 314.6 kg ha⁻¹), P₂O₅ (14, 19.1 and 17.2 kg ha⁻¹), K₂O (383.4, 373.37 and 276.29 kg ha⁻¹), S (17.06, 19.73 and 19.60 ppm), exchangeable Ca (4.51, 5.0 and 2.90 c mol (P⁺) kg⁻¹) and exchangeable Mg (2.22, 2.80 and 1.78 c mol (P⁺) kg⁻¹) at maximum tillering stage, ear head initiation and harvesting stage, respectively compare to 100 per cent RDF.

Shruthi (2014) revealed that application of 100 per cent NPK (POP) + FYM+ phosphorus and potassium solubilizers reduced soil pH (7.22) and increased EC (0.38 dS m⁻¹), OC (0.60 %), available nitrogen (233.04 kg ha⁻¹), phosphorus (116.13 kg ha⁻¹) and potassium (440.70 kg ha⁻¹) compare to treatment which received 100 per cent NPK alone.

Ram *et al.* (2015) found that co-inoculation of *Azotobacter* + PSB increased the available nitrogen (0.5 and 2.02 %), phosphorus (3.63 and 9.61 %) and potassium (1.32 and 1.91 %) over independent inoculation of PSB and *Azotobacter*, respectively in pearl millet grown soil for four years.

Study on effect of biofertilizers consortium (PSB + PGPR), organic and inorganic fertilizers on physico-chemical properties of rhizospheric soil in pea crop revealed that Soil electrical conductivity (0.224 dS m⁻¹), available nitrogen (123.8 kg ha⁻¹) and available potassium (121.9 kg ha⁻¹) were significantly higher in treatments which received 50 per cent farm yard manure + 50 per cent recommended dose of nitrogen and phosphorus + consortium. However, soil organic carbon (0.35 %) and available phosphorus (28.4 kg ha⁻¹) were significantly higher in treatments which received 100 per cent farm yard manure + consortium compare to EC (0.22 dS m⁻¹), OC (0.32 %), available N, P and K (110.4, 20.3

and 113.2 kg ha⁻¹, respectively) in treatments which received recommended dose of fertilizer alone (Kaur, 2016).

Kumar (2016) reported that application of 50 per cent P + FYM @ 7.5 kg ha⁻¹+ PSB @ 5.0 kg ha⁻¹ increased soil nitrogen (69.20 kg ha⁻¹), phosphorus (13.41 kg ha⁻¹) and potassium (130.70 kg ha⁻¹) status compared to 100 per cent P (59.64, 12.99 and 127.97 kg ha⁻¹, respectively) alone in finger millet cropping system.

Yuvaraj (2016) worked on effect of biofertilizers and inorganic fertilizers on soil health, growth and yield of rice (*Oryza sativa* L.) crop and recorded maximum soil pH (7.18) in treatment which received only inorganic fertilizers alone. Whereas, statistically higher electric conductivity (0.24), organic carbon (0.35 %), available nitrogen (140.29 kg ha⁻¹), phosphorus (25.39 kg ha⁻¹) and potassium (169 kg ha⁻¹) was observed in the treatment with inorganic fertilizers and consortium biofertilizers.

Chetan *et al.* (2017) conducted an experiment with four fertilizer levels (control, 50 % RDF, 75 % RDF and 100 % RDF) and four biofertilizers levels (control, PSB, Rhizobium and Rhizobium + PSB) on black gram. The application through seed inoculation with Rhizobium + PSB significantly increased the organic carbon (12.69 %), available N (15.80 %), P₂O₅ (21.32 %), K₂O (6.34 %), Cu (11.45 %), Zn (14.59 %), Fe (22.37 %) and Mn (25.45 %) content in soil over uninoculated control treatment.

Khipla (2017) found that application of 75 per cent N+ 100 per cent P recorded highest pH (7.63), while lowest pH (7.51) was observed with application of 100 per cent N+ 75 per cent P + *Azotobacter*. However, application of 100 per cent RDF + microbial consortia showed higher organic carbon (0.32 %), available nitrogen (168.2 kg ha⁻¹), phosphorus (21.3 kg ha⁻¹) and potassium (142 kg ha⁻¹) compared to 100 per cent RDF (0.30 % of OC, 150.6, 14.3 and 128.1 kg ha⁻¹ of NPK, respectively).

Ashok Kumar Roy (2018) studied performance of finger millet (*Eleusine coracana* L. Gaertn.) under integrated nutrient management practices and found that application of FYM (10 t ha⁻¹) + biofertilizer (*Azospirillum brasilense* + *Bacillus* sp. + *Psuedomonas fluorescens* @ 20 g kg⁻¹ grain each) + ZnSO₄ (12.5 kg ha⁻¹) + borax (5 kg ha⁻¹) + 100 per

cent RDF showed higher available nitrogen (233.83 kg ha⁻¹), phosphorus (19.68 kg ha⁻¹) and potassium (108.96 kg ha⁻¹) followed by treatment which received FYM (10 t ha⁻¹) + biofertilizer + ZnSO₄ (12.5 kg ha⁻¹) + borax (5 kg ha⁻¹) + 100 per cent RDF with available N (230.43 kg ha⁻¹), P (18.94 kg ha⁻¹) and K (108.32 kg ha⁻¹) in soil.

Effect of biofertilizers (*Azotobacter chroococcum* + *Aspergillus niger*) on soil chemical properties in chilli cropping system was studied by Dhopavkar (2018) and reported increase in EC (10.67, 2.70, 1.88 and 6.6 %), available nitrogen (9.08, 10.11, 5.95 and 6.84 %), phosphorus (13.18, 7.73, 10.69 and 9.24 %) and potassium (9.48, 10.09, 9.66 and 8.85 %) at 30, 60, 90 and at harvest, respectively with combined application of P solubilizer and K solubilizers over uninoculated treatment.

Gupta (2018) worked on integrated use of fertilizers and biofertilizers in maize crop and found that application of RDF + *Azotobacter* + *Azospirillum* + PSB+ VAM resulted in higher EC (0.273, 0.231 and 0.223 dS m⁻¹), OC (5.38, 5.11 and 4.97 g kg⁻¹) and reduced pH (7.39, 7.36 and 7.35) compared to EC (0.251, 0.203 and 0.185 dS m⁻¹), OC (5.25, 4.87 and 4.65 g kg⁻¹) and pH (7.40, 7.37 and 7.36) with application of RDF alone at 40, 80 and at harvest, respectively. Whereas, higher available nitrogen (199.39, 156.61 and 152.35 kg ha⁻¹), phosphorus (19.75, 17.13 and 16.75 kg ha⁻¹) and potassium (388.91, 329.88 and 320.95 kg ha⁻¹) was recorded with application of RDF + *Azotobacter* + *Azospirillum* + PSB+ VAM compare to application of RDF at 40, 80 DAS and at harvest respectively.

Study conducted on effect of inoculation of efficient biofertilizers consortia MC1 (*Azospirillum* + P solubiliser + K solubiliser + VAM) and MC2 (*Azotobacter* + P solubilizer + K solubilizer + VAM) on growth and yield of Pearl millet by Rekha *et al.* (2018) revealed highest available nitrogen (147.98 kg ha⁻¹), phosphorus (38.09 kg ha⁻¹) and potassium (288.87 kg ha⁻¹) in the treatment which received MC1 + 75 per cent RDF + FYM. Whereas, lowest available nitrogen (100.35 kg ha⁻¹) in the treatment MC2 and available phosphorus (21.67 kg ha⁻¹) and potassium (245.53 kg ha⁻¹) were recorded with application of 100 per cent RDF.

2.5 Effect of bio- enriched FYM and inorganic fertilizer on soil biological properties

Gogoi *et al.* (2004) studied the effect of biofertilizer on soil characteristics and reported significant increase in microbial biomass carbon ($87.02 \mu\text{g g}^{-1}$ soil) and dehydrogenase activity ($112.40 \mu\text{g TPF g}^{-1}$ soil) in the treatment which received 50 per cent N + recommended dose of P and K+ *Azospirillum* + PSB compared to treatment which received recommended NPK ($46.62 \mu\text{g g}^{-1}$ soil and $65.04 \mu\text{g TPF g}^{-1}$ soil, respectively).

Wu *et al.* (2005) carried out greenhouse study to evaluate the effects of four biofertilizers containing arbuscular mycorrhizal fungus (*Glomus mosseae* or *Glomus intraradices*) with or without N-fixer (*Azotobacter chroococcum*), P solubilizer (*Bacillus megaterium*) and K solubilizer (*Bacillus mucilaginous*) on soil properties and growth of *Zea mays* and found significantly higher count of N₂ fixers (81.4×10^4 CFU g⁻¹), P solubilizers (23.5×10^6 CFU g⁻¹) and K solubilizers (25.4×10^6 CFU g⁻¹) in treatment which received 50 per cent biofertilizer + organic matter + AMF compared to chemical fertilizer treatment (1.22×10^4 CFU g⁻¹, 0.36×10^6 CFU g⁻¹ and 0.72×10^6 CFU g⁻¹, respectively) in soil.

The effect of biofertilizers application on microbial population in black cotton soil during the cropping period were observed by Ramalakshmi *et al.* (2008) and found higher (110×10^6 CFU g⁻¹) bacterial population with application of phosphobacteria + 75 per cent NP and fungal population (110×10^6 CFU g⁻¹) in *Azospirillum* + 75 per cent NP treatment. Whereas, higher actinomycetes population (39×10^4 CFU g⁻¹) was recorded in treatment which received Azophos + Mycorrhiza+ 75 per cent NP at 120 DAG.

Saha *et al.* (2010) observed that continuous application of 100 per cent NPK, FYM, lime and bio fertilizer recorded significantly higher microbial biomass carbon (97.10 %), microbial biomass nitrogen (196.20 %) and microbial biomass phosphorus (148.56 %), than the control.

Experiment entitled nutrient management in rice – sorghum conducted by Goutami (2013) found that application of 150 kg N ha^{-1} + FYM + biofertilizers (*Azospirillum*, PSB and PGPR) significantly increased urease (31.18 and 20.12 %) and dehydrogenase (7.06

and 9.91 %) activity during flowering and after harvest, respectively compared to application of 150 kg N ha⁻¹ alone.

Nandini (2013) studied population dynamics in microbially enriched organic manures and their influence on microbial population and enzymatic activities in soil and found that treatment which received RDF + enriched FYM showed higher dehydrogenase activity by 11.59, 15.79 and 23.52 per cent and urease activity by 15.20, 8.69 and 12.02 per cent at 30, 60 and 90 DAT, respectively over control.

Application of biofertilizers (*Azospirillum*, *Azotobacter* P-solubilizing bacteria and *Trichoderma*) + 50 per cent N through FYM recorded higher microbial biomass carbon (541.3 and 487.4 µg g⁻¹ of soil), urease activity (1344 and 1288 µg NH₄-N g⁻¹ soil d⁻¹) and acid phosphatase activity (270 and 204 µg PNP g⁻¹ soil h⁻¹) at 90 DAP and 120 DAP of sweet potato compared to control (186.8 and 172.4 µg g⁻¹ of soil of MBC; 1268 and 1234 µg NH₄-N g⁻¹ soil d⁻¹ of urease activity and 132 and 122 µg PNP g⁻¹ soil h⁻¹ of acid phosphatase activity) (Nedunchezhiyan *et al.*, 2013).

Shruthi (2014) worked on effect of reduced phosphorus (P) and potassium (K) level on K fractions and phosphatase activity in post-harvest soils of finger millet and found that application of 100 per cent RDF with P solubilizer and K solubilizers increased acid phosphatase (17.21 µg PNP g⁻¹ soil hr⁻¹) and alkaline phosphatase activity compare to 100 per cent RDF (14.97 µg PNP g⁻¹ soil hr⁻¹).

Yuvaraj (2016) reported significantly higher soil alkaline phosphatase activity (9.19 µg PNP g⁻¹ of soil h⁻¹), soil dehydrogenase (1.60 µg TPF g⁻¹ of soil h⁻¹) and soil urease activity (324.16 µg urease formed g⁻¹ of soil h⁻¹) in the treatment which received inorganic fertilizer + consortium biofertilizers.

The study conducted by Khipla (2017) with aim to investigate the synergistic effect of inorganic fertilizers (75 % and 100 % of recommended dose of nitrogen and phosphorus fertilizer) and biofertilizers (*Azotobacter*, PSB, Consortium) on microbial population and enzyme activities in the rhizospheric soil under nursery conditions. The results indicated significantly higher dehydrogenase activity (14.35 µg TPF formed min⁻¹ g⁻¹ of soil),

alkaline phosphatase activity (2.95 $\mu\text{g PNP formed hr}^{-1} \text{g}^{-1}$ of soil) and urease activity (394.3 $\mu\text{g urea formed hr}^{-1} \text{g}^{-1}$ of soil) under conjoint application of consortium biofertilizer with recommended dose of fertilizers.

Effect of integrated nutrient management on soil enzymes, microbial biomass carbon and microbial population under okra cultivation by Kumar *et al.* (2017) showed that application of farm yard manure enriched with microbial consortia (Phosphate solubilizing bacteria, *Azotobacter*, *Azospirillum*, and *Rhizobium*) recorded higher microbial biomass carbon (212.52 $\mu\text{g g}^{-1}$) and dehydrogenase activity (118.60 $\mu\text{g TPF g}^{-1} \text{soil } 24 \text{ h}^{-1}$) compared to application of RDF+ FYM (180.02 $\mu\text{g g}^{-1}$ and 103.50 $\mu\text{g TPF g}^{-1} \text{soil } 24 \text{ h}^{-1}$, respectively).

Dhopavkar (2018) worked on effect of biofertilizers (*Azotobacter chroococcum* + *Aspergillus niger*) on soil biological properties in chilli cropping system and found that application of N fixers and P solubilizers together increased microbial biomass carbon (18.34, 23.63, 21.38 and 20.99 %), microbial biomass nitrogen (26.81, 25.81, 18.84 and 16.80 %), acid phosphatase (10.93, 12.93, 11.67 and 11.51 %), dehydrogenase (9.78, 19.12, 18.13 and 13.49 %) and urease activity (11.64, 14.58, 12.39 and 13.19 %) at 30, 60, 90 days after transplanting and after harvest, respectively over uninoculated treatment.

Gao *et al.* (2020) carried out field experiment to study the effect of different biofertilizers and organic fertilizers and their combination on hybrid maize. Results revealed higher number of bacterial (15.64, 153.61 and 112.52 $\times 10^6 \text{ CFU g}^{-1}$), *Azotobacter* species (1.03, 11.43 and 10.38 $\times 10^4 \text{ CFU g}^{-1}$), P solubilizers (102.33, 187.30 and 111.28 $\times 10^4 \text{ CFU g}^{-1}$) and K releasing bacteria (179.96, 315.24 and 183.00 $\times 10^4 \text{ CFU g}^{-1}$) at 30, 60 and 90 days after planting, respectively with application of 50 per cent NPK + biofertilizers (*Azotobacter*, *Bacillus* and AMF)

2.8 Effect of bio- enriched FYM and inorganic fertilizer on nutrient content and uptake

Mudalagiriappa *et al.* (2012) studied growth and yield of *rabi* sorghum and revealed that application of 50 per cent RDF + FYM 2.5 t ha⁻¹ + microbial consortia

increased uptake of nitrogen (50.8 kg ha⁻¹) and phosphorus (8.8 kg ha⁻¹) compared to treatment which received 50 per cent RDF + FYM 2.5 t ha⁻¹ (38.6 kg ha⁻¹ nitrogen and 8.1 kg ha⁻¹ phosphorus).

Experiment entitled nutrient management in rice – sorghum was conducted by Goutami in 2013 and found that application of 150 kg N ha⁻¹ + FYM + biofertilizers (*Azospirillum*, PSB and PGPR) increased, nitrogen (77.41 and 63.17 kg ha⁻¹), phosphorus (17.18 and 16.28 kg ha⁻¹), potassium (24.37 and 116.63 kg ha⁻¹) zinc (76.3 and 198.5 g ha⁻¹), copper (26.52 and 62.48 g ha⁻¹), manganese (148 and 301 g ha⁻¹) and iron (591 and 1818 g ha⁻¹) in grain and stover, respectively over sole application of 150 kg N ha⁻¹ in sorghum.

Ramakrishnan and Bhuvaneshwari (2014) studied the effect of inoculation of AM fungi and beneficial microorganisms on growth and nutrient uptake by *Eleusine coracana* (L.) Gaertn. (finger millet) under pot culture experiment and noticed that application of AM fungi + *Azospirillum*+ PSB significantly increased uptake of nitrogen (5.42, 10.12 and 12.40 kg ha⁻¹) and phosphorus (3.08, 70 and 6.43 kg ha⁻¹) at 30, 60 and 90 days of plants respectively, followed by inoculation with AM fungi+ PSB alone.

Shruthi (2014) found that application of 100 per cent NPK + FYM + P and K solubilizer to finger millet increased content of nitrogen (1.08 and 0.71 %), phosphorus (0.38 and 0.19 %), potassium (0.90 and 1.07 %), calcium (0.51 and 1.03 %), magnesium (0.30 and 0.66 %), sulphur (0.38 and 0.75 %), iron (58.63 and 55.35 mg kg⁻¹), copper (10.38 and 7.54 mg kg⁻¹), zinc (30.77 and 22.42 mg kg⁻¹) and manganese (92.57 and 69.09 mg kg⁻¹) in grain and straw, respectively compared to 100 per cent NPK + FYM. Similar was the trend with respect to NPK uptake in both grain and straw.

Abdel-Salam *et al.* (2015) carried out a pot experiment to study the interaction effect of biofertilizers using N₂-fixers (*A. chroococcum* + *A. brasilense*), P-solubilizers (*Bacillus megaterium*) and K-solubilizers (*Bacillus circulans*) on sorghum. The study revealed that nutrient uptake increased from 63 per cent with K solubilizers to 140 per cent with N₂ fixers + PSB. The nitrogen and phosphorus uptake ranged from 88 per cent (N₂

fixers + K solubilizers) to 224 per cent (N₂ fixers + PSB + K solubilizers). However sole application of K solubilizers gave 130 per cent potassium uptake compared to control.

Kumar (2016) found that application of 50 per cent P + FYM @ 7.5 kg ha⁻¹ + PSB @ 5.0 kg ha⁻¹ increased grain and straw uptake of nitrogen by 43.90 and 39.67 per cent, potassium by 58.46 and 21.66 per cent, phosphorus by 45.76 and 105.88 per cent, calcium by 22.95 and 27.94 per cent and iron by 66.66 and 24.44 per cent over 50 per cent P + FYM @ 7.5 kg ha⁻¹ in finger millet.

Pallavi *et al.* (2016) studied the effect of INM on soil fertility and productivity on finger millet and recorded higher nitrogen concentration (2.67, 1.27 and 0.72 %) with application of 75 per cent RD N + *Azospirillum* + PSB, followed by treatment which received 75 per cent RD N + *Azospirillum* (2.64, 1.26 and 0.72 %) and 75 per cent RD N + PSB (2.56, 1.25 and 0.71 %) at 30, 60 DAS and at harvest, respectively. The concentration of phosphorus was high (0.256, 0.200 and 0.146 %) with application of 75 per cent RD N + *Azospirillum* + PSB, followed by treatment which received 75 per cent RD N + *Azospirillum* (0.254, 0.195 and 0.143 %), while potassium concentration was found high with application of 75 per cent RD N + *Azospirillum* + PSB (0.96, 1.80 and 2.51 %), followed by treatment which received 75 per cent RD N + *Azospirillum* (0.95, 1.79 and 2.36 %) at 30, 60 DAS and at harvest, respectively.

Yuvaraj (2016) conducted experiment on effect of biofertilizers and inorganic fertilizers on soil health, growth and yield of rice (*Oryza sativa* L.) and observed that 100 per cent NP + *Azospirillum* + PSB + PGPR application increased concentration of N and K in straw (0.69 % N and 1.8 % K) and in grain (1.49 % N and 0.75 % K). Whereas, phosphorus uptake in straw (0.05 %) and grain (0.39 %) was high in treatment which received 75 per cent NP + microbial consortia.

Togas *et al.*, 2017 conducted an experiment on effect of *Azotobacter* on growth and yield of pearl millet and revealed that application of *Azotobacter* increased N (1.76 and 0.51 %), P (0.279 and 0.135 %) and K (0.592 and 1.955 %) content in grain and straw

respectively, compared to uninoculated treatment (1.65 and 0.47 % of N, 0.264 and 0.128 % of P and 0.543 and 1.868 % of K).

Ashok Kumar Roy (2018) studied the performance of finger millet (*Eleusine coracana* L. Gaertn.) under integrated nutrient management practices and found that application of FYM (10 t ha⁻¹) + biofertilizer (*Azospirillum brasilense* + *Bacillus* spp. + *Psuedomonas fluorescens* @ 20 g kg⁻¹ seed each) + ZnSO₄ (12.5 kg ha⁻¹) + Borax (5 kg ha⁻¹) + 75 per cent RDF increased total uptake of nitrogen (93.10 kg ha⁻¹) and phosphorus (20.36 kg ha⁻¹), but uptake of potassium was highest (107.14 kg ha⁻¹) in treatment which received FYM (10 t ha⁻¹) + biofertilizer + ZnSO₄ (12.5 kg ha⁻¹) + Borax (5 kg ha⁻¹) + 100 per cent RDF compared to control.

Dhobavkar (2018) worked on effect of biofertilizers (*Azotobacter chroococcum* + *Aspergillus niger*) on nutrient uptake in chilli and found that application of N fixers and P solubilizers together increased uptake of nitrogen by 28.75, 27.66, 26.05 and 37.07 per cent, phosphorus by 27.27, 22.77, 18.46 and 25.77 per cent, potassium by 31.21, 24.73, 24.18 and 31.77 per cent, iron by 20.06, 18.44, 16.06 and 20.64 per cent, manganese by 16.55, 16.44, 9.93 and 17.04 per cent, copper by 21.18, 19.32, 9.86 and 20.58 per cent and zinc by 17.21, 14.53, 11.04 and 20.84 per cent over non inoculated treatment at 30, 60, 90 days after transplanting and after harvest respectively.

Gupta (2018) found that application of RDF + *Azotobacter* + *Azospirillum* + PSB + VAM showed higher content of nitrogen (1.63, 1.57 and 1.55 %), phosphorus (0.45, 0.43 and 0.41 %) and potassium (0.71, 0.59 and 0.48 %) compared to concentration of nitrogen (1.48, 1.31 and 1.23 %), phosphorus (0.31, 0.27 and 0.24 %) and potassium (0.47, 0.31 and 0.16 %) in RDF at 40, 80 DAS and at harvest.

Lavanya *et al.* (2018) conducted a work on yield and nutrient uptake of finger millet as influenced by organics and liquid biofertilizer consortium and revealed that application of RDF + liquid microbial consortia (phosphorus solubilising bacteria (PSB) + *Azospirillum* + Potash releasing bacteria (KRB) @ 3.75 l ha⁻¹ + Vesicular Arbuscular Mycorrhizae (VAM @ 12.5 kg ha⁻¹) increased uptake of N (89.1 kg ha⁻¹), P (30.0 kg ha⁻¹)

and K (106.7 kg ha⁻¹) compared to application of RDF alone (87.2, 27.3 and 103.0 kg ha⁻¹, respectively).

Pot culture experiment conducted by Rekha *et al.* (2018) with two microbial consortia MC1 (*Azospirillum* + P solubiliser + K solubiliser + VAM) and MC2 (*Azotobacter* + P solubiliser + K solubiliser + VAM) along with recommended dose of FYM and chemical fertilizers found highest NPK uptake was observed in the treatment which received MC1 +75 per cent RDF+ FYM (40.51 kg ha⁻¹, 25.02 kg ha⁻¹, 60.24 kg ha⁻¹, respectively) and lowest N (23.25 kg ha⁻¹), P (14.97 kg ha⁻¹) was in the treatment which received MC2, while K (46.56 kg ha⁻¹) was in 100 per cent RDF.

Rangesh Kumar *et al.* (2018) interpreted the long-term experiment (6 years) on upland irrigated system in finger millet and found that 100 per cent NPK (52:15:32 kg ha⁻¹) + FYM (5 kg ha⁻¹) + lime + biofertilizer (*Azotobacter* and PSB @ 4 kg each ha⁻¹) resulted in highest phosphorus (3.7 g kg⁻¹), potassium (6.1 g kg⁻¹), calcium (3.9 g kg⁻¹), magnesium (2.4 g kg⁻¹), sulphur (0.9 g kg⁻¹), manganese (104 mg kg⁻¹), iron (46 mg kg⁻¹), zinc (24 mg kg⁻¹) and copper (11 mg kg⁻¹) in grain compared to the absolute control.

Singh *et al.* (2018) inoculated pearl millet seed with biofertilizer and observed that combined treatment having all the bioinoculants (*Pseudomonas fluorescens*, *Azotobacter chroococcum*, *Azospirillum lipoferum*, *Acetobacter diazotrophicus* and one fungi-*Trichoderma viride* @ 10 - 25 g kg⁻¹) enhanced uptake of nitrogen (59.03 kg ha⁻¹ in grain and 79.76 kg ha⁻¹ in stover) and phosphorus (9.21 kg ha⁻¹ in grain and 8.71 kg ha⁻¹ in stover) over control.

Application of PGPR + PSB+ 100 per cent NP and PGPR + PSB + 75 per cent NP showed per cent increase in phosphorus content by 8.09 and 6.22 per cent in straw and 18.68 and 0.47 per cent in grain, respectively over control in maize crop (Ahmed *et al.*, 2020).

Gangaraddi *et al.* (2020) reported that inoculation of finger millet with *Azotobacter chroococcum* + *Bacillus megaterium* + *Pseudomonas fluorescens* increased uptake of nitrogen (106.46 mg) and phosphorus (64.84 mg) per plant followed by *A. chroococcum*

+*B. megaterium* (94.06 and 57.29 mg, respectively) and *B. megaterium* + *P. fluorescens* (82.92 and 50.63 mg, respectively). Among single strain biofertilizers, nitrogen and phosphorus per plant was higher (62.24 and 38.30 mg) with application of *B. megaterium* compared to *P. fluorescens* (55.49 and 33.30 mg) and *A. chroococcum* (46.94 and 28.59 mg).

2.9 Effect of bio- enriched FYM and inorganic fertilizer on economics of finger millet

Effect of nutrient and biofertilizers (*Azospirillum* + *Phosphobacterin*) application on yield and yield component of rice was conducted by Mathews *et al.* (2006) and recorded higher cost of cultivation (Rs. 14724), gross return (Rs. 54728), net return (Rs. 40004) and B: C ratio (3.71) with application of 150 per cent RDF + biofertilizer compared to cost of cultivation (Rs. 14514), gross return (Rs. 54020), net return (Rs. 39506) and B: C ratio (3.72) in the treatment which received 150 per cent RDF alone.

Prabudoss *et al.* (2014) worked on Integrated nutrient management (INM) on growth, yield and economics of transplanted kodo millet and revealed that application of 75 per cent RDF+ *Azospirillum* recorded higher cost of cultivation (Rs. 19672), gross return (Rs. 36941), net return (Rs. 17269) and return per rupee invested (1.87) compared to 75 per cent RDF alone (Rs. 18192, Rs. 33711, Rs. 15519 and 1.85, respectively).

Kumar (2016) revealed that application of 50 per cent P + FYM @ 7.5 kg ha⁻¹ + PSB @ 5.0 kg ha⁻¹ recorded higher gross return (Rs. 28675), net return (Rs. 18209) and B: C ratio (1.73) compared to 50 per cent P + FYM @ 7.5 kg ha⁻¹ (Rs. 22113, Rs. 11827 and 1.15, respectively).

Economic evaluation of finger millet under different nutrient management practices by Pallavi *et al.* (2016) showed that application of 75 per cent N+ *Azospirillum* + PSB resulted in higher gross return (Rs. 34011), net return (Rs. 18990) and B:C ratio (2.26) compared to 75 per cent N+ 25 per cent FYM (Rs. 29293, Rs. 12762 and 1.77, respectively).

Application of recommended NPK+ FYM 7.5 t ha⁻¹+ PGPR @ 2 kg ha⁻¹ showed higher gross return (Rs. 82572), net return (Rs. 58452) and B: C ratio (2.42) compared to application of recommended NPK+ FYM 7.5 t ha⁻¹ with gross return Rs. 72730, net return Rs. 49610 and B: C ratio 2.14 in finger millet (Thimmaiah *et al.*, 2016)

According to Vachan and Tripathim (2017) addition of 75 per cent RDF+ *Azospirillum* + PSB to onion resulted in higher gross return (Rs. 193494), net return (Rs. 134246) and B: C ratio (3.27) compared to 100 per cent RDF alone (Rs. 147678 gross return, Rs. 84103 net return and 2.32 B: C ratio).

Application of FYM (10 t ha⁻¹) + biofertilizers (*Azospirillum brasilense*, *Bacillus* spp., *Pseudomonas fluorescens* @ 20 g kg⁻¹ seed each recorded higher gross return (Rs. 40104), net return (Rs. 22851) and B: C ratio (1.32) compared to FYM 10 t ha⁻¹ (Rs. 34597, Rs. 17524 and 1.03) in finger millet (Ashok kumar Roy, 2018).

Shankar *et al.* (2018) conducted a study on yield and economics of finger millet and redgram in rotation, influenced by zinc, boron and biofertilizer nutrition and revealed that application of NPK + ZnSO₄ @ 12.5 kg ha⁻¹+ VAM + PSB+ *Rhizobium* recorded higher B: C ratio (1.47) compared to application of NPK + ZnSO₄ @ 12.5 kg ha⁻¹ alone (1.42) in finger millet.

Effect of different levels of P and liquid biofertilizers application on growth, yield attributes and yield of maize was studied by Sivamurugan *et al.* (2018) and reported that application of 60 kg P₂O₅ ha⁻¹ + NPK consortia resulted in higher net return (Rs. 44834) and B: C ratio (2.02) compared to application of 90 kg ha⁻¹ of P₂O₅ alone (Rs. 28388 and 1.63, respectively).

Study on effect of liquid biofertilizers on growth and yield of *rabi* sorghum (*Sorghum bicolor* L.) revealed that seed treatment with *Azospirillum* @ 4ml +PSB @ 4ml kg⁻¹ seed increased gross return (Rs. 75850), net return (Rs.51217) and B:C ratio (2.10) compared to control (Rs. 50501, Rs. 26667 and 1.14, respectively) (Rani *et al.*, 2019).

III MATERIAL AND METHODS

A field experiment entitled “Studies on bio-enriched farm yard manure (FYM) on soil properties and productivity of finger millet (*Eleusine coracana* (L.) Gaertn) under dryland condition” was conducted during the year 2019-20. The details of materials used, procedures and methods adopted during experimentation are presented in this chapter.

3.1 Location of the experimental site

The field experiment was carried out during *Kharif*-2019 at AICRP for Dry Land Agriculture, UAS, GKVK, Bengaluru – 65. It is located in the Eastern Dry zone of Karnataka at 13° 05' N latitude and 77° 34' E longitude with an altitude of 924 meters above Mean Sea Level (MSL).

3.2 Climatic condition

The meteorological data pertaining to monthly total rainfall, maximum and minimum temperature, mean relative humidity and their normal value are presented in Table 3.1 and Fig. 3.1.

3.2.1 Normal climatic condition

The normal meteorological data was taken between 1972 and 2018 for rainfall and between 1976 and 2018 for temperature and mean relative humidity (Fig 3.1). The normal maximum rainfall was observed during September (195.0 mm) and minimum in January (1.4 mm) with total normal rainfall of 915.9 mm. Whereas, the maximum (29.3 °C) and minimum (17.9 °C) normal mean temperatures was observed with a mean relative humidity of 85.0 per cent during the cropping year.

3.3.2 Actual weather condition

The total rainfall of 2019 at AICRP for Dryland Agriculture, GKVK, Bengaluru was 899.1 mm with maximum rainfall during October (233.0 mm) and minimum during January and March (0.0 mm). Comparing to the normal rainfall data, a higher positive deviation in rainfall was observed during October (71.2 mm) and negative deviation during

July (68.9 mm) and however, 16.8 mm of lower rainfall was observed during 2019. The maximum and minimum temperature of 29.8 °C and 18.2 °C was observed during the cropping year, which showed 0.5 °C and 0.3 °C increase over mean normal maximum and minimum temperature. Relative humidity of 87.6 per cent was recorded during the cropping period and showed 2.6 per cent increase over normal relative humidity.

Table 3.1: Meteorological data of the experimental area during 2019 and normal value at GKVK, Bengaluru.

Year/ Months	Rainfall (mm)			Mean temperature (°C)						Mean Relative Humidity (%)		
				Maximum			Minimum					
2019	N	A	D	N	A	D	N	A	D	N	A	D
January	1.4	0.0	-1.4	27.4	27.9	0.5	14.0	13.1	-0.9	86.0	89.5	3.5
February	8.5	24.0	15.5	30.0	30.6	0.6	15.4	17.2	1.8	81.0	87.9	6.9
March	17.5	0.0	-17.5	32.6	33.8	1.2	18.0	20.1	2.1	76.0	81.0	5.0
April	45.9	22.8	-23.1	33.8	34.7	0.9	20.5	20.7	0.2	80.0	78.1	-1.9
May	106.8	126.4	19.6	33.0	33.7	0.7	20.5	20.3	-0.2	82.0	80.6	-1.4
June	78.6	88.3	9.7	29.5	30.6	1.1	19.6	19.5	-0.1	86.0	86.0	0
July	103.1	34.2	-68.9	28.2	29.5	1.3	19.1	18.8	-0.3	88.0	90.0	2.0
August	129.0	172.2	43.2	27.7	27.5	-0.2	18.9	18.1	-0.8	89.0	92.5	3.5
September	195.0	186.6	-8.4	28.2	27.9	-0.3	18.9	18.5	-0.4	89.0	92.1	3.1
October	161.8	233.0	71.2	27.9	27.7	-0.2	18.3	18.3	0	88.0	92.6	4.6
November	55.5	10.0	-45.5	26.7	27.7	1	16.6	16.9	0.3	87.0	90.3	3.3
December	12.7	1.6	-11.1	26.3	26.0	-0.3	14.7	16.4	1.7	87.0	91.2	4.2
Total/Mean	915.9	899.1	-16.8	29.3	29.8	0.5	17.9	18.2	0.3	85.0	87.6	2.6

Note: N- Normal meteorological data (mean of 1972 – 2018 for rainfall and mean of 1976-2018 for temperature and relative humidity), A - Actual meteorological data, D - Deviation from the normal (A-N)

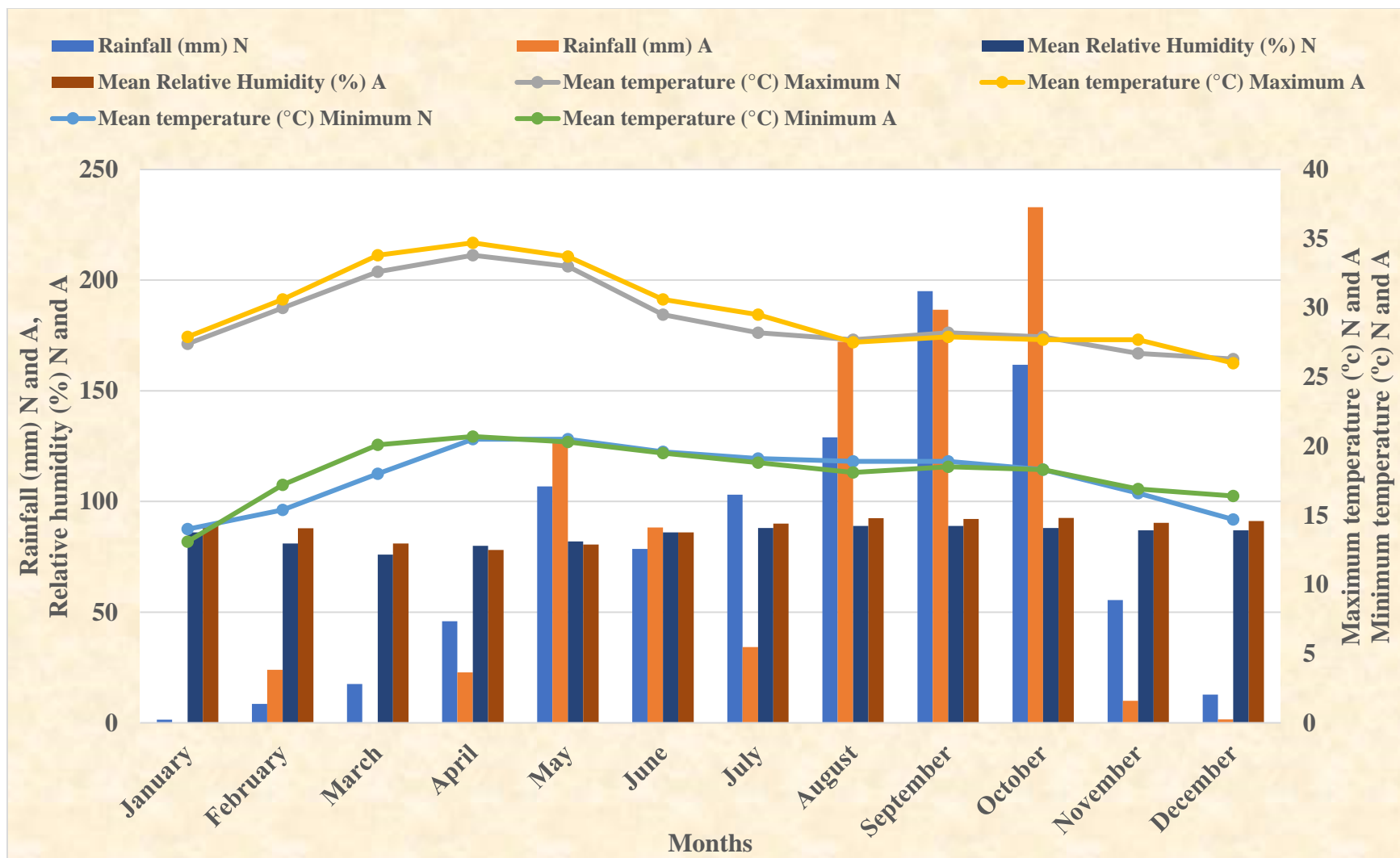


Fig. 3.1: Normal and actual monthly weather data during 2019 at UAS, GKVK, Bengaluru.

3.3 Soil characteristics of the experimental site

The soils of the experimental site belong to the Vijayapura soil series and are classified as Kandic paleustalfs. According to FAO classification, the soils are ferric luvisols. Soils are reddish - brown laterite derived from genesis under subtropical semiarid climate. Composite soil sample collected at 0-15 cm depth were air dried in shade, gently ground using wooden pestle and mortar and passed through 2 mm sieve. The sieved samples were used for further analysis of different physical, chemical and biological properties. The parameter analysed and methodology followed are furnished in Table 3.3, 3.4 and 3.5.

3.4 Cropping history of the experimental plot

In the experimental plot finger millet (*Eleusine coracana* (L.) Gaertn) was grown in the previous year during *Kharif* 2018 and later it was left fallow till the present experiment.

3.5 Experimental details

The field experiment entitled “Studies on bio-enriched farm yard manure (FYM) on soil properties and productivity of finger millet (*Eleusine coracana* (L.) Gaertn) under dryland condition” in randomized complete block design (RCBD) with 10 treatments and 3 replications (Fig 3.2) was conducted during *Kharif* 2019 with following details

Crop	Finger millet
Variety	GPU-28
Design	Factorial randomized complete block design (RCBD)
Spacing	30 cm × 10 cm
Treatments	10
Replications	3
Seed rate	12.5 kg ha ⁻¹
Gross plot size	2.5 m × 4.5 m
Net plot size	2.3 m × 3.9 m
Recommended Dose of Fertilizer (RDF)	50: 40: 37.5 kg NPK ha ⁻¹
Location	AICRP for Dryland Agriculture, GKVK

3.5.1 Treatment details

T ₁	Control
T ₂	7.5 t ha ⁻¹ FYM+ 100 % RDF
T ₃	7.5 t ha ⁻¹ enriched FYM (nitrogen fixers + PGPR) + 60 % RDF
T ₄	7.5 t ha ⁻¹ enriched FYM (nitrogen fixers + PGPR) + 80 % RDF
T ₅	7.5 t ha ⁻¹ enriched FYM (phosphate solubilizer + PGPR) + 60 % RDF
T ₆	7.5 t ha ⁻¹ enriched FYM (phosphate solubilizer + PGPR) + 80 % RDF
T ₇	7.5 t ha ⁻¹ enriched FYM (potassium solubilizer + PGPR) + 60 % RDF
T ₈	7.5 t ha ⁻¹ enriched FYM (potassium solubilizer + PGPR) + 80 % RDF
T ₉	7.5 t ha ⁻¹ enriched FYM (microbial consortia) + 60 % RDF
T ₁₀	7.5 t ha ⁻¹ enriched FYM (microbial consortia) + 80 % RDF

Note : RDF : Recommended Dose of Fertilizer,
PGPR : Plant Growth Promoting Rhizobacteria

3.5.2 Varietal description

GPU-28 (Germ Plasm Unit) is a medium duration variety matures in about 110-115 days. It is a blast - resistant variety suitable for both rainfed and irrigated ecosystem. Under rainfed ecosystem, it serves as a contingent variety for delayed sowing up to August. The ear shape is semi-compact, tillers profusely and has 4-6 productive tillers. The finger length ranges from 5-7 cm and grows to a medium height with yield potential of 25-40 q ha⁻¹.

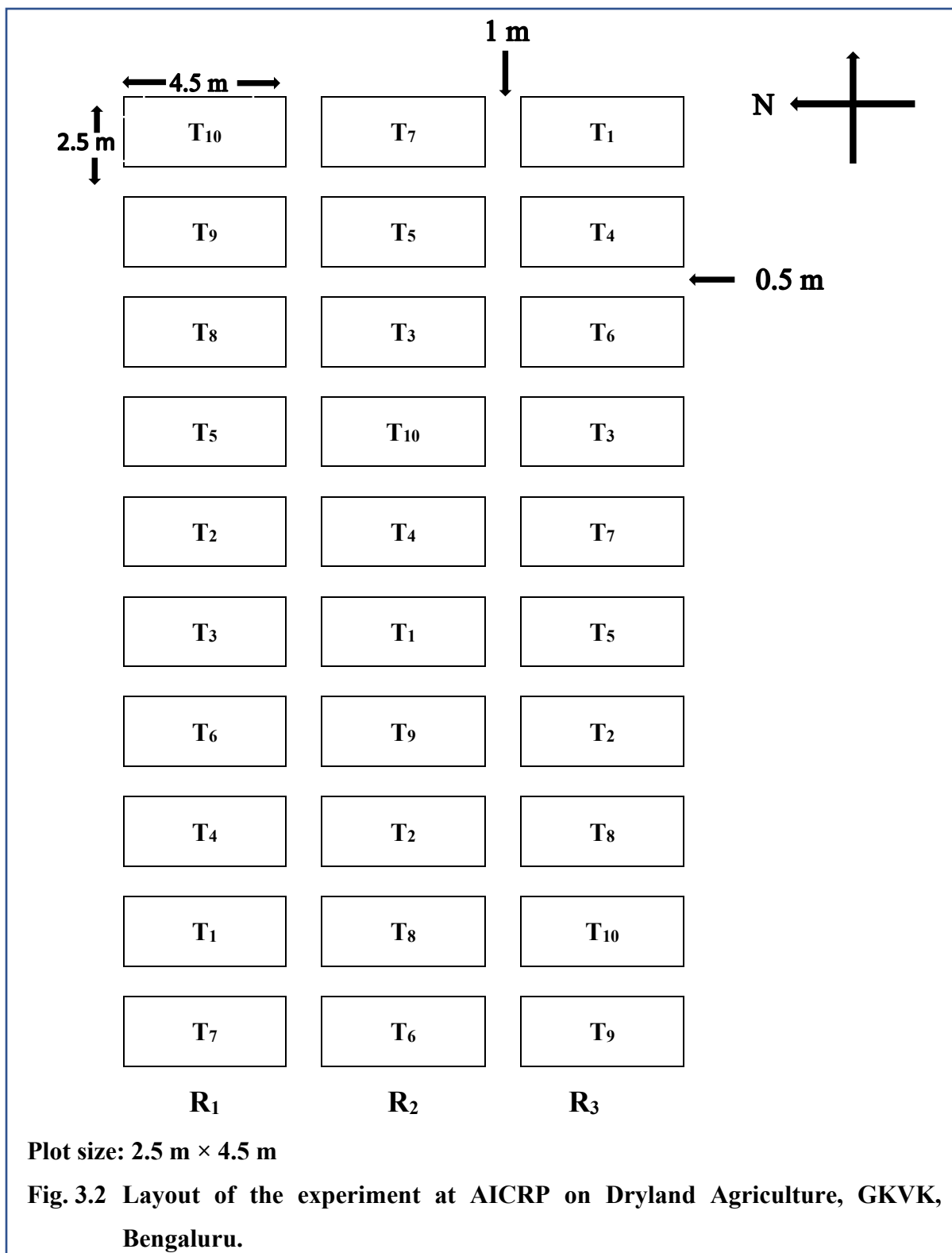
3.6 Methodology

3.6.1 Land preparation

The experimental land was prepared by ploughing once using bullock drawn country plough and later by- passing cultivator for removing weeds and crushing clods, followed by harrowing to bring the soil to fine tilth condition and land was divided into fine required plot size (2.5 m × 4.5 m). Later, small channel was created between the replication for removing excess water during heavy rain.



Plate 1: General view of experimental plot



T₁: Absolute control
 T₂: 7.5 t ha⁻¹ FYM + 100 % RDF
 T₃: 7.5 t ha⁻¹ enriched FYM (NFB + PGPR) + 60 % RDF
 T₄: 7.5 t ha⁻¹ enriched FYM (NFB + PGPR) + 80 % RDF
 T₅: 7.5 t ha⁻¹ enriched FYM (PSB + PGPR) + 60 % RDF

T₆: 7.5 t ha⁻¹ enriched FYM (PSB + PGPR) + 80 % RDF
 T₇: 7.5 t ha⁻¹ enriched FYM (KSB + PGPR) + 60 % RDF
 T₈: 7.5 t ha⁻¹ enriched FYM (KSB + PGPR) + 80 % RDF
 T₉: 7.5 t ha⁻¹ enriched FYM (MC) + 60 % RDF
 T₁₀: 7.5 t ha⁻¹ enriched FYM (MC) + 80 % RDF

3.6.2 Manures and fertilizer application

Enriched farm yard manure (7.5 t ha⁻¹) was applied uniformly two weeks before sowing. The recommended fertilizer dose of 50: 40: 37.5 kg NPK ha⁻¹ was applied as per University of Agricultural Science, Bengaluru package. 50 per cent nitrogen and full dose of phosphorus and potassium were applied as basal dose at the time of sowing and the remaining 50 per cent nitrogen was applied as a top dressing at 30 days after sowing (DAS).

3.6.2.1 Enrichment of FYM

One kilogram each of biofertilizers viz., N fixers (*Azotobacter chroococcum*), P solubilizer (*Bacillus megaterium*), K solubilizer (*Frateuria aurantia*), microbial consortia and 500 gram of PGPR (Plant growth promoting rhizobacteria) (*Pseudomonas fluorescens*) were mixed thoroughly with 1 ton of FYM 15 days in advance and mixed together, for maintaining uniform growth of microorganisms.

3.6.2.2 Analysis of FYM

The FYM was analysed for different chemical properties before enriching with biofertilizers.

3.6.2.2.1 pH and EC

The pH of FYM was measured in 1:10 of FYM: water suspension, using pH meter (Jackson, 1973). The clear supernatant solution of the FYM - water suspension was taken out and electrical conductivity was measured using conductivity bridge (Jackson, 1973) and expressed as dS m⁻¹.

3.6.2.2.2 Organic carbon

A known weight (0.2 g) of 0.2 mm sieved FYM was treated with 25 ml of 1 N K₂Cr₂O₇ and 50 ml of concentrated H₂SO₄. After oxidation, the excess K₂Cr₂O₇ was quantified by back titrating against standard FAS using ferroin as an indicator (Walkley and Black, 1934).



Land preparation



Laying out of experimental plots preparation

Plate 2: Experimental field preparation



Thinning



Weeding

Plate 3: Cultural operation in the experimental field

3.6.2.2.3 Macro and micro nutrient analysis

The FYM samples were analyzed for macro and micro nutrients (N, P, K, Ca, Mg, S, Zn, Fe, Mn and Cu) following the standard methods similar to that of plant analysis as given below in Table 3.6.

3.6.3 Sowing

Line sowing of finger millet seeds was done manually in furrows made using a marker at the spacing of 30 cm between rows. After sowing, seeds were covered with soil.

3.6.4 Aftercare

3.6.4.1 Gap filling and thinning

After 30 days of sowing thinning was carried out to remove excess seedling and gap filling was done by transplanting simultaneously using the excess seedling in the same treatments where an intra row gap is wider than 10 cm.

3.6.4.2 Weeding

The plots were hand weeded twice at 30 and 60 days after sowing to keep it weed free and inter-cultivated at 45 days of sowing to loosen the top soil for good root aeration.

3.6.4.3 Harvesting and threshing

The crop was harvested at physiological maturity. The ear heads in the net plot were harvested separately from each treatment and sun dried for 4 days, threshed by beating with stick, then cleaned and weighed. The straw was harvested separately and allowed to dry in the threshing yard and weight was recorded.

3.7 Collection of experimental data

The growth and yield parameters were recorded from randomly selected five plants in each plot and labelled. Periodical observations were taken in these plants. The techniques used and the details of observations recorded are given in Table 3.2.

Table 3.2 Details of observations recorded in the field experiments

Observations	Method followed	Interval
1. Growth parameters		
Plant height (cm)	The tagged five plants in the net plot were measured from ground level up to base of the node of fully opened top leaf using linear scale and the mean plant height was expressed in cm.	30, 60, 90 DAS and at harvest
Number of tillers hill ⁻¹	The number of tillers per hill was counted in the tagged five plants of net plot and mean number of tillers per hill was worked out.	30, 60, 90 DAS and at harvest
Dry matter accumulation (g plant ⁻¹)	Five randomly selected plants in border rows were air-dried for 2 days. Later kept in oven at 65°C for 2 days till the constant weight was observed and weight was recorded and mean dry weight was worked out and expressed in gram per plant.	30, 60, 90 DAS and at harvest
2. Yield parameter		
Number of ear heads per hill	Number of ear heads from randomly selected five plants was counted and expressed as the mean value of number of ear head per hill.	At harvest
Number of fingers per ear head	Number of fingers per ear head was counted from randomly tagged five plants and the mean value was computed.	At harvest
1000 seed weight	One thousand grains were counted from the grain samples obtained from net plot and weight of these grains were recorded and expressed in grams.	At harvest
Grain yield	Grain yield per hectare was worked out using grain yield per net plot and expressed in kg ha ⁻¹ . The grain yield per hectare is calculated using the following formula. $\text{Grain yield (kg ha}^{-1}\text{)} = \frac{\text{Grain yield per net plot (kg)} \times 10000 \text{ m}^2}{\text{Net plot size (m}^2\text{)}}$	At harvest
Straw yield	The straw was harvested separately from net plot. The dry weight of the straw was recorded and expressed in kg ha ⁻¹ . $\text{Straw yield (kg ha}^{-1}\text{)} = \frac{\text{Straw yield per net plot (kg)} \times 10000 \text{ m}^2}{\text{Net plot size (m}^2\text{)}}$	At harvest



Absolute control



7.5 t ha⁻¹ FYM + 100 % RDF



7.5 t ha⁻¹ Bio-enriched FYM (nitrogen fixers + PGPR) + 60 % RDF



7.5 t ha⁻¹ Bio-enriched FYM (nitrogen fixers + PGPR) + 80 % RDF

Plate 4.1: Effect of bio-enriched FYM and levels of fertilizers on growth of finger millet



7.5 t ha⁻¹ Bio-enriched FYM (PSB + PGPR) + 60 % RDF



7.5 t ha⁻¹ Bio-enriched FYM (PSB + PGPR) + 80 % RDF



7.5 t ha⁻¹ Bio-enriched FYM (KSB + PGPR) + 60 % RDF



7.5 t ha⁻¹ Bio-enriched FYM (KSB + PGPR) + 80 % RDF

Plate 4.2: Effect of bio-enriched FYM and levels of fertilizers on growth of finger millet



7.5 t ha⁻¹ Bio-enriched FYM (microbial consortia) + 60 % RDF



7.5 t ha⁻¹ Bio-enriched FYM (microbial consortia) + 80 % RDF

Plate 4.3: Effect of bio-enriched FYM and levels of fertilizers on growth of finger millet

3.8 Soil analysis

3.8.1 Soil sampling and preparation of sample

Soil samples from experimental area were collected from 0 – 15 cm at 30, 60, 90 days after sowing (DAS) and after the harvest of the crop. The collected soil samples were air dried, powdered with a wooden mallet, passed through 2 mm sieve, stored in polythene bags and analysed for various physical and chemical properties adopting standard procedure. Whereas, soil sample for analysing biological properties were kept in refrigerator.

3.8.2 Physical properties

Table 3.3 Methodologies adopted for soil physical properties analysis

Sl. No.	Parameters	Procedure	Reference
1	Particle size analysis	Soil was pre-digested with H ₂ O ₂ , dispersed with sodium hexa metaphosphate and later solution was passed through > 0.05 mm mesh sieve to separate sand particles. From the suspension obtained after sieving an aliquot of clay + silt and clay were pipetted out from the specified depth at specific time intervals depending on the suspension temperature.	International Pipette method (Piper, 1966)
2	B.D, P.D, MWHC and Porosity	Bulk density (BD), particle density (PD), porosity and water holding capacity was analysed using the Keen–Rackzowski cup method. Keen cup was weighed with filter paper, then air dried soil sample was filled uniformly by tapping to get good compactness and levelled. The cup was placed in water for 24 hours. After saturation, cup was removed and oven- dried (105° C) till constant weight was obtained.	Keen rackzowski method (Baruah and Barthakur, 1997)

3.8.3 Chemical properties

Table 3.4 Methodologies adopted for soil chemical properties analysis

Sl. No.	Parameters	Procedure	Reference
1	Soil reaction	The soil pH was determined in 1: 2.5 soil: water suspension using glass electrode pH meter	Potentiometry, (Jackson, 1973)
2	Electrical conductivity	Electrical conductivity of the clear soil water (1: 2.5) extract was determined using conductivity bridge.	Conductometry (Jackson, 1973)
3	Organic carbon	0.5 g of finely powdered sample (0.2 mm) was treated with 10 ml of 1N $K_2Cr_2O_7$ (potassium dichromate) and 20 ml of concentrated H_2SO_4 . After oxidation, excess $K_2Cr_2O_7$ was quantified by back titrating it with standard FAS using ferroin as an indicator	Wet oxidation (Walkley and Black, 1934)
4	Available nitrogen	Soil was oxidized and distilled with alkaline potassium permanganate. The liberated ammonia was trapped in boric acid containing mixed indicator and then titrated against standard acid.	Alkaline permanganate method (Subbaiah and Asija, 1956)
5	Available phosphorus	The available phosphorus was extracted with Bray's extractant (1: 10 of soil: extractant). The phosphorus in the extract was determined by stannous chloride reduced molybdophosphoric blue colour method and the intensity of blue color was read at 660 nm using a spectrophotometer.	Bray's extraction method (Bray and Kurtz, 1945)
6	Available potassium	The available potassium was determined by using flame photometer after extracting the soil with neutral normal ammonium acetate	Flame photometry (Jackson, 1973)
7	Exchangeable calcium and magnesium	Exchangeable calcium and magnesium in soil was extracted using neutral normal ammonium acetate. The calcium + magnesium in the extract was determined by adding buffer with EBT indicator titrated against standard EDTA. For calcium using ammonium acetate extract and NaOH with Patton reader indicator titrated against standard EDTA. From the first value calcium content was subtracted to obtain magnesium content in soil and expressed in meq in 100 g soil	Complexometric titration method (Jackson, 1973)

8	Available Sulphur	Available sulphur in soil was determined using 0.15 % calcium chloride solution and acid seed solution and conditioning agents were added to extractant. The turbidity developed by addition of barium chloride was measured in spectrophotometer with optical density of 420 nm and expressed in ppm	CaCl ₂ extractant method, Turbidometry (Black, 1965)
9	DTPA extractable micronutrients	Available zinc, iron, copper and manganese was extracted by using DTPA extractant. The concentration of metal ions in the extract was estimated using Atomic adsorption spectrophotometer and expressed in ppm.	Atomic absorption spectrophotometry (Lindsay and Norwell, 1978)

3.8.4 Biological properties

Table 3.5 Methodologies adopted for soil biological properties analysis

Sl. No.	Parameter	Method and reference
1	Microbial biomass carbon ($\mu\text{g g}^{-1}$)	Fumigation extract method (Carter, 1991)
2	Microbial biomass nitrogen ($\mu\text{g g}^{-1}$)	Fumigation extract method (Carter, 1991)
3	Microbial biomass phosphorus ($\mu\text{g g}^{-1}$)	Fumigation extract method (Brookes <i>et al.</i> , 1982)
4	Dehydrogenase ($\mu\text{g TPF g}^{-1} \text{ soil } 24 \text{ h}^{-1}$)	2-3-5-triphenyl tetrazolium chloride reduction method (Casida <i>et al.</i> , 1964)
5	Urease ($\mu\text{g NH}_4\text{- N g}^{-1} \text{ soil h}^{-1}$)	KCl-Ag ₂ SO ₄ solution method (Eivazi and Tabatabai, 1977)
6	Acid phosphatase ($\mu\text{g PNP g}^{-1} \text{ soil h}^{-1}$)	<i>p</i> -nitrophenyl phosphatase method (Eivazi and Tabatabai, 1977)

3.8.4.1 Microbial biomass carbon and nitrogen

Soil microbial biomass carbon and nitrogen were determined by chloroform fumigation and incubation method (Carter, 1991). Ten grams of sieved (< 2 mm) soil sample was taken in screw cap tubes (two sets) and the moisture level was adjusted to field capacity. Only soil samples of fumigated set were treated with 2 ml of ethanol-free

chloroform and the tubes of both sets were incubated for 5 days at room temperature. The soil ninhydrin reactive nitrogen (microbial nitrogen) was extracted by adding 50 ml of 2 M KCl and swirled then filtered through Whatman No.1 filter paper. 2 ml of extract was taken in test tube and 4 ml of freshly prepared ninhydrin reagent was added and kept in boiling water bath till the development of the purple color. Then 4 ml of isopropyl alcohol was added and the purple color was read (absorbance value) in spectrophotometer at 570 nm wavelength.

$$\text{Biomass C } \mu\text{g g}^{-1} \text{ soil} = \frac{\text{Ninhydrin reactive N in fumigated soil} - \text{Ninhydrin reactive N in unfumigated soil}}{\text{Weight of soil samples (g)}} \times 24$$

$$\text{Biomass N } \mu\text{g g}^{-1} \text{ soil} = \frac{\text{Ninhydrin reactive N in fumigated soil} - \text{Ninhydrin reactive N in unfumigated soil}}{\text{Weight of soil samples (g)}} \times 2.8$$

3.8.4.2 Microbial biomass phosphorus

The microbial biomass phosphorus was determined as per the procedure given by Brookes *et al.* (1982). Ten grams of the soil samples were placed in a screw cap tube in three sets. The first set was fumigated with chloroform for five days and the other two sets were incubated aerobically for the same period. Later, the first and second sets were extracted with Bray's extractant solution (0.03 N NH₄F in 0.25 N HCl) and the third set were extracted with Bray's extractant solution spiked with inorganic P (as KH₂PO₄ equivalent 25 μg P g⁻¹ of oven- dry soil). The suspension was filtered using Whatman No.1 filter paper after shaking. Chloromolybdic acid of 5 ml was added to a filtered aliquot of 2 ml and 1ml of working stannous chloride solution was added and the volume was made up to 50 ml using distilled water. The intensity of the blue color was read using spectrophotometer at 660 nm. The microbial biomass P was calculated using the following formula:

$$\text{Biomass P } \mu\text{g g}^{-1} \text{ soil} = \frac{25 (b-a)}{0.4 (c-a)}$$

Where

a = P extracted from unfumigated soil

b = P extracted from fumigated soil

c = P extracted from unfumigated soil spiked with inorganic P (as KH_2PO_4)

3.8.4.3 Soil dehydrogenase activity

The dehydrogenase activity in the soil samples was determined as described by Casida *et al.* (1964). Five grams of soil was mixed with 1 ml of 3 per cent 2, 3, 5- triphenyl tetrazolium chloride (TTC), 0.2 g of CaCO_3 and 2.5 ml of distilled water in screw cap tube and incubated at 30° C for 24 hours. Later, 10 ml of methanol was added and the suspension was filtered using Whatman No. 15 filter paper into 50 ml volumetric flask. Additional methanol was added until the disappearance of red color. The volume of the filtrate was made to 50 ml using methanol and mixed well. The intensity of the red color was measured using spectrophotometer at 485 nm. The amount of dehydrogenase activity of the sample was measured by referring to TPF from the standard curve and calculated using the following formulae:

$$\text{Dehydrogenase activity as } \mu\text{g TPF g}^{-1} \text{ soil} = \frac{\text{Amount of TPF from standard curve } (\mu\text{g})}{\text{Dry weight of soil (g)}} \times \frac{\text{final volume made (ml)}}{50}$$

3.8.4.4 Soil urease activity

The procedure followed was according to the method given by Eivazi and Tabatabai (1977). About 5 g soil sample (two set) was treated with 9 ml Tris buffer (THAM) and 1 ml of 0.2 M urea solution was added for non-control treatment and incubated at 37°C for 2 h. After incubation period, 1 ml of 0.2 M urea solution was added to only control set and the final volume of both the sets was made up to 50 ml with the addition of $\text{KCl-Ag}_2\text{SO}_4$ solution and swirled for 15 minutes, then filtered through Whatman No.1 filter paper. 5 ml of the filtrate was pipetted out to 50 ml volumetric flask to which 2 ml of 10 per cent sodium tartrate, 1 ml of 1 per cent gum acacia and distilled water was added and volume made up to 43 ml and 5 ml of Nessler's reagent was added and the contents mixed rapidly and the final volume was made up to 50 ml with the distilled

water. The absorbance of the yellow color was read at 410 nm with extractant as blank after 25 min.

3.8.4.5 Soil phosphatase activity:

1 g of soil sample was treated with 4 ml of modified universal buffer (MUB- pH 6.5 for acid phosphatase assay) and 1 ml of para-nitrophenyl phosphate solution swirled for few seconds and incubated at 37° C for one hour. Further soil was extracted with 0.5 M CaCl₂ and 0.5 M NaOH. The intensity of yellow color filtrate was read using spectrophotometer at 420 nm and expressed in µg PNP g⁻¹ soil h⁻¹ (Eivazi and Tabatabai,1977).

3.9 Plant analysis

3.9.1 Collection and preparation

Plant samples collected at different growth stages *viz.*, 30, 60, 90 DAS and at harvest were dried at 65 ± 5 °C in hot air oven and powdered using willey stainless steel mill, preserved in polythene bag for further analysis.

3.9.2 Nutrient Uptake

The uptake of macro and micro nutrients by different parts at different intervals was worked out by multiplying nutrient content and biomass yield of plant part as given in the formulae

$$\text{Macro nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient concentration (\%)} \times \text{Biomass (kg ha}^{-1}\text{)}}{100}$$

$$\text{Micro nutrient uptake (g ha}^{-1}\text{)} = \frac{\text{Nutrient concentration (ppm)} \times \text{Biomass (kg ha}^{-1}\text{)}}{1000}$$

Table 3.6 Methodologies adopted for plant analysis

Sl. No.	Parameters	Procedure	Method and Reference
1	Total nitrogen	In this method 0.5 g of powdered samples (grain and straw) was digested with concentrated sulphuric acid (H ₂ SO ₄) in the presence of digestion mixture (K ₂ SO ₄ : CuSO ₄ .5H ₂ O: Selenium in 100:20:1 proportion) and distilled under alkaline medium. The liberated ammonia was trapped in boric acid containing mixed indicator and titrated against standard sulphuric acid.	Kjeldahl digestion and distillation method (Piper, 1966)
	Digestion of plant samples using diacid mixture	Powdered grain and straw samples (0.5 g) were predigested with 5 ml of concentrated HNO ₃ and then digested using 10 ml diacid mixture (HNO ₃ : HClO ₄ in 9:4 ratio) on sand bath. The residue was cooled and volume made up to 100 ml with distilled water and preserved for total elemental analysis.	Piper (1966)
2	Total phosphorus	The phosphorus content in the di-acid digested plant samples was estimated by Vanado-molybdo-phosphoric yellow color method and the color intensity was measured at 430 nm wave length.	Diacid digestion and vanadomolybdate method (Piper, 1966)
3	Total potassium	The potassium content in plant samples was determined by flame photometer.	Diacid digestion and flame photometer method (Piper, 1966)
4	Total calcium and magnesium	Diacid digested samples were titrated against standard EDTA with EBT indicator for calcium+ magnesium and Patton readers indicator for calcium. The magnesium content observed by subtracting calcium value from calcium + magnesium value.	Diacid digestion and Complexometric titration method (Piper, 1966)
5	Total Sulphur	Digested sample was treated with barium chloride in the presence of stabilizing agent. Turbidity thus formed was measured using spectrophotometer at 420 nm	Diacid digestion and 0.15 % CaCl ₂ and Turbidometry (Black, 1965)
6	Micro nutrient	The digested extracts of samples were diluted and fed to AAS to determine the content of respective metal ions (Cu, Zn, Fe and Mn) using suitable hollow cathode lamp and expressed in ppm.	Diacid digestion and atomic absorption spectrophotometry (Lindsay and Norvell, 1978)

3.10 Economics

3.10.1 Cost of cultivation

The price of inputs that were prevailing at the time of their use was considered to work out cost of cultivation. Treatment wise cost of cultivation was worked out. Net return per hectare was calculated by deducting the cost of cultivation from gross income.

3.10.2 Benefit: cost (B:C) ratio

Benefit cost ratio is computed using following formula,

$$\text{Benefit cost ratio} = \frac{\text{Net return}}{\text{Cost of cultivation}}$$

3.11 Statistical analysis of data

The observations recorded in these studies were analyzed statistically for test of significance following the Fisher's method of analysis of variance (ANOVA) as outlined by Gomez and Gomez (1984). Whenever F-test was significant for comparison amongst the treatments means an appropriate value of critical differences (CD) was worked out. Otherwise against CD values, abbreviation NS (Non-Significant) was indicated. All the data were analyzed and the results are presented and discussed at a probability level of 0.05 per cent and correlation and regression study was done as given by Gomez and Gomez (1984).

IV RESULTS AND DISCUSSION

The results of field experiment conducted to study the effect of application of bio enriched FYM along with inorganic fertilizers on soil properties and productivity of finger millet under dryland condition is presented in this chapter.

4.1 Characterization of FYM

Before enriching FYM with biofertilizers the farm yard manure was characterized for its chemical properties using standard procedure. The FYM was dark grey in color with slightly alkaline in reaction (7.7) with higher EC of 2.1 dS m⁻¹ and organic carbon (21.5 %). Among the major nutrients, the total nitrogen was higher (0.62 %) followed by total potassium (0.49 %) and total phosphorus (0.23 %). The secondary nutrients were total calcium (0.44 %), total magnesium (0.18 %) and sulphur (20.32 mg kg⁻¹). The iron content of FYM was high (895.6 mg kg⁻¹), followed by Mn (632.6 mg kg⁻¹), Zn (147.6 mg kg⁻¹) and Cu (99.5 mg kg⁻¹) (Table 4.1).

Table 4.1 Chemical properties of FYM before enrichment with biofertilizers

Sl. No.	Parameters	Values
1	pH	7.7
2	EC (dS m ⁻¹)	2.1
3	OC (%)	21.5
4	Total N (%)	0.62
5	Total P ₂ O ₅ (%)	0.23
6	Total K ₂ O (%)	0.49
7	Total Ca (%)	0.44
8	Total Mg (%)	0.18
9	S (mg kg ⁻¹)	20.32
10	Fe (mg kg ⁻¹)	895.6
11	Mn (mg kg ⁻¹)	632.6
12	Cu (mg kg ⁻¹)	99.5
13	Zn (mg kg ⁻¹)	147.6

4.2 Soil characteristics before sowing

The soil of the experimental site was sandy loam in texture (Table 4.2). Sand content was highest (64.7 %) followed by clay (18.6 %) and silt (16.4 %). The bulk density of soil was 1.39 Mg m^{-3} with particle density of 2.46 Mg m^{-3} . Higher porosity (38.88 %) was observed with MWHC of 37.39 per cent.

With respect to chemical properties, the soil was slightly acidic in reaction with pH of 6.06 with low electrical conductivity (0.04 dS m^{-1}) and organic carbon (0.31 %). The available nitrogen ($148.60 \text{ kg ha}^{-1}$) and potassium ($111.93 \text{ kg ha}^{-1}$) was found lower, while phosphorus status was higher ($118.40 \text{ kg ha}^{-1}$).

Among secondary nutrients, calcium content of $1.63 \text{ c mol (p}^+) \text{ kg}^{-1}$, magnesium content of $0.77 \text{ c mol (p}^+) \text{ kg}^{-1}$ and available sulphur content of 14.93 mg kg^{-1} . Whereas, DTPA extractable micronutrients (Fe, Mn, Zn and Cu) content was found to be 8.98, 9.03, 0.83 and 0.92 mg kg^{-1} , respectively.

With respect to biological properties, higher microbial biomass carbon ($109.4 \text{ } \mu\text{g g}^{-1}$) was recorded in the experimental soil followed by microbial biomass nitrogen ($12.76 \text{ } \mu\text{g g}^{-1}$) and microbial biomass phosphorus ($3.44 \text{ } \mu\text{g g}^{-1}$). Maximum dehydrogenase activity of $13.71 \text{ } \mu\text{g TPF g}^{-1} \text{ soil } 24 \text{ h}^{-1}$, $18.45 \text{ } \mu\text{g NH}_4\text{- N g}^{-1} \text{ soil h}^{-1}$ of urease activity and $14.56 \text{ } \mu\text{g PNP g}^{-1} \text{ soil h}^{-1}$ acid phosphatase activity was recorded.

4.3 Effect of bio- enriched FYM and levels of fertilizers on growth attributes of finger millet at different growth stages.

The data on growth attributes such as plant height, number of tillers per plant and dry weight per plant as influenced by different biofertilizers enriched FYM and levels of RDF are presented in Table 4.3, 4.4 and 4.5, respectively.

4.3.1 Plant height

The data on plant height of finger millet as influenced by combined application of biofertilizer enriched FYM with different levels of inorganic fertilizer at different growth stages are presented in Table 4.3. Plant height differed significantly at 60, 90 DAS and at

Table 4.2: Initial physico-chemical and biological properties of the experimental site, AICRP for Dryland Agriculture, UAS, Bengaluru

Sl. No.	Parameters	Values
Physical properties		
01	Texture	Sandy loam
	Sand (%)	64.7
	Silt (%)	16.4
	Clay (%)	18.6
02	Bulk density (Mg m^{-3})	1.39
03	Particle density (Mg m^{-3})	2.46
04	MWHC (%)	37.39
05	Porosity (%)	38.88
Chemical properties		
01	pH (1:2.5)	6.06
02	EC (dS m^{-1})	0.040
03	Organic Carbon (%)	0.31
04	Avail. N (kg ha^{-1})	148.60
05	Avail. P_2O_5 (kg ha^{-1})	118.40
06	Avail. K_2O (kg ha^{-1})	111.93
07	Exchangeable Ca [$\text{c mol (p+) kg}^{-1}$ of soil]	1.63
08	Exchangeable Mg [$\text{c mol (p+) kg}^{-1}$ of soil]	0.77
09	Available S (mg kg^{-1})	14.93
10	DTPA extractable Fe (mg kg^{-1})	8.98
11	DTPA extractable Mn (mg kg^{-1})	9.03
12	DTPA extractable Zn (mg kg^{-1})	0.83
13	DTPA extractable Cu (mg kg^{-1})	0.92
Biological properties		
01	Microbial biomass carbon ($\mu\text{g g}^{-1}$)	109.4
02	Microbial biomass nitrogen ($\mu\text{g g}^{-1}$)	12.76
03	Microbial biomass phosphorus ($\mu\text{g g}^{-1}$)	3.44
04	Dehydrogenase ($\mu\text{g TPF g}^{-1}$ soil 24 h^{-1})	13.71
05	Urease ($\mu\text{g NH}_4\text{- N g}^{-1}$ soil h^{-1})	18.45
06	Phosphatase (acid) ($\mu\text{g PNP g}^{-1}$ soil h^{-1})	14.56

harvest with different treatments and it increased progressively with increase in age of the crop up to 90 days after sowing and thereafter increase was meagre (Fig. 4.1).

Plant height is an important parameter related to growth and development of crop. There was no significant difference in plant height at 30 DAS due to application of different biofertilizers enriched FYM, levels of fertilizers, interaction of both (B×L) and among treatments.

Application of MC enriched FYM showed higher plant height (84.27, 108.78 and 112.76 cm), while least was recorded in PSB+ PGPR (73.52, 90.08 and 93.85 cm) compared to other biofertilizers at 60, 90 DAS and at harvest, respectively. Among levels of fertilizers, 80 per cent RDF recorded higher plant height (80.07, 101.99 and 105.73 cm) compared to 60 per cent RDF (75.08, 96.15 and 99.75 cm) at 60, 90 DAS and at harvest, respectively. Interaction was found non-significant. However, among treatments, significantly higher plant height was observed with application of MC +80 per cent RDF (T₁₀: 86.38, 111.52 and 115.33 cm) and was on par with MC+ 60 per cent RDF (T₉ : 82.15, 106.05 and 110.19 cm) and was lower in absolute control (46.30, 55.42 and 57.79 cm) at 60, 90 DAS and at harvest, respectively.

The results are in line with, Singh *et al.* (2016) who reported that application of different biofertilizers did not affect the plant height at early stages of growth. This may be due to the slower rate of mineralization of nutrients, because at early stage the nutrients are better utilized by microorganisms for multiplication and establishment, thus lowering the availability of nutrients for plant growth. Plant height was significantly increased with combined application of both biofertilizer and inorganic fertilizers at 60, 90 DAS and at harvest. The highest height observed with application of microbial consortia (NFB + PSB + KSB and PGPR) may be attributed to continuous uptake of nutrient by the plant, which was made available through nitrogen fixation, P and K solubilization which helped in increasing plant height. Similar result was observed by Singh *et al.* (2016) in pearl millet. According to Narula and Guptha (1986) application of nitrogen fixers such as *Azotobacter* synthesizes and secretes considerable amount of biologically active substance like B vitamin, nicotinic acid, pantothenic acid, biotin, heteroauxins, and gibberellins *etc.*, which



Plate 5: Growth and yield observation

Table 4.3: Plant height (cm) of finger millet at different growth stages as influenced by different bio-enriched FYM and levels of fertilizers.

	30 DAS	60 DAS	90 DAS	At harvest
Factor 1: Biofertilizers enrichment (B)				
B₁: NFB + PGPR	26.77	77.59	102.34	106.13
B₂: PSB + PGPR	24.97	73.52	90.08	93.85
B₃: KSB + PGPR	25.74	74.92	95.08	98.22
B₄: MC	28.63	84.27	108.78	112.76
S.Em.±	1.55	2.12	2.65	2.50
CD @ 5 %	NS	6.43	8.03	7.58
Factor 2: Levels of fertilizers (L)				
L₁:60 % RDF	26.00	75.08	96.15	99.75
L₂: 80 % RDF	27.05	80.07	101.99	105.73
S.Em.±	1.09	1.50	1.87	1.77
CD @ 5 %	NS	4.55	5.68	5.36
Interaction (B× L)				
S.Em.±	2.19	3.00	3.74	3.53
CD @ 5 %	NS	NS	NS	NS
Treatments				
T₁-Control	16.30	46.30	55.42	57.79
T₂-100 % RDF	23.65	70.72	88.07	90.00
T₃-B₁L₁	26.05	74.53	99.73	104.23
T₄-B₁L₂	27.48	80.64	104.94	108.02
T₅-B₂L₁	24.20	71.35	87.74	90.68
T₆-B₂L₂	25.74	75.69	92.42	97.02
T₇-B₃L₁	25.24	72.28	91.08	93.89
T₈-B₃L₂	26.24	77.57	99.08	102.56
T₉-B₄L₁	28.50	82.15	106.05	110.19
T₁₀-B₄L₂	28.76	86.38	111.52	115.33
S.Em.±	2.54	2.81	4.16	4.24
CD @ 5 %	NS	8.36	12.36	12.60

*100 per cent was added with 7.5 t ha⁻¹ of FYM, remaining treatments received 7.5 t ha⁻¹ of bio-enriched FYM.

NFB: Nitrogen fixing biofertilizers

PSB: Phosphate solubilizing biofertilizers

KSB: Potassium solubilizing biofertilizers

PGPR: Plant growth promoting rhizobacteria

MC: Microbial consortia

enhance growth of plants. Pallavi *et al.* (2017) reported that increased availability of nutrients in the soil through mineralization of organic sources could have triggered cell elongation and multiplication resulting in higher growth rate of shoots and in turn plant height of finger millet over control. The increase in plant height may be attributed to increased uptake of nitrogen and phosphorus by the plants, which was made available through nitrogen fixation and phosphate solubilization by the microorganisms (Singh *et al.*, 2016). Similar result was also observed by Ashok Kumar Roy (2018).

4.3.2 Number of tillers per plant

The data on number of tillers per plant of finger millet as influenced by different biofertilizers enriched FYM and levels of fertilizers at different growth stages are presented in Table 4.4. The number of tillers per plant differed significantly at all growth stages except at 30 DAS with different treatment combinations of biofertilizers enrichment and inorganic fertilizers.

There was no significant increase in number of tillers at 30 DAS in finger millet with application of different biofertilizers, levels of RDF independently and due to combined application of both and between treatments. But significant increase in number of tillers per hill was recorded at 60, 90 DAS and at harvest.

Among different biofertilizers application of MC enriched FYM recorded significantly higher number of tillers per hill (4.39, 5.16 and 5.38), followed by application of KSB+ PGPR (4.10, 4.87 and 5.06) at 60, 90 DAS and at harvest, respectively. Whereas, 80 per cent RDF showed significantly higher number of tillers per hill (4.26, 5.03 and 5.25) compared to 60 per cent RDF (3.99, 4.75 and 4.95) at 60, 90 DAS and at harvest, respectively. Interaction was found non-significant. Among different treatments application of MC + 80 per cent RDF (T₁₀) recorded highest number of tillers (4.42, 5.20 and 5.42) compared to absolute control (T₁) (2.47, 2.54 and 2.67) and 100 per cent RDF (T₂) (3.73, 4.53 and 4.69).

Number of tillers per plant varied significantly with application of different biofertilizers and levels of RDF at 60, 90 DAS and after harvest. The process of nitrogen

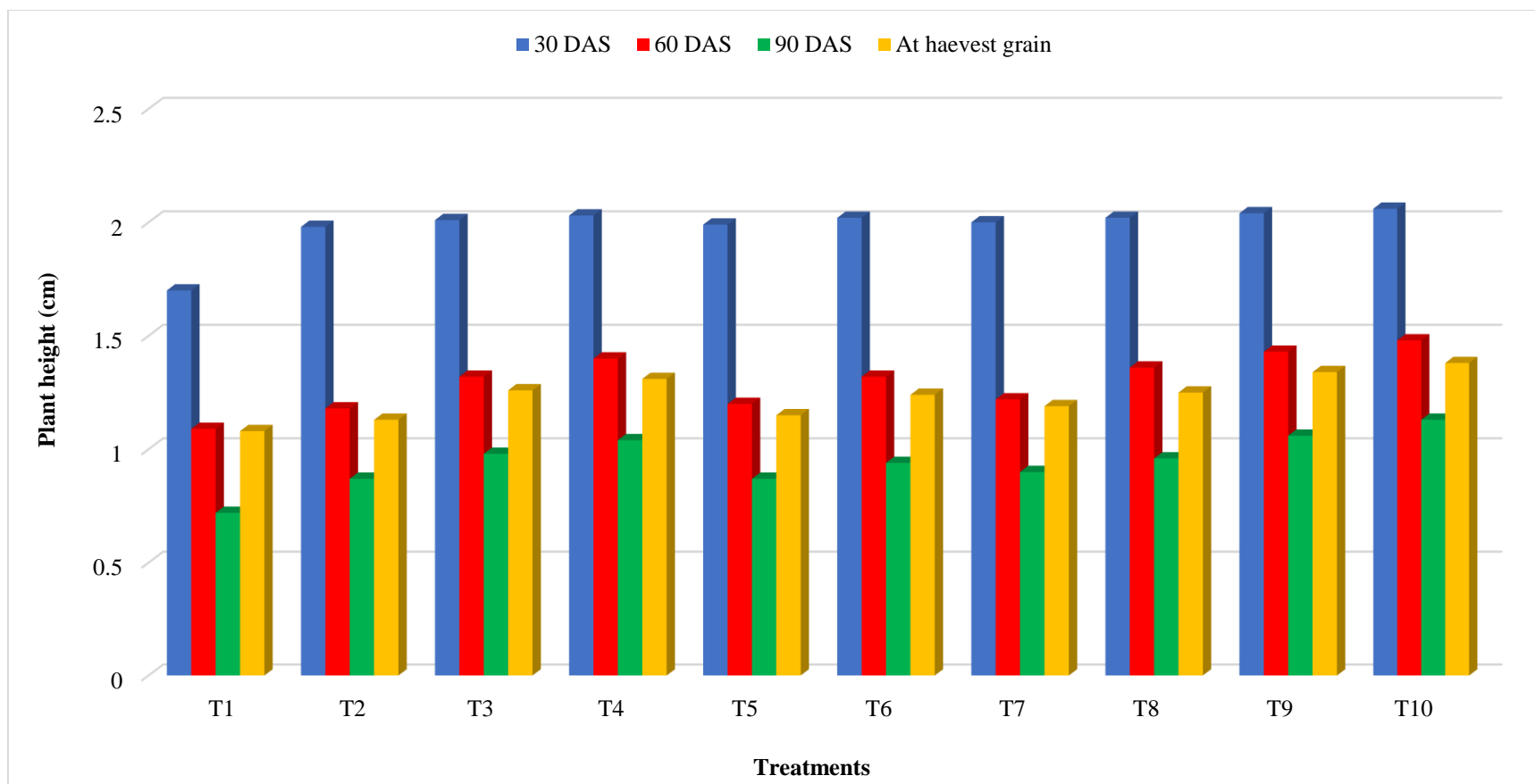


Fig. 4.1: Bio- enriched FYM and different levels of fertilizers on plant height of finger millet at different growth stages.

Treatment details:

T₁: Absolute control

T₂: 7.5 t ha⁻¹ FYM + 100 % RDF

T₃: 7.5 t ha⁻¹ enriched FYM (NFB + PGPR) + 60 % RDF

T₄: 7.5 t ha⁻¹ enriched FYM (NFB + PGPR) + 80 % RDF

T₅: 7.5 t ha⁻¹ enriched FYM (PSB + PGPR) + 60 % RDF

T₆: 7.5 t ha⁻¹ enriched FYM (PSB + PGPR) + 80 % RDF

T₇: 7.5 t ha⁻¹ enriched FYM (KSB + PGPR) + 60 % RDF

T₈: 7.5 t ha⁻¹ enriched FYM (KSB + PGPR) + 80 % RDF

T₉: 7.5 t ha⁻¹ enriched FYM (MC) + 60 % RDF

T₁₀: 7.5 t ha⁻¹ enriched FYM (MC) + 80 % RDF

Table 4.4: No. of tillers per plant of finger millet at different growth stages as influenced by different bio-enriched FYM and levels of fertilizers.

	30 DAS	60 DAS	90 DAS	At harvest
Factor 1: Biofertilizers enrichment (B)				
B₁: NFB+ PGPR	1.81	4.06	4.82	5.02
B₂: PSB + PGPR	1.78	3.96	4.73	4.94
B₃: KSB + PGPR	1.83	4.10	4.87	5.06
B₄: MC	1.92	4.39	5.16	5.38
S.Em.±	0.06	0.10	0.10	0.11
CD @ 5 %	NS	0.30	0.31	0.32
Factor 2: Levels of fertilizers (L)				
L₁:60 % RDF	1.80	3.99	4.75	4.95
L₂: 80 % RDF	1.88	4.26	5.03	5.25
S.Em.±	0.04	0.07	0.07	0.07
CD @ 5 %	NS	0.21	0.22	0.23
Interaction (B× L)				
S.Em.±	0.09	0.14	0.14	0.15
CD @ 5 %	NS	NS	NS	NS
Treatments				
T₁-Control	1.16	2.47	2.54	2.67
T₂-100 % RDF	1.73	3.73	4.53	4.69
T₃-B₁L₁	1.76	3.89	4.64	4.83
T₄-B₁L₂	1.86	4.22	4.99	5.22
T₅-B₂L₁	1.73	3.79	4.56	4.75
T₆-B₂L₂	1.83	4.13	4.90	5.12
T₇-B₃L₁	1.80	3.92	4.69	4.88
T₈-B₃L₂	1.87	4.27	5.04	5.23
T₉-B₄L₁	1.90	4.35	5.12	5.33
T₁₀-B₄L₂	1.94	4.42	5.20	5.42
S.Em.±	0.12	0.23	0.22	0.25
CD @ 5 %	NS	0.70	0.64	0.73

*100 per cent was added with 7.5 t ha⁻¹ of FYM, remaining treatments received 7.5 t ha⁻¹ of bio-enriched FYM.

NFB: Nitrogen fixing biofertilizers

PSB: Phosphate solubilizing biofertilizers

KSB: Potassium solubilizing biofertilizers

PGPR: Plant growth promoting rhizobacteria

MC: Microbial consortia

fixation and solubilization of P and K increased availability of nutrients to plant with the application of microbial consortia. The increased NPK in plant play an important role in nutrient and sugar translocation in plant, maintenance of turgor pressure of plant cell and increase the plant growth and number of tillers per plant. Similarly, Monisha *et al.* (2019) reported that higher availability of NPK during crop growth period might have improved the plant growth characters like plant height and number of tillers per hill. The PGPR include regulating hormonal and nutritional balance, inducing resistance against plant pathogens, and solubilizing nutrients for easy uptake by plants and indirectly boosts plant growth rate (Vejan *et al.*, 2016). The improved physico-chemical properties and availability of nutrients at slow rate for longer time with the use of organics might be responsible for more number of tillers (Pallavi *et al.*, 2017). Yuvaraj (2016) reported that combined inoculation of microbial consortia with inorganic fertilizer increased number of tillers per plant compared to single strain biofertilizer in paddy and similar result was observed by Shruthi (2014) with application of 100 per cent NPK (POP) + FYM + P and K solubilizer compared to 100 per cent NPK (POP) + FYM + P solubilizer and 100 per cent NPK (POP) + FYM + K solubilizer in finger millet.

4.3.3 Dry weight per plant

The data on dry matter production of finger millet at different growth stages as influenced by biofertilizers enriched FYM and different levels of inorganic fertilizers are presented in Table 4.5 and Fig. 4.2.

There was no significant effect due to application of biofertilizer enriched FYM, inorganic fertilizer and interaction (B×L) on dry matter production of finger millet at 30 DAS. Whereas, it was found significant at 60, 90 DAS and at harvest.

Among different biofertilizers enrichment application of MC recorded significantly higher dry matter per plant (5.40, 14.87 and 26.93 g plant⁻¹), followed by application of KSB+ PGPR (4.98, 13.94 and 25.21 g plant⁻¹) at 60, 90 DAS and at harvest, respectively. Whereas, among different levels of fertilizers, 80 per cent RDF showed significantly higher dry matter per plant (5.22, 14.34 and 26.20 g plant⁻¹) compared to 60 per cent RDF (4.90, 13.67 and 24.70 g plant⁻¹) at 60, 90 DAS and at harvest, respectively. Interaction of

Table 4.5: Dry weight (g plant⁻¹) of finger millet at different growth stages as influenced by different bio-enriched FYM and levels of fertilizers.

	30 DAS	60 DAS	90 DAS	At harvest
Factor 1: Biofertilizers enrichment (B)				
B₁: NFB + PGPR	1.07	5.05	13.79	24.91
B₂: PSB + PGPR	1.04	4.81	13.42	24.75
B₃: KSB + PGPR	1.08	4.98	13.94	25.21
B₄: MC	1.14	5.40	14.87	26.93
S.Em.±	0.04	0.12	0.29	0.43
CD @ 5 %	NS	0.36	0.88	1.29
Factor 2: Levels of fertilizers (L)				
L₁:60 % RDF	1.06	4.90	13.67	24.70
L₂: 80 % RDF	1.10	5.22	14.34	26.20
S.Em.±	0.03	0.08	0.21	0.30
CD @ 5 %	NS	0.26	0.62	0.91
Interaction (B× L)				
S.Em.±	0.06	0.17	0.41	0.60
CD @ 5 %	NS	NS	NS	NS
Treatments				
T₁-Control	0.53	2.69	5.44	9.97
T₂-100 % RDF	0.99	4.66	12.76	23.38
T₃-B₁L₁	1.04	4.83	13.43	24.11
T₄-B₁L₂	1.09	5.28	14.16	25.71
T₅-B₂L₁	1.02	4.69	12.98	23.83
T₆-B₂L₂	1.07	4.94	13.85	25.67
T₇-B₃L₁	1.05	4.80	13.58	24.27
T₈-B₃L₂	1.10	5.17	14.30	26.16
T₉-B₄L₁	1.12	5.31	14.69	26.58
T₁₀-B₄L₂	1.15	5.50	15.05	27.27
S.Em.±	0.05	0.33	0.53	0.66
CD @ 5 %	0.16	0.98	1.59	1.95

*100 per cent was added with 7.5 t ha⁻¹ of FYM, remaining treatments received 7.5 t ha⁻¹ of bio-enriched FYM.

NFB: Nitrogen fixing biofertilizers

PSB: Phosphate solubilizing biofertilizers

KSB: Potassium solubilizing biofertilizers

PGPR: Plant growth promoting rhizobacteria

MC: Microbial consortia

different biofertilizers and levels of fertilizers was found non-significant. Among different treatments, application of MC enriched FYM + 80 per cent RDF (T₁₀) recorded higher dry matter accumulation per plant (1.15, 5.50, 15.05 and 27.27 g plant⁻¹) compared to absolute control (0.53, 2.69, 5.44 and 9.97 g plant⁻¹) and 100 per cent RDF (0.99, 4.66, 12.76 and 23.38 g plant⁻¹) at 60, 90 DAS and at harvest, respectively.

Significantly higher dry matter production observed at 60, 90 DAS and at harvest might be due to fact that biofertilizers have an ability to mobilise nutrients from non-useable form to useable form and increase the availability of nutrients to plant during their growth period, which might result in increased dry matter production. Abdullahi *et al.* (2014) recorded similar result with application of bio-fertilizer alone or in combination with cow dung (CD) or poultry manure (PM) on growth of pearl millet and observed significant increase in dry matter production compared to control. Similarly, Cleyet-Marel *et al.* (2001) found that inoculation of plant with plant growth promoting rhizobacteria at early stage of development made positive impact on biomass production through direct effect on root growth, production of phytohormones by bacteria, mineral enhancement uptake and transfer of nutrient to plant.

4.4 Effect of bio- enriched FYM and levels of fertilizers on yield attributes and grain and straw yield of finger millet at harvest.

The data on yield attributes *viz.*, ear head per plant, number of fingers per plant, test weight of 1000 grains and also grain and straw yield per hectare as influenced by different biofertilizers enrichment and levels of fertilizers are presented in Table 4.6.

4.4.1 Yield attributes

4.4.1.1 Ear head per hill

There was a significant difference in ear head count per plant at harvest with application of different biofertilizers enrichment and levels of fertilizers and also interaction recorded non-significant effect on ear head count per hill. Microbial consortia significantly increased ear head per hill (5.08), followed by KSB+ PGPR (4.92), PSB+ PGPR (4.84) and NFB+ PGPR (4.77). Application of inorganic fertilizers showed

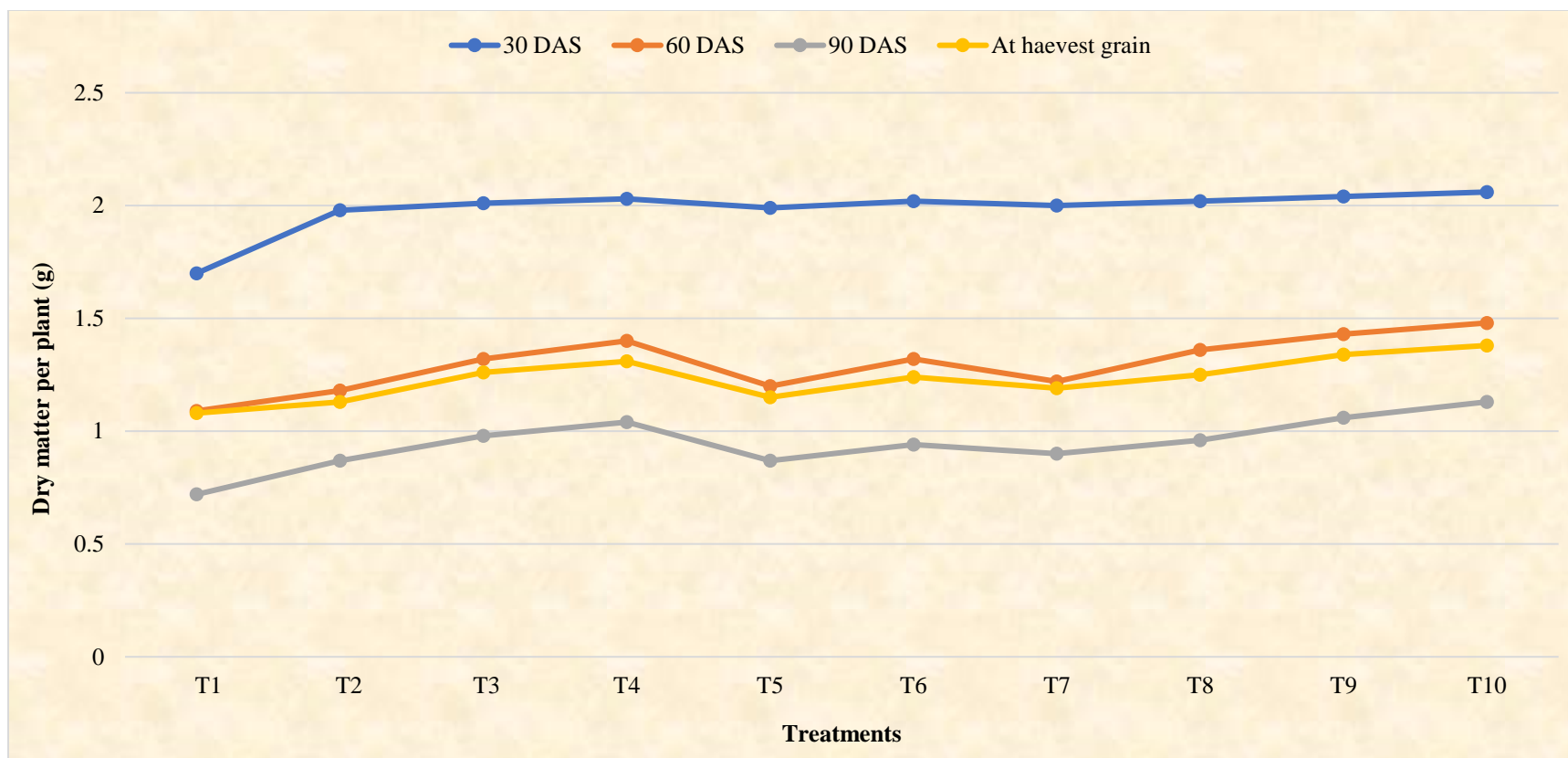


Fig. 4.2: Bio- enriched FYM and different levels of fertilizers on dry matter production (g plant⁻¹) of finger millet at different growth stages.

Treatment details:

T₁: Absolute control

T₂: 7.5 t ha⁻¹ FYM + 100 % RDF

T₃: 7.5 t ha⁻¹ enriched FYM (NFB + PGPR) + 60 % RDF

T₄: 7.5 t ha⁻¹ enriched FYM (NFB + PGPR) + 80 % RDF

T₅: 7.5 t ha⁻¹ enriched FYM (PSB + PGPR) + 60 % RDF

T₆: 7.5 t ha⁻¹ enriched FYM (PSB+ PGPR) + 80 % RDF

T₇: 7.5 t ha⁻¹ enriched FYM (KSB + PGPR) + 60 % RDF

T₈: 7.5 t ha⁻¹ enriched FYM (KSB+ PGPR) + 80 % RDF

T₉: 7.5 t ha⁻¹ enriched FYM (MC) + 60 % RDF

T₁₀: 7.5 t ha⁻¹ enriched FYM (MC) + 80 % RDF

significant increase with application of 80 per cent RDF (5.01) compared to 60 per cent RDF (4.80). However, significant increase in ear head per plant was observed in the treatment which received microbial consortia + 80 per cent RDF (5.13), while the least count of ear head was obtained in absolute control treatment (3.33).

4.4.1.2 Number of fingers per ear head

Application of different biofertilizers enriched FYM and levels of fertilizers recorded non-significant effect on number of fingers per ear head. Number of fingers per ear head ranged from 6.26 to 6.80 due to application of different biofertilizers. The interaction recorded non-significant effect. Similarly, different combination of biofertilizers and levels of fertilizers when compared with control, also recorded non-significant effect on number of fingers per ear head. However, it was found higher with application of MC + 80 per cent RDF (6.77) compared to control (4.90).

4.4.1.3 1000 grains weight

1000 grains weight ranged from 2.89 g to 3.21 g due to application of different bio-enriched FYM. Similarly, application of 80 per cent RDF showed higher test weight (3.09 g) compared to 60 per cent RDF (2.93 g). The interaction recorded non-significant effect, while among different treatments higher test weight (3.25 g) was recorded in treatment which received MC + 80 per cent RDF (T₁₀) compared to control (2.47 g).

There was significant difference found with application of different biofertilizers and levels of fertilizers. Higher yield attributes recorded with application of microbial consortia, followed by application of K solubilizers. Microbial consortia not only increased nitrogen fixation and solubilization of P and K, but it also improved relative microorganism in soil which helped in mineralization. NPK are essential nutrients required for the promotion of the meristematic and physiological activities, these activities promote higher photosynthetic activities leading to the production of enough assimilates for subsequent translocation to various sink thereby leading to production of higher sink components like productive tillers, number of fingers per plant, weight of grains and test weight per plant (Pallavi *et al.*, 2017) PGPR helped in regulating hormones and improved nutrient uptake

by plant by reducing pest and disease incidence. However, it was found that K solubilizer when applied along with PGPR helped in increasing potassium uptake by plant and helped to regulate enzymatic activity and translocation of photosynthates which improved yield attributes. This result has conformity with Shruthi (2014) who observed similar results in finger millet crop.

4.4.2 Grain and straw yield

4.4.2.1 Grain yield

There was significant increase in grain yield with application of biofertilizers and followed order of MC > KSB + PGPR > PSB + PGPR > NFB + PGPR which ranged from 2692 kg ha⁻¹ to 2952 kg ha⁻¹. Independent of biofertilizers, application of 80 per cent RDF recorded higher grain yield of 2857 kg ha⁻¹ compared to 60 per cent RDF. Interaction had no significant effect on grain yield. Significantly higher grain yield was observed in treatment with combined application of MC + 80 per cent RDF (2999 kg ha⁻¹) which was found to be on par with treatment which received MC + 60 per cent RDF (2905 kg ha⁻¹) and lower was found in absolute control (1132 kg ha⁻¹).

4.4.2.2 Straw yield

Application of different biofertilizers enriched FYM and levels of fertilizers significantly varied the straw yield at harvest. Among different biofertilizers, application of microbial consortia recorded higher straw yield (4228 kg ha⁻¹) at harvest. In case of different levels of fertilizers, the treatment which received 80 per cent RDF recorded higher straw yield (4130 kg ha⁻¹) at harvest compared to 60 per cent RDF. The interaction effect of different biofertilizers and levels of RDF was non-significant. Whereas, among treatments significantly higher straw yield was recorded in treatment which received MC + 80 per cent RDF (4274 kg ha⁻¹) and was on par with treatment which received MC + 60 per cent RDF (4183 kg ha⁻¹). The lower straw yield was observed in absolute control (1528 kg ha⁻¹).

Grain and straw yield were significantly increased with application of different biofertilizers enriched FYM and levels of fertilizers (Fig. 4.3), application of microbial

Table 4.6: Yield attributes and grain and straw yield of finger millet as influenced by different bio-enriched FYM and levels of fertilizers.

	No. of Ear heads hill ⁻¹	No. of Fingers ear head ⁻¹	1000 grain weight (g)	Grain yield (kg ha ⁻¹)	Straw yield (kg ha ⁻¹)
Factor 1: Biofertilizers enrichment (B)					
B₁: NFB + PGPR	4.77	6.26	2.89	2692	3951
B₂: PSB + PGPR	4.84	6.45	2.94	2708	3892
B₃: KSB + PGPR	4.92	6.54	3.01	2733	3991
B₄: MC	5.08	6.80	3.21	2952	4228
S.Em.±	0.07	0.14	0.09	61.48	79.56
CD @ 5 %	0.22	0.42	NS	186.48	241.31
Factor 2: Levels of fertilizers (L)					
L₁:60 % RDF	4.80	6.39	2.93	2686	3901
L₂: 80 % RDF	5.01	6.64	3.09	2857	4130
S.Em.±	0.05	0.10	0.06	43.47	56.26
CD @ 5 %	0.16	0.30	NS	131.86	170.63
Interaction (B× L)					
S.Em.±	0.10	0.20	0.12	86.95	112.51
CD @ 5 %	NS	NS	NS	NS	NS
Treatments					
T₁-Control	3.33	4.90	2.47	1132	1528
T₂-100 % RDF	4.45	5.96	2.76	2524	3710
T₃-B₁L₁	4.60	6.11	2.80	2598	3831
T₄-B₁L₂	4.93	6.41	2.98	2786	4070
T₅-B₂L₁	4.72	6.24	2.85	2608	3747
T₆-B₂L₂	4.97	6.67	3.02	2808	4037
T₇-B₃L₁	4.83	6.39	2.90	2631	3841
T₈-B₃L₂	5.00	6.70	3.12	2834	4141
T₉-B₄L₁	5.03	6.83	3.16	2905	4183
T₁₀-B₄L₂	5.13	6.77	3.25	2999	4274
S.Em.±	0.13	0.40	0.15	77.46	145.87
CD @ 5 %	0.38	NS	NS	230.15	433.40

*100 per cent was added with 7.5 t ha⁻¹ of FYM, remaining treatments received 7.5 t ha⁻¹ of bio-enriched FYM.

NFB: Nitrogen fixing biofertilizers PSB: Phosphate solubilizing biofertilizers KSB: Potassium solubilizing biofertilizers PGPR: Plant growth promoting rhizobacteria MC: Microbial consortia

consortia increased availability of all the nutrients for uptake by plant throughout the growth period while PGPR regulated hormones and nutrient balance and also induced resistance against plant pathogen. Similarly, Vessey (2003) cited that microbial consortia often reveal multiple ways of benefiting plant health like fixation of nitrogen for host plant, mobilization or solubilization of phosphorus, production of phytohormones and plant fungal symbiosis as supportive bacteria or combination of those. Among single strain biofertilizers application of KSB showed higher straw and grain yield as they help in numerous enzymatic activities, formation of organic acid substances and build-up of compounds such as carbohydrates as it helps in cell development and trigger young tissues and help in meristematic growth. Similar result was observed by Neeraj (2014), Yuvaraj (2016) and Rangesh Kumar *et al.* (2018). The increased availability of the nutrients especially nitrogen due to combined application of FYM, inorganic fertilizers and biofertilizers, led to enhancement of the photosynthetic rate resulting in more vegetative growth and dry matter production (Roy *et al.*, 2018). Organic manure and bio-fertilizers increased the formation of the root hairs and lateral root which helps in higher nutrient uptake and resulted in higher biomass production (Thumar *et al.*, 2016). This could also be attributed to the higher availability of NPK during crop growth period which might have improved the plant height, number of tillers eventually increase the straw yield (Monisha *et al.*, 2019). The yield increase in the same crop was reported in field trials using a combination of *B. megaterium* and *A. chroococcum* was 10–20 per cent (Brown, 1974). Similarly, Rekha *et al.* (2018) recorded higher straw yield in the plants of the pots inoculated with microbial consortia +75 per cent RDF + FYM. Shruthi (2014) found that combined application of PSB + KSB + inorganic fertilizer increased grain and straw yield compare to single strain inoculation of biofertilizers with inorganic fertilizer.

4.5 Effect of bio- enriched FYM and levels of fertilizers on nutrient concentration and uptake of finger millet at different growth stages.

The result of the field experiment conducted to know the effect of bio- enriched FYM and levels of fertilizers on nutrient concentration and uptake at different growth stages of finger millet *viz.*, 30, 60, 90 DAS and at harvest are presented below

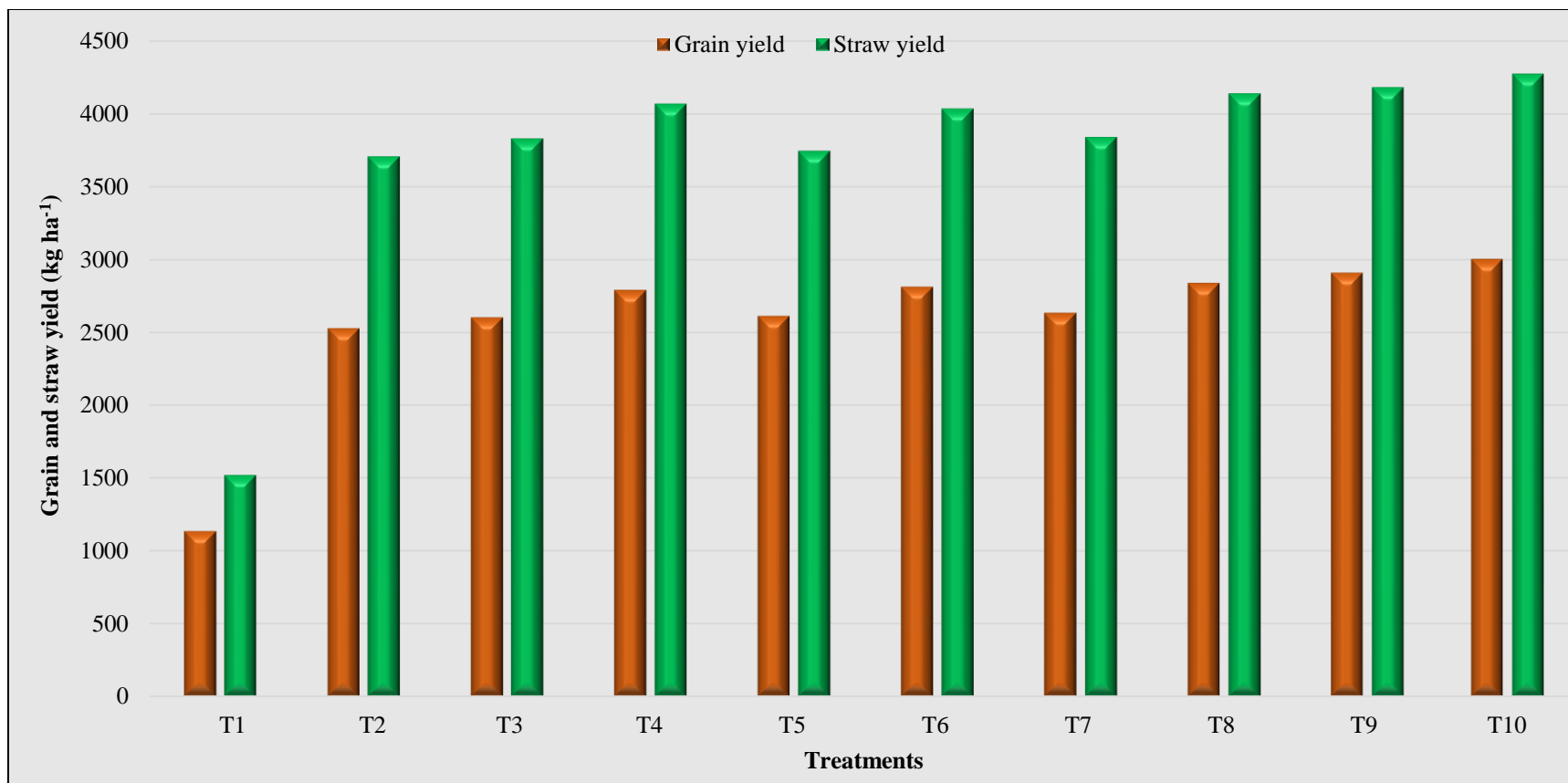


Fig. 4.3: Bio- enriched FYM and different levels of fertilizers on grain and straw yield (kg ha⁻¹) of finger millet at harvest.

Treatment details:

T₁: Absolute control

T₂: 7.5 t ha⁻¹ FYM + 100 % RDF

T₃: 7.5 t ha⁻¹ enriched FYM (NFB + PGPR) + 60 % RDF

T₄: 7.5 t ha⁻¹ enriched FYM (NFB + PGPR) + 80 % RDF

T₅: 7.5 t ha⁻¹ enriched FYM (PSB + PGPR) + 60 % RDF

T₆: 7.5 t ha⁻¹ enriched FYM PSB+ PGPR) + 80 % RDF

T₇: 7.5 t ha⁻¹ enriched FYM (KSB + PGPR) + 60 % RDF

T₈: 7.5 t ha⁻¹ enriched FYM (KSB+ PGPR) + 80 % RDF

T₉: 7.5 t ha⁻¹ enriched FYM (MC) + 60 % RDF

T₁₀: 7.5 t ha⁻¹ enriched FYM (MC) + 80 % RDF

4.5.1 Primary nutrients

4.5.1.1 Nitrogen content and uptake at different growth stages of finger millet

The concentration and uptake of nitrogen in finger millet at different growth stages viz., 30, 60, 90 DAS and at harvest are presented in Table 4.7 and Fig. 4.4.

The concentration and uptake of nitrogen in finger millet at 30 DAS showed non-significant results with application of different biofertilizer enriched FYM, levels of fertilizer and their interaction. Numerically higher content (2.05 %) and uptake (6.20 kg ha⁻¹) was recorded in B₄ (microbial consortia). Similarly, application of higher levels of fertilizers (80 % RDF) resulted in higher content (2.03 %) and uptake (5.97 kg ha⁻¹). Among different treatments, significantly higher uptake (6.33 kg ha⁻¹) was obtained in T₁₀ (B₄L₂: MC+ 80 % RDF), followed by 6.08 kg ha⁻¹ in T₉ (B₄L₁: MC+ 60 % RDF) compared to control T₁ (2.40 kg ha⁻¹).

However, at 60 DAS and 90 DAS significantly higher concentration (1.46 and 1.10 %, respectively) and uptake (20.99 and 43.50 kg ha⁻¹, respectively) was observed with application of microbial consortia (B₄). Similar was the trend with levels of fertilizers (L₂: 80 % RDF). The interaction effect with respect to nitrogen content and uptake at different growth stages of finger millet was non-significant. Among treatments, significantly higher concentration of N (1.48 and 1.13 %) and uptake (21.68 and 45.39 kg ha⁻¹) at 60 and 90 DAS, respectively was recorded with application of MC along with 80 per cent RDF (B₄L₂) followed by B₄L₁ (MC + 60 % RDF) over control.

The concentration and uptake of nitrogen in finger millet grain and straw also followed the same trend with higher concentration in grain (1.36 %) and straw (0.67 %) with application of B₄ (microbial consortia). With respect to levels of fertilizers, application of 80 per cent RDF resulted in higher concentration (1.30 and 0.59 %) and uptake (37.05 and 24.58 kg ha⁻¹) in grain and straw respectively. Among treatments significantly higher concentration of nitrogen in grain (1.38 %) and straw (0.69 %) was observed in T₁₀ (B₄L₂: MC+ 80 % RDF). Similar was trend with uptake in grain and straw (41.27 and 29.31 kg ha⁻¹, respectively) over control (12.16 and 6.47 kg ha⁻¹, respectively) and 100 per cent RDF (28.61 and 17.55 kg ha⁻¹, respectively).

Table 4.7: Nitrogen concentration and uptake by finger millet at different growth stages as influenced by different bio-enriched FYM and levels of fertilizers.

	30 DAS		60 DAS		90 DAS		AT HARVEST					
	Content (%)	Uptake (kg ha ⁻¹)	Content (%)	Uptake (kg ha ⁻¹)	Content (%)	Uptake (kg ha ⁻¹)	GRAIN		STRAW		Total uptake (kg ha ⁻¹)	
							Content (%)	Uptake (kg ha ⁻¹)	Content (%)	Uptake (kg ha ⁻¹)		
Factor 1: Biofertilizers enrichment (B)												
B₁: NFB + PGPR	2.02	5.72	1.36	18.34	1.01	37.27	1.29	34.70	0.59	23.42	58.12	
B₂: PSB + PGPR	2.00	5.58	1.26	16.18	0.91	32.53	1.20	32.39	0.50	19.52	51.90	
B₃: KSB + PGPR	2.01	5.77	1.29	17.29	0.93	34.49	1.22	33.33	0.52	21.00	54.33	
B₄: MC	2.05	6.20	1.46	20.99	1.10	43.50	1.36	40.13	0.67	28.25	68.38	
S.Em.±	0.05	0.24	0.04	0.77	0.02	1.15	0.03	0.90	0.02	1.01	1.72	
CD @ 5 %	NS	NS	0.11	2.33	0.07	3.50	0.09	2.74	0.05	3.07	5.22	
Factor 2: Levels of fertilizers (L)												
L₁:60 % RDF	2.01	5.67	1.29	16.98	0.95	34.83	1.23	33.23	0.55	21.51	54.74	
L₂: 80 % RDF	2.03	5.97	1.39	19.42	1.02	39.06	1.30	37.05	0.59	24.58	61.63	
S.Em.±	0.03	0.17	0.03	0.54	0.02	0.81	0.02	0.64	0.01	0.71	1.22	
CD @ 5 %	NS	NS	0.08	1.65	0.05	2.47	0.06	1.94	0.04	2.17	3.69	
Interaction (B× L)												
S.Em.±	0.07	0.35	0.05	1.08	0.03	1.63	0.04	1.28	0.03	1.43	2.43	
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
Treatments												
T₁-Control	1.70	2.40	1.09	7.87	0.72	10.49	1.08	12.16	0.42	6.47	18.63	
T₂-100 % RDF	1.98	5.22	1.18	14.66	0.87	29.71	1.13	28.61	0.47	17.55	46.16	
T₃-B₁L₁	2.01	5.57	1.32	16.92	0.98	35.10	1.26	32.82	0.56	21.42	54.24	
T₄-B₁L₂	2.03	5.87	1.40	19.76	1.04	39.45	1.31	36.58	0.63	25.43	62.01	
T₅-B₂L₁	1.99	5.40	1.20	14.99	0.87	30.24	1.15	29.90	0.48	17.95	47.85	
T₆-B₂L₂	2.02	5.75	1.32	17.37	0.94	34.81	1.24	34.87	0.52	21.08	55.95	
T₇-B₃L₁	2.00	5.62	1.22	15.72	0.90	32.38	1.19	31.19	0.51	19.47	50.66	
T₈-B₃L₂	2.02	5.91	1.36	18.86	0.96	36.60	1.25	35.47	0.54	22.52	58.00	
T₉-B₄L₁	2.04	6.08	1.43	20.30	1.06	41.60	1.34	38.99	0.65	27.19	66.19	
T₁₀-B₄L₂	2.06	6.33	1.48	21.68	1.13	45.39	1.38	41.27	0.69	29.31	70.58	
S.Em.±	0.07	0.32	0.05	1.33	0.03	1.90	0.04	1.16	0.02	1.37	2.28	
CD @ 5 %	NS	0.96	0.14	3.95	0.10	5.65	0.13	3.45	0.07	4.07	6.79	

*100 per cent was added with 7.5 t ha⁻¹ of FYM, remaining treatments received 7.5 t ha⁻¹ of bio-enriched FYM.

NFB: Nitrogen fixing biofertilizers PSB: Phosphate solubilizing biofertilizers KSB: Potassium solubilizing biofertilizers PGPR: Plant growth promoting rhizobacteria MC: Microbial consortia

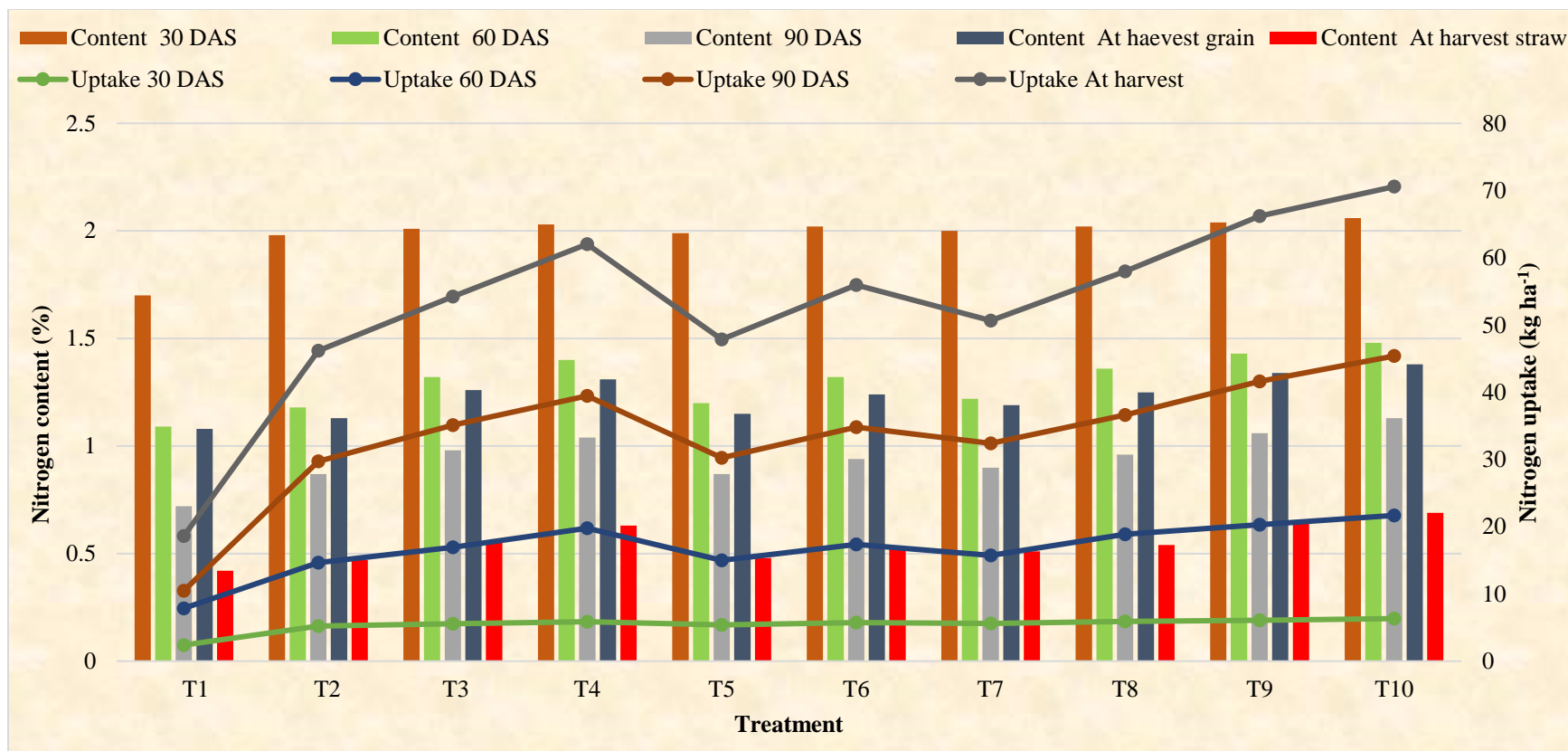


Fig. 4.4: Bio- enriched FYM and different levels of fertilizers on nitrogen content (%) and uptake (kg ha^{-1}) of finger millet at different growth stages.

Treatment details:

T₁: Absolute control

T₂: 7.5 t ha⁻¹ FYM + 100 % RDF

T₃: 7.5 t ha⁻¹ enriched FYM (NFB + PGPR) + 60 % RDF

T₄: 7.5 t ha⁻¹ enriched FYM (NFB + PGPR) + 80 % RDF

T₅: 7.5 t ha⁻¹ enriched FYM (PSB + PGPR) + 60 % RDF

T₆: 7.5 t ha⁻¹ enriched FYM (PSB + PGPR) + 80 % RDF

T₇: 7.5 t ha⁻¹ enriched FYM (KSB + PGPR) + 60 % RDF

T₈: 7.5 t ha⁻¹ enriched FYM (KSB + PGPR) + 80 % RDF

T₉: 7.5 t ha⁻¹ enriched FYM (MC) + 60 % RDF

T₁₀: 7.5 t ha⁻¹ enriched FYM (MC) + 80 % RDF

Higher nitrogen concentration and uptake observed with application of FYM enriched with microbial consortia followed by NFB + PGPR, may be due to conversion of elemental nitrogen in atmosphere into plant usable form by NFB and its association with plant root exudation which would have increased nutrient uptake by plant. This might be attributed also due to higher amount of nitrogen content present in bio enriched FYM which might have hastened the process of mineralization during crop growth period. Presence of PGPR along with nitrogen fixers regulates hormonal and nutritional balance, inducing resistance against plant pathogens, and solubilizing nutrients for easy uptake by plants (Vejan *et al.*, 2016). Shruthi *et al.* (2018) recorded increased uptake and concentration of N, P and K in grain and straw of finger millet due to the application of fertilizers and FYM along with the dual inoculation of biofertilizers (consortia). This can be correlated with higher microbial biomass and enzymatic activity which signifies release of nutrients (Yuvaraj, 2016).

4.5.1.2 Phosphorus content and uptake at different growth stages of finger millet

The data pertaining to phosphorus concentration and uptake as influenced by different biofertilizers and levels of fertilizers are presented in Table 4.8 and Fig. 4.5.

At 30 DAS, concentration and uptake of phosphorus in finger millet showed non-significant effect with application of different biofertilizer enriched FYM, levels of fertilizers and also interaction among them (B×L). Numerically higher content (0.26 %) and uptake (0.82 kg ha⁻¹) was recorded with application of microbial consortia (B₄). Among levels of fertilizers application of 80 per cent RDF (L₂) resulted in higher content (0.24 %) and uptake (0.72 kg ha⁻¹). Among the treatments significantly higher uptake (0.87 kg ha⁻¹) was observed in T₁₀ (B₄L₂: MC + 80 % RDF) compared to control (0.23 kg ha⁻¹) and 100 per cent RDF (0.50 kg ha⁻¹).

Whereas, at 60 DAS and 90 DAS higher concentration (0.26 and 0.24 kg ha⁻¹, respectively) and uptake (3.76 and 9.42 kg ha⁻¹, respectively) was recorded in B₄ (MC). Similarly, higher content (0.24 and 0.22 %, respectively) and uptake (3.29 and 8.29 kg ha⁻¹) was recorded with application of 80 per cent RDF (L₂) compared to 60 per cent RDF (L₁). The interaction effect (B×L) with respect to phosphorus content and uptake at

Table 4.8: Phosphorus concentration and uptake by finger millet at different growth stages as influenced by different bio-enriched FYM and levels of fertilizers.

	30 DAS		60 DAS		90 DAS		AT HARVEST				
	Content (%)	Uptake (kg ha ⁻¹)	Content (%)	Uptake (kg ha ⁻¹)	Content (%)	Uptake (kg ha ⁻¹)	GRAIN		STRAW		Total uptake (kg ha ⁻¹)
							Content (%)	Uptake (kg ha ⁻¹)	Content (%)	Uptake (kg ha ⁻¹)	
Factor 1: Biofertilizers enrichment (B)											
B₁: NFB + PGPR	0.21	0.60	0.19	2.53	0.18	6.44	0.30	8.13	0.16	6.44	14.56
B₂: PSB + PGPR	0.24	0.67	0.23	3.00	0.21	7.63	0.33	8.99	0.20	7.77	16.76
B₃: KSB + PGPR	0.22	0.64	0.22	2.92	0.20	7.47	0.32	8.65	0.18	7.02	15.66
B₄: MC	0.26	0.82	0.26	3.76	0.24	9.42	0.37	10.81	0.23	9.70	20.51
S.Em.±	0.02	0.06	0.01	0.13	0.009	0.36	0.01	0.29	0.005	0.27	0.48
CD @ 5 %	NS	NS	0.03	0.39	0.03	1.09	0.03	0.88	0.02	0.82	1.47
Factor 2: Levels of fertilizers (L)											
L₁:60 % RDF	0.23	0.65	0.21	2.82	0.20	7.19	0.32	8.57	0.18	7.15	15.72
L₂: 80 % RDF	0.24	0.72	0.24	3.29	0.22	8.29	0.34	9.72	0.20	8.31	18.03
S.Em.±	0.01	0.04	0.006	0.09	0.006	0.25	0.006	0.20	0.004	0.19	0.34
CD @ 5 %	NS	NS	0.02	0.28	0.02	0.77	0.02	0.62	0.01	0.58	1.04
Interaction (B× L)											
S.Em.±	0.02	0.08	0.01	0.18	0.01	0.51	0.01	0.41	0.01	0.38	0.68
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Treatments											
T₁-Control	0.16	0.23	0.14	1.14	0.11	1.59	0.24	2.66	0.10	1.58	4.25
T₂-100 % RDF	0.19	0.50	0.17	2.07	0.15	5.17	0.27	6.83	0.14	5.14	11.97
T₃-B₁L₁	0.20	0.56	0.18	2.29	0.17	5.95	0.29	7.55	0.15	5.86	13.41
T₄-B₁L₂	0.22	0.64	0.20	2.77	0.18	6.93	0.31	8.70	0.17	7.02	15.72
T₅-B₂L₁	0.24	0.64	0.22	2.72	0.20	6.87	0.32	8.35	0.19	6.93	15.29
T₆-B₂L₂	0.25	0.71	0.25	3.27	0.23	8.38	0.34	9.63	0.21	8.61	18.24
T₇-B₃L₁	0.22	0.61	0.21	2.68	0.19	6.96	0.31	8.09	0.17	6.48	14.57
T₈-B₃L₂	0.23	0.67	0.23	3.15	0.21	7.99	0.32	9.20	0.18	7.55	16.75
T₉-B₄L₁	0.26	0.78	0.25	3.57	0.23	8.99	0.35	10.29	0.22	9.33	19.62
T₁₀-B₄L₂	0.27	0.87	0.27	3.95	0.25	9.85	0.38	11.33	0.24	10.07	21.40
S.Em.±	0.03	0.08	0.02	0.26	0.01	0.55	0.02	0.44	0.01	0.49	0.75
CD @ 5 %	NS	0.22	0.04	0.76	0.04	1.63	0.07	1.30	0.03	1.46	2.24

*100 per cent was added with 7.5 t ha⁻¹ of FYM, remaining treatments received 7.5 t ha⁻¹ of bio-enriched FYM.

NFB: Nitrogen fixing biofertilizers PSB: Phosphate solubilizing biofertilizers KSB: Potassium solubilizing biofertilizers PGPR: Plant growth promoting rhizobacteria MC: Microbial consortia

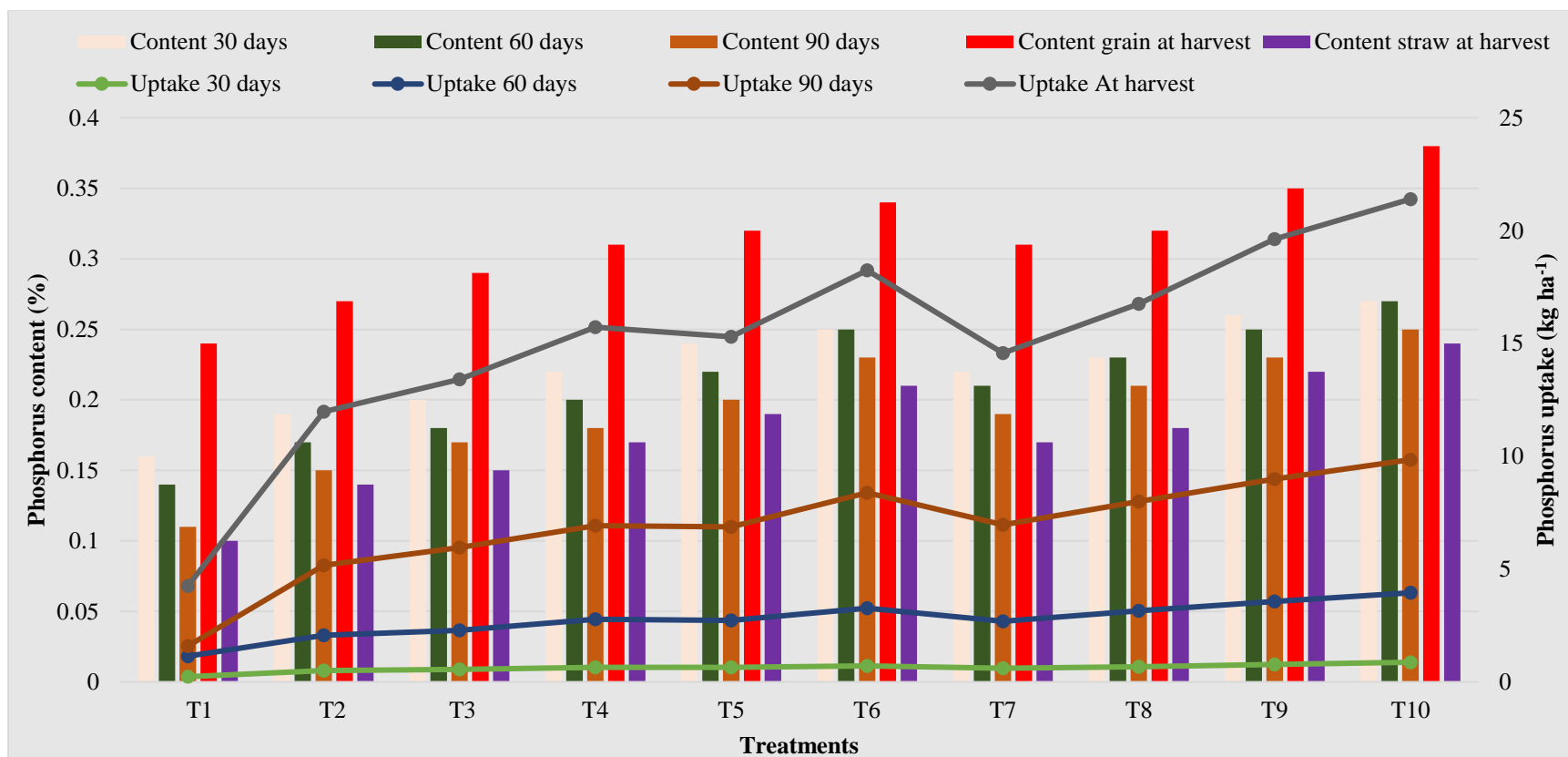


Fig. 4.5: Bio- enriched FYM and different levels of fertilizers on phosphorus content (%) and uptake (kg ha⁻¹) of finger millet at different growth stages.

Treatment details:

T₁: Absolute control

T₂: 7.5 t ha⁻¹ FYM + 100 % RDF

T₃: 7.5 t ha⁻¹ enriched FYM (NFB + PGPR) + 60 % RDF

T₄: 7.5 t ha⁻¹ enriched FYM (NFB + PGPR) + 80 % RDF

T₅: 7.5 t ha⁻¹ enriched FYM (PSB + PGPR) + 60 % RDF

T₆: 7.5 t ha⁻¹ enriched FYM (PSB + PGPR) + 80 % RDF

T₇: 7.5 t ha⁻¹ enriched FYM (KSB + PGPR) + 60 % RDF

T₈: 7.5 t ha⁻¹ enriched FYM (KSB + PGPR) + 80 % RDF

T₉: 7.5 t ha⁻¹ enriched FYM (MC) + 60 % RDF

T₁₀: 7.5 t ha⁻¹ enriched FYM (MC) + 80 % RDF

different growth stages of finger millet was non-significant. Among treatments significantly higher concentration (0.27 and 0.25 %) and uptake (3.95 and 9.85 kg ha⁻¹) at 60 and 90 DAS, respectively was recorded with application of MC + 80 per cent RDF (T₁₀) followed by MC+ 60 per cent RDF (T₉) over control.

Significantly higher concentration (0.37 and 0.23 %) and uptake (10.81 and 9.70 kg ha⁻¹) in finger millet grain and straw, respectively was recorded with application of MC (B₄). With respect to levels of fertilizers, application of 80 per cent RDF resulted in higher concentration (0.34 and 0.20 %) and uptake (9.72 and 8.31 kg ha⁻¹) in grain and straw, respectively. Among treatments, significantly higher concentration and uptake in grain (0.38 % and 11.33 kg ha⁻¹, respectively) and straw (0.24 % and 10.07 kg ha⁻¹, respectively) was observed in T₁₀ (B₄L₂: MC+ 80 % RDF) over control and 100 per cent RDF. Similar was the trend with uptake of phosphorus at harvest.

The higher available phosphorus content might be due to the release of organic acids during microbial decomposition of organic matter which helped in the solubility of native phosphates thus increasing available phosphorus. Increased availability of phosphorus increased root proliferation which resulted in better utilization of macro and micro nutrients in soil which was due to presence of PGPR along with PSB. Gangaraddi *et al.* (2020) reported in finger millet that application of triple inoculants (*Azotobacter chroococcum* + *Bacillus megaterium* + *Pseudomonas fluorescens*) increased uptake of nitrogen and phosphorus per plant followed by double inoculated treatments with *A. chroococcum* + *B. megaterium*, *B. megaterium* + *P. fluorescens*, *A. chroococcum* + *P. fluorescens*, respectively. Similar was the results with application of microbial consortia (Pallavi *et al.*, 2016).

4.5.1.3 Potassium concentration and uptake at different growth stages of finger millet

The data pertaining to the effect of different biofertilizer enriched FYM and levels of fertilizer application on potassium content and uptake at different growth stages are presented in Table 4.9 and Fig. 4.6.

The concentration and uptake of potassium in finger millet at 30 DAS showed non-significant results with application of different biofertilizers, levels of fertilizer and their interaction. Numerically higher content (1.37 %) and uptake (4.19 kg ha^{-1}) was recorded in B₄ (microbial consortia). Similarly, application of higher levels of fertilizers (L₂: 80 % RDF) resulted in higher content (1.35 %) and uptake (3.99 kg ha^{-1}). Among different treatments, significantly higher uptake (4.28 kg ha^{-1}) was obtained in B₄L₂ (MC+ 80 % RDF), followed by B₄L₁ (4.09 kg ha^{-1}) compared to control (1.66 kg ha^{-1}).

Significantly higher concentration and uptake at 60 DAS (1.24 % and 17.88 kg ha^{-1} , respectively) and 90 DAS (1.03 % and 40.79 kg ha^{-1} , respectively) was observed with application of MC (B₄). Similar was the trend with application of 80 per cent RDF compared to 60 per cent RDF. The interaction effect with respect to potassium content and uptake at different growth stages of finger millet was non-significant. Among treatments, significantly higher concentration of potassium (1.27 and 1.05 %) and uptake (18.58 and 41.98 kg ha^{-1}) at 60 and 90 DAS, respectively was recorded with application of MC along with 80 per cent RDF (B₄L₂: MC+ 80 % RDF) followed by B₄L₁ (MC + 60 % RDF) over control.

The concentration and uptake of potassium in finger millet grain and straw also followed the same trend with higher concentration and uptake in grain (0.58 % and 17.15 kg ha^{-1} , respectively) and straw (0.97 % and 41.17 kg ha^{-1} , respectively) with application of B₄ (MC). With respect to levels of fertilizers, application of 80 per cent RDF resulted in higher concentration (0.56 and 0.94 %) and uptake (15.95 and 38.88 kg ha^{-1}) in grain and straw respectively. Among treatments significantly higher concentration and uptake of potassium in straw (0.99 % and 42.14 kg ha^{-1} , respectively) and grain (0.59 % and 17.70 kg ha^{-1} , respectively) was observed in T₁₀ (B₄L₂: MC+ 80 % RDF), followed by T₉ (B₄L₁: MC + 60 % RDF) over absolute control.

Application of different biofertilizers and levels of RDF significantly increased concentration and uptake of nutrients at harvest. Higher nutrient concentration and higher uptake might be due to the application of nutrients through bio-enriched FYM and inorganic sources which might have increased nutrients in the available pool through

Table 4.9: Potassium concentration and uptake by finger millet at different growth stages as influenced by different bio-enriched FYM and levels of fertilizers.

	30 DAS		60 DAS		90 DAS		AT HARVEST				
	Content (%)	Uptake (kg ha ⁻¹)	Content (%)	Uptake (kg ha ⁻¹)	Content (%)	Uptake (kg ha ⁻¹)	GRAIN		STRAW		Total uptake (kg ha ⁻¹)
							Content (%)	Uptake (kg ha ⁻¹)	Content (%)	Uptake (kg ha ⁻¹)	
Factor 1: Biofertilizers enrichment (B)											
B₁: NFB + PGPR	1.30	3.71	1.08	14.63	0.89	32.74	0.51	13.78	0.86	34.14	47.92
B₂: PSB + PGPR	1.32	3.67	1.12	14.40	0.92	32.74	0.53	14.46	0.89	34.71	49.17
B₃: KSB + PGPR	1.35	3.88	1.19	15.79	0.97	36.10	0.55	15.02	0.92	36.84	51.87
B₄: MC	1.37	4.19	1.24	17.88	1.03	40.79	0.58	17.15	0.97	41.17	58.32
S.Em.±	0.02	0.18	0.03	0.48	0.02	1.21	0.01	0.52	0.02	1.05	1.34
CD @ 5 %	NS	NS	0.09	1.46	0.07	3.66	0.04	1.57	0.06	3.18	4.07
Factor 2: Levels of fertilizers (L)											
L₁:60 % RDF	1.32	3.74	1.13	14.77	0.92	33.70	0.53	14.26	0.88	34.55	48.81
L₂: 80 % RDF	1.35	3.99	1.19	16.58	0.98	37.49	0.56	15.95	0.94	38.88	54.82
S.Em.±	0.02	0.13	0.02	0.34	0.02	0.85	0.01	0.37	0.01	0.74	0.95
CD @ 5 %	NS	NS	0.06	1.03	0.05	2.59	0.03	1.11	0.04	2.25	2.88
Interaction (B× L)											
S.Em.±	0.03	0.26	0.04	0.68	0.03	1.71	0.02	0.73	0.03	1.48	1.90
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Treatments											
T₁-Control	1.19	1.66	0.98	7.11	0.77	11.38	0.43	4.84	0.75	11.43	16.28
T₂-100 % RDF	1.32	3.51	1.02	12.67	0.84	28.86	0.47	11.82	0.80	29.71	41.52
T₃-B₁L₁	1.28	3.56	1.04	13.44	0.85	30.39	0.49	12.74	0.82	31.57	44.31
T₄-B₁L₂	1.32	3.85	1.12	15.82	0.93	35.10	0.53	14.83	0.90	36.71	51.54
T₅-B₂L₁	1.30	3.52	1.09	13.61	0.89	30.60	0.52	13.58	0.86	31.97	45.54
T₆-B₂L₂	1.33	3.82	1.15	15.19	0.94	34.88	0.55	15.35	0.93	37.45	52.80
T₇-B₃L₁	1.34	3.77	1.16	14.83	0.94	34.19	0.54	14.13	0.90	34.48	48.61
T₈-B₃L₂	1.36	3.99	1.21	16.74	1.00	38.01	0.56	15.92	0.95	39.20	55.12
T₉-B₄L₁	1.37	4.09	1.21	17.19	1.01	39.60	0.57	16.60	0.96	40.20	56.80
T₁₀-B₄L₂	1.38	4.28	1.27	18.58	1.05	41.98	0.59	17.70	0.99	42.14	59.84
S.Em.±	0.04	0.24	0.04	0.98	0.04	2.18	0.02	0.75	0.03	1.46	1.86
CD @ 5 %	NS	0.71	0.12	2.92	0.12	6.46	0.07	2.22	0.08	4.35	5.51

*100 per cent was added with 7.5 t ha⁻¹ of FYM, remaining treatments received 7.5 t ha⁻¹ of bio-enriched FYM.

NFB: Nitrogen fixing biofertilizers PSB: Phosphate solubilizing biofertilizers KSB: Potassium solubilizing biofertilizers PGPR: Plant growth promoting rhizobacteria MC: Microbial consortia

solubilization and mineralization. Application of biofertilizers enhances the soil nutrients by quick release of nutrients through production of organic acids leading to enhanced translocation, absorption and utilization of all other plant nutrients, thus resulting in more nutrient content (Singh *et al.*, 2018). Similar result was cited by Balogh-Brunstad *et al.* (2008) that certain microbial strains form a biofilm on the rhizospheric mineral surfaces and release organic acids, metabolites and drops the pH that help in K mineral solubilization and uptake by plants. Archana *et al.* (2013) reported that KSB (*Bacillus* species) inoculation increased plant growth, nutrient uptake (K) and yield component of maize plants significantly over control plants. Increase in growth vigour, biomass yield and K uptake to different degrees in available K deficient soil in ryegrass upon inoculation with KSB strains was noticed by Xiao *et al.* (2017).

4.5.1.4 Correlation of nitrogen, Phosphorus and potassium content with uptake at different growth stages of finger millet.

Correlation between nutrient content and uptake at different stages of crop growth of finger millet as influenced by different biofertilizers enriched FYM and levels of RDF are presented in Table 4.10. Correlation studies indicated that nitrogen ($r= 0.77^{**}$, 0.89^{**} and 0.93^{**}), phosphorus ($r= 0.91^{**}$, 0.97^{**} and 0.95^{**}) and potassium ($r= 0.79^{**}$, 0.82^{**} and 0.89^{**}) content were significantly and positively correlated with uptake at 30, 60 and 90 DAS, respectively of finger millet. Similarly, grain and straw nitrogen (0.76^{**} and 0.92^{**} , respectively), phosphorus (0.74^{**} and 0.96^{**} , respectively) and potassium (0.81^{**} and 0.83^{**} , respectively) content were significantly and positively correlated. This clearly shows that there was significant increase in content of nutrient *viz.*, NPK during different growth stages of finger millet which due to application of different biofertilizers along with inorganic fertilizers which helped in easier mineralization and increase in concentration of nutrients which positively correlated with increased nutrient uptake by finger millet.

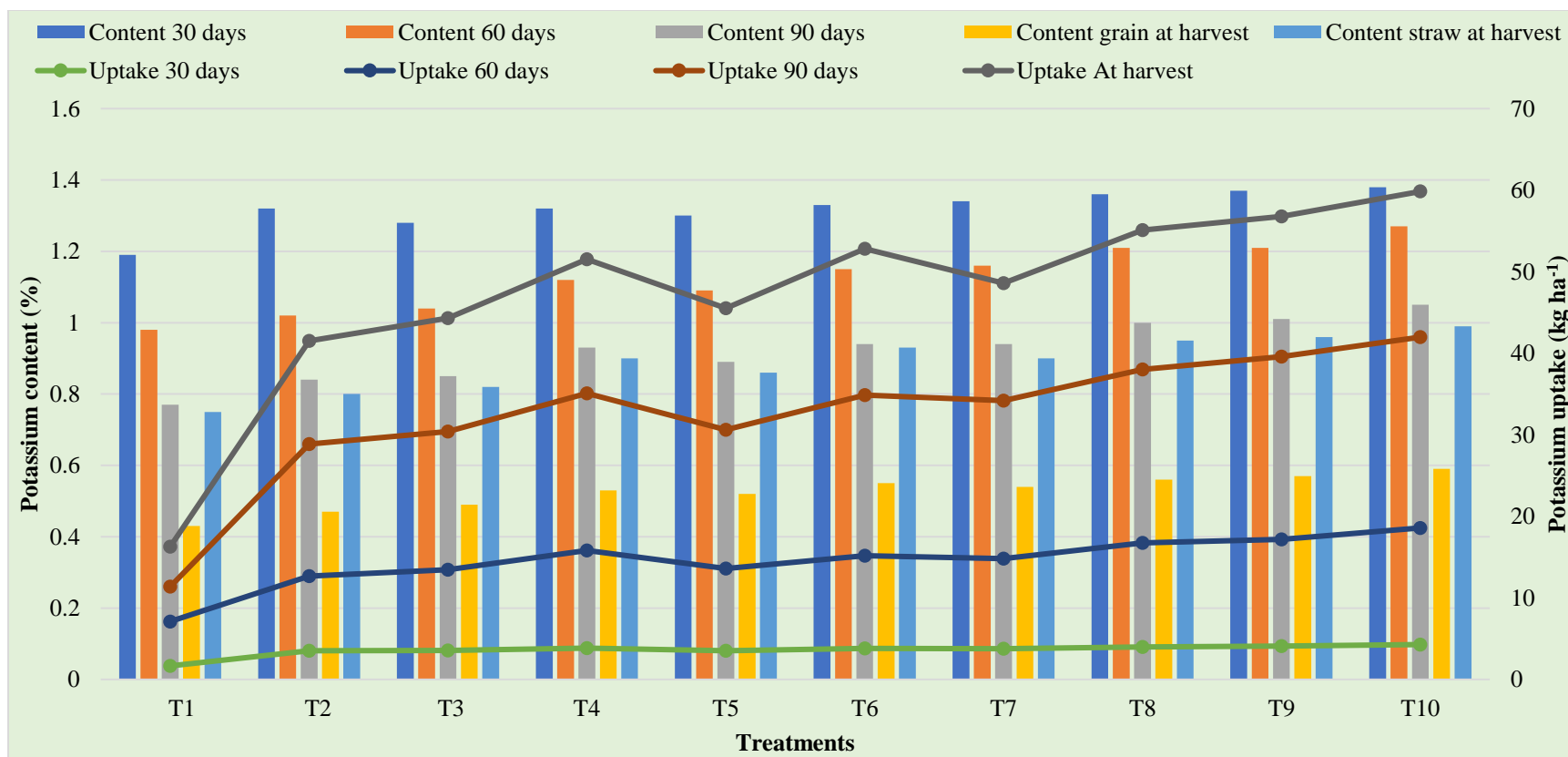


Fig. 4.6: Bio- enriched FYM and different levels of fertilizers on potassium content (%) and uptake (kg ha⁻¹) of finger millet at different growth stages.

Treatment details:

T₁: Absolute control

T₂: 7.5 t ha⁻¹ FYM + 100 % RDF

T₃: 7.5 t ha⁻¹ enriched FYM (NFB + PGPR) + 60 % RDF

T₄: 7.5 t ha⁻¹ enriched FYM (NFB + PGPR) + 80 % RDF

T₅: 7.5 t ha⁻¹ enriched FYM (PSB + PGPR) + 60 % RDF

T₆: 7.5 t ha⁻¹ enriched FYM (PSB + PGPR) + 80 % RDF

T₇: 7.5 t ha⁻¹ enriched FYM (KSB + PGPR) + 60 % RDF

T₈: 7.5 t ha⁻¹ enriched FYM (KSB + PGPR) + 80 % RDF

T₉: 7.5 t ha⁻¹ enriched FYM (MC) + 60 % RDF

T₁₀: 7.5 t ha⁻¹ enriched FYM (MC) + 80 % RDF

Table 4.10: Correlation matrix of nitrogen, phosphorus and potassium content and uptake at different stages of finger millet as influenced by different bio-enriched FYM and levels of fertilizers.

Correlation					
Content/ Uptake	30 DAS	60 DAS	90 DAS	At harvest	
				Grain	Straw
Nitrogen	0.77**	0.89**	0.93**	0.76**	0.92**
Phosphorus	0.91**	0.97**	0.95**	0.74**	0.96**
Potassium	0.79**	0.82**	0.89**	0.81**	0.83**

Note: ** Correlation is significant at $p = 1$ per cent.

4.5.2 Secondary nutrients

4.5.2.1 Calcium content and uptake at different growth stages of finger millet

Data presented in Table 4.11 reveals nutrient concentration and uptake of calcium in finger millet at different growth stages.

The uptake (23.61 kg ha^{-1}) of calcium in finger millet at harvest and uptake of calcium (5.76 kg ha^{-1}) was found significantly higher in microbial consortia B₄ (MC). Similar was the trend with levels of fertilizers. Significantly higher uptake (21.24 kg ha^{-1}) was observed with application of 80 per cent RDF compared to 60 per cent RDF (17.91 kg ha^{-1}) at harvest. However, significantly higher uptake (5.29 kg ha^{-1}) was at 60 DAS with application of 80 per cent RDF (L₂) compared to (4.56 kg ha^{-1}) with 60 per cent RDF (L₁).

Interaction of different biofertilizers and levels of fertilizers recorded no significant effect on content and uptake of calcium at different growth stages of finger millet. Between treatments, significantly higher content was observed at 30 DAS with higher concentration (0.43 %) in B₄L₂ (MC+ 80 % RDF) compared to control. Application of MC+ 80 per cent RDF (B₄L₂) recorded significantly higher uptake at 30 DAS (1.31 kg ha^{-1}), 60 DAS (6.08 kg ha^{-1}), 90 DAS (14.07 kg ha^{-1}) and at harvest (24.96 kg ha^{-1}) with higher grain and straw uptake of 12.96 kg ha^{-1} and 12.00 kg ha^{-1} , respectively over control and 100 per cent RDF.

Table 4.11: Calcium concentration and uptake by finger millet at different growth stages as influenced by different bio-enriched FYM and levels of fertilizers.

	30 DAS		60 DAS		90 DAS		AT HARVEST				Total uptake (kg ha ⁻¹)	
	Content (%)	Uptake (kg ha ⁻¹)	Content (%)	Uptake (kg ha ⁻¹)	Content (%)	Uptake (kg ha ⁻¹)	GRAIN		STRAW			
							Content (%)	Uptake (kg ha ⁻¹)	Content (%)	Uptake (kg ha ⁻¹)		
Factor 1: Biofertilizers enrichment (B)												
B₁: NFB + PGPR	0.38	1.08	0.35	4.75	0.30	11.00	0.38	10.18	0.22	8.75	18.93	
B₂: PSB + PGPR	0.37	1.02	0.35	4.48	0.27	9.72	0.37	9.96	0.19	7.33	17.30	
B₃: KSB + PGPR	0.37	1.06	0.36	4.72	0.29	10.78	0.38	10.39	0.20	8.08	18.47	
B₄: MC	0.42	1.28	0.40	5.76	0.34	13.53	0.42	12.31	0.27	11.29	23.61	
S.Em.±	0.03	0.09	0.02	0.28	0.03	0.97	0.01	0.52	0.02	0.97	1.17	
CD @ 5 %	NS	NS	NS	0.84	NS	NS	NS	1.58	NS	NS	3.54	
Factor 2: Levels of fertilizers (L)												
L₁:60 % RDF	0.37	1.05	0.35	4.56	0.29	10.56	0.37	9.97	0.20	7.95	17.91	
L₂: 80 % RDF	0.40	1.17	0.38	5.29	0.31	11.95	0.40	11.45	0.24	9.72	21.24	
S.Em.±	0.02	0.07	0.01	0.20	0.02	0.69	0.01	0.37	0.02	0.69	0.82	
CD @ 5 %	NS	NS	NS	0.60	NS	NS	NS	1.11	NS	NS	2.50	
Interaction (B× L)												
S.Em.±	0.04	0.13	0.02	0.39	0.04	1.37	0.02	0.73	0.03	1.38	1.65	
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
Treatments												
T₁-Control	0.26	0.37	0.24	1.88	0.18	5.09	0.32	3.58	0.13	1.99	5.57	
T₂-100 % RDF	0.34	0.90	0.30	3.74	0.24	8.45	0.34	8.67	0.17	6.44	15.11	
T₃-B₁L₁	0.37	1.01	0.34	4.33	0.29	10.31	0.36	9.42	0.20	7.71	17.13	
T₄-B₁L₂	0.40	1.14	0.37	5.17	0.31	11.70	0.39	10.93	0.24	9.79	20.72	
T₅-B₂L₁	0.34	0.93	0.33	4.16	0.26	9.06	0.35	9.17	0.17	6.44	15.61	
T₆-B₂L₂	0.39	1.12	0.36	4.80	0.28	10.39	0.38	10.75	0.20	8.23	18.98	
T₇-B₃L₁	0.36	1.00	0.34	4.34	0.27	9.89	0.37	9.64	0.18	7.01	16.65	
T₈-B₃L₂	0.38	1.12	0.37	5.11	0.31	11.66	0.39	11.15	0.22	9.14	20.29	
T₉-B₄L₁	0.41	1.24	0.38	5.43	0.33	12.99	0.40	11.67	0.25	10.59	22.25	
T₁₀-B₄L₂	0.43	1.31	0.41	6.08	0.35	14.07	0.43	12.96	0.28	12.00	24.96	
S.Em.±	0.04	0.12	0.02	0.45	0.04	1.46	0.02	0.72	0.03	1.35	1.68	
CD @ 5 %	NS	0.36	0.07	1.34	NS	4.34	NS	2.13	NS	4.00	4.99	

*100 per cent was added with 7.5 t ha⁻¹ of FYM, remaining treatments received 7.5 t ha⁻¹ of bio-enriched FYM.

NFB: Nitrogen fixing biofertilizers PSB: Phosphate solubilizing biofertilizers KSB: Potassium solubilizing biofertilizers PGPR: Plant growth promoting rhizobacteria MC: Microbial consortia

4.5.2.2 Magnesium content and uptake at different growth stages of finger millet

Result of different biofertilizers and levels of fertilizers application on magnesium concentration and uptake at different growth stages of finger millet are presented in Table 4.12.

Application of different biofertilizers enriched FYM recorded non-significant effect on content at 30, 60, 90 DAS and at harvest. Whereas, total uptake was found significant at harvest with higher uptake of 15.95 kg ha⁻¹ in B₄ (MC) followed by 12.88 kg ha⁻¹ (B₁: NFB+ PGPR).

With respect to levels of fertilizers, no significant effect on content was recorded at 30, 60, 90 DAS and at harvest. While, significantly higher uptake (14.55 kg ha⁻¹) was observed at harvest with application of 80 per cent RDF compared to 60 per cent RDF (12.08 kg ha⁻¹).

Interaction effect with respect to magnesium content and uptake at different growth stages of finger millet was non-significant. Among treatments, total concentration and uptake at harvest followed same trend with higher concentration and uptake (0.47 % and 17.13 kg ha⁻¹, respectively) with application of MC+ 80 per cent RDF (T₁₀) compared to control (0.24 % and 3.03 kg ha⁻¹, respectively). Similar was the trend with respect to uptake at 60 and 90 DAS. However, uptake in grain (6.94 kg ha⁻¹) and straw (10.19 kg ha⁻¹) was significantly higher in same treatment (MC+ 80 % RDF) compared to control (1.47 and 1.56 kg ha⁻¹, respectively).

4.5.2.3 Sulphur content and uptake at different growth stages of finger millet

The data pertaining to sulphur concentration and uptake by finger millet at different growth stages are presented in Table 4.13.

The sulphur content at different growth stages viz., 30, 60, 90 DAS and at harvest did not differ significantly with respect to different bio-enriched FYM and levels of fertilizers. Similar was the trend with interaction. Numerically higher sulphur content 0.46 per cent was observed with application of microbial consortia (B₄) and 0.44 per cent with

Table 4.12: Magnesium concentration and uptake by finger millet at different growth stages as influenced by different bio-enriched FYM and levels of fertilizers.

	30 DAS		60 DAS		90 DAS		AT HARVEST				
	Content (%)	Uptake (kg ha ⁻¹)	Content (%)	Uptake (kg ha ⁻¹)	Content (%)	Uptake (kg ha ⁻¹)	GRAIN		STRAW		Total uptake (kg ha ⁻¹)
							Content (%)	Uptake (kg ha ⁻¹)	Content (%)	Uptake (kg ha ⁻¹)	
Factor 1: Biofertilizers enrichment (B)											
B₁: NFB + PGPR	0.27	0.76	0.25	3.42	0.22	8.11	0.20	5.32	0.19	7.56	12.88
B₂: PSB + PGPR	0.26	0.73	0.24	3.08	0.21	7.48	0.19	5.12	0.18	6.91	12.03
B₃: KSB + PGPR	0.27	0.77	0.24	3.15	0.22	8.09	0.19	5.28	0.18	7.12	12.40
B₄: MC	0.29	0.88	0.28	4.07	0.26	10.35	0.22	6.43	0.22	9.52	15.95
S.Em.±	0.02	0.07	0.02	0.29	0.02	0.81	0.01	0.36	0.02	0.92	0.88
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	2.67
Factor 2: Levels of fertilizers (L)											
L₁:60 % RDF	0.26	0.74	0.24	3.13	0.21	7.69	0.19	5.16	0.18	6.91	12.08
L₂: 80 % RDF	0.28	0.83	0.27	3.72	0.24	9.33	0.21	5.90	0.21	8.64	14.55
S.Em.±	0.02	0.05	0.01	0.20	0.02	0.57	0.007	0.26	0.01	0.65	0.62
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	1.88
Interaction (B× L)											
S.Em.±	0.03	0.10	0.03	0.41	0.03	1.14	0.01	0.51	0.03	1.30	1.24
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Treatments											
T₁-Control	0.16	0.22	0.14	1.08	0.13	3.62	0.13	1.47	0.11	1.56	3.03
T₂-100 % RDF	0.23	0.60	0.19	2.31	0.17	5.71	0.16	4.17	0.14	5.06	9.23
T₃-B₁L₁	0.26	0.72	0.24	3.09	0.20	7.18	0.19	4.95	0.17	6.51	11.45
T₄-B₁L₂	0.28	0.81	0.27	3.74	0.24	9.04	0.20	5.69	0.21	8.62	14.31
T₅-B₂L₁	0.25	0.68	0.23	2.82	0.19	6.53	0.18	4.82	0.16	5.88	10.70
T₆-B₂L₂	0.27	0.78	0.25	3.34	0.23	8.44	0.19	5.41	0.20	7.95	13.36
T₇-B₃L₁	0.26	0.70	0.22	2.84	0.20	7.25	0.19	4.99	0.17	6.42	11.40
T₈-B₃L₂	0.28	0.83	0.25	3.45	0.23	8.92	0.20	5.57	0.19	7.82	13.39
T₉-B₄L₁	0.28	0.85	0.27	3.78	0.25	9.79	0.20	5.91	0.21	8.85	14.76
T₁₀-B₄L₂	0.30	0.91	0.30	4.35	0.27	10.91	0.23	6.94	0.24	10.19	17.13
S.Em.±	0.04	0.10	0.02	0.39	0.03	1.08	0.02	0.58	0.03	1.15	1.12
CD @ 5 %	NS	0.28	0.07	1.15	NS	3.20	NS	1.73	NS	3.43	3.33

*100 per cent was added with 7.5 t ha⁻¹ of FYM, remaining treatments received 7.5 t ha⁻¹ of bio-enriched FYM.

NFB: Nitrogen fixing biofertilizers PSB: Phosphate solubilizing biofertilizers KSB: Potassium solubilizing biofertilizers PGPR: Plant growth promoting rhizobacteria MC: Microbial consortia

Table 4.13: Sulphur concentration and uptake by finger millet at different growth stages as influenced by different bio-enriched FYM and levels of fertilizers.

	30 DAS		60 DAS		90 DAS		AT HARVEST					
	Content (%)	Uptake (kg ha ⁻¹)	Content (%)	Uptake (kg ha ⁻¹)	Content (%)	Uptake (kg ha ⁻¹)	GRAIN		STRAW		Total uptake (kg ha ⁻¹)	
							Content (%)	Uptake (kg ha ⁻¹)	Content (%)	Uptake (kg ha ⁻¹)		
Factor 1: Biofertilizers enrichment (B)												
B₁: NFB + PGPR	0.43	1.21	0.40	5.40	0.36	13.14	0.16	4.34	0.35	13.58	17.92	
B₂: PSB + PGPR	0.42	1.16	0.37	4.70	0.34	12.20	0.15	4.09	0.33	12.82	16.91	
B₃: KSB + PGPR	0.42	1.20	0.39	5.21	0.35	13.09	0.15	4.17	0.34	13.44	17.61	
B₄: MC	0.46	1.40	0.43	6.18	0.38	15.24	0.18	5.23	0.38	16.14	21.37	
S.Em.±	0.01	0.07	0.02	0.24	0.01	0.45	0.01	0.25	0.02	0.88	0.91	
CD @ 5 %	NS	NS	NS	0.73	NS	1.36	NS	0.76	NS	NS	2.77	
Factor 2: Levels of fertilizers (L)												
L₁:60 % RDF	0.42	1.19	0.38	4.98	0.35	12.74	0.15	4.10	0.34	13.12	17.23	
L₂: 80 % RDF	0.44	1.30	0.41	5.77	0.37	14.10	0.17	4.82	0.36	14.87	19.68	
S.Em.±	0.01	0.05	0.01	0.17	0.01	0.32	0.006	0.18	0.02	0.62	0.65	
CD @ 5 %	NS	NS	NS	0.52	NS	0.96	NS	0.54	NS	NS	1.96	
Interaction (B× L)												
S.Em.±	0.02	0.10	0.02	0.34	0.02	0.63	0.01	0.36	0.03	1.24	1.29	
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
Treatments												
T₁-Control	0.35	0.50	0.31	2.38	0.28	3.91	0.10	1.09	0.26	4.16	5.25	
T₂-100 % RDF	0.39	1.03	0.34	4.22	0.32	11.03	0.13	3.35	0.31	11.40	14.75	
T₃-B₁L₁	0.41	1.15	0.38	4.93	0.35	12.52	0.16	4.04	0.33	12.70	16.74	
T₄-B₁L₂	0.44	1.26	0.42	5.87	0.37	13.76	0.17	4.65	0.36	14.45	19.10	
T₅-B₂L₁	0.40	1.09	0.33	4.16	0.32	11.21	0.14	3.69	0.31	11.68	15.37	
T₆-B₂L₂	0.43	1.22	0.40	5.23	0.36	13.18	0.16	4.49	0.35	13.96	18.45	
T₇-B₃L₁	0.41	1.16	0.38	4.81	0.34	12.20	0.15	3.81	0.33	12.49	16.30	
T₈-B₃L₂	0.43	1.25	0.41	5.61	0.37	13.98	0.16	4.53	0.35	14.39	18.92	
T₉-B₄L₁	0.45	1.35	0.42	6.00	0.38	15.01	0.17	4.87	0.37	15.62	20.50	
T₁₀-B₄L₂	0.48	1.46	0.44	6.36	0.39	15.48	0.19	5.59	0.39	16.66	22.25	
S.Em.±	0.03	0.09	0.02	0.44	0.02	0.80	0.01	0.33	0.03	1.20	1.24	
CD @ 5 %	NS	0.28	0.07	1.30	NS	2.39	0.04	0.99	NS	3.55	3.68	

*100 per cent was added with 7.5 t ha⁻¹ of FYM, remaining treatments received 7.5 t ha⁻¹ of bio-enriched FYM.

NFB: Nitrogen fixing biofertilizers PSB: Phosphate solubilizing biofertilizers KSB: Potassium solubilizing biofertilizers PGPR: Plant growth promoting rhizobacteria MC: Microbial consortia

application of 80 per cent RDF (L₂) at 30 DAS. Sulphur uptake differed significantly at 30, 60, 90 DAS and at harvest in finger millet grain only. Maximum uptake of sulphur at 90 DAS was with application of MC (B₄) and 14.10 kg ha⁻¹ in L₂: 80 per cent RDF. The grain uptake of 5.23 kg ha⁻¹ was observed with application of microbial consortia (B₄) and 4.82 kg ha⁻¹ with application of 80 per cent RDF (L₂). The interaction effect between different bio-enriched FYM and levels of fertilizers was found non-significant. Among different treatments content was found non-significant at 60 and 90 DAS, whereas uptake was found significant at all growth stages and highest uptake (22.25 kg ha⁻¹) was recorded with application of MC+ 80 per cent RDF (T₁₀) compared to control and 100 per cent RDF.

Mineralization of nutrient present in FYM might have increased nutrient availability for the uptake of calcium, magnesium and sulphur by plant. Similarly, FYM inoculated with heterotrophs lead to conversion of unavailable form to available form of nutrients (mineralization) compared to application of uninoculated FYM and thereby increased uptake by plant (Nandini and Sreenivasa, 2014). This might have contributed available calcium, magnesium and sulphur to soil after the mineralization of FYM. Huang *et al.* (2013) reported that microbial decomposition of organic materials also produces ammonia and hydrogen sulfide and that hydrogen ions displace K⁺, Mg²⁺, Ca²⁺, and Mn²⁺ from the cation-exchange complex in a soil and thereby enhances uptake. Similar result was observed by Shruthi (2014) and Rangesh Kumar *et al.* (2018).

4.5.3 Micronutrients content and uptake at different growth stages of finger millet

Data presented in Table 4.14, 4.15, 4.16 and 4.17 revealed the effect of bio-enriched FYM and levels of fertilizers on iron, manganese, zinc and copper concentration and uptake in finger millet at different growth stages, respectively.

Application of different biofertilizers enriched FYM, levels of fertilizers and interaction of both (B×L) recorded no significant effect on micronutrient (Fe, Mn, Zn and Cu) content and uptake at 30, 60, 90 DAS and at harvest (grain and straw). Similar was the trend among treatments.

With respect to treatments, application of MC + 80 per cent RDF recorded significantly higher Fe (21.17, 96.91, 224.71 and 360.39 g ha⁻¹) and Mn (11.09, 43.76, 94.04 and 181.39 g ha⁻¹) at 30, 60, 90 DAS and at harvest, respectively compared to Fe (5.85, 28.11, 49.71 and 85.10 g ha⁻¹, respectively) and Mn (2.46, 9.69, 17.07 and 37.50 g ha⁻¹, respectively) in absolute control. Similar trend was observed in grain and straw, where in higher uptake of Fe (138.05 and 222.34 g ha⁻¹) and Mn (101.34 and 80.05 g ha⁻¹) was recorded with application of MC + 80 per cent RDF compared to control in grain (32.75 g ha⁻¹ and 20.93 g ha⁻¹, respectively) and straw (52.34 g ha⁻¹ and 16.58 g ha⁻¹, respectively).

Uptake of Zn and Cu was found significant at 30, 60, 90 DAS and at harvest. Application of MC+ 80 per cent RDF recorded significantly higher Zn (10.71, 48.17, 102.43 and 176.46 g ha⁻¹) and Cu (0.71, 3.31, 8.99 and 24.81 g ha⁻¹) at 30, 90 DAS and at harvest, respectively, compared to Zn (2.85, 13.45, 18.10 and 35.29 g ha⁻¹) and Cu (0.26, 1.23, 2.69 and 7.73 g ha⁻¹) in absolute control. Similarly, significantly higher Zn uptake in grain (84.91 g ha⁻¹) and Cu uptake in grain (15.44 g ha⁻¹) and straw (9.37 g ha⁻¹) was recorded with application of MC + 80 per cent RDF (T₁₀) compared to absolute control (T₁).

Increase in concentration and uptake of micro-nutrient due to application of bio-enriched FYM, might be due to increased mineralization which increased available micronutrient content and uptake by plant, which improved mineralization and consequent release of complex organic substances, which prevented micronutrient from precipitation, fixation, oxidation and leaching (Sushma, 2005). Significant enhancement in the availability of various micronutrients may be due to the creation of an acidic environment by various microbial inoculants which promote mineral nutrient solubilization, mobility and availability, besides the formation of a wide range of chelating agents (Baba *et al.*, 2010). Among biofertilizers the significant improvement in content and removal of nutrients as a consequence of inorganic fertilizer with biofertilizer was due to improvement in nutrient availability pattern of soil which might have reflected on biological yield and resulted ultimately in nutrient content and uptake of micro nutrient (Pallavi *et al.*, 2016).

Table 4.14: Iron concentration and uptake by finger millet at different growth stages as influenced by different bio-enriched FYM and levels of fertilizers.

	30 DAS		60 DAS		90 DAS		AT HARVEST				
	Content (ppm)	Uptake (g ha ⁻¹)	Content (ppm)	Uptake (g ha ⁻¹)	Content (ppm)	Uptake (g ha ⁻¹)	GRAIN		STRAW		Total uptake (g ha ⁻¹)
							Content (ppm)	Uptake (g ha ⁻¹)	Content (ppm)	Uptake (g ha ⁻¹)	
Factor 1: Biofertilizers enrichment (B)											
B₁: NFB + PGPR	59.46	16.85	57.24	77.46	46.32	172.20	37.67	101.92	42.29	167.36	269.28
B₂: PSB + PGPR	61.06	17.07	58.86	75.80	47.81	170.98	38.59	104.86	44.91	175.04	279.90
B₃: KSB + PGPR	63.49	18.23	60.55	80.05	49.37	183.88	41.61	114.12	46.09	183.15	297.27
B₄: MC	67.21	20.36	64.91	93.67	54.10	215.39	45.56	134.23	49.21	209.44	343.67
S.Em.±	2.25	1.01	3.56	5.23	3.35	14.59	3.84	10.10	4.43	18.07	23.75
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Factor 2: Levels of fertilizers (L)											
L₁:60 % RDF	61.15	17.27	58.95	77.36	47.02	172.07	38.58	104.01	43.77	171.02	275.03
L₂: 80 % RDF	64.46	18.99	61.83	86.13	51.78	199.15	43.14	123.56	47.49	196.47	320.03
S.Em.±	1.59	0.71	2.52	3.70	2.37	10.32	2.72	7.14	3.13	12.78	16.80
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (B× L)											
S.Em.±	3.18	1.43	5.04	7.40	4.74	20.64	5.43	14.29	6.26	25.56	33.59
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Treatments											
T₁-Control	42.20	5.85	40.60	28.11	33.14	49.71	29.12	32.75	32.32	52.34	85.10
T₂-100 % RDF	55.37	14.48	52.22	65.05	40.80	139.02	32.93	83.06	36.98	134.44	217.50
T₃-B₁L₁	57.41	15.88	55.78	72.19	43.54	156.63	35.65	93.17	40.98	157.99	251.16
T₄-B₁L₂	61.50	17.83	58.70	82.74	49.09	187.78	39.70	110.67	43.60	176.73	287.40
T₅-B₂L₁	59.38	16.18	56.80	71.06	45.30	156.01	34.32	88.72	43.50	161.95	250.67
T₆-B₂L₂	62.73	17.97	60.93	80.53	50.31	185.95	42.86	121.01	46.32	188.14	309.14
T₇-B₃L₁	62.20	17.45	59.43	75.79	46.71	169.59	39.45	103.72	44.05	167.63	271.36
T₈-B₃L₂	64.79	19.00	61.67	84.32	52.04	198.17	43.78	124.52	48.12	198.67	323.18
T₉-B₄L₁	65.60	19.56	63.80	90.42	52.51	206.06	44.89	130.42	46.52	196.53	326.95
T₁₀-B₄L₂	68.82	21.17	66.02	96.91	55.68	224.71	46.23	138.05	51.90	222.34	360.39
S.Em.±	5.86	1.64	6.21	8.94	5.78	22.96	5.15	13.21	6.42	25.06	32.97
CD @ 5 %	NS	4.87	NS	26.58	NS	68.23	NS	39.25	NS	74.46	97.97

*100 per cent was added with 7.5 t ha⁻¹ of FYM, remaining treatments received 7.5 t ha⁻¹ of bio-enriched FYM.

NFB: Nitrogen fixing biofertilizers PSB: Phosphate solubilizing biofertilizers KSB: Potassium solubilizing biofertilizers PGPR: Plant growth promoting rhizobacteria MC: Microbial consortia

Table 4.15: Manganese concentration and uptake by finger millet at different growth stages as influenced by different bio-enriched FYM and levels of fertilizers.

	30 DAS		60 DAS		90 DAS		AT HARVEST				
	Content (ppm)	Uptake (g ha ⁻¹)	Content (ppm)	Uptake (g ha ⁻¹)	Content (ppm)	Uptake (g ha ⁻¹)	GRAIN		STRAW		Total uptake (g ha ⁻¹)
							Content (ppm)	Uptake (g ha ⁻¹)	Content (ppm)	Uptake (g ha ⁻¹)	
Factor 1: Biofertilizers enrichment (B)											
B₁: NFB + PGPR	28.95	8.20	22.42	30.55	16.35	60.62	24.61	66.53	14.53	57.77	124.30
B₂: PSB + PGPR	30.15	8.52	23.45	30.25	17.21	61.77	27.80	75.80	15.16	57.77	134.93
B₃: KSB + PGPR	31.12	9.02	24.59	32.52	18.69	69.72	28.61	78.55	15.95	59.12	142.58
B₄: MC	35.94	10.90	28.57	41.27	22.50	89.71	32.87	97.58	17.92	64.03	174.17
S.Em.±	2.61	0.94	2.71	3.72	1.90	7.73	2.63	8.14	1.83	8.16	12.20
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Factor 2: Levels of fertilizers (L)											
L₁:60 % RDF	29.63	8.44	22.68	29.90	17.48	64.51	26.62	72.27	15.22	59.82	132.09
L₂: 80 % RDF	33.45	9.88	26.84	37.40	19.89	76.40	30.33	86.97	16.55	68.94	155.90
S.Em.±	1.85	0.66	1.92	2.63	1.35	5.46	1.86	5.75	1.29	5.77	8.62
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (B× L)											
S.Em.±	3.70	1.33	3.83	5.26	2.69	10.93	3.72	11.51	2.58	11.54	17.25
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Treatments											
T₁-Control	17.59	2.46	14.30	9.69	12.09	17.07	18.41	20.93	10.61	16.58	37.50
T₂-100 % RDF	20.81	5.31	17.61	21.94	14.18	48.15	21.64	54.55	13.00	48.23	102.78
T₃-B₁L₁	26.63	7.34	19.77	25.80	15.37	55.85	22.30	58.29	13.73	52.86	111.15
T₄-B₁L₂	31.27	9.06	25.07	35.29	17.33	65.39	26.92	74.77	15.32	62.67	137.45
T₅-B₂L₁	27.64	7.62	21.44	26.84	16.04	55.69	25.96	67.62	14.27	52.92	120.55
T₆-B₂L₂	32.65	9.42	25.45	33.66	18.39	67.85	29.64	83.98	16.04	65.32	149.31
T₇-B₃L₁	28.38	8.09	22.18	28.17	16.78	61.11	26.37	69.33	15.63	60.37	129.69
T₈-B₃L₂	33.87	9.95	27.00	36.88	20.60	78.33	30.86	87.77	16.26	67.69	155.47
T₉-B₄L₁	35.85	10.71	27.32	38.78	21.75	85.38	31.84	93.83	17.24	73.13	166.96
T₁₀-B₄L₂	36.02	11.09	29.82	43.76	23.25	94.04	33.89	101.34	18.59	80.05	181.39
S.Em.±	4.50	1.39	3.81	5.01	2.40	9.81	3.39	10.39	2.57	10.83	15.89
CD @ 5 %	NS	4.14	NS	14.87	NS	29.16	NS	30.87	NS	32.17	47.22

*100 per cent was added with 7.5 t ha⁻¹ of FYM, remaining treatments received 7.5 t ha⁻¹ of bio-enriched FYM.

NFB: Nitrogen fixing biofertilizers PSB: Phosphate solubilizing biofertilizers KSB: Potassium solubilizing biofertilizers PGPR: Plant growth promoting rhizobacteria MC: Microbial consortia

Table 4.16: Zinc concentration and uptake by finger millet at different growth stages as influenced by different bio-enriched FYM and levels of fertilizers.

	30 DAS		60 DAS		90 DAS		AT HARVEST					
	Content (ppm)	Uptake (g ha ⁻¹)	Content (ppm)	Uptake (g ha ⁻¹)	Content (ppm)	Uptake (g ha ⁻¹)	GRAIN		STRAW		Total uptake (g ha ⁻¹)	
							Content (ppm)	Uptake (g ha ⁻¹)	Content (ppm)	Uptake (g ha ⁻¹)		
Factor 1: Biofertilizers enrichment (B)												
B₁: NFB + PGPR	28.36	7.99	24.19	32.99	19.28	71.22	20.98	56.76	14.36	56.63	113.39	
B₂: PSB + PGPR	29.79	8.32	25.42	32.44	20.38	73.48	22.94	62.22	16.89	66.21	128.43	
B₃: KSB + PGPR	30.99	8.96	27.69	36.94	21.42	79.59	22.93	62.64	16.76	66.89	129.53	
B₄: MC	34.03	10.29	31.57	45.45	24.52	97.60	27.30	79.82	20.42	88.13	167.94	
S.Em.±	1.50	0.57	2.84	3.97	2.13	8.52	2.61	7.08	2.96	12.85	13.75	
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
Factor 2: Levels of fertilizers (L)												
L₁:60 % RDF	29.38	8.32	25.26	33.25	19.94	73.13	21.93	58.76	16.12	63.72	122.48	
L₂: 80 % RDF	32.21	9.46	29.17	40.66	22.87	87.81	25.15	71.95	18.10	75.21	147.16	
S.Em.±	1.06	0.40	2.01	2.81	1.51	6.03	1.84	5.01	2.09	9.08	9.73	
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
Interaction (B× L)												
S.Em.±	2.12	0.80	4.01	5.62	3.02	12.05	3.69	10.01	4.18	18.17	19.45	
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	
Treatments												
T₁-Control	19.67	2.85	16.21	13.45	12.85	18.10	16.62	18.82	10.85	16.47	35.29	
T₂-100 % RDF	24.10	6.25	20.38	25.24	15.89	54.05	20.20	51.12	13.23	49.27	100.39	
T₃-B₁L₁	26.33	7.23	21.70	28.31	17.98	64.77	18.77	48.80	14.19	54.46	103.25	
T₄-B₁L₂	30.39	8.75	26.68	37.67	20.58	77.67	23.19	64.72	14.53	58.80	123.52	
T₅-B₂L₁	28.93	7.87	23.34	29.18	18.53	64.37	21.15	54.96	15.01	56.64	111.60	
T₆-B₂L₂	30.65	8.77	27.49	35.71	22.23	82.58	24.74	69.48	18.77	75.78	145.26	
T₇-B₃L₁	29.06	8.31	25.76	32.78	19.66	70.62	21.61	56.58	15.62	59.07	115.65	
T₈-B₃L₂	32.91	9.62	29.61	41.10	23.18	88.56	24.25	68.71	17.90	74.71	143.41	
T₉-B₄L₁	33.20	9.86	30.24	42.73	23.57	92.76	26.18	74.72	19.65	84.71	159.43	
T₁₀-B₄L₂	34.87	10.71	32.90	48.17	25.47	102.43	28.41	84.91	21.19	91.54	176.46	
S.Em.±	3.63	0.92	4.16	5.96	3.22	11.48	3.32	9.05	3.72	16.22	17.63	
CD @ 5 %	NS	2.73	NS	17.70	NS	34.11	NS	26.89	NS	NS	52.37	

*100 per cent was added with 7.5 t ha⁻¹ of FYM, remaining treatments received 7.5 t ha⁻¹ of bio-enriched FYM.

NFB: Nitrogen fixing biofertilizers PSB: Phosphate solubilizing biofertilizers KSB: Potassium solubilizing biofertilizers PGPR: Plant growth promoting rhizobacteria MC: Microbial consortia

Table 4.17: Copper concentration and uptake by finger millet at different growth stages as influenced by different bio-enriched FYM and levels of fertilizers.

	30 DAS		60 DAS		90 DAS		AT HARVEST				
	Content (ppm)	Uptake (g ha ⁻¹)	Content (ppm)	Uptake (g ha ⁻¹)	Content (ppm)	Uptake (g ha ⁻¹)	GRAIN		STRAW		Total uptake (g ha ⁻¹)
							Content (ppm)	Uptake (g ha ⁻¹)	Content (ppm)	Uptake (g ha ⁻¹)	
Factor 1: Biofertilizers enrichment (B)											
B₁: NFB + PGPR	2.15	0.61	2.10	2.84	2.04	7.48	4.80	12.95	1.97	7.78	20.74
B₂: PSB + PGPR	2.22	0.62	2.15	2.77	2.10	7.51	4.85	13.07	2.03	7.92	20.99
B₃: KSB + PGPR	2.19	0.62	2.18	2.89	2.12	7.88	4.87	13.33	2.06	8.22	21.54
B₄: MC	2.28	0.69	2.24	3.23	2.20	8.75	5.07	14.96	2.16	9.18	24.13
S.Em.±	0.08	0.03	0.10	0.18	0.09	0.43	0.25	0.71	0.11	0.57	1.10
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Factor 2: Levels of fertilizers (L)											
L₁:60 % RDF	2.19	0.62	2.14	2.82	2.09	7.63	4.82	12.93	2.02	7.93	20.86
L₂: 80 % RDF	2.23	0.65	2.19	3.05	2.14	8.18	4.98	14.22	2.08	8.62	22.84
S.Em.±	0.06	0.02	0.07	0.12	0.07	0.30	0.18	0.50	0.08	0.40	0.78
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (B× L)											
S.Em.±	0.12	0.05	0.15	0.25	0.13	0.61	0.35	1.01	0.16	0.80	1.55
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Treatments											
T₁-Control	1.86	0.26	1.86	1.23	1.83	2.69	4.46	4.99	1.76	2.74	7.73
T₂-100 % RDF	2.09	0.55	2.05	2.54	2.00	6.84	4.56	11.47	1.95	7.19	18.65
T₃-B₁L₁	2.13	0.59	2.08	2.69	2.01	7.23	4.72	12.33	1.94	7.47	19.80
T₄-B₁L₂	2.16	0.63	2.12	2.99	2.06	7.73	4.87	13.58	1.99	8.10	21.68
T₅-B₂L₁	2.19	0.60	2.13	2.66	2.08	7.21	4.76	12.27	2.00	7.52	19.79
T₆-B₂L₂	2.24	0.64	2.18	2.87	2.11	7.81	4.93	13.87	2.05	8.32	22.19
T₇-B₃L₁	2.17	0.60	2.15	2.76	2.09	7.59	4.81	12.65	2.02	7.74	20.40
T₈-B₃L₂	2.21	0.65	2.21	3.03	2.14	8.18	4.94	14.00	2.09	8.69	22.69
T₉-B₄L₁	2.26	0.68	2.21	3.16	2.16	8.50	4.98	14.48	2.13	8.98	23.46
T₁₀-B₄L₂	2.29	0.71	2.26	3.31	2.23	8.99	5.16	15.44	2.19	9.37	24.81
S.Em.±	0.13	0.05	0.15	0.23	0.14	0.66	0.37	0.94	0.15	0.75	1.45
CD @ 5 %	NS	0.13	NS	0.70	NS	1.96	NS	2.80	NS	2.23	4.30

*100 per cent was added with 7.5 t ha⁻¹ of FYM, remaining treatments received 7.5 t ha⁻¹ of bio-enriched FYM.

NFB: Nitrogen fixing biofertilizers **PSB:** Phosphate solubilizing biofertilizers **KSB:** Potassium solubilizing biofertilizers **PGPR:** Plant growth promoting rhizobacteria **MC:** Microbial consortia

4.6 Effect of bio- enriched FYM and levels of fertilizers on physico- chemical and biological properties of soil at different growth stages.

The result of the field experiment conducted to know the effect of bio- enriched FYM and levels of fertilizers on physico- chemical and biological properties of soil at different growth stages of finger millet *viz.*, 30, 60, 90 DAS and at harvest are presented below.

4.6.1 Soil bulk density (Mg m^{-3}), porosity (%) and water holding capacity (%) after harvest of finger millet.

The physical properties of soil are very important for agricultural production and sustainable use of soil. It influences movement, supporting capacity, ease of penetration of roots, retention, availability of water and nutrients to plants and flow of heat and air. The addition of organic manure results in decrease in bulk density, increase in porosity and there by water holding capacity of soil (Chikkaramappa *et al.*, 2014).

The data pertaining to bulk density, porosity and water holding capacity (WHC) as influenced by different biofertilizers and levels of fertilizers after harvest is presented in Table 4.18.

4.6.1.1 Bulk density

Bulk density is one of the important indicators of soil health and its compactness, affects infiltration, plant root development, soil aeration and plant, water and nutrient availability. There was no significant difference observed in bulk density with application of different biofertilizers and levels of fertilizers after harvesting of finger millet. Among different treatments bulk density was found non-significant and it ranged from 1.35 to 1.39 Mg m^{-3} . Interaction effect (B×L) was also found non-significant.

The non-significant variation in bulk density among the biofertilizer enrichment, levels of fertilizers, interaction (B×L) and also among treatments may be due to the quality of FYM applied (7.5 t ha^{-1}) which is meagre compared to the volume of soil. This lower volume brought some variation in the observation between treatments over control, but failed to produce statistical difference. Similar result was also reported by Chikkaramappa

et al. (2014), who cited that addition of organic manure results in decrease in bulk density and increase in porosity of soil.

4.6.1.2 Porosity (%)

The increased organic matter status, aggregation and pore size distribution influence porosity of soil. Application of different biofertilizers and levels of fertilizers recorded non-significant effect on porosity of soil. However, among different treatments, it was found higher with application of MC+ 80 per cent RDF (42.01 %) compared to control (38.63 %) without significant variation.

Porosity is a function of soil aggregation and in turn bulk density. The treatment failed to produce statistical difference in bulk density but were on par among treatments. Similar findings was reported by Chetan *et al.*, 2017 who reported that bulk density, particle density and porosity does not change in one cropping season.

4.6.1.3 Water holding capacity (%)

The water holding capacity of soil depends on organic matter content, number of pores, size of pores and specific surface area of soil. The application of different biofertilizer and levels of fertilizers recorded non-significant effect on water holding capacity of soil. Similarly, different combination of biofertilizers and levels of fertilizers also recorded non-significant impact on water holding capacity. However, it was found higher with application of MC + 80 per cent RDF (41.19 %) compared to control (37.11 %).

The water holding capacity of the soil is a function of soil porosity. The non-significant variation in porosity might be the reason for on par results of water holding capacity. The results are in agreement with the findings of Saha *et al.*, 2010 who reported increase in porosity due to better aggregation and changing pore-size distribution of the soil and WHC is governed by porosity of soil.

Table 4.18: Bulk density (Mg m^{-3}), porosity (%) and water holding capacity (%) of soil after harvest of finger millet as influenced by different bio-enriched FYM and levels of fertilizers.

	BD (Mg m^{-3})	Porosity (%)	WHC (%)
Factor 1: Biofertilizers enrichment (B)			
B₁: NFB + PGPR	1.36	40.46	39.55
B₂: PSB + PGPR	1.37	40.36	39.14
B₃: KSB + PGPR	1.36	40.81	39.66
B₄: MC	1.35	41.56	40.78
S.Em.±	0.017	0.93	0.77
CD @ 5 %	NS	NS	NS
Factor 2: Levels of fertilizers (L)			
L₁:60 % RDF	1.36	40.28	39.16
L₂: 80 % RDF	1.36	41.32	40.41
S.Em.±	0.012	0.66	0.55
CD @ 5 %	NS	NS	NS
Interaction (B× L)			
S.Em.±	0.02	1.31	1.09
CD @ 5 %	NS	NS	NS
Treatments			
T₁-Control	1.39	38.63	37.11
T₂-100 % RDF	1.38	39.01	38.31
T₃-B₁L₁	1.36	39.78	38.69
T₄-B₁L₂	1.35	41.13	40.41
T₅-B₂L₁	1.37	39.81	38.66
T₆-B₂L₂	1.36	40.91	39.63
T₇-B₃L₁	1.36	40.40	38.91
T₈-B₃L₂	1.36	41.21	40.41
T₉-B₄L₁	1.35	41.11	40.37
T₁₀-B₄L₂	1.35	42.01	41.19
S.Em.±	0.02	1.29	1.20
CD @ 5 %	NS	NS	NS

*100 per cent was added with 7.5 t ha⁻¹ of FYM, remaining treatments received 7.5 t ha⁻¹ of bio-enriched FYM.

NFB: Nitrogen fixing biofertilizers

PSB: Phosphate solubilizing biofertilizers

KSB: Potassium solubilizing biofertilizers

PGPR: Plant growth promoting rhizobacteria

MC: Microbial consortia

4.6.2 Soil pH, electrical conductivity and organic carbon content at different growth stages of finger millet.

The data on soil pH, EC and OC as influenced by bio- enriched FYM and levels of fertilizers at different growth stages of finger millet are presented in Table 4.19.

4.6.2.1 Soil pH

The pH of soil is important to plant growth as it determines the availability of essential nutrients to plant and microbial population in soil. The pH of soil at different growth stages did not differ significantly due to bio-enriched FYM and levels of fertilizers and also their interaction. However, the range of soil pH was between 6.03 to 6.10. Interaction effect between biofertilizers and levels of fertilizers (B×L), were found to be on par.

No significant difference was observed due to application of biofertilizers and levels of RDF. It might be due to organic acid produced by PSB and KSB which nullifies the mineralization action of FYM, without significant effect on soil pH. These results are in accordance with Lin *et al.*, 2006 and they showed that microbe's lower the soil pH by releasing organic acids which nullifies with application of organic manure.

4.6.2.2 Electrical conductivity

Soil electrical conductivity is an indirect measurement that correlate with several physical and chemical properties. Electrical conductivity of soil did not differ significantly due to different biofertilizers enrichment, levels of fertilizers and their interaction. The range of electrical conductivity lies between 0.033 to 0.047 dS m⁻¹. Also, the electrical conductivity was found non-significant among different treatments.

The treatments failed to produce statistical difference in electrical conductivity. The increase in electrical conductivity over control may be due to increased solubility of nutrients by the addition of biofertilizer along with FYM. Similar, results were obtained by Selvakumar *et al.* (2012) who reported that application of biofertilizers with FYM increased the soil EC. This may be due to increased solubility of many nutrients, due to

production of acids or their intermediates through the decomposition of organic compounds, which reacted either with the partially soluble salts already present in the soil or converted them into soluble salts thereby increasing their solubility (Kaur *et al.*, 2016). Similarly, Yuvaraj (2016) cited that increased electrical conductivity might be due to production of acid or acid forming compound that react with sparingly soluble salt already present in soil and increase solubility.

4.6.2.3 Organic carbon

Organic carbon of soil did not differ significantly due to application of biofertilizers enriched FYM and levels of fertilizers. However, among different biofertilizer enrichment it ranged from 0.31 per cent to 0.35 per cent at 30 DAS and at harvest, respectively with application of MC and 0.32 per cent to 0.34 per cent with application of 80 per cent RDF (L₂). Combined application of biofertilizers enriched FYM and levels of fertilizers did not show significant difference for soil organic carbon content.

Soil organic carbon is largely governed by the management practices and climatic condition, addition and/ or removal of organic carbon takes place through management practices. No significant variation was recorded in organic carbon content of soil. But, slight increase among treatments over control might be due to application of bio-enriched FYM and root exudation by plant, which is source of carbon that might have increased organic carbon status of soil. Similar finding was reported by Wu *et al.* (2005) that organic matter content in the rhizosphere was mainly influenced by plant growth, especially root exudates through the root metabolism and physiological activities. The organic carbon content of soil increased from 0.30 per cent to 0.35 per cent in control and treatment having 100 per cent FYM + consortium respectively (Kaur *et al.*, 2016). High microbial biomass production and high rhizo-deposits of carbonaceous materials through root exudates may be one of the reasons for higher organic carbon in organically treated soils (Franzluebbers *et al.*, 1995). Similar results were reported by Kumar and Sharma (2015) showing increase in organic carbon content of soil with the addition of organic manures and biofertilizers.

Table 4.19: pH, EC and OC of soil at different growth stages of finger millet as influenced by different bio-enriched FYM and levels of fertilizers.

	pH				EC (dS m ⁻¹)				OC (%)			
	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest
Factor 1: Biofertilizers enrichment (B)												
B₁: NFB + PGPR	6.07	6.08	6.08	6.09	0.043	0.044	0.044	0.045	0.32	0.33	0.33	0.34
B₂: PSB + PGPR	6.06	6.07	6.07	6.08	0.044	0.045	0.047	0.047	0.32	0.34	0.34	0.34
B₃: KSB + PGPR	6.06	6.07	6.08	6.08	0.044	0.045	0.045	0.045	0.32	0.34	0.34	0.34
B₄: MC	6.07	6.07	6.08	6.08	0.044	0.045	0.047	0.047	0.31	0.34	0.35	0.35
S.Em.±	0.05	0.05	0.05	0.05	0.003	0.003	0.003	0.003	0.003	0.01	0.01	0.01
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Factor 2: Levels of fertilizers (L)												
L₁:60 % RDF	6.06	6.07	6.07	6.08	0.043	0.044	0.045	0.045	0.32	0.33	0.34	0.34
L₂: 80 % RDF	6.06	6.08	6.08	6.09	0.044	0.045	0.046	0.046	0.32	0.34	0.34	0.35
S.Em.±	0.04	0.03	0.04	0.04	0.002	0.002	0.002	0.002	0.002	0.01	0.01	0.01
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (B×L)												
S.Em.±	0.07	0.06	0.07	0.08	0.005	0.004	0.004	0.004	0.004	0.01	0.01	0.01
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Treatments												
T₁-Control	6.06	6.05	6.04	6.03	0.040	0.036	0.034	0.033	0.31	0.30	0.30	0.30
T₂-100 % RDF	6.05	6.05	6.05	6.04	0.044	0.044	0.044	0.044	0.32	0.32	0.32	0.32
T₃-B₁L₁	6.06	6.07	6.08	6.08	0.042	0.043	0.044	0.044	0.32	0.33	0.33	0.33
T₄-B₁L₂	6.07	6.09	6.09	6.10	0.044	0.044	0.044	0.045	0.32	0.33	0.33	0.34
T₅-B₂L₁	6.06	6.06	6.07	6.07	0.043	0.044	0.046	0.046	0.31	0.34	0.34	0.34
T₆-B₂L₂	6.06	6.07	6.07	6.08	0.044	0.046	0.047	0.047	0.32	0.34	0.35	0.35
T₇-B₃L₁	6.06	6.07	6.07	6.08	0.043	0.044	0.044	0.044	0.32	0.33	0.33	0.34
T₈-B₃L₂	6.06	6.07	6.08	6.08	0.044	0.045	0.045	0.045	0.32	0.34	0.34	0.34
T₉-B₄L₁	6.07	6.08	6.08	6.08	0.044	0.045	0.046	0.046	0.32	0.34	0.35	0.35
T₁₀-B₄L₂	6.06	6.07	6.08	6.09	0.044	0.045	0.047	0.047	0.32	0.35	0.36	0.36
S.Em.±	0.07	0.06	0.07	0.07	0.004	0.004	0.004	0.004	0.01	0.01	0.01	0.01
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

*100 per cent was added with 7.5 t ha⁻¹ of FYM, remaining treatments received 7.5 t ha⁻¹ of bio-enriched FYM.

NFB: Nitrogen fixing biofertilizers PSB: Phosphate solubilizing biofertilizers KSB: Potassium solubilizing biofertilizers PGPR: Plant growth promoting rhizobacteria MC: Microbial consortia

4.6.3 Major nutrient status of soil at different growth stages of finger millet.

The data pertaining to available nitrogen, phosphorus and potassium (kg ha^{-1}) as influenced by different biofertilizers enrichment and levels of fertilizers at 30, 60, 90 DAS and at harvest are presented in Table 4.20.

4.6.3.1 Available nitrogen

The available nitrogen status at 30 DAS was found non-significant with application of different biofertilizers enrichment, levels of fertilizers and their interaction. However, significant difference was recorded at 60, 90 DAS and at harvest.

Among the different biofertilizer enrichment, significantly higher available nitrogen ($186.95 \text{ kg ha}^{-1}$) was recorded in bio-enriched FYM (B_4 : microbial consortia), followed by B_1 : NFB + PGPR ($182.54 \text{ kg ha}^{-1}$) at 60 DAS. Similar was trend at 90 DAS ($169.76 \text{ kg ha}^{-1}$ and $166.54 \text{ kg ha}^{-1}$, respectively) and at harvest ($152.95 \text{ kg ha}^{-1}$ and $149.39 \text{ kg ha}^{-1}$, respectively).

With respect to levels of fertilizers, higher available nitrogen was observed with application of 80 per cent RDF ($181.64 \text{ kg ha}^{-1}$) and lowest available nitrogen was with application of 60 per cent RDF ($175.85 \text{ kg ha}^{-1}$) at 60 DAS. Similarly, at 90 DAS and at harvest, higher available nitrogen was with application of 80 per cent RDF ($167.15 \text{ kg ha}^{-1}$ and $148.95 \text{ kg ha}^{-1}$, respectively) compared to 60 per cent RDF ($159.62 \text{ kg ha}^{-1}$ and $143.55 \text{ kg ha}^{-1}$, respectively).

The interaction effect between different biofertilizer enrichment and levels of fertilizers ($B \times L$) was found non-significant. Among the treatments significantly higher available nitrogen of 175.60 , 189.40 , 172.00 and $155.07 \text{ kg ha}^{-1}$ at 30, 60, 90 DAS and at harvest, respectively was recorded in T_{10} (MC+ 80 % RDF) compared to control (144.89 , 137.76 , 129.29 and $123.86 \text{ kg ha}^{-1}$, respectively) and 100 per cent RDF (156.21 , 167.72 , 151.53 and $135.15 \text{ kg ha}^{-1}$, respectively). There was an increase in available nitrogen status of soil by 4.35 per cent over its initial value (Fig. 4.7).

The increase in available nitrogen content of soil in bio-enriched FYM with nitrogen fixers such as *Azotobacter* might be due to the characteristics of nitrogen fixers which release ammonia, when it interacts with root exudation and thereby enhances the nitrogen content. Also, conjugate use of biofertilizers along with inorganic fertilizers resulted in better nutrient availability through nitrogen fixation and mineralization of FYM. The result is in conformity with Narula and Gupta (1986). The combined application of microbial consortia along with inorganic fertilizers enhanced the microbial population in the rhizosphere and increased efficiency of crop production by nourishing and fortifying the host plant with required nutrients (Nutti and Giovannetti, 2015). The increase in available nitrogen at 60 DAS might be due to increased nitrogen fixers population during flowering stage, increased root exudation, thereby enhancing the nitrogen status.

4.6.3.2 Available phosphorus

Application of different biofertilizers enrichment, levels of fertilizers, interaction between them (B×L) and treatment showed no significant effect on available phosphorus status of soil at 30 DAS. Whereas, significant difference was recorded at 60, 90 DAS and at harvest.

Significantly higher available phosphorus was recorded with application of bio-enriched FYM with MC (B₄: 130.83, 124.13 and 118.80 kg ha⁻¹), followed by bio-enrichment with PSB+ PGPR (B₂: 123.47, 119.46 and 115.80 kg ha⁻¹) at 60, 90 DAS and at harvest, respectively.

Among different levels of fertilizers, application of 80 per cent RDF (L₂) recorded significantly higher available phosphorus (125.61, 120.68 and 116.10 kg ha⁻¹) compared to 60 per cent RDF (120.16, 115.63 and 110.72 kg ha⁻¹) at 60, 90 DAS and at harvest respectively.

The interaction effect between different biofertilizers and levels of fertilizers (B×L) was found non-significant. However, among different treatments significantly higher available phosphorus was recorded with application of MC + 80 per cent RDF (T₁₀: 132.64, 124.42 and 119.76 kg ha⁻¹) compared to control (110.66, 104.98 and 90.65 kg

ha⁻¹) and 100 per cent RDF (114.95, 107.29 and 102.29 kg ha⁻¹) at 60, 90 DAS and at harvest, respectively. There was increase in phosphorus content of soil by 1.14 per cent over initial value (Fig. 4.8).

Available phosphorus was found higher with application of microbial consortia (MC), followed by phosphorus solubilizers (PSB+ PGPR). It may be attributed to organic acid production by PSB, which solubilize phosphorus by reducing soil pH, competing with adsorption site and chelation of cation which thereby increase available phosphorus in soil. Similar findings were reported by Sagoe *et al.* (1998) that phosphorus solubilizing activity is the ability of microbes to produce metabolites such as organic acids, which through their carboxyl and hydroxyl groups chelation with cation bound to phosphate, the being converted to soluble forms. Ponmurugan and Gopi (2006) pointed out that phosphate solubilizing microorganism's secret organic acids and enzymes that act on insoluble phosphates and convert it into soluble form, thus, increase available P for plants. Similar result was observed by Gupta (2018) and Kaur (2016) with combined application of microbial consortia and inorganic fertilizer, where in the P- solubilizing potential of the isolates used in microbial consortia increases phosphorus availability in soil.

4.6.3.3 Available potassium

There was non-significant increase in available potassium content of soil due to application of different bio-enriched FYM and levels of fertilizers at 30 DAS. The interaction (B×L) was also found non-significant.

However, there was significant difference at 60, 90 DAS and at harvest. Among the different bio-enriched FYM, maximum potassium content was observed in B₄ (135.05 kg ha⁻¹) at 60 DAS, while minimum in B₁ (106.60 kg ha⁻¹) at harvest. Significantly higher available potassium was recorded in L₂: 80 per cent RDF (131.23 kg ha⁻¹) and lower was at harvest in L₁: 60 per cent RDF (109.12 kg ha⁻¹). The interaction effect between different biofertilizers and levels of fertilizers at 60, 90 DAS and at harvest was found non-significant. Among treatments, combined application of microbial consortia along with 80 per cent RDF (B₄L₂) was significantly superior (117.80 kg ha⁻¹) over control (88.83 kg

Table 4.20: Available major nutrient status of soil at different growth stages of finger millet as influenced by different bio-enriched FYM and levels of fertilizers.

	Available N (kg ha ⁻¹)				Available P ₂ O ₅ (kg ha ⁻¹)				Available K ₂ O (kg ha ⁻¹)			
	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest
Factor 1: Biofertilizers enrichment (B)												
B₁: NFB + PGPR	171.21	182.54	166.54	149.39	120.96	116.96	113.11	108.11	132.57	123.83	115.60	106.60
B₂: PSB + PGPR	160.75	171.28	158.23	140.72	127.47	123.47	119.46	115.80	134.33	125.45	118.83	109.13
B₃: KSB + PGPR	163.54	174.20	159.03	141.93	124.29	120.29	115.93	110.93	137.99	131.55	122.15	113.98
B₄: MC	174.20	186.95	169.76	152.95	133.83	130.83	124.13	118.80	141.87	135.05	124.58	116.13
S.Em.±	3.64	2.69	2.88	2.51	3.36	2.53	2.24	2.13	3.27	1.92	2.07	2.04
CD @ 5 %	NS	8.15	8.75	7.62	NS	7.67	6.80	6.47	NS	5.82	6.29	6.19
Factor 2: Levels of fertilizers (L)												
L₁: 60 % RDF	165.91	175.85	159.62	143.55	124.16	120.16	115.63	110.72	135.17	126.72	117.47	109.12
L₂: 80 % RDF	168.94	181.64	167.15	148.95	129.11	125.61	120.68	116.10	138.21	131.23	123.12	113.81
S.Em.±	2.57	1.90	2.04	1.78	2.38	1.79	1.58	1.51	2.31	1.36	1.47	1.44
CD @ 5 %	NS	5.76	6.19	5.38	NS	5.42	4.81	4.57	NS	4.12	4.45	4.37
Interaction (B × L)												
S.Em.±	5.14	3.80	4.08	3.55	4.75	3.58	3.17	3.02	4.62	2.71	2.93	2.88
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Treatments												
T₁-Control	144.89	137.76	129.29	123.86	114.66	110.66	104.98	90.65	109.59	100.93	96.40	88.83
T₂-100 % RDF	156.21	167.72	151.53	135.15	118.95	114.95	107.29	102.29	126.00	118.80	109.17	101.27
T₃-B₁L₁	169.86	177.29	164.21	146.27	119.96	115.96	109.76	104.76	131.23	120.60	111.40	103.60
T₄-B₁L₂	172.56	187.78	168.86	152.50	121.95	117.95	116.45	111.45	133.90	127.07	119.80	109.60
T₅-B₂L₁	158.93	169.30	152.84	137.73	123.14	119.14	116.71	113.04	132.59	122.73	115.27	106.13
T₆-B₂L₂	162.58	173.26	163.61	143.71	131.80	127.80	122.22	118.55	136.06	128.17	122.40	112.13
T₇-B₃L₁	162.06	172.30	153.92	139.35	120.54	116.54	112.23	107.23	136.65	129.60	120.93	112.27
T₈-B₃L₂	165.02	176.10	164.14	144.51	128.05	124.05	119.63	114.63	139.33	133.50	123.37	115.70
T₉-B₄L₁	172.80	184.50	167.52	150.83	133.01	129.01	123.84	117.84	140.20	133.93	122.27	114.47
T₁₀-B₄L₂	175.60	189.40	172.00	155.07	134.64	132.64	124.42	119.76	143.53	136.17	126.90	117.80
S.Em.±	5.23	4.96	5.36	5.35	4.93	4.15	4.00	5.14	5.03	4.42	4.75	4.57
CD @ 5 %	15.54	14.75	15.91	15.90	NS	12.33	11.90	15.27	14.95	13.12	14.11	13.57

*100 per cent was added with 7.5 t ha⁻¹ of FYM, remaining treatments received 7.5 t ha⁻¹ of bio-enriched FYM.

NFB: Nitrogen fixing biofertilizers PSB: Phosphate solubilizing biofertilizers KSB: Potassium solubilizing biofertilizers PGPR: Plant growth promoting rhizobacteria MC: Microbial consortia

ha⁻¹) and 100 per cent RDF (101.27 kg ha⁻¹). There was an increase in available potassium status of soil by 5.24 per cent over its initial value (Fig. 4.9).

Available potassium was at par among different biofertilizer enriched FYM and levels of RDF at 30 DAS and found significant thereafter at 60, 90 DAS and at harvest. This may be due to production of organic acid, chelation and solubilization of potassium that might increase the availability of potassium by potassium solubilizing biofertilizer during critical crop growth. The finding is in line with Meena *et al.* (2016) who reported that in addition to decreasing soil pH, organic acids produced by KSB can release K⁺ ions from the mineral K⁺ by chelating (complex formation) Si⁴⁺, Al³⁺, Fe²⁺, and Ca²⁺ ions associated with K minerals. This resulted in significant build-up of available potassium status of soil over its initial status. Similar result is in line with work of Shruthi (2014) who noticed build-up in available potassium content in soil with application of 100 per cent NPK + FYM + P and K solubilizers. The co-inoculation of microorganisms in consortia with inorganic fertilizers increased the available potassium content in soil. This might be due to presence of potassium releasing bacteria in the biofertilizers consortia which when applied to soil released soluble potassium (Maurya *et al.*, 2014).

4.6.4 Exchangeable calcium, magnesium and available sulphur of soil at different growth stages of finger millet.

The data pertaining to exchangeable calcium, magnesium and available sulphur content of soil drawn at different growth stages are presented in Table 4.21.

4.6.4.1 Exchangeable calcium

Application of different biofertilizers enriched FYM, levels of fertilizers and their interaction (B×L) was found non-significant with respect to exchangeable calcium content of soil. Similar was the trend with respect to treatments at different growth stages of finger millet. Among treatments, numerically higher calcium content (1.74 c mol (p⁺) kg⁻¹) was recorded at 60 DAS in treatment which received microbial consortia along with 80 per cent RDF (B₄L₂) than in control with 1.61 c mol (p⁺) kg⁻¹ of calcium.

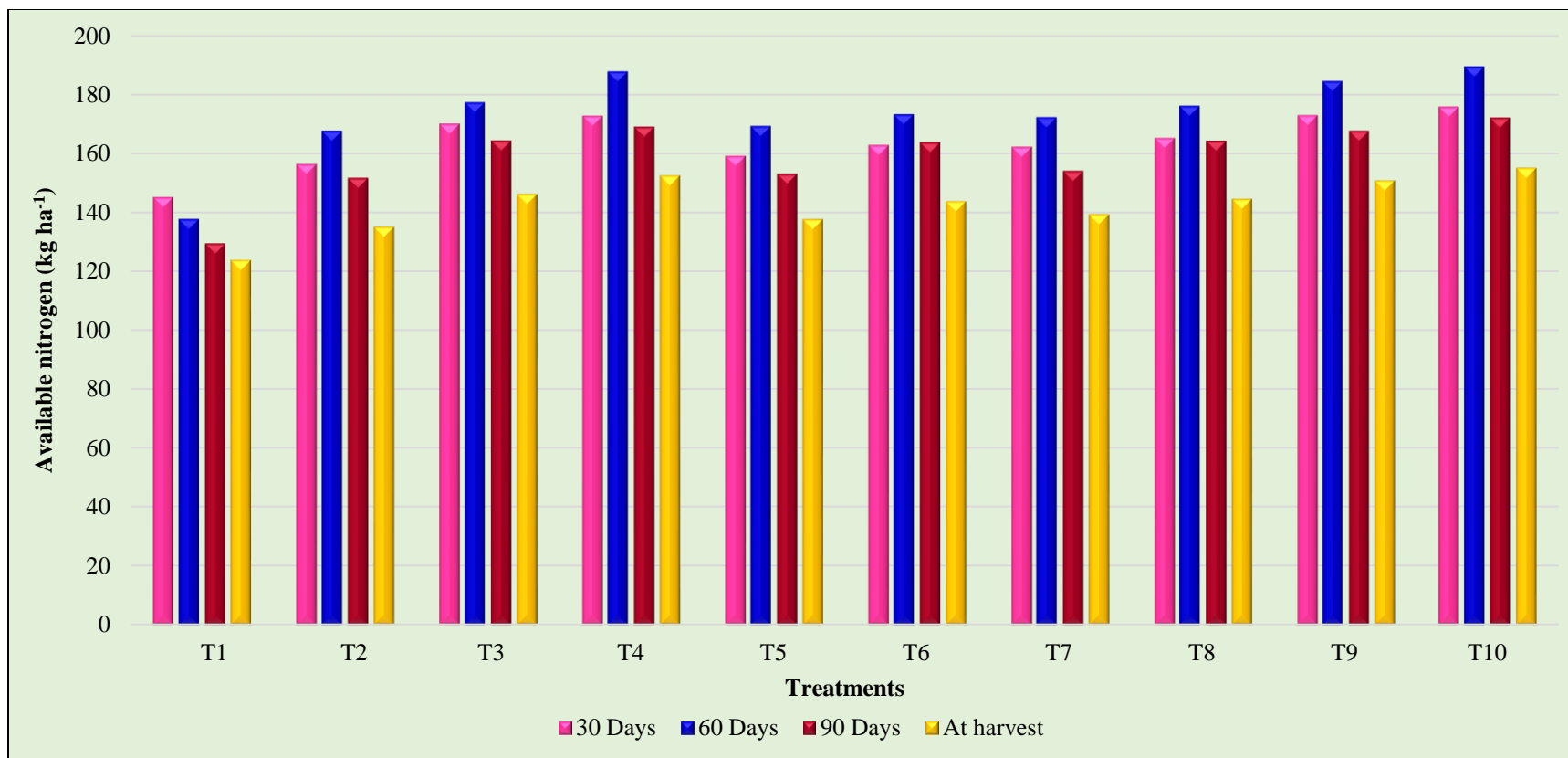


Fig. 4.7: Bio- enriched FYM and different levels of fertilizers on soil available nitrogen (kg ha⁻¹) of finger millet at different growth stages.

Treatment details:

T₁: Absolute control

T₂: 7.5 t ha⁻¹ FYM + 100 % RDF

T₃: 7.5 t ha⁻¹ enriched FYM (NFB + PGPR) + 60 % RDF

T₄: 7.5 t ha⁻¹ enriched FYM (NFB + PGPR) + 80 % RDF

T₅: 7.5 t ha⁻¹ enriched FYM (PSB + PGPR) + 60 % RDF

T₆: 7.5 t ha⁻¹ enriched FYM (PSB + PGPR) + 80 % RDF

T₇: 7.5 t ha⁻¹ enriched FYM (KSB + PGPR) + 60 % RDF

T₈: 7.5 t ha⁻¹ enriched FYM (KSB + PGPR) + 80 % RDF

T₉: 7.5 t ha⁻¹ enriched FYM (MC) + 60 % RDF

T₁₀: 7.5 t ha⁻¹ enriched FYM (MC) + 80 % RDF

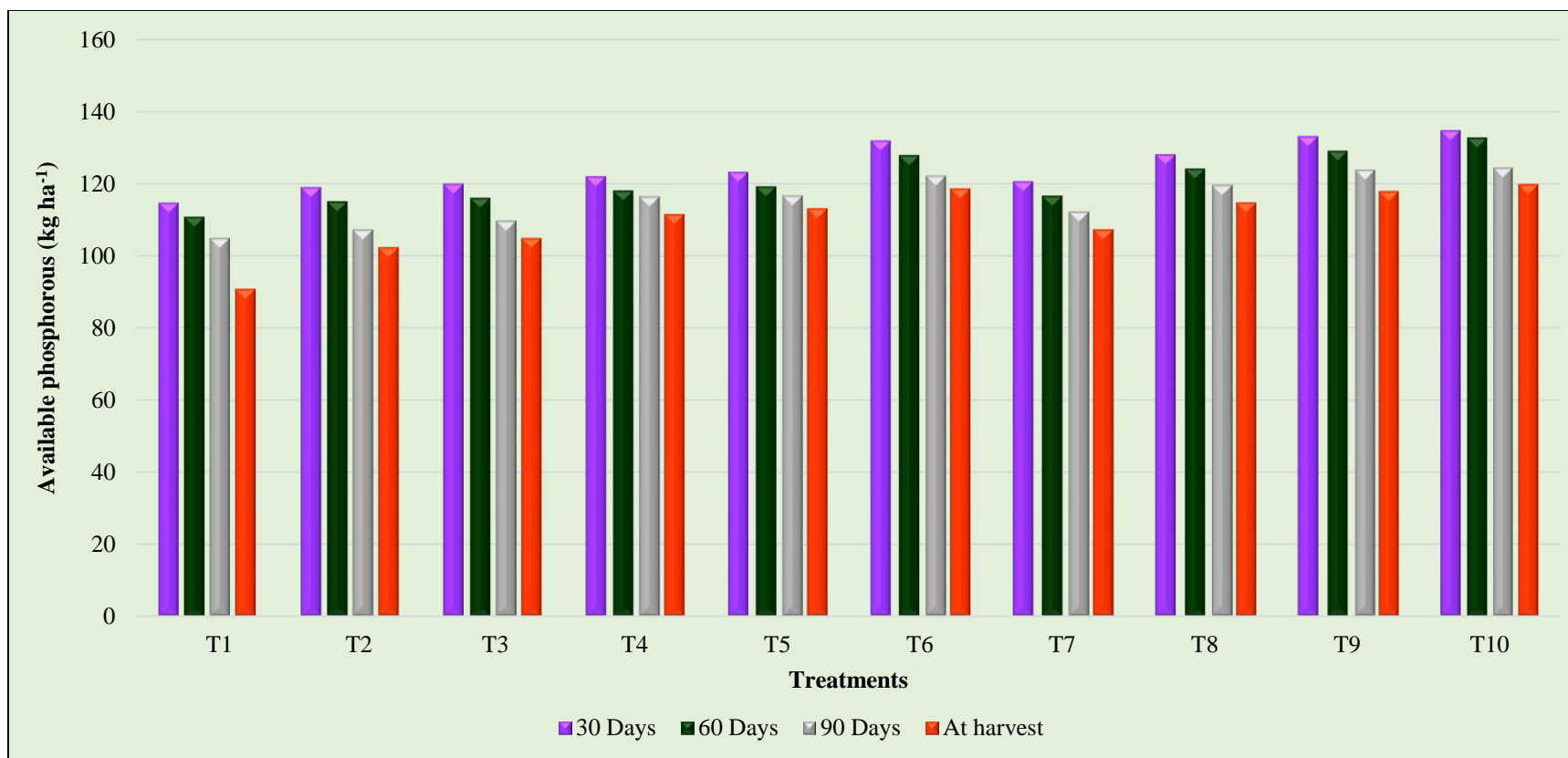


Fig. 4.8: Bio- enriched FYM and different levels of NPK on soil available phosphorus (kg ha⁻¹) of finger millet at different growth stages.

Treatment details:

T₁: Absolute control

T₂: 7.5 t ha⁻¹ FYM + 100 % RDF

T₃: 7.5 t ha⁻¹ enriched FYM (NFB + PGPR) + 60 % RDF

T₄: 7.5 t ha⁻¹ enriched FYM (NFB + PGPR) + 80 % RDF

T₅: 7.5 t ha⁻¹ enriched FYM (PSB + PGPR) + 60 % RDF

T₆: 7.5 t ha⁻¹ enriched FYM (PSB + PGPR) + 80 % RDF

T₇: 7.5 t ha⁻¹ enriched FYM (KSB + PGPR) + 60 % RDF

T₈: 7.5 t ha⁻¹ enriched FYM (KSB + PGPR) + 80 % RDF

T₉: 7.5 t ha⁻¹ enriched FYM (MC) + 60 % RDF

T₁₀: 7.5 t ha⁻¹ enriched FYM (MC) + 80 % RDF

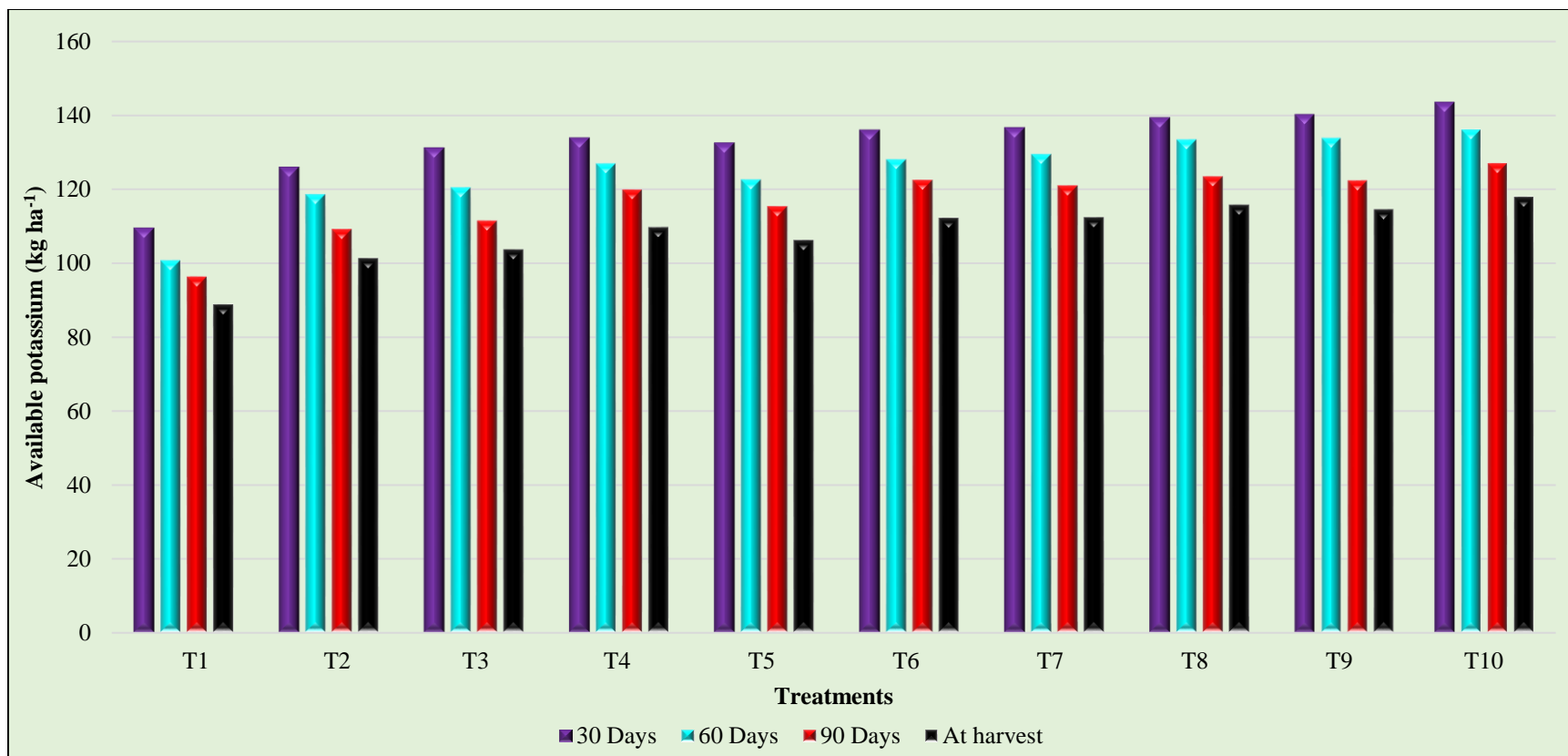


Fig. 4.9: Bio- enriched FYM and different levels of NPK on soil available potassium (kg ha⁻¹) of finger millet at different growth stages.

Treatment details:

T₁: Absolute control

T₂: 7.5 t ha⁻¹ FYM + 100 % RDF

T₃: 7.5 t ha⁻¹ enriched FYM (NFB + PGPR) + 60 % RDF

T₄: 7.5 t ha⁻¹ enriched FYM (NFB + PGPR) + 80 % RDF

T₅: 7.5 t ha⁻¹ enriched FYM (PSB + PGPR) + 60 % RDF

T₆: 7.5 t ha⁻¹ enriched FYM (PSB+ PGPR) + 80 % RDF

T₇: 7.5 t ha⁻¹ enriched FYM (KSB + PGPR) + 60 % RDF

T₈: 7.5 t ha⁻¹ enriched FYM (KSB+ PGPR) + 80 % RDF

T₉: 7.5 t ha⁻¹ enriched FYM (MC) + 60 % RDF

T₁₀: 7.5 t ha⁻¹ enriched FYM (MC) + 80 % RDF

Table 4.21: Secondary nutrient status of soil at different growth stages of finger millet as influenced by different bio-enriched FYM and levels of fertilizers.

	Ex. Calcium (c mol (p ⁺) kg ⁻¹)				Ex. Magnesium (c mol (p ⁺) kg ⁻¹)				Available Sulphur (ppm)			
	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest
Factor 1: Biofertilizers enrichment (B)												
B₁: NFB + PGPR	1.66	1.67	1.65	1.62	0.80	0.82	0.79	0.78	15.34	15.47	15.39	14.91
B₂: PSB + PGPR	1.63	1.64	1.64	1.60	0.78	0.80	0.77	0.76	15.11	15.32	15.19	14.63
B₃: KSB + PGPR	1.65	1.65	1.64	1.61	0.79	0.81	0.79	0.78	15.18	15.38	15.27	14.70
B₄: MC	1.70	1.73	1.69	1.67	0.82	0.85	0.81	0.80	15.49	15.64	15.56	15.08
S.Em.±	0.04	0.05	0.04	0.05	0.05	0.03	0.04	0.03	0.50	0.39	0.38	0.39
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Factor 2: Levels of fertilizers (L)												
L₁: 60 % RDF	1.64	1.66	1.65	1.61	0.79	0.81	0.78	0.77	15.21	15.36	15.27	14.74
L₂: 80 % RDF	1.68	1.69	1.66	1.64	0.80	0.83	0.80	0.79	15.35	15.55	15.43	14.92
S.Em.±	0.03	0.04	0.03	0.03	0.04	0.02	0.03	0.02	0.36	0.27	0.27	0.28
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (B×L)												
S.Em.±	0.06	0.07	0.06	0.07	0.07	0.05	0.05	0.05	0.71	0.55	0.50	0.56
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Treatments												
T₁-Control	1.62	1.61	1.58	1.54	0.75	0.73	0.71	0.70	14.73	14.05	13.63	13.21
T₂-100 % RDF	1.63	1.64	1.61	1.57	0.76	0.78	0.75	0.73	14.88	14.55	14.15	13.55
T₃-B₁L₁	1.65	1.66	1.64	1.61	0.79	0.81	0.78	0.77	15.29	15.38	15.30	14.83
T₄-B₁L₂	1.67	1.69	1.66	1.64	0.80	0.83	0.80	0.79	15.39	15.56	15.48	14.98
T₅-B₂L₁	1.62	1.62	1.63	1.59	0.77	0.79	0.76	0.74	15.03	15.21	15.10	14.49
T₆-B₂L₂	1.64	1.66	1.64	1.61	0.79	0.80	0.78	0.77	15.19	15.44	15.27	14.76
T₇-B₃L₁	1.61	1.63	1.62	1.59	0.78	0.80	0.79	0.76	15.09	15.27	15.17	14.60
T₈-B₃L₂	1.69	1.66	1.65	1.63	0.80	0.82	0.80	0.79	15.27	15.49	15.37	14.81
T₉-B₄L₁	1.69	1.72	1.69	1.66	0.80	0.84	0.80	0.79	15.42	15.58	15.51	15.03
T₁₀-B₄L₂	1.71	1.74	1.70	1.68	0.83	0.85	0.82	0.81	15.55	15.70	15.60	15.12
S.Em.±	0.07	0.07	0.05	0.06	0.07	0.05	0.06	0.04	0.78	0.52	0.53	0.50
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

*100 per cent was added with 7.5 t ha⁻¹ of FYM, remaining treatments received 7.5 t ha⁻¹ of bio-enriched FYM.

NFB: Nitrogen fixing biofertilizers PSB: Phosphate solubilizing biofertilizers KSB: Potassium solubilizing biofertilizers PGPR: Plant growth promoting rhizobacteria MC: Microbial consortia

4.6.4.2 Exchangeable magnesium

Exchangeable magnesium status of soil at different growth stages of finger millet did not differ significantly due to application of bio-enriched FYM, levels of fertilizers and also among treatments. However, the range of soil exchangeable magnesium was between 0.70 c mol (p⁺) kg⁻¹ to 0.81 c mol (p⁺) kg⁻¹ at harvest.

4.6.4.3 Available sulphur

Available sulphur content of soil did not differ significantly due to different biofertilizers and levels of fertilizers. The interaction effect was also non-significant. With respect to different treatments, the available sulphur content ranged from 13.21 ppm to 15.70 ppm with no significant variation.

The secondary nutrient status in soil was not influenced by treatments, Whereas, increase in bio-enriched FYM treatments compared to control and 100 per cent RDF, may be due to increased mineralization due to bio-enrichment of FYM. Chikkaramappa *et al.*, (2014) cited that organic matter contains abundant quantity of calcium magnesium and sulphur. It is reported that FYM is being a good source of calcium, magnesium and sulphur which increases secondary nutrient content of plots added with FYM. Whereas, application of NPK fertilizers alone showed lesser calcium and magnesium content due to replacement of calcium and magnesium by the H⁺ due to reduction of soil pH by application of fertilizers. That the increased availability of nutrients was due to improvement in soil physical, chemical and biological health through application of organic and inorganic fertilizers along with biofertilizer (Roy *et al.*, 2018).

4.6.5 Available micronutrient nutrients (Fe, Mn, Zn and Cu) of soil at different growth stages of finger millet.

The data on available iron, manganese, zinc and copper content of soil at different growth stages *viz.*, 30, 60, 90 DAS and at harvest of finger millet is presented in Table 4.22.

Application of bio-enriched FYM, levels of fertilizers and interaction (B×L) resulted in non-significant build-up in available micronutrients *viz.*, Fe, Mn, Zn and Cu at different growth stages of finger millet. However, among the treatments higher micronutrient content was recorded by conjugate use of bio-enriched FYM along with higher levels of fertilizers (B₄L₂: MC + 80 % RDF) over control and 100 per cent RDF.

Non- significant influence on micronutrient was recorded with application of bio-enriched FYM and levels of fertilizers. Availability of micronutrient greatly depend on pH and organic manure applied which increased availability of micronutrient through mineralization. As application of bio- enriched FYM with inorganic fertilizer has increased microbial activity in soil and the consequent release of complex organic substances would have prevented micronutrients loss from soil (Sushma, 2005). Similar result was observed by Shruthi (2014) in finger millet with application of FYM with P and K solubilizers.

4.6.6 Microbial biomass carbon, nitrogen and phosphorus in soil at different growth stages of finger millet.

The result of field experiment conducted to know the effect of bio- enriched FYM and levels of fertilizer on soil microbial biomass carbon, nitrogen and phosphorus at different growth stages are presented in Table 4.23, 4.24 and 4.25, respectively.

4.6.6.1 Microbial biomass carbon (MBC)

The microbial biomass carbon (MBC) observed was higher at 30 and 60 DAS compared to at 90 DAS and at harvest.

Application of different biofertilizers (B) and levels of fertilizers (L) resulted significantly higher microbial biomass carbon at 60 DAS. Among biofertilizer enriched FYM, higher microbial biomass carbon was recorded in microbial consortia (B₄: 410.05 $\mu\text{g g}^{-1}$) followed by KSB + PGPR (B₃). With respect to levels of fertilizers, application of 80 per cent RDF resulted in higher microbial biomass carbon (392.78 $\mu\text{g g}^{-1}$) at 60 DAS. Interaction effect between biofertilizers (B) and levels of fertilizers (L) was found non-significant (Fig. 4.10).

Table 4.22: Micronutrient nutrient status of soil at different growth stages of finger millet as influenced by different bio-enriched FYM and levels of fertilizers.

	DTPA extractable Iron (ppm)				DTPA extractable Manganese (ppm)				DTPA extractable Zinc (ppm)				DTPA extractable copper (ppm)			
	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest	30 DAS	60 DAS	90 DAS	At harvest
Factor 1: Biofertilizers enrichment (B)																
B₁: NFB + PGPR	9.05	9.11	8.94	8.89	9.15	9.29	8.97	8.87	0.88	0.89	0.85	0.81	0.90	0.91	0.89	0.84
B₂: PSB + PGPR	9.09	9.23	9.03	8.95	9.26	9.36	9.09	8.97	0.90	0.91	0.87	0.83	0.93	0.95	0.92	0.87
B₃: KSB + PGPR	9.11	9.27	9.10	8.98	9.31	9.40	9.13	8.99	0.90	0.92	0.88	0.84	0.94	0.96	0.93	0.88
B₄: MC	9.23	9.44	9.31	9.14	9.43	9.57	9.26	9.16	0.94	0.95	0.92	0.89	0.96	0.98	0.96	0.91
S.Em.±	0.14	0.15	0.20	0.20	0.15	0.26	0.25	0.22	0.02	0.03	0.02	0.02	0.02	0.02	0.03	0.02
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Factor 2: Levels of fertilizer (L)																
L₁:60 % RDF	9.07	9.20	9.03	8.92	9.22	9.33	9.05	8.94	0.89	0.90	0.86	0.83	0.92	0.94	0.92	0.87
L₂: 80 % RDF	9.16	9.32	9.16	9.06	9.36	9.47	9.17	9.05	0.92	0.94	0.90	0.86	0.94	0.96	0.93	0.88
S.Em.±	0.10	0.10	0.14	0.14	0.11	0.19	0.18	0.16	0.02	0.02	0.02	0.01	0.02	0.02	0.02	0.01
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (B × L)																
S.Em.±	0.20	0.21	0.28	0.28	0.22	0.37	0.35	0.32	0.03	0.04	0.03	0.03	0.03	0.03	0.03	0.04
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Treatments																
T₁-Control	8.70	8.48	8.24	8.21	8.82	8.55	8.46	8.33	0.82	0.80	0.76	0.74	0.87	0.83	0.78	0.75
T₂-100 % RDF	8.85	8.83	8.62	8.47	8.98	8.89	8.74	8.60	0.83	0.84	0.80	0.78	0.89	0.86	0.84	0.80
T₃-B₁L₁	9.01	9.04	8.90	8.81	9.06	9.21	8.91	8.82	0.86	0.88	0.84	0.80	0.89	0.90	0.88	0.83
T₄-B₁L₂	9.08	9.18	8.99	8.96	9.25	9.37	9.03	8.91	0.89	0.91	0.86	0.82	0.91	0.92	0.90	0.85
T₅-B₂L₁	9.04	9.17	8.96	8.87	9.16	9.28	9.02	8.90	0.88	0.89	0.85	0.81	0.92	0.93	0.91	0.86
T₆-B₂L₂	9.13	9.29	9.10	9.03	9.35	9.43	9.15	9.03	0.91	0.94	0.90	0.85	0.94	0.96	0.92	0.87
T₇-B₃L₁	9.06	9.20	8.99	8.88	9.25	9.33	9.06	8.93	0.88	0.89	0.85	0.82	0.93	0.94	0.92	0.87
T₈-B₃L₂	9.15	9.33	9.20	9.07	9.37	9.47	9.19	9.05	0.92	0.95	0.90	0.86	0.94	0.97	0.94	0.89
T₉-B₄L₁	9.19	9.40	9.28	9.10	9.40	9.51	9.21	9.11	0.93	0.94	0.91	0.88	0.95	0.97	0.95	0.91
T₁₀-B₄L₂	9.28	9.48	9.33	9.17	9.46	9.62	9.30	9.21	0.94	0.96	0.92	0.89	0.97	0.99	0.96	0.91
S.Em.±	0.21	0.21	0.28	0.30	0.23	0.33	0.32	0.29	0.03	0.05	0.04	0.04	0.03	0.05	0.04	0.03
CD @ 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

*100 per cent was added with 7.5 t ha⁻¹ of FYM, remaining treatments received 7.5 t ha⁻¹ of bio-enriched FYM.

NFB: Nitrogen fixing biofertilizers PSB: Phosphate solubilizing biofertilizers KSB: Potassium solubilizing biofertilizers PGPR: Plant growth promoting rhizobacteria MC: Microbial consortia

Similar was the trend among treatments at 60 DAS with highest microbial biomass carbon ($416.10 \mu\text{g g}^{-1}$) in T₁₀ (B₄L₂: MC+ 80 % RDF) and lowest ($146.67 \mu\text{g g}^{-1}$) microbial biomass carbon in T₁ (control).

4.6.6.2 Microbial biomass nitrogen (MBN)

Bio-enriched FYM with different biofertilizer enrichment (B) and levels of fertilizers (L) recorded higher microbial biomass nitrogen at 30 and 60 DAS compared to 90 DAS and at harvest.

Significantly higher value of microbial biomass nitrogen was recorded in B₄ ($47.84 \mu\text{g g}^{-1}$) and ($45.82 \mu\text{g g}^{-1}$) in L₂ (80 % RDF) at 60 DAS compared to other treatments. Among treatments, combination of B₄L₂ (MC+ 80 % RDF) resulted in higher microbial biomass nitrogen ($48.55 \mu\text{g g}^{-1}$) compared to other treatment combination. However, no significant result was obtained with interaction of biofertilizers (B) and levels of fertilizers (L) at all the different growth stages of finger millet (Fig. 4.10).

4.6.6.3 Microbial biomass phosphorus (MBP)

Similar was the trend with respect to microbial biomass phosphorus as in the case of microbial biomass carbon and microbial biomass nitrogen. There was significant increase from 30 DAS to 60 DAS, while it declined at later stages (90 DAS and at harvest).

Higher microbial biomass phosphorus ($12.32 \mu\text{g g}^{-1}$) was at 60 DAS in B₄ (MC) and ($10.76 \mu\text{g g}^{-1}$) in L₂ (80 % RDF). Similarly, the combination of B₄L₂ in treatment T₁₀ resulted in higher microbial biomass phosphorus ($12.60 \mu\text{g g}^{-1}$) than control ($3.99 \mu\text{g g}^{-1}$) (Fig. 4.11).

The increased microbial biomass with enriched FYM might be associated with the food source for the rapid multiplication of microbes. FYM being source for survival of microbes in soil, its application resulted in rapid multiplication and increased biomass. Microbial biomass carbon, nitrogen and phosphorus was found higher with application of bio- enriched FYM, enriched with MC consisting of NFB, PSB, KSB and PGPR and it was found higher at 60 DAS there after decreased eventually. Increase at 60 DAS may be due

Table 4.23: Microbial biomass carbon ($\mu\text{g g}^{-1}$) at different growth stages of finger millet as influenced by different bio-enriched FYM and levels of fertilizers.

	30 DAS	60 DAS	90 DAS	Harvest
Factor 1: Biofertilizers enrichment (B)				
B₁: NFB + PGPR	345.55	376.22	287.90	235.00
B₂: PSB + PGPR	336.60	371.65	282.00	232.10
B₃: KSB + PGPR	332.60	365.50	273.60	226.15
B₄: MC	363.10	410.05	306.95	261.35
S.Em.±	6.53	8.27	7.11	4.89
CD @ 5 %	19.81	25.08	21.56	14.83
Factor 2: Levels of fertilizers (L)				
L₁:60 % RDF	333.35	368.93	276.53	229.50
L₂: 80 % RDF	355.58	392.78	298.70	247.80
S.Em.±	4.62	5.85	5.03	3.46
CD @ 5 %	14.01	17.74	15.25	10.49
Interaction (B× L)				
S.Em.±	9.24	11.69	10.05	6.91
CD @ 5 %	NS	NS	NS	NS
Treatments				
T₁-Control	122.30	146.67	125.60	104.60
T₂-100 % RDF	178.40	218.30	181.60	132.60
T₃-B₁L₁	334.60	361.23	277.40	226.40
T₄-B₁L₂	356.50	391.20	298.40	243.60
T₅-B₂L₁	320.60	357.60	269.40	222.60
T₆-B₂L₂	352.60	385.70	294.60	241.60
T₇-B₃L₁	316.60	352.90	256.80	214.70
T₈-B₃L₂	348.60	378.10	290.40	237.60
T₉-B₄L₁	361.60	404.00	302.50	254.30
T₁₀-B₄L₂	364.60	416.10	311.40	268.40
S.Em.±	8.44	12.12	9.00	6.17
CD @ 5 %	25.09	36.01	26.74	18.33

*100 per cent was added with 7.5 t ha⁻¹ of FYM, remaining treatments received 7.5 t ha⁻¹ of bio-enriched FYM.

NFB: Nitrogen fixing biofertilizers

PSB: Phosphate solubilizing biofertilizers

KSB: Potassium solubilizing biofertilizers

PGPR: Plant growth promoting rhizobacteria

MC: Microbial consortia

Table 4.24: Microbial biomass nitrogen ($\mu\text{g g}^{-1}$) at different growth stages of finger millet as influenced by different bio-enriched FYM and levels of fertilizers.

	30 DAS	60 DAS	90 DAS	Harvest
Factor 1: Biofertilizers enrichment (B)				
B₁: NFB + PGPR	40.31	43.89	33.59	27.42
B₂: PSB + PGPR	39.27	43.36	32.90	27.08
B₃: KSB + PGPR	38.80	42.64	31.92	26.38
B₄: MC	42.54	47.84	35.81	30.49
S.Em.±	0.79	0.96	0.83	0.57
CD @ 5 %	2.39	2.93	2.52	1.73
Factor 2: Levels of fertilizers (L)				
L₁:60 % RDF	38.98	43.04	32.26	26.78
L₂: 80 % RDF	41.48	45.82	34.85	28.91
S.Em.±	0.56	0.68	0.59	0.40
CD @ 5 %	1.69	2.07	1.78	1.22
Interaction (B× L)				
S.Em.±	1.08	1.36	1.17	0.81
CD @ 5 %	NS	NS	NS	NS
Treatments				
T₁-Control	14.27	17.11	14.65	12.20
T₂-100 % RDF	20.81	25.47	21.19	15.47
T₃-B₁L₁	39.04	42.14	32.36	26.41
T₄-B₁L₂	41.59	45.64	34.81	28.42
T₅-B₂L₁	37.40	41.72	31.43	25.97
T₆-B₂L₂	41.14	45.00	34.37	28.19
T₇-B₃L₁	36.94	41.17	29.96	25.05
T₈-B₃L₂	40.67	44.11	33.88	27.72
T₉-B₄L₁	42.19	47.13	35.29	29.67
T₁₀-B₄L₂	42.54	48.55	36.33	31.31
S.Em.±	0.99	1.41	1.05	0.72
CD @ 5 %	2.93	4.20	3.12	2.14

*100 per cent was added with 7.5 t ha⁻¹ of FYM, remaining treatments received 7.5 t ha⁻¹ of bio-enriched FYM.

NFB: Nitrogen fixing biofertilizers

PSB: Phosphate solubilizing biofertilizers

KSB: Potassium solubilizing biofertilizers

PGPR: Plant growth promoting rhizobacteria

MC: Microbial consortia

Table 4.25: Microbial biomass phosphorus ($\mu\text{g g}^{-1}$) at different growth stages of finger millet as influenced by different bio-enriched FYM and levels of fertilizers.

	30 DAS	60 DAS	90 DAS	Harvest
Factor 1: Biofertilizers enrichment (B)				
B₁: NFB + PGPR	7.50	8.75	8.11	7.43
B₂: PSB + PGPR	9.05	10.19	9.67	8.94
B₃: KSB + PGPR	8.23	9.72	9.24	8.47
B₄: MC	9.61	12.32	11.25	10.26
S.Em.±	0.18	0.27	0.32	0.29
CD @ 5 %	0.55	0.82	0.98	0.87
Factor 2: Levels of fertilizers (L)				
L₁: 60 % RDF	8.40	9.73	8.95	8.35
L₂: 80 % RDF	8.80	10.76	10.18	9.20
S.Em.±	0.13	0.19	0.23	0.20
CD @ 5 %	0.39	0.58	0.69	0.62
Interaction (B× L)				
S.Em.±	0.25	0.38	0.46	0.41
CD @ 5 %	NS	NS	NS	NS
Treatments				
T₁-Control	3.87	3.99	3.34	3.11
T₂-100 % RDF	4.90	5.30	5.01	4.68
T₃-B₁L₁	7.20	8.23	7.40	7.01
T₄-B₁L₂	7.80	9.27	8.83	7.84
T₅-B₂L₁	8.90	9.43	9.08	8.36
T₆-B₂L₂	9.20	10.95	10.25	9.52
T₇-B₃L₁	7.90	9.23	8.60	7.94
T₈-B₃L₂	8.57	10.20	9.88	8.99
T₉-B₄L₁	9.60	12.03	10.73	10.09
T₁₀-B₄L₂	9.62	12.60	11.77	10.43
S.Em.±	0.22	0.35	0.41	0.36
CD @ 5 %	0.67	1.03	1.22	1.08

*100 per cent was added with 7.5 t ha⁻¹ of FYM, remaining treatments received 7.5 t ha⁻¹ of bio-enriched FYM.

NFB: Nitrogen fixing biofertilizers

PSB: Phosphate solubilizing biofertilizers

KSB: Potassium solubilizing biofertilizers

PGPR: Plant growth promoting rhizobacteria

MC: Microbial consortia

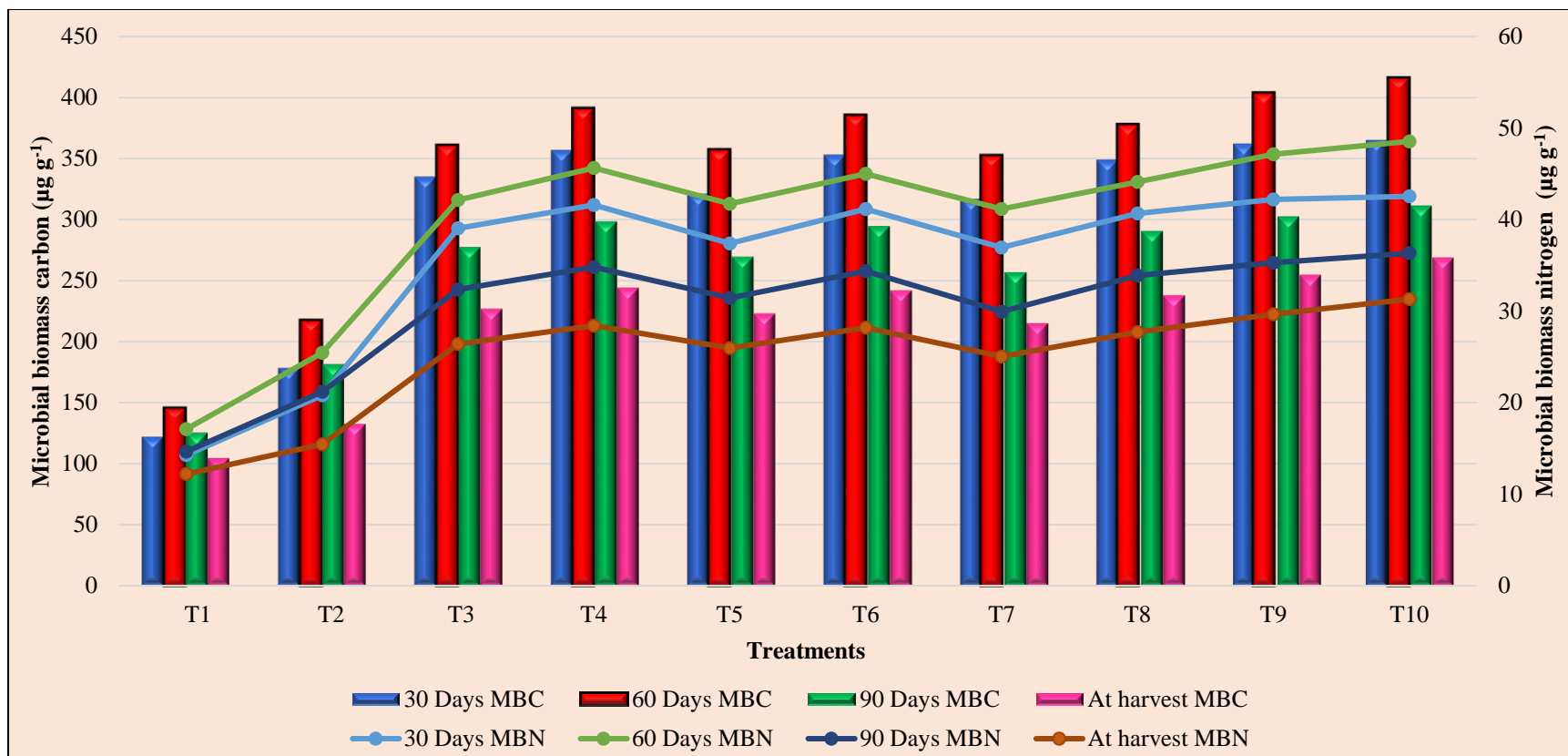


Fig. 4.10: Bio- enriched FYM and different levels of fertilizers on microbial biomass carbon ($\mu\text{g g}^{-1}$) and microbial biomass nitrogen ($\mu\text{g g}^{-1}$) of finger millet at different growth stages

Treatment details:

T₁: Absolute control

T₂: 7.5 t ha⁻¹ FYM + 100 % RDF

T₃: 7.5 t ha⁻¹ enriched FYM (NFB + PGPR) + 60 % RDF

T₄: 7.5 t ha⁻¹ enriched FYM (NFB + PGPR) + 80 % RDF

T₅: 7.5 t ha⁻¹ enriched FYM (PSB + PGPR) + 60 % RDF

T₆: 7.5 t ha⁻¹ enriched FYM PSB+ PGPR) + 80 % RDF

T₇: 7.5 t ha⁻¹ enriched FYM (KSB + PGPR) + 60 % RDF

T₈: 7.5 t ha⁻¹ enriched FYM (KSB+ PGPR) + 80 % RDF

T₉: 7.5 t ha⁻¹ enriched FYM (MC) + 60 % RDF

T₁₀: 7.5 t ha⁻¹ enriched FYM (MC) + 80 % RDF

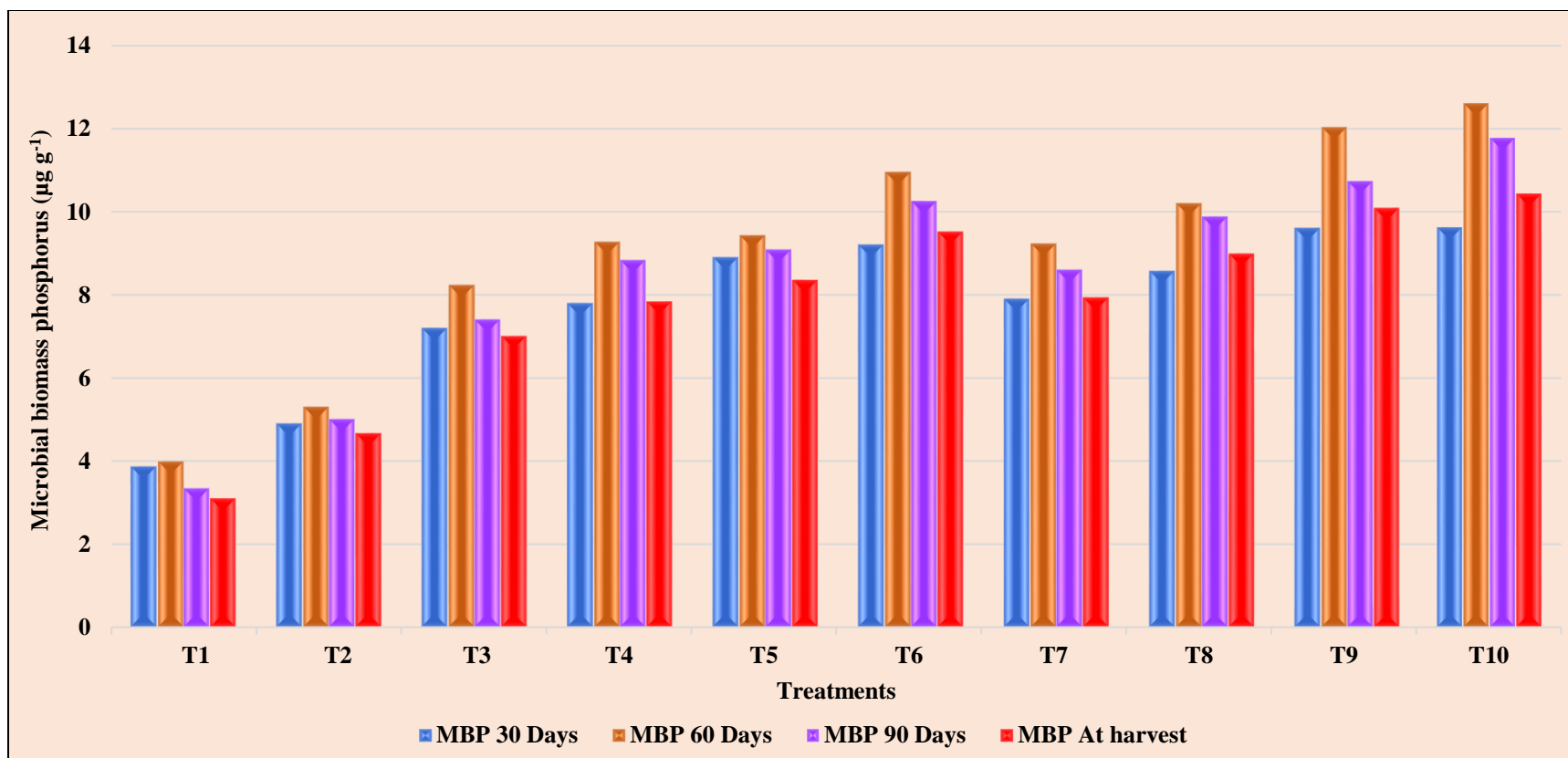


Fig. 4.11: Bio- enriched FYM and different levels of fertilizers on microbial biomass phosphorus ($\mu\text{g g}^{-1}$) of finger millet at different growth stages.

Treatment details:

T₁: Absolute control

T₂: 7.5 t ha⁻¹ FYM + 100 % RDF

T₃: 7.5 t ha⁻¹ enriched FYM (NFB + PGPR) + 60 % RDF

T₄: 7.5 t ha⁻¹ enriched FYM (NFB + PGPR) + 80 % RDF

T₅: 7.5 t ha⁻¹ enriched FYM (PSB + PGPR) + 60 % RDF

T₆: 7.5 t ha⁻¹ enriched FYM (PSB + PGPR) + 80 % RDF

T₇: 7.5 t ha⁻¹ enriched FYM (KSB + PGPR) + 60 % RDF

T₈: 7.5 t ha⁻¹ enriched FYM (KSB + PGPR) + 80 % RDF

T₉: 7.5 t ha⁻¹ enriched FYM (MC) + 60 % RDF

T₁₀: 7.5 t ha⁻¹ enriched FYM (MC) + 80 % RDF

to increased root exudation during flowering stage and increased microbial population in rhizosphere (Yuvaraj, 2016).

Manjaiah and Singh (2001) reported an increase of MBC by combined application of FYM and mineral N-fertilizer in a semiarid Cambisol. This observation is in agreement with that of Hopkins and Shiel (1996), who reported that the MBC was greater in soils receiving annual additions of FYM for nearly 100 years in addition to inorganic NPK. However, in a different study, a significant increase in MBC was found only in soils fertilized with compost, while treatment with mineral fertilizers was characterized by lesser MBC, as small as in the control soil (Grego *et al.*, 1998). Similar result was observed by Saha *et al.* (2010) where application of FYM, biofertilizers along with inorganic fertilizers increased MBC, MBN and MBP compared to inorganic fertilizers alone. Similarly, Dhopavkar (2018) found increase in MBC and MBN at different interval compared to uninoculated treatments.

4.6.7 Soil enzymatic activity

Application of bio-enriched FYM and levels of fertilizer influenced the soil enzymatic activity viz., dehydrogenase, urease and acid phosphatase, the results are presented in Table 4.26 and 4.27.

4.6.7.1 Dehydrogenase activity at different growth stages

Among different biofertilizers, application of microbial consortia (B₄) recorded significantly higher dehydrogenase activity (61.52, 74.57, 59.01 and 45.86 $\mu\text{g TPF g}^{-1}$ soil 24 h⁻¹), followed by NFB+ PGPR (53.78, 67.66, 51.76 and 38.80 $\mu\text{g TPF g}^{-1}$ soil 24 h⁻¹) at 30, 60, 90 DAS and at harvest, respectively.

Application of 80 per cent RDF (55.00, 68.71, 52.81 and 40.40 $\mu\text{g TPF g}^{-1}$ soil 24 h⁻¹) recorded higher dehydrogenase activity compared to 60 per cent RDF (48.24, 62.79, 46.39 and 35.21 $\mu\text{g TPF g}^{-1}$ soil 24 h⁻¹) at 30, 60, 90 DAS and at harvest, respectively.

Interaction was found non-significant. Among different treatments, significantly higher MBN was recorded with application of MC + 80 per cent RDF (T₁₀: 64.30, 75.85,

61.45 and 47.88 $\mu\text{g TPF g}^{-1}$ soil 24 h^{-1}), followed by MC + 60 per cent RDF (T_9 : 58.74, 73.29, 56.56 and 43.83 $\mu\text{g TPF g}^{-1}$ soil 24 h^{-1}) and least in absolute control (T_1 : 14.63, 26.85, 10.45 and 8.12 $\mu\text{g g}^{-1}$) at 30, 60, 90 DAS and at harvest, respectively (Fig 4.12).

The enzyme activity in soil is considered as an index of microbial activity, which is influenced by nature, age of crop and addition of fertilizers and manures. The presence of microorganisms in soil depends on chemical composition, moisture, pH, and structure. The transformation of nutrients to available forms. The dehydrogenase activity is proposed as the best indicator of microbiological redox system, which is considered as good and adequate parameter of microbial oxidative action in soil. It was found higher with application of microbial consortia and it was positively correlated with increased fertilizer level. The higher dehydrogenase activity observed with application of microbial consortia was due to the combination of microorganisms which increased nitrogen fixation, mineralization and solubilization of nutrient and in turn increased microbial population in soil. The result is in line with Yuvaraj (2016) who reported that more organic carbon content in soil and higher microbial population which cause greater dehydrogenase activity and it is positively correlated with microbial biomass. While, Khipla (2017) showed greater biological activity due to microbial consortia and presence of inorganic fertilizers favoured higher dehydrogenase activity.

4.6.7.2 Urease activity at harvest

Among different biofertilizers, urease activity in soil significantly increased in order of MC ($29.09 \mu\text{g NH}_4\text{-N g}^{-1}$ soil h^{-1}) > NFB+ PGPR ($27.66 \mu\text{g NH}_4\text{-N g}^{-1}$ soil h^{-1}) > KSB+PGPR ($24.71 \mu\text{g NH}_4\text{-N g}^{-1}$ soil h^{-1}) > PSB+ PGPR ($22.91 \mu\text{g NH}_4\text{-N g}^{-1}$ soil h^{-1}).

Application of 80 per cent RDF recorded higher urease activity ($26.91 \mu\text{g NH}_4\text{-N g}^{-1}$ soil h^{-1}) in soil than 60 per cent RDF ($25.27 \mu\text{g NH}_4\text{-N g}^{-1}$ soil h^{-1}) at harvest.

Interaction of different biofertilizers and levels fertilizers was found non-significant. Whereas, among different treatments significantly higher urease activity in soil was observed in T_{10} ($29.20 \mu\text{g NH}_4\text{-N g}^{-1}$ soil h^{-1}) and was on par with T_9 treatment which received MC + 60 per cent RDF ($28.98 \mu\text{g NH}_4\text{-N g}^{-1}$ soil h^{-1}), while it was lower ($16.05 \mu\text{g NH}_4\text{-N g}^{-1}$ soil h^{-1}) in absolute control.

Table 4.26: Dehydrogenase activity ($\mu\text{g TPF g}^{-1} \text{ soil } 24 \text{ h}^{-1}$) at different growth stages of finger millet as influenced by different bio-enriched FYM and levels of fertilizers.

	30 DAS	60 DAS	90 DAS	Harvest
Factor 1: Biofertilizers enrichment (B)				
B₁: NFB + PGPR	53.78	67.66	51.76	38.80
B₂: PSB + PGPR	44.86	59.91	43.01	32.30
B₃: KSB + PGPR	46.32	60.87	44.64	34.25
B₄: MC	61.52	74.57	59.01	45.86
S.Em.±	1.82	1.61	1.84	1.37
CD @ 5 %	5.51	4.89	5.60	4.16
Factor 2: Levels of fertilizers (L)				
L₁:60 % RDF	48.24	62.79	46.39	35.21
L₂: 80 % RDF	55.00	68.71	52.81	40.40
S.Em.±	1.28	1.14	1.30	0.97
CD @ 5 %	3.90	3.46	3.96	2.94
Interaction (B× L)				
S.Em.±	2.57	2.28	2.61	1.94
CD @ 5 %	NS	NS	NS	NS
Treatments				
T₁-Control	14.63	26.85	10.45	8.12
T₂-100 % RDF	22.65	34.20	27.80	14.56
T₃-B₁L₁	50.63	65.18	49.78	35.90
T₄-B₁L₂	56.92	70.14	53.74	41.70
T₅-B₂L₁	40.30	54.85	38.45	29.70
T₆-B₂L₂	49.41	64.96	47.56	34.90
T₇-B₃L₁	43.30	57.85	40.78	31.40
T₈-B₃L₂	49.35	63.90	48.50	37.10
T₉-B₄L₁	58.74	73.29	56.56	43.83
T₁₀-B₄L₂	64.30	75.85	61.45	47.88
S.Em.±	2.28	2.83	2.30	1.72
CD @ 5 %	6.78	8.40	6.84	5.10

*100 per cent was added with 7.5 t ha⁻¹ of FYM, remaining treatments received 7.5 t ha⁻¹ of bio-enriched FYM.

NFB: Nitrogen fixing biofertilizers

PSB: Phosphate solubilizing biofertilizers

KSB: Potassium solubilizing biofertilizers

PGPR: Plant growth promoting rhizobacteria

MC: Microbial consortia

Microorganisms provide living environment to soil and perform various function like urea added as a source of nitrogen needs urease enzyme that aids in breakdown of urea and thereby increase plant available nitrogen, the activity was found higher with application of MC with higher 80 per cent RDF. Deepthi (2018) cited that soil microorganisms produce urease and secrete it into soil as and when urea is added to soil, thus supports higher urease activity of the soils under agriculture system. The study by Smith and Powlson (2003) showed that the presence of added nitrogen source acts as readily available N pool stimulates the urease activity. Similar result was observed by Kumar *et al.* (2017) and Dhopavkar (2018).

4.6.7.3 Acid phosphatase activity at harvest

Significantly higher acid phosphatase activity in soil, 37.04, 34.30, 31.98 and 31.15 $\mu\text{g pNP g}^{-1} \text{ soil h}^{-1}$ was observed with application of microbial consortia (MC), PSB + PGPR, KSB+PGPR and NFB+PGPR, respectively.

Among different inorganic levels, application of 80 per cent RDF recorded significantly higher acid phosphatase activity ($34.76 \mu\text{g pNP g}^{-1} \text{ soil h}^{-1}$) in soil than 60 per cent RDF ($32.48 \mu\text{g pNP g}^{-1} \text{ soil h}^{-1}$).

The interaction of different biofertilizers and levels of fertilizers recorded non-significant effect on acid phosphatase activity at harvest. Application of MC + 80 per cent RDF (T_{10}) recorded significantly higher acid phosphatase activity ($37.65 \mu\text{g pNP g}^{-1} \text{ soil h}^{-1}$), which was on par with urease activity ($36.43 \mu\text{g pNP g}^{-1} \text{ soil h}^{-1}$) in T_9 treatment (B_4L_1 : MC + 60 % RDF) and least activity ($13.17 \mu\text{g pNP g}^{-1} \text{ soil h}^{-1}$) was observed in absolute control.

Phosphatase enzyme catalyse the hydrolysis of organic phosphorus and increase the availability of inorganic phosphorus for plant uptake and found higher with application of MC, followed by PSB. Similar result was found by Shruthi (2014) with application of 100 per cent RDF + P and K solubilizers compared to 100 per cent RDF alone in finger millet. Yuvaraj (2016) cited that treatment having integrated application of consortium

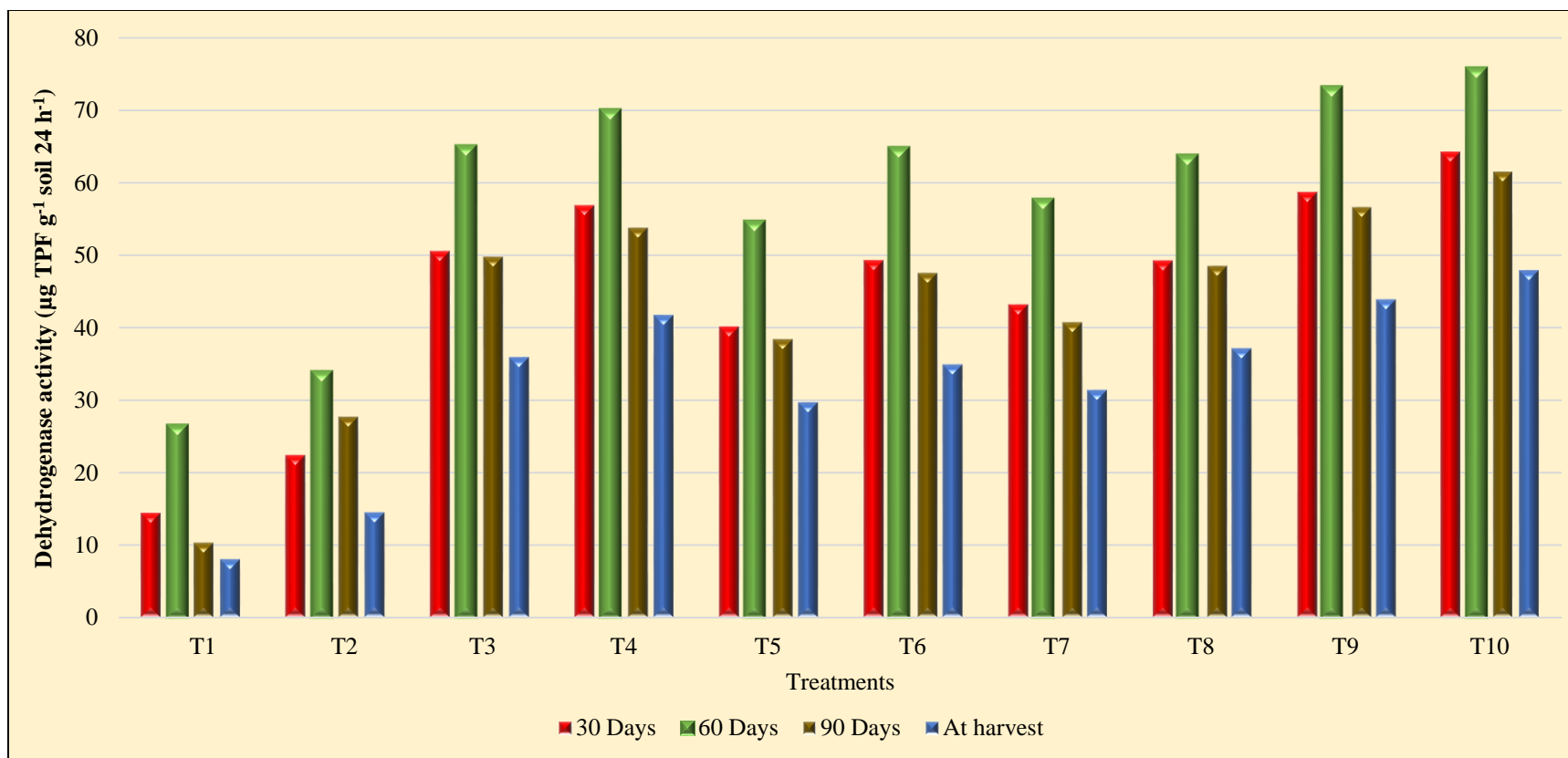


Fig. 4.12: Bio- enriched FYM and different levels of fertilizers on dehydrogenase activity ($\mu\text{g TPF g}^{-1} \text{ soil } 24 \text{ h}^{-1}$) of finger millet at different growth stages.

Treatment details:

T₁: Absolute control

T₂: 7.5 t ha⁻¹ FYM + 100 % RDF

T₃: 7.5 t ha⁻¹ enriched FYM (NFB + PGPR) + 60 % RDF

T₄: 7.5 t ha⁻¹ enriched FYM (NFB + PGPR) + 80 % RDF

T₅: 7.5 t ha⁻¹ enriched FYM (PSB + PGPR) + 60 % RDF

T₆: 7.5 t ha⁻¹ enriched FYM PSB+ PGPR) + 80 % RDF

T₇: 7.5 t ha⁻¹ enriched FYM (KSB + PGPR) + 60 % RDF

T₈: 7.5 t ha⁻¹ enriched FYM (KSB+ PGPR) + 80 % RDF

T₉: 7.5 t ha⁻¹ enriched FYM (MC) + 60 % RDF

T₁₀: 7.5 t ha⁻¹ enriched FYM (MC) + 80 % RDF

Table 4.27: Urease ($\mu\text{g NH}_4\text{- N g}^{-1}\text{ soil h}^{-1}$) and acid phosphatase ($\mu\text{g PNP g}^{-1}\text{ soil h}^{-1}$) activity at harvest of finger millet as influenced by different bio-enriched FYM and levels of fertilizers.

	Urease ($\mu\text{g NH}_4\text{- N g}^{-1}\text{ soil h}^{-1}$)	Acid phosphatase ($\mu\text{g PNP g}^{-1}\text{ soil h}^{-1}$)
Factor 1: Biofertilizers enrichment (B)		
B₁: NFB + PGPR	27.66	31.15
B₂: PSB + PGPR	22.91	34.30
B₃: KSB + PGPR	24.71	31.98
B₄: MC	29.09	37.04
S.Em.±	0.54	0.73
CD @ 5 %	1.62	2.21
Factor 2: Levels of fertilizers (L)		
L₁: 60 % RDF	25.27	32.48
L₂: 80 % RDF	26.91	34.76
S.Em.±	0.38	0.52
CD @ 5 %	1.15	1.56
Interaction (B× L)		
S.Em.±	0.76	1.03
CD @ 5 %	NS	NS
Treatments		
T₁-Control	16.05	13.17
T₂-100 % RDF	20.13	19.37
T₃-B₁L₁	27.11	29.97
T₄-B₁L₂	28.21	32.34
T₅-B₂L₁	21.18	32.94
T₆-B₂L₂	24.64	35.66
T₇-B₃L₁	23.81	30.59
T₈-B₃L₂	25.61	33.38
T₉-B₄L₁	28.98	36.43
T₁₀-B₄L₂	29.20	37.65
S.Em.±	0.79	1.06
CD @ 5 %	2.35	3.14

*100 per cent was added with 7.5 t ha⁻¹ of FYM, remaining treatments received 7.5 t ha⁻¹ of bio-enriched FYM.

NFB: Nitrogen fixing biofertilizers

PSB: Phosphate solubilizing biofertilizers

KSB: Potassium solubilizing biofertilizers

PGPR: Plant growth promoting rhizobacteria

MC: Microbial consortia

biofertilizer with inorganic fertilizer recorded higher phosphatase activity compared to control.

4.6.8 Correlation of biological properties with chemical properties of soil at different growth stages of finger millet.

There was significant positive correlation ($p= 0.01$) found between microbial biomass carbon and soil available nitrogen ($r= 0.68^{**}$, 0.80^{**} , 0.76^{**} and 0.72^{**}) at 30, 60, 90 DAS and at harvest of finger millet, respectively. Same trend was also noticed with organic carbon content ($r= 0.51^{**}$, 0.57^{**} and 0.55^{**}) at 60, 90 DAS and at harvest, respectively except at 30 DAS (Table 4.28).

Table 4.28: Correlation matrix of biological properties with soil available nutrient status at different growth stages of finger millet as influenced by different bio-enriched FYM and levels of fertilizers.

Correlation				
	30 DAS	60 DAS	90 DAS	Harvest
MBC Vs. Avail. N	0.68**	0.80**	0.76**	0.72**
MBP Vs. Avail. P	0.59**	0.66**	0.71**	0.72**
MBC Vs. OC	0.15	0.51**	0.57**	0.55**
DHS Vs. Avail. N	0.71**	0.81**	0.84**	0.76**
Urease activity Vs. Avail. N	-	-	-	0.73**
Phosphatase activity Vs. avail. P₂O₅	-	-	-	0.72**

Note: **. Correlation is significant at $p= 1$ per cent.

Microbial biomass phosphorus showed significant and positive correlation ($p= 0.01$) with available phosphorus ($r= 0.59^{**}$, 0.66^{**} , 0.71^{**} and 0.72^{**}) at 30, 60, 90 DAS and at harvest, respectively.

With respect to enzymatic activity, there was significant positive correlation ($p= 0.01$) between dehydrogenase activity and available nitrogen ($r= 0.71^{**}$, 0.81^{**} ,

0.84** and 0.76**) at 30, 60, 90 DAS and at harvest, respectively which clearly indicates as microbial activity increases, available nitrogen status in soil increases.

Urease activity was significant and positively correlated ($p= 0.01$) with available nitrogen (0.73**) and phosphatase activity was correlated positively with available phosphorus (0.72**) at harvest stage of finger millet. This clearly indicates that as microbial activity increased in soil, considerably available nutrient status also increased.

Enzymes play a key role in biochemical process of organic matter decomposition in soil (Sinsabaugh *et al.*, 1991). They are important in catalysing several vital reactions necessary for life processes of organisms in soil and stabilization of structure. Enzyme levels in soil vary due to soil type, quantity of organic matter, composition and activity of microorganisms. In practice biochemical reaction are brought about largely through the catalytic contribution of enzyme and presence of substrate that serve as energy sources for microorganisms Shukla and Varma (2011), Geeta Singh *et al.* (2015) support this finding and stated that addition of enriched FYM increased activity of microorganisms and enzymes.

4.6.9 Correlation of nitrogen, Phosphorus and potassium content in plant with soil nutrient availability at different growth stages of finger millet.

Soil nutrient status is one of the indicators for measuring soil fertility the availability of nutrient for plant growth. It is in this context, the correlations between soil nutrient status and the plant nutrient content under different treatments applied to finger millet were studied and data is given in Table 4.29. Correlation studies revealed significant positive correlation between plant nutrient content and soil available nutrients at different growth stages in the case of N ($r= 0.54^{**}$, 0.66^{**} and 0.70^{**}), P ($r= 0.46^{*}$, 0.52^{**} and 0.61^{**}), K ($r=0.69^{**}$, 0.70^{**} and 0.57^{**}) at 30, 60 and 90 DAS respectively. Similarly, grain and straw nitrogen (0.57^{**} and 0.78^{**} , respectively), phosphorus (0.47^{*} and 0.73^{**} , respectively) and potassium (0.47^{**} and 0.67^{**} , respectively) content were significantly and positively correlated. This indicated that the plant nutrient content viz., N, P, K, increased in different growth stages and was better reflected by increase soil nutrient status at $p < 0.01$.

Table 4.29: Correlation matrix of nitrogen, phosphorus and potassium content and soil available nutrient status at different stages of finger millet as influenced by different bio-enriched FYM and levels of fertilizers.

Correlation					
Content / availability	30 DAS	60 DAS	90 DAS	At harvest	
				Grain	Straw
Nitrogen	0.54**	0.66**	0.70**	0.57**	0.78**
Phosphorus	0.46*	0.52**	0.61**	0.47*	0.73**
Potassium	0.69**	0.70**	0.57**	0.47**	0.67**

Note: ** Correlation is significant at $p = 1$ per cent. *Correlation is significant at $p = 5$ per cent.

4.7 Effect of bio- enriched FYM and different levels of fertilizers on economics of finger millet at harvest.

The effect of bio-enriched FYM and levels of fertilizers on cost of cultivation, gross return, net return and B: C ratio at harvest are presented in Table 4.30.

4.7.1 Cost of cultivation

Among different treatments cost of cultivation was found lower in absolute control (Rs. 13038) and higher cost of cultivation (Rs. 27692) was observed in treatment which received NFB+ PGPR + 80 per cent RDF (T₄), PSB+ PGPR + 80 per cent RDF (T₆) and KSB + PGPR + 80 per cent RDF (T₈).

4.7.2 Gross return

Application of MC + 80 per cent RDF (T₁₀) recorded higher gross return (Rs. 90373) and lower (Rs. 33975) was observed in absolute control (T₁).

4.7.3 Net return

Application of MC + 80 per cent RDF (T₁₀) recorded higher net return (Rs. 62981), followed by MC + 60 per cent RDF (Rs. 60606) (T₉) and least (Rs. 20937) was observed in absolute control (T₁).

4.7.4 B: C ratio

Among different treatments higher B: C ratio (2.30) was observed in MC + 80 per cent RDF (T₁₀), followed by MC+ 60 per cent RDF (T₉) (2.24) and least (1.61) was observed in absolute control (T₁).

Higher level of biomass accumulation and efficient translocation to the reproductive parts due to supply of adequate nutrients might be responsible for greater yield. Which resulted in higher monetary returns and B: C ratio (Roy *et al.*, 2018). The differences in the B: C ratio is attributed to yield differences and varying costs when different organic manures were added. It is evident that organic manures such as FYM and bio compost can be used in combination for more profitable income (Thumar *et al.*, 2016).

Table 4.30: Economics of finger millet as influenced by different bio-enriched FYM and levels of fertilizers.

Treatments	Cost of cultivation (Rs.)	Gross returns (Rs.)	Net returns (Rs.)	B: C ratio
T₁-Control	13038	33975	20937	1.61
T₂-100 % RDF	27171	76237	49066	1.81
T₃-B₁L₁	27313	78498	51185	1.87
T₄-B₁L₂	27692	84109	56417	2.04
T₅-B₂L₁	27313	78636	51323	1.88
T₆-B₂L₂	27692	84672	56980	2.06
T₇-B₃L₁	27313	79437	52124	1.91
T₈-B₃L₂	27692	85560	57868	2.09
T₉-B₄L₁	27013	87619	60606	2.24
T₁₀-B₄L₂	27392	90373	62981	2.30

*100 per cent was added with 7.5 t ha⁻¹ of FYM, remaining treatments received 7.5 t ha⁻¹ of bio-enriched FYM.

NFB: Nitrogen fixing biofertilizers

PSB: Phosphate solubilizing biofertilizers

KSB: Potassium solubilizing biofertilizers

PGPR: Plant growth promoting rhizobacteria

MC: Microbial consortia



Plate 6: Comparison between treatment combination



Air drying of soil



Keen- Raczowski cup method



Acid Phosphatase analysis



Microbial biomass carbon and nitrogen analysis



Dehydrogenase activity



Soil phosphorus analysis

Plate 7: Soil sample preparation and analysis

V SUMMARY

A field experiment entitled “Studies on bio-enriched farm yard manure (FYM) on soil properties and productivity of finger millet (*Eleusine coracana* (L.) Gaertn) under dryland condition” was conducted during *khariif*-2019 at AICRP for Dry Land Agriculture, UAS, GKVK, Bengaluru – 65 is summarized hereunder.

The experiment was conducted in randomized complete block design (RCBD) with three replications. FYM bio-enriched with N fixers (*Azotobacter chroococcum*), P solubilizer (*Bacillus megaterium*), K solubilizers (*Frateruria aurantia*), Microbial consortia and PGPR (*Pseudomonas fluorescens*) was applied in combination with two levels of fertilizers, 60 and 80 per cent RDF.

Taller plant height (28.76, 86.38, 111.52 and 115.33 cm) was observed with application of MC+ 80 per cent RDF (T₁₀), while shorter plants were in control (16.30, 46.30, 55.42 and 57.79 cm) at 30, 60, 90 DAS and at harvest, respectively, plant height showed significant difference at 60, 90 DAS and at harvest.

Higher number of tillers hill⁻¹ (1.94, 4.42, 5.20 and 5.42) was found with application of MC+ 80 per cent RDF (T₁₀) and was on par with MC + 60 per cent RDF (T₉) (1.90, 4.35, 5.12 and 5.33) at 30, 60, 90 DAS and at harvest, respectively. Application of different biofertilizers and levels of fertilizers showed significant influence at all growth stages of finger millet, except at 30 DAS.

Among different biofertilizers enriched FYM and levels of fertilizers, application of microbial consortia (5.40, 14.87 and 26.93 g plant⁻¹) and 80 per cent RDF (5.22, 14.34 and 26.20 g plant⁻¹) resulted in significantly higher dry matter production plant⁻¹ at 60, 90 DAS and at harvest, respectively.

Yield attributes such as number of ear heads per hill (5.13), number of fingers per ear head (6.77), 1000 grain weight (3.25 g) was found maximum in T₁₀ with application of MC+ 80 per cent RDF (T₁₀) and minimum number of ear heads per plant (3.33), number of fingers per ear head (4.90) and 1000 grain weight (2.47 g) was in control.

Among different biofertilizers, application of MC recorded significantly higher grain (2952 kg ha^{-1}) and straw (4228 kg ha^{-1}) yield, followed by KSB + PGPR (2733 and 3991 kg ha^{-1} , respectively). Similarly, application of 80 per cent RDF resulted in higher grain (2857 kg ha^{-1}) and straw (4130 kg ha^{-1}) yield compared to 60 per cent RDF (2686 and 3901 kg ha^{-1} , respectively).

Among different treatments significantly higher content of nitrogen (1.48 and 1.13 %), phosphorus (0.27 and 0.25 %) and potassium (1.27 and 1.05 %) at 60 and 90 DAS was found in T_{10} consisting of MC+ 80 per cent RDF and lower nitrogen (1.09 and 0.72 %), phosphorus (0.14 and 0.11 %) and potassium (0.98 and 0.77 %) at 60 and 90 DAS, respectively in control. The major nutrient content at 30 DAS was found non-significant. Similarly, higher NPK in grain (1.38, 0.38 and 0.59 %, respectively) and straw (0.69, 0.24 and 0.99 %, respectively) was found in T_{10} (MC+ 80 % RDF) compared to T_1 (control).

Non-significant effect on major nutrient uptake was found at 30 DAS. Whereas, in case of different biofertilizers, application of MC recorded significantly higher nitrogen (20.99 , 43.50 and 68.38 kg ha^{-1}), phosphorus (3.76 , 9.42 and 20.51 kg ha^{-1}) and potassium (17.88 , 40.79 and 58.32 kg ha^{-1}) at 60, 90 DAS and at harvest, respectively. In case of different levels of fertilizers, application of 80 per cent RDF observed significantly higher nitrogen (19.42 , 39.06 and 61.63 kg ha^{-1}), phosphorus (3.29 , 8.29 and 18.03 kg ha^{-1}) and potassium (16.58 , 37.49 and 54.82 kg ha^{-1}) at 60, 90 DAS and at harvest, respectively compared to 60 per cent RDF.

Among different treatments, significantly higher content of calcium (0.41 %), magnesium (0.30 %) and sulphur (0.44 %) was in T_{10} (MC+ 80 % RDF) compared to control (T_1) at 60 DAS.

Application of MC+ 80 per cent RDF (T_{10}) recorded significantly higher calcium (1.31 , 6.08 , 14.07 and 24.96 kg ha^{-1}), magnesium (0.91 , 4.35 , 10.91 and 17.13 kg ha^{-1}) and sulphur (1.46 , 6.36 , 15.48 and 22.25 kg ha^{-1}) at 30, 60, 90 DAS and at harvest, respectively, followed by MC+ 60 per cent RDF (T_9).

Micronutrient content was found non-significant at 30, 60, 90 DAS and at harvest, except manganese at harvest.

With respect to micronutrients, uptake of iron (21.17, 96.91, 224.71 and 360.39 g ha⁻¹), manganese (11.09, 43.76, 94.04 and 181.39 g ha⁻¹), zinc (10.71, 48.17, 102.43 and 176.46 g ha⁻¹) and copper (0.71, 3.31, 8.99, 24.81 g ha⁻¹) was found to be higher with application of MC + 80 per cent RDF (T₁₀) and least uptake was recorded in control (T₁).

Bio-enriched FYM and levels of fertilizers showed no-significant effect on bulk density (BD), water holding capacity (WHC) and porosity. However, lower BD (1.35 Mg m⁻³), higher porosity (42.01 %) and WHC (41.19 %) was observed in T₁₀ (MC + 80 % RDF) compared to other treatments.

Application of different biofertilizers and levels of fertilizers recorded non-significant effect on pH, electrical conductivity and organic carbon of soil at different growth stages of finger millet, where in pH ranged from 6.03 to 6.10, EC from 0.033 to 0.047 dS m⁻¹ and OC from 0.30 to 0.36 per cent.

Treatment which received microbial consortia + 80 per cent RDF (T₁₀) recorded higher available nitrogen (175.60, 189.40, 172.00 and 155.07 kg ha⁻¹), phosphorus (134.64, 132.64, 124.42 and 119.76 kg ha⁻¹) and potassium (143.53, 136.17, 126.90 and 117.80 kg ha⁻¹) at different growth stages, viz., 30, 60, 90 DAS and at harvest, respectively and least in absolute control. There was 4.35, 1.14 and 5.24 per cent increase in available NPK content of soil over its initial value.

Non-significant effect on secondary nutrient status of soil was resulted with application of different bio-enriched FYM and levels of chemical fertilizers at different growth stages of finger millet. T₁₀ (B₄L₂: MC + 80 per cent RDF) recorded higher exchangeable calcium (1.71, 1.74, 1.70 and 1.68 c mol (p⁺) kg⁻¹), magnesium (0.83, 0.85, 0.82 and 0.81 c mol (p⁺) kg⁻¹) and available sulphur (15.55, 15.70, 15.60, 15.12 ppm) at 30, 60, 90 DAS and at harvest, respectively.

Higher DTPA extractable iron (9.28, 9.48, 9.33 and 9.17 ppm), manganese (9.46, 9.62, 9.30 and 9.21 ppm), zinc (0.94, 0.96, 0.92 and 0.89 ppm) and copper (0.97, 0.99, 0.96 and 0.91 ppm) was at 30, 60, 90 DAS and at harvest, respectively in post-harvest soil with application of MC+ 80 per cent RDF (T₁₀) compared to control (T₁).

Among different biofertilizers, application of MC recorded higher MBC (363.10, 410.05, 306.95 and 261.35 $\mu\text{g g}^{-1}$), MBN (42.54, 47.84, 35.81 and 30.49 $\mu\text{g g}^{-1}$) and MBP (9.61, 12.32, 11.25 and 10.26 $\mu\text{g g}^{-1}$) at different growth stages, viz., 30, 60, 90 DAS and at harvest, respectively. Whereas, application of 80 per cent RDF recorded significantly higher MBC (355.58, 392.78, 298.70 and 247.80 $\mu\text{g g}^{-1}$, respectively), MBN (41.48, 45.82, 34.85 and 28.91 $\mu\text{g g}^{-1}$, respectively) and MBP (8.80, 10.76, 10.18 and 9.20 $\mu\text{g g}^{-1}$, respectively) than 60 per cent RDF.

Enzymatic activity was observed to be significantly influenced with application of different biofertilizers and levels of fertilizers. Higher dehydrogenase activity was with application of MC (61.52, 74.57, 59.01 and 45.86 $\mu\text{g TPF g}^{-1} \text{ soil } 24 \text{ h}^{-1}$) and 80 per cent RDF (55.00, 68.71, 52.81 and 40.40 $\mu\text{g TPF g}^{-1} \text{ soil } 24 \text{ h}^{-1}$) at 30, 60, 90 DAS and at harvest, respectively compared to other FYM enriched with biofertilizers and levels of fertilizers.

Urease and phosphatase activity (acid) was significantly higher in T₁₀ which consisted of MC+ 80 per cent RDF (29.20 $\mu\text{g NH}_4\text{-N g}^{-1} \text{ soil h}^{-1}$ and 37.65 $\mu\text{g pNP g}^{-1} \text{ soil h}^{-1}$) compared to absolute control (16.05 $\mu\text{g NH}_4\text{-N g}^{-1} \text{ soil h}^{-1}$ and 13.17 $\mu\text{g pNP g}^{-1} \text{ soil h}^{-1}$) at harvest.

Higher gross return (Rs. 90373) and net return (Rs. 62981) with B: C ratio of 2.30 was recorded with application of MC +80 per cent RDF (T₁₀), while lower B: C ratio (1.61) was recorded in absolute control with gross return of rupees, 33975 and net return of rupees 20937.

PRACTICAL UTILITY OF WORK

- Soil application of bio-enriched FYM with microbial consortia + 80 per cent RDF increased available nutrient status *viz.*, nitrogen, phosphorus and potassium of soil by 4.35, 1.14 and 5.24 per cent, respectively over initial soil.
- Bio-enriched FYM (microbial consortia) + 80 per cent RDF recorded higher grain (2999 kg ha⁻¹) and straw (4274 kg ha⁻¹) yield compared to 100 per cent RDF (2524 and 3710 kg ha⁻¹, respectively).
- Application of bio-enriched FYM (microbial consortia) + 80 per cent RDF recorded additional returns of rupees 12683 per ha⁻¹ over recommended use of fertilizers
- Bio-enriched FYM (microbial consortia) + 80 per cent RDF saved application of inorganic fertilizer by 20 per cent.
- Nutrient release and uptake by finger millet crop during entire growth period enhanced with application of bio-enriched FYM (microbial consortia) + 80 per cent RDF compared to 100 per cent RDF.

FUTURE LINE OF WORK

1. Identification of competitive and effective multi-functional bio-fertilizers in combination with inorganic fertilizers for dryland crop.
2. To study persistence of biofertilizers in soil environment under different stressful condition and their impact on growth of crop.
3. To study tripartite interaction between microbial inoculants, mineral fertilizers and crop species application.
4. Use of enriched organic manure on soil integrity index, *viz.*, level of microbial diversity, changes to soil carbon content and soil water holding capacity has to be studies.

VI REFERENCES

- ABDEL-SALAM, A. A., ELHOSAINY, O. H., ZAHRA, W. R., ABDEL-SALAM, M. A. AND HASHEM, I. A., 2015, NPK biofertilizers on sorghum (*Sorghum bicolor*) grown on a light clay torrifuvent soil and interactions among them. *Egypt. J. Appl. Sci.*, **30** (7): 383- 400.
- ABDULLAHI, R., SHERIFF, H. H. AND BUBA, A., 2014, Effect of biofertilizer and organic manure on growth and nutrients content of pearl millet. *ARPN J. Agric. Biolog. Sci.*, **9**: 351-355.
- AHMED, A., SULTAN, T., QADIR, G., AFZAL, O., AHMED, M., SHAH, S. S. AND MEHMOOD, M. Z., 2020, Impact assessment of plant growth promoting rhizobacteria on growth and nutrient uptake of maize (*Zea Mays*). *Pakistan J. Agri. Res.*, **33**(2): 234-246.
- ALIKHANI, H. A., HEMATI, A., RASHTABARI, M. AND SCOTT, D. T., 2016, Enriching vermicompost using P- solubilizing and N- fixing bacteria under different temperature conditions, *Commun. Soil Sci. Plant Anal.*, **48** (2): 139-147.
- ANNONYMOUS, 2017, Socio-economic statistical information about agriculture in India. <http://www.indiaagristat.com/>
- ARCHANA, D., NANDISH, M., SAVALAGI, V. AND ALAGAWADI, A., 2013, Characterization of potassium solubilizing bacteria (KSB) from rhizosphere soil. *BIOINFOLET-A Quarterly J. Life Sci.* **10**: 248-257.
- ASHOK KUMAR ROY, 2018, Performance of finger millet (*Eleusine coracana* L. Gaertn.) Under integrated nutrient management practices. *Ph. D. Thesis*, Birsa Agricultural University, Ranchi, Jharkhand-6.
- BABA, Z. A., ZARGAR, M. Y. AND MIR, S. A., 2010, Effect of inorganic and biofertilizers on soil physico chemical properties and micronutrient availability in strawberry (*Fragaria × ananassa* Duch). *The Asian J. Soil Sci.*, **5** (1): 90-93.

- BALOGH-BRUNSTAD, Z., KELLER, C. K., GILL, R. A., BORMANN, B. T., AND LI, C. Y., 2008, The effect of bacteria and fungi on chemical weathering and chemical denudation fluxes in pine growth experiments. *Biogeochem.*, **88**(2): 153-167.
- BAMA, M. E. AND RAMAKRISHNAN, K., 2010, Effects of combined inoculation of *Azospirillum* and AM fungi on the growth and yield of finger millet (*Eleusine coracana* Gaertn) Var. Co 12. *J. Exp. Sci.*, **1**(8): 10-11.
- BANERJEE, A., DATTA, J. K., MONDAL, N. K. AND CHANDA, T., 2011, Influence of integrated nutrient management on soil properties of old alluvial soil under mustard cropping system. *Commun. Soil Sci. Plant Anal.*, **42**(20): 2473-2492.
- BARUAH, T. C. AND BARTHAKUR, H. P., 1997, *A text book of soil analysis*, Vikas Publishing Housing, PVT LTD, New Delhi Pp. 35-67.
- BLACK, C. A., 1965, *Method of Soil Analysis part II Agronomy monograph No, 9*, American Society of Agronomy, Madison, Wisconsin, p.148.
- BRAY, R. H. AND KURTZ, L. T., 1945, Determination of total, organic, and available forms of phosphorus in soils. *Soil Sci.*, **59**(1): 39-46.
- BROOKES, P. C., POWLSON, D. S. AND JENKINSON, D. S., 1982, Measurement of microbial biomass phosphorus in soil. *Soil Biol. Biochem.*, **14**:319-329.
- BROWN, M. E., 1974, Seed and root bacterization. *Ann. Rev. Phytopath.*, **12**(1): 181-197.
- CARTER, M. R., 1991, Ninhydrin- reactive N released by the fumigation extraction method as a measure of microbial biomass under field condition. *Soil Biol. Biochem.*, **23**(2): 139-143.
- CASIDA, L. E., KLEIN, D. A. AND SANTOTO, T., 1964, Soil dehydrogenase activity. *Soil Sci.*, **98**:371-376

- CHE TAN, K. J., SINGH, D. P., MEENA, R. H. AND MAHENDRA YADAV., 2017, Effect of Fertility Levels and Biofertilizers on Physical and Chemical Properties of Soil under Blackgram (*Vigna mungo* L.). *Int. J. Curr. Microbiol. App. Sci.* **6**(3): 223-228.
- CHIKKARAMAPPA, T., SHIVANNA, B., PRASHANTH, G. M. AND PRAKASH, S. S., 2014, Effect of Integrated nutrient management practices on physico - chemical properties of soil under different growth stages of finger millet. *JANRM*, **1**(4): 280-284.
- CLEYET-MAREL, J., LARCHER, M., BERTRAND, H. AND RAPIOR, S., 2001, Pinochet X. diversity in plant growth-promoting rhizobacteria. *Nitrogen Assimilation by Plants: Physiological, Biochemical and Molecular Aspects*, 185.
- DASS, A., SUDHISHRI, S. AND LENKA, N. K., 2013, Integrated nutrient management to improve finger millet productivity and soil conditions in hilly region of Eastern India. *J. crop Improv.*, **27**(5): 528-546.
- DEEPTHI, K., 2018, microbial biomass carbon stocks at home garden agroforestry system in parts of western ghats, *M. Sc. Thesis*, University of agricultural sciences, Bengaluru.
- DHOPAVKAR R. V., 2018, Effect of different levels of N and P fertilizers on yield, biochemical parameters, soil properties and nutrient uptake by chilli (*Capsicum annum* L.) in Lateritic soil of Konkan. *M. Sc. Thesis*, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Ratnagiri.
- DOIFODE, V. D., 2016, Influence of Biofertilizers on the Soil Status of Cotton Field. *Int. J. Life Sci.*, **6**: 93-96.
- EIVAZI, F. AND TABATABAI, M. A., 1977, Phosphatase in soils. *Soil Biol. Biochem.*, **9**:167-177.

- FRANZLUEBBERS, A. J., HONS, F. M. AND ZUBERER, D. A., 1995, Soil organic carbon, microbial biomass, and mineralizable carbon and nitrogen in sorghum. *Soil Sci. Soc. Am. J.*, **59**(2): 460-466.
- GANGARADDI, V., BRAHMAPRAKASH, G. P. AND NAIK, K., 2020, Screening of the selected formulations of a microbial consortium for their effectiveness on the growth of finger millet (*Eleusine coracana* L. Gaertn.). *J. Pharmacogn. Phytochem.*, **9**(2): 01-09.
- GAO, C., AHMED M. EL-SAWAH, DINA FATHI ISMAIL ALI, YOUSEF ALHAJ HAMOUD, HIBA SHAGHALEH AND MOHAMED S. SHETEIWY, 2020, The Integration of Bio and Organic Fertilizers Improve Plant Growth, Grain Yield, Quality and Metabolism of Hybrid Maize (*Zea mays* L.). *Agron. J.*, **10**: 319.
- GEETA SINGH, KUMAR, D. AND SHARMA, P., 2015, Effect of organics, biofertilizers and crop residue application on soil microbial activity in rice-wheat and rice-wheat mungbean cropping systems in the Indo-Gangetic plains. *Cogent Geosci.*, **1**:1-14.
- GOGOI. D., KOTOKY, U. AND HAZARIKA, S., 2004, Effect of biofertilizer on productivity and soil characteristics in banana. *Indian J. Hortic.* **6**(4):354-356.
- GOMEZ, K. A. AND GOMEZ, A. A., 1984, *Statistical procedures for Agric. Res. II Ed.* John Wiley & Sons, New York.
- GOUTAMI N., 2013, Nutrient management in rice – fallow sorghum, 2013, *M. Sc. Thesis*, Acharya N.G. Ranga Agricultural University, Rajendranagar, Hyderabad.
- GREGO, S., MARINARI, S., MOSCATELLI, M. C. AND BADALUCCO, L., 1998, Effect of ammonium nitrate and stabilized farmyard manure on microbial biomass and metabolic quotient of soil under *Zea mays*. *Agric. Meditern.*, **128**: 132-137.
- GULL, A., JAN, R., NAYIK, G. A., PRASAD, K., AND KUMAR, P., 2014, Significance of finger millet in nutrition, health and value-added products: a review., *J. Environ. Sci. Comp. Sci. Eng. Technol.* **130** (32): 120-124.

- GUPTA, S., 2018, Effect of Integrated use of fertilizers and biofertilizers on performance of maize and soil properties in a vertisol. *Ph. D. Thesis*, Jawaharlal Nehru Krishi Vishwa Vidyalalya Jabalpur, Madhya Pradesh.
- HARIKA, J. V., MAITRA, S., SHANKAR, T., BERA, M. AND MANASA, P., 2019, Growth, Yield and Quality of Finger Millet (*Eleusine coracana* L. Gaertn) as Influenced by Integrated Nutrient Management. *IJBS*, **6**(2): 65-70.
- HOPKINS, D. W. AND SHIEL, R. S., 1996, Size and activity of soil microbial communities in long-term experimental grassland plots treated with manure and inorganic fertilizers. *Biol. Fertil. Soils.*, **22**: 66-70.
- HUANG, Z., HE, L., SHENG, X. AND HE, Z., 2013, Weathering of potash feldspar by *Bacillus* sp. L11. Wei sheng wu xue bao. *Acta Microbiol. Sinica.*, **53**:1172-1178.
- IWUAGWU, M., CHUKWUKA, K. S., UKA, U. N. AND AMANDIANEZE, M. C., 2012, Effects of biofertilizers on the growth of *Zea mays* L. *Asian J. Microbiol., Biotechnol. Environ. Sci.*, **15**(2): 235-240.
- JACKSON, M. L., 1973, *Soil Chemical Analysis*. Prentice Hall of India (Pvt.) Ltd., New Delhi.
- KAUR, H., 2016, Effect of biofertilizers and organic fertilizers on soil health, growth and yield of green pea (*Pisum sativum* L.). (Doctoral dissertation, Punjab Agricultural University, Ludhiana).
- KEJIYA, P., VAJANTHA, B., NAIDU, M. V. S. AND NAGAVANI, A.V., 2019, Effect of phosphatic fertilizers on yield and quality of finger millet (*Eleusine coracana* L.). *Int. J. Curr. Microbiol. App. Sci.*, **8** (7): 846-852.
- KHIPLA, N., 2017, Effect of biofertilizer and inorganic fertilizers on soil health and growth of poplar under nursery condition. *MSc. Thesis*, Punjab Agricultural University, Ludhiana.

- KUMAR, R. AND NARWAL, R. P., 2016, Long-term effect of FYM and nitrogen fertilizer on the distribution of K fraction in soil under pearl millet-wheat cropping system. *Forage Res.*, **42** (2):131-134.
- KUMAR, S. K., 2016, Effect of phosphorous management on yield and quality of finger millet (*Eleusine coracana* (L.)), *thesis*, Acharya N. G. Ranga Agricultural University, GUNTUR, Andhra Pradesh.
- KUMAR, S., AND SHARMA, M. K., 2015, Effect of zinc and farmyard manure on yield and nutrient content of vegetable pea (*Pisum sativum* L.). *Progr. Hort.*, **47**(1): 112-115.
- KUMAR, V. AND SINGH, K. P., 2001, Enriching vermicompost by nitrogen fixing and phosphate solubilizing bacteria. *Bioresource Tech.*, **76**(2): 173-175.
- KUMAR, V., SAIKIA, J., BARIK, N. AND DAS, T., 2017, Effect of integrated nutrient management on soil enzymes, microbial biomass carbon and microbial population under okra cultivation. *Int. J. Biochem. Res. Rev.*, **20**(4): 1-7.
- LAVANYA, G., 2019, Effect of phosphorus enriched biocompost on soil properties, growth and yield of finger millet (*Eleusine coracana* L.). *M. Sc. Thesis*, University of Agricultural science, Bengaluru.
- LAVANYA, K., REDDY, G. K., REDDY, A. P. K., REDDY, P. V. R. M. AND KUMARI, P. L., 2018, Yield and nutrient uptake of finger millet as influenced by organics and liquid biofertilizer consortium. *J. Res. ANGRAU.*, **46** (3): 41-44.
- LI, R., TAO, R., LING, N. AND CHU, G., 2017, Chemical, organic and bio-fertilizer management practices effect on soil physicochemical property and antagonistic bacteria abundance of a cotton field: Implications for soil biological quality. *Soil Till. Res.*, **167**: 30–38.

- LIN, T. F., HUANG, H. I., SHEN, F. T. AND YOUNG, C. C., 2006, The protons of gluconic acid are the major factor responsible for the dissolution of tricalcium phosphate by *Burkholderia cepacia* CC-A174. *Biores. Tech.*, **97**(7): 957-960.
- LINDSAY, W.L. AND NORVELL, W.A., 1978, Development of DTPA soil test for Zinc, iron, manganese and copper. *Soil Sci. Soc. American J.*, **42**:421-428.
- MAHANTA, K., JHA, D. K., RAJKHOWA, D. J. AND MANOJ-KUMAR, 2012, Microbial enrichment of vermicompost prepared from different plant biomasses and their effect on rice (*Oryza sativa* L.) growth and soil fertility. *Bio. Agric. Hort. J.*, **28**(4): 241-250.
- MANJAIHAH, M. AND SINGH, D., 2001, Soil organic matter and biological properties after 26 years of maize–wheat–cowpea cropping as affected by manure and fertilization in a Cambisol in semiarid region of India. *Agric. Ecosyst. Environ.*, **86**: 155-162.
- MATHEWS, D. V., PATIL, P. L. AND DASOG, G. S., 2006, Effect of nutrients and biofertilizers on yield and yield components of rice in coastal alluvial soil of Karnataka. *Karnataka J. Agric. Sci.*, **19**(4):799-803.
- MAURYA, B. R., MEENA, V. S. AND MEENA, O. P., 2014, Influence of *Inceptisol* and *Alfisol*'s potassium solubilizing bacteria (KSB) isolates on release of K from Waste mica. *Vegetos.*, **27**: 181-187.
- MEENA, V. S., MAURYA, B. R., VERMA, J. P. AND MEENA, R. S., 2016, *Potassium solubilizing microorganisms in evergreen agriculture: An review*. Springer: New Delhi.
- MONISHA, V., RATHINASWAMY, A., MAHENDRAN, P. P. AND KUMUTHA, K., 2019, Influence of integrated nutrient management on growth attributes and yield of foxtail millet in red soil. *Int. J.Chem. Stud.*, **7**(3): 3536-3539.

- MUDALAGIRIYAPPA, RAMACHANDRAPPA, B. K. AND NANJAPPA, H. V., 2012, Moisture conservation practices and nutrient management on growth and yield of Rabi sorghum (*Sorghum bicolor*) in the *vertisols* of peninsular India. *Agric. Sci.*, **3**(4): 588-593.
- NANDINI, M. AND SREENIVASA, M. N., 2014, Effect of microbial enrichment of organic manures on microbial population and nutrient status of organic manures. *Karnataka J. Agric. Sci.*, **27**(2): 156-159.
- NANDINI, M., 2013, Population dynamics in microbially enriched organic manures and their influence on microbial population and enzymatic activities in soil, growth and yield of tomato (*Lycopersicon esculentum* Mill). *M.Sc. Thesis*, Univ. Agric. Sci., Dharwad.
- NARULA, N. AND GUPTHA, K. G., 1986, Ammonia excretion by *Azotobacter* in liquid culture and soil in the presence of manganese and clay minerals. *Plant Soil*, **93**: 205 - 209.
- NEDUNCHEZHIAN, M., BYJU, G., DASH, S. N. AND RANASINGH, N., 2013, Selected soil enzyme activities, soil microbial biomass carbon, and root yield as influenced by organic production systems in sweet potato. *Comm. Soil Sci. Plant Anal.*, **44**(8): 1322-1339.
- NEERAJ, Y., 2014, Studies on N, P and biofertilizer management practices on growth, yield and nutrient uptake of pearl millet [*Pennisetum glaucum* (L.) R. Br.], *Ph. D. Thesis*, Acharya N.G. Ranga Agricultural University.
- NISHA, R., KAUSHIK, A. AND KAUSHIK, C. P., 2007, Effect of indigenous cyanobacterial application on structural stability and productivity of an organically poor semi-arid soil. *Geoderma*, **138**(1-2): 49-56.

- NUTI, M. AND GIOVANNETTI, G., 2015, Borderline products between bio-fertilizers/ bio-effectors and plant protectants: the role of microbial consortia. *J. Agric. Sci. Tech.* **5**:305–315.
- PALLAVI, C. H., JOSEPH, B., KHAN, M. A. AND HEMALATHA, S., 2017, Effect of organic fertilizers and biofertilizers on yield and yield attributing traits of direct sown rainfed finger millet, *Eleusine coracana* (L) Gaertn. *Int. J. Farm Sci.*, **7**(3): 101-105.
- PALLAVI, C., JOSEPH, B., KHAN, M. A., AND HEMALATHA, S., 2016, Effect of integrated nutrient management on nutrient uptake, soil available nutrients and productivity of rainfed finger millet. *Int. J. Sci., Environ. Tech.*, **5**(5): 2798-2813.
- PARIHAR, C. M., RANA, K. S., JAT, M. L., JAT, S. L., PARIHAR, M. D., KANTWA, S. R., ... AND SHARMA, S., 2013, Carbon footprint and economic sustainability of pearl millet-mustard system under different tillage and nutrient management practices in moisture stress conditions. *Afr. J. Microb. Res.*, **6** (23):5052-61.
- PIPER, C. S., 1966, *Soil and plant Analysis*, Hans Publications, Bombay.
- PONMURUGAN, P. AND GOPI, G., 2006, Distribution pattern and screening of phosphate solubilizing bacteria isolated from different food and forage crops. *Agron. J.*, **5**(4): 600-604.
- PRABUDOSS, V., JAWAHAR, S., SHANMUGARAJA, P. AND DHANAM, K., 2014, Effect of integrated nutrient management on growth, yield and economics of transplanted kodo millet. *European J. Biotech. Biosci.*, **1** (4): 30-33.
- RAM, C., PATEL, N. I., SINGH, R. N. AND VYAS, K. G., 2015, Effect of bio-fertilizers and nitrogen management on yield and soil fertility of pearl millet under rainfed condition. *The Bioscan*, **10**(1): 319-322.

- RAMAKRISHNAN, K. AND BHUVANESWARI, G., 2014, Effect of inoculation of am fungi and beneficial microorganisms on growth and nutrient uptake of *Eleusine coracana* (L.) Gaertn. (Finger millet). *Int. Lett. Nat. Sci.*, **8**(2): 59-69.
- RAMALAKSHMI, A., INIYAKUMAR, M., RAJ, S. A. AND INDIA, C. T., 2008, Influence of biofertilizers on soil physico-chemical and biological properties during cropping period. *Asian J. Bio Sci.*, **3** (2): 348-351.
- RANGESH KUMAR, PATTANAYAK, S. K., JAGTARAN AND PILESHWAR, S. R., 2018, Studying the influence of long term INM practices on yield and quality of ragi crop. *J. Pharmacogn. Phytochem.*, **7**(1): 2175-2177.
- RANI, K. S., SATISH, P., RANI, S. AND SUDHAKAR, C., 2019, Effect of Liquid Biofertilizers on Growth and Yield of Rabi Sorghum (*Sorghum bicolor* L.). *Chem. Sci. Rev. Lett.*, **8**(32): 190-194.
- RAO, H. C., SREENIVASA, M. N., HEBSUR, N. S., GEETHA, S. AND BABALAD, H. B., 2012, Influence of microbial enrichment on microbial population and nutrient status of organic manures. *Karnataka J. Agric. Sci.*, **25**(4): 545-547.
- REKHA, D. L. M., LAKSHMIPATHY, R. AND GOPAL, G. A., 2018, Effect of integrated use of bio-fertilizers, chemical fertilizers and farmyard manure on soil health parameters of pearl millet (*Pennisetum glaucum* L.). *J. Soil. Sci. Plant. Health*, **2**(2).
- ROY, A.K., N. ALI, R.K. LAKRA, P. ALAM, P. MAHAPATRA AND NARAYAN, R., 2018, Effect of Integrated Nutrient Management Practices on Nutrient Uptake, Yield of Finger Millet (*Eleusine coracana* L. Gaertn.) and PostHarvest Nutrient Availability under Rainfed Condition of Jharkhand. *Int. J. Curr. Microbiol. App. Sci.*, **7**(8): 339-347.
- SAGOE, C., ANDO, T., KOUNO, K. AND NAGAOKA T., 1998, Relative importance of protons and solution calcium concentration in phosphate rock dissolution by organic acids. *J. Soil Sci. Plant Nutr.*, **44**(4): 617-625.

- SAHA, R., MISHRA, V. K., MAJUMDAR, B., LAXMINARAYANA, K. AND GHOSH, P. K., 2010, Effect of Integrated Nutrient Management on Soil Physical Properties and Crop Productivity under a Maize (*Zea mays*)–Mustard (*Brassica campestris*) Cropping Sequence in Acidic Soils of Northeast India. *Comm. Soil Sci. Plant Anal.*, **41**(18): 2187-2200.
- SELVAKUMAR, G., REETHA, S. AND THAMIZHINIYAN, P., 2012, Response of biofertilizers on growth, yield attributes and associated protein profiling changes of black gram (*Vigna mungo* L. Hepper). *World Appl. Sci. J.*, **16**(10): 1368-1374.
- SHANKAR, M. A., THIMMEGOWDA, M. N., BHAVITHA, N. C. AND MANJUNATHA, B. N., 2018, Yield and Economics of Finger Millet and Redgram Rotation as Influenced by Zinc, Boron and Biofertilizer Nutrition. *Mysore J. Agric. Sci.*, **52**(1): 43-48.
- SHRUTHI, 2014, Management of phosphorus and potassium in finger millet under Alfisols of Bangalore rural district in Karnataka. *M. Sc. Thesis*, University of Agricultural Sciences GKVK, Bangalore.
- SHRUTHI, GOWDA, R. C. AND BASAVARAJA, P. K., 2018, nutrient content and uptake in finger millet as influenced by fym and biofertilizers along with different levels of phosphorus and potassium. *Int. J. Agric. Sci.*, **10** (15): 6817-6819.
- SHUKLA, G. AND VARMA, A., 2011, *Soil enzymes*, Springer Publications, XVI, p. 384.
- SINGH, D., RAGHUVANSHI, K., CHAURASIYA, A., DUTTA, S. K. AND DUBEY, S. K., 2018, Enhancing the nutrient uptake and quality of pearl millet (*Pennisetum glaucum* L.) through use of biofertilizers. *Int. J. Curr. Microbiol. Appl. Sci.*, **7**: 3296-3306.
- SINGH, D., RAGHUVANSHI, K., PANDEY, S. K. AND GEORGE, P. J., 2016, Effect of biofertilizers on growth and yield of pearl millet (*Pennisetum glaucum* L.). *Res. Environ. Life Sci.*, **9**(3): 385-386.

- SINSABAUGH, R. L., ANTIBUS, R. K. AND LINKINS, A. E., 1991, An enzymic approach to the analysis of microbial activity during plant litter decomposition. *Agri. Ecosyst. Environ.*, **34**: 43–54.
- SIVAMURUGAN, A. P., RAVIKESAVAN, R., SINGH, A. K. AND JAT, S. L., 2018, Effect of different levels of P and liquid biofertilizers on growth, yield attributes and yield of maize. *Chem. Sci. Rev. Lett.*, **7**: 520-523.
- SMITH, P. AND POWLSON, D. S., 2003, Sustainability of soil management practices - a global perspective. In Abbott, LK; Murphy (eds.): *Soil Biological Fertility: A Key to Sustainable Land Use in Agriculture. Springer Netherlands*, pp. 241–254.
- SRIDHARA, C. J., MAVARKAR, N. S. AND KRISHNA NAIK, S., 2010, Yield maximization in Ragi under rainfed condition. *Karnataka J. Agric. Sci.*, **16**(2): 220-222.
- SUBBIAH, B. V. AND ASIJA, C. L., 1956, A rapid procedure for method for the estimation of available nitrogen in soils. *Curr. Sci.*, **25**: 259-260.
- SUSHMA, A. R., 2005, Residual effect of coir pith-based compost with other organics and inorganics on ragi crop yield and soil properties. *M.Sc. (Agri.) Thesis*, University of Agricultural Sciences, Bengaluru.
- THEUNISSEN, J., NDAKIDEMI, P. A. AND LAUBSCHER, C. P., 2010, Potential of vermicompost produced from plant waste on the growth and nutrient status in vegetable production. *Int. J. Phys. Sci.*, **5**(13): 1964-1973.
- THIMMAIAH, M., DINESH KUMAR, M., NANDISH, M. S. AND VEERANNA, H. K., (2016). Effect of integrated nutrient management on growth, yield and economics of rainfed finger millet [*Eleusine coracana* (L.) G.]. *Green Farm.*, **7**: 875-79.
- THUMAR, C. M., DUDHAT, M. S., CHAUDHARI, N. N., HADIYA, N. J. AND AHIR N. B., 2016, Growth, yield attributes, yield and economics of summer pearl millet (*Pennisetum glaucum* L.) as influenced by integrated nutrient management. *Int. J. Agric. Sci.*, **8**(15): 3344-3346.

- TOGAS, R., YADAV, L. R., CHOUDHARY, S. L. AND SHISUVINAHALLI, G. V., 2017, Effect of *Azotobacter* on growth, yield and quality of pearl millet. *J. Pharmacogn. Phytochem.*, **6**(4): 889-891.
- VACHAN, R. AND TRIPATHIM, S. M., 2017, Study on the effect of bio-fertilizer with chemical fertilizer on plant growth, Yield and economics of Rabi season onion (*Allium cepa* L.) cv. NHRDF Red 2. *J. Pharmacogn. Phytochem*, **6**(5): 1496-1499.
- VEERESHA, S. AND GOPAKKALI, P., 2014, Economics and Nutrient Balance of Irrigated Maize (*Zea Mays* L.) as Influenced by Various Levels of FYM and Cattle Urine Application. *Environ. Eco.*, **32**(4A): 1518-1522.
- VEJAN, P., ABDULLAH, R., KHADIRAN, T., ISMAIL, S. AND NASRULHAQ BOYCE, A., 2016, Role of plant growth promoting rhizobacteria in agricultural sustainability—a review. *Molecules*, **21**(5): 573.
- VESSEY, J. K., 2003, Plant growth promoting rhizobacteria as biofertilizers. *Plant and soil*, **255**(2): 571-586.
- WALKLEY, A. J. AND BLACK, C. A., 1934, An examination of the method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Sci.*, **37**: 29-38.
- WIJEBANDARA, I., DASOG, G. S., PATIL, P. L. AND HEBBAR, M., 2009, Response of rice to nutrients and bio fertilizers under conventional and system of rice intensification methods of cultivation in Tungabhadra command of Karnataka. *Karnataka J. Agric. Sci.*, **22**(4).
- WU, S. C., CAO, Z. H., LI, Z. G., CHEUNG, K. C. AND WONG, M. H., 2005, Effects of biofertilizer containing N-fixer, P and K solubilizers and AM fungi on maize growth: a greenhouse trial, *Geoderma* **125**: 155–166.

XIAO, Y., WANG, X., CHEN, W. AND HUANG, Q., 2017, Isolation and identification of three potassium-solubilizing bacteria from rape rhizospheric soil and their effects on ryegrass. *Geomicrobiol. J.*, 1-8.

YUVARAJ, K., 2016, Effect of biofertilizers and inorganic fertilizers on soil health, growth and yield of rice (*Oryza sativa* L.) crop. *M.Sc. Thesis*, Maharana Pratap Univ. Agri. Technol, Udaipur.

APPENDIX – I

Preparation of different solution for biological analysis

THAM (Trishydroxymethyl amino methane) buffer (0.05 M, pH 9)

6.1 g of THAM was dissolved in about 700 ml distilled water. The pH of this solution was adjusted to 9 with H₂SO₄ of 0.2 M and the final volume was brought to 1 L with distilled water.

Modified universal buffer (MUB)

Dissolve 12.1 g of Tris (hydroxymethyl) amino methane, 11.6 g of maleic acid, 14.0 g of citric acid and 6.3 g of boric acid in 488 ml of 1N NaOH solution and dilute to 1000 ml with distilled water.

Modified universal buffer (MUB) pH 6.5 and 11

200 ml of MUB stock solution in 500 ml beaker. Titrate the solution to pH 6.5 using 0.1 N HCl and 11 by using 0.1 N NaOH and make up the volume to 1000 ml using distilled water.

KCl-Ag₂SO₄ solution

100 mg Ag₂SO₄ was dissolved in 700 ml of distilled water. To this 188 g of KCl was added and dissolved. The final volume of the solution was brought to 1 L with distilled water

Ninhydrin reagent

Reagent A

50 ml of methoxy-ethanol and 50 ml distilled water mixed together (1:1 ratio) to prepare solution. 2 g of ninhydrin was dissolved in the above prepared solution.

Reagent B

16 ml of 0.1 M citric acid was mixed with 34 ml of 0.1 M sodium citrate. To this solution 50 ml of distilled water was added. To this 160 mg of stannous chloride (SnCl₂) was added and dissolved.

The reagent A and reagent B were mixed and this constitutes ninhydrin reagent.

Chloromolybdic acid

15 g of ammonium molybdate was dissolved in 300 ml of hot water and 350 ml of 10 N HCl was added slowly with rapid stirring. The solution is cooled and volume was made to 1000 ml.

APPENDIX – II

Amount of NPK, FYM added according to treatments

Treatments	FYM (t ha ⁻¹)	Nitrogen (kg ha ⁻¹)	Phosphorous (kg ha ⁻¹)	Potassium (kg ha ⁻¹)
T ₁ : Absolute control	-	-	-	-
T ₂ : 7.5 t ha ⁻¹ FYM + 100 % RDF	7.5	50	40	37.5
T ₃ : 7.5 t ha ⁻¹ enriched FYM (nitrogen fixers + PGPR) + 60 % RDF	7.5	30	24	22.5
T ₄ : 7.5 t ha ⁻¹ enriched FYM (nitrogen fixers + PGPR) + 80 % RDF	7.5	40	32	30
T ₅ : 7.5 t ha ⁻¹ enriched FYM (phosphate solubilizer + PGPR) + 60 % RDF	7.5	30	24	22.5
T ₆ : 7.5 t ha ⁻¹ enriched FYM (phosphate solubilizer + PGPR) + 80 % RDF	7.5	40	32	30
T ₇ : 7.5 t ha ⁻¹ enriched FYM (potassium solubilizer + PGPR) + 60 % RDF	7.5	30	24	22.5
T ₈ : 7.5 t ha ⁻¹ enriched FYM (potassium solubilizer + PGPR) + 80 % RDF	7.5	40	32	30
T ₉ : 7.5 t ha ⁻¹ enriched FYM (microbial consortia) + 60 % RDF	7.5	30	24	22.5
T ₁₀ : 7.5 t ha ⁻¹ enriched FYM (microbial consortia) + 80 % RDF	7.5	40	32	30

APPENDIX – III

Growth and yield parameter

	Productive tillers per hill	Grain weight per hill (g hill ⁻¹)
Factor 1: Biofertilizers enrichment (B)		
B₁: NFB + PGPR	4.95	10.10
B₂: PSB + PGPR	4.90	10.15
B₃: KSB + PGPR	4.99	10.25
B₄: MC	5.32	11.07
S.Em.±	0.10	0.23
CD @ 5 %	0.31	0.70
Factor 2: Levels of fertilizers (L)		
L₁:60 % RDF	4.88	10.07
L₂: 80 % RDF	5.20	10.71
S.Em.±	0.07	0.163
CD @ 5 %	0.22	0.49
Interaction (B× L)		
S.Em.±	0.15	0.33
CD @ 5 %	NS	NS
Treatments		
T₁-Control	2.59	4.24
T₂-100 % RDF	4.56	9.46
T₃-B₁L₁	4.72	9.74
T₄-B₁L₂	5.19	10.45
T₅-B₂L₁	4.72	9.78
T₆-B₂L₂	5.08	10.53
T₇-B₃L₁	4.82	9.87
T₈-B₃L₂	5.17	10.63
T₉-B₄L₁	5.26	10.89
T₁₀-B₄L₂	5.38	11.25
S.Em.±	0.23	0.29
CD @ 5 %	0.69	0.86

*100 per cent was added with 7.5 t ha⁻¹ of FYM, remaining treatments received 7.5 t ha⁻¹ of bio-enriched FYM.

NFB: Nitrogen fixing biofertilizers **PSB:** Phosphate solubilizing biofertilizers **KSB:** Potassium solubilizing biofertilizers **PGPR:** Plant growth promoting rhizobacteria

MC: Microbial consortia

APPENDIX – IV

Cost of inputs and prices of output

Particulars	Quantity	Per unit cost	Cost (Rs.)
Land preparation	2	500	1000
FYM (t ha ⁻¹)	7.5	1520	11725
Seed (kg ha ⁻¹)	12.5	43	537.5
Fertilizer cost			
a. urea (kg ha ⁻¹)	50	5.75	285
b. DAP (kg ha ⁻¹)	40	25	1000
c. MOP (kg ha ⁻¹)	37.5	16	600
Labour (sowing, weeding, inter-cultivation and harvest)	33	280	9240
Bullock pair	2	150	300
Biofertilizers (kg)	1	80	80
Returns per product			
Grain yield (q)	1	2800	-
Straw yield (q)	1	150	-