RESPONSE OF FINGER MILLET TO PHOSPHORUS AND POTASSIUM LEVELS IN ALFISOLS OF RAMANAGARA DISTRICT OF KARNATAKA

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UNIVERSITY OF AGRICULTURAL SCIENCES
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in

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BENGALURU JULY, 2016

DEDICATED TO MY

FAMILY, FRIENDS

&

BELOVED CHAIRPERSON

UNIVERSITY OF AGRICULTURAL SCIENCES
DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY, BENGALURU - 560 065

CERTIFICATE

This is to certify that the thesis entitled **"Response of finger millet to phosphorus and potassium levels in *Alfisols* of Ramanagara district of Karnataka"** submitted by **Mr, SUNDARESH, R., ID No. PALB 4290,** for the degree of **MASTER OF SCIENCE (Agriculture) in SOIL SCIENCE AND AGRICULTURAL CHEMISTRY** to the University of Agricultural Sciences, Bengaluru, is a record of research work done by him during the period of his study in this University under my guidance and supervision and the thesis has not previously formed the basis for the award of any other degree, diploma, associateship, fellowship or similar other titles.

Bengaluru
July, 2016

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July, 2016 ***(Sundaresh. R)***

RESPONSE OF FINGER MILLET TO PHOSPHORUS AND POTASSIUM LEVELS IN ALFISOLS OF RAMANAGARA DISTRICT OF KARNATAKA

SUNDARESH, R.

ABSTRACT

A field experiment was carried out in farmer's field where soil was deficient in available phosphorus and potassium at Kodihalli village, Soluru hobli, Magadi taluk, Ramanagara district of Karnataka to study the influence of different levels of phosphorus and potassium on growth, yield, nutrient uptake and nutrient use efficiency by finger millet. The experiment was laid out in randomized block design comprising 16 treatments replicated thrice. The results revealed that significantly higher grain (52.03 q ha^{-1}) and straw yield (87.57 q ha^{-1}), higher total uptake of major nutrients (179.20 kg N ha^{-1}, 29.56 kg P_2O_5 ha^{-1} and 70.89 kg K_2O ha^{-1} respectively), secondary nutrients (84.25 kg Ca ha^{-1}, 61.21 kg Mg ha^{-1} and 23.76 kg S ha^{-1}) and micronutrients uptake *viz*; Fe (623.79 g ha^{-1}) and Cu (59.96 g ha^{-1}) by finger millet was recorded in treatment which received 100 per cent RDN, 150 per cent RDP and 125 per cent RDK (100 : 75 : 62.50 kg NPK ha^{-1}) along with FYM at 10 t ha^{-1} as compared to RDF (100 : 50 : 50 kg NPK ha^{-1}). Whereas, higher total uptake of Mn (279.92 g ha^{-1}), Zn (334.27 g ha^{-1}) and B (52.21 g ha^{-1}) was recorded in treatment which received 100 : 75 : 75 kg NPK ha^{-1}. Higher phosphorus use efficiency (PUE) of 18.43 per cent, agronomic phosphorus use efficiency (29.09 kg kg^{-1}) and agronomic potassium use efficiency (25.21 kg kg^{-1}) was noticed in treatment which received 100 percent RDN, 150 percent RDP and 100 percent RDK along with 10 t ha^{-1} of FYM (100:75:50 kg NPK ha^{-1}). Whereas, higher potassium use efficiency (65.82 %) and higher B: C ratio (2.88) was recorded in treatment which received 100: 75: 62.50 kg NPK ha^{-1}. The present study evidently concluded that application of 100 per cent RDN, 150 per cent RDP and 125 per cent RDK along with FYM at 10 t ha^{-1}(100:75:62.5 kg NPK ha^{-1}) under protective irrigation is beneficial for getting higher yield of finger millet as well as higher benefit cost ratio (2.88) as compared to the present RDF (100:50:50 kg NPK ha^{-1}) in low phosphorus and potassium soils of Ramanagara district of Karnataka.

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Major Advisor

ಕರ್ನಾಟಕ ರಾಜ್ಯದ ರಾಮನಗರ ಜಿಲ್ಲೆಯ ಆಲ್ಫೀಸಾಲ್ ನಲ್ಲಿ ರಂಜಕ ಮತ್ತು ಪೊಟ್ಯಾಸಿಯಂ ಪ್ರಮಾಣಗಳಿಗೆ ರಾಗಿ ಬೆಳೆಯ ಸ್ಪಂಧನೆ

ಸುಂದರೇಶ್. ಆರ್

ಪ್ರಬಂಧದ ಸಾರಾಂಶ

ಪ್ರಸ್ತುತ ಸಂಶೋಧನೆ ಸಂಶೋಧನಾ ಪ್ರಯೋಗವನ್ನು ರಾಮನಗರ ಜಿಲ್ಲೆಯ ಮಾಗಡಿ ತಾಲ್ಲೂಕಿನ ಕೋಡಿಹಳ್ಳಿ ಗ್ರಾಮದ ರಂಜಕ ಮತ್ತು ಪೊಟ್ಯಾಸಿಯಮ್ ಪೋಷಕಾಂಶ ಕಡಿಮೆ ಇರುವ ರೈತನ ಜಮೀನಿನಲ್ಲಿ ಕೈಗೊಳ್ಳಲಾಗಿತ್ತು. ಈ ಪ್ರಯೋಗದಲ್ಲಿ ವಿವಿಧ ಪ್ರಮಾಣದ ರಂಜಕ ಮತ್ತು ಪೊಟ್ಯಾಸಿಯಂ ಪೋಷಕಾಂಶಗಳಿಂದಾಗುವ ಪ್ರಬಾವವನ್ನು ರಾಗಿಯ ಬೆಳವಣಿಗೆ, ಇಳುವರಿ, ಪೋಷಕಾಂಶ ಗ್ರಹಿಸುವಿಕೆ ಮತ್ತು ಪೋಷಕಾಂಶ ಬಳಕೆಯ ದಕ್ಷತೆಯ ಬಗ್ಗೆ ಅಧ್ಯಯನ ನಡೆಸಲಾಯಿತು. ಹದಿನಾರು ಉಪಚಾರಗಳುಳ್ಳ ಈ ಪ್ರಯೋಗವನ್ನು ಯಾದೃಚ್ಛಿಕ ಬ್ಲಾಕ್ ವಿನ್ಯಾಸದಲ್ಲಿ (ಆರ್, ಸಿ, ಬಿ. ಡಿ) ಮೂರು ಬಾರಿ ಪುನರಾವರ್ತನೆಗೊಳಿಸಲಾಯಿತು ಈ ಪ್ರಯೋಗದಿಂದ ತಿಳಿದು ಬಂದ ಅಂಶವೇನೆಂದರೆ ರಾಗಿ ಬೆಳೆಯಲ್ಲಿ ಗಮನಾರ್ಹವಾದ ಹೆಚ್ಚಿನ ಧಾನ್ಯ (52.03 ಕ್ವಿ ಪ್ರತಿ ಹೆ) ಮತ್ತು ಒಣಹುಲ್ಲಿನ ಇಳುವರಿ (87.57 ಕ್ವಿ ಪ್ರತಿ ಹೆ), ಪ್ರಮುಖ ಪೋಷಕಾಂಶಗಳ (ಸಾರಜನಕ , ರಂಜಕ ಮತ್ತು ಪೊಟ್ಯಾಸಿಯಮ್) ಹೆಚ್ಚಿನ ಗ್ರಹಿಸುವಿಕೆ, ದ್ವಿತೀಯ ಪೋಷಕಾಂಶಗಳ (ಕ್ಯಾಲ್ಸಿಯಂ, ಮೆಗ್ನೀಷಿಯಂ ಮತ್ತು ಸಲ್ಫರ್) ಹೆಚ್ಚಿನ ಗ್ರಹಿಸುವಿಕೆ, ಮತ್ತು ಲಘು ಪೋಷಕಾಂಶಗಳಾದ ಕಬ್ಬಿಣ ಮತ್ತು ತಾಮ್ರದ ಹೆಚ್ಚಿನ ಗ್ರಹಿಸುವಿಕೆ ಶಿಫಾರಸ್ಸು ಮಾಡಿದ ಶೇ. 100 ರಷ್ಟು ಸಾರಜನಕ, ಶೇ. 150 ರಷ್ಟು ರಂಜಕ ಶೇ. 125 ರಷ್ಟು ಪೊಟ್ಯಾಸಿಯಮ್ ಹಾಗೂ 10 ಟನ್ ಕೊಟ್ಟಿಗೆ ಗೊಬ್ಬರ (100:75:62.50 ಕೆಜಿ ಪ್ರತಿ ಹೆ ಸಾರಜನಕ, ರಂಜಕ, ಮತ್ತು ಪೊಟ್ಯಾಸಿಯಂ) ಉಪಚರಿಸಿದ ತಾಕುಗಳಲ್ಲಿ ಕಂಡು ಬಂದಿದೆ. ಆದರೆ ಮ್ಯಾಂಗನೀಸ್, ಸತು, ಮತ್ತು ಬೋರಾನ್‌ನ ಹೆಚ್ಚಿನ ಗ್ರಹಿಸುವಿಕೆಯು 100:75:75 ಕೆಜಿ ಪ್ರತಿ ಹೆ ಸಾರಜನಕ, ರಂಜಕ, ಮತ್ತು ಪೊಟ್ಯಾಸಿಯಂ ಹಾಕಿದ ತಾಕುಗಳಲ್ಲಿ ಕಂಡು ಬಂದಿದೆ.ಹೆಚ್ಚಿನ ರಂಜಕ ಬಳಕೆಯ ದಕ್ಷತೆ (ಶೇ. 18.43), ರಂಜಕದ ಬಳಕೆಯ ದಕ್ಷತೆ (29.09 ಕೆಜಿ ಪ್ರತಿ ಕೆಜಿ) ಮತ್ತು ಫಸಲಿಗೆ ಪೊಟ್ಯಾಸಿಯಮ್ ಬಳಕೆಯ ದಕ್ಷತೆಯು (25.21 ಕೆಜಿ ಪ್ರತಿ ಕೆಜಿ) ಶಿಫಾರಸ್ಸು ಮಾಡಿದ ಶೇ. 100 ರಷ್ಟು ಸಾರಜನಕ, ಶೇ. 150 ರಷ್ಟು ರಂಜಕ ಶೇ. 100 ರಷ್ಟು ಪೊಟ್ಯಾಸಿಯಮ್ ಹಾಗೂ 10 ಟನ್ ಕೊಟ್ಟಿಗೆ ಗೊಬ್ಬರ (100:75:50 ಕೆಜಿ ಪ್ರತಿ ಹೆ ಸಾರಜನಕ, ರಂಜಕ, ಮತ್ತು ಪೊಟ್ಯಾಸಿಯಂ) ಉಪಚರಿಸಿದ ತಾಕುಗಳಲ್ಲಿ ಕಂಡು ಬಂದಿದೆ. ಆದರೆ, ಹೆಚ್ಚಿನ ಪೊಟ್ಯಾಸಿಯಮ್ ಬಳಕೆಯ ದಕ್ಷತೆ (ಶೇ 65.82) ಮತ್ತು ಹೆಚ್ಚಿನ ಲಾಭ: ವೆಚ್ಚದ ಅನುಪಾತವು (2.88) 100:75:75 ಕೆಜಿ ಪ್ರತಿ ಹೆ ಸಾರಜನಕ, ರಂಜಕ, ಮತ್ತು ಪೊಟ್ಯಾಸಿಯಂ ಉಪಚಾರದಲ್ಲಿ ದಾಖಲಾಗಿದೆ. ಪ್ರಸ್ತುತ ಅಧ್ಯಯನದಲ್ಲಿ ಸಾಕ್ಷೀಕರಿಸಿದ ಅಂಶವೇನೆಂದರೆ, ಅತಿ ಕಡಿಮೆ ರಂಜಕ ಮತ್ತು ಪೊಟ್ಯಾಸಿಯಂ ಪೋಷಕಾಂಶಗಳಿರುವ ರಾಮನಗರ ಜಿಲ್ಲೆಯ ಮಣ್ಣಿನಲ್ಲಿ ಶಿಫಾರಸ್ಸು ಮಾಡಿದ ಶೇ. 100 ರಷ್ಟು ಸಾರಜನಕ, ಶೇ. 150 ರಷ್ಟು ರಂಜಕ ಶೇ. 125 ರಷ್ಟು ಪೊಟ್ಯಾಸಿಯಮ್ ಹಾಗೂ 10 ಟನ್ ಕೊಟ್ಟಿಗೆ ಗೊಬ್ಬರವನ್ನು (100:75:62.50 ಕೆಜಿ ಪ್ರತಿ ಹೆ ಸಾರಜನಕ, ರಂಜಕ, ಮತ್ತು ಪೊಟ್ಯಾಸಿಯಂ) ರಕ್ಷಣಾತ್ಮಕ ನೀರಾವರಿ ಅಡಿಯಲ್ಲಿ ಒದಗಿಸಿದಾಗ ರಾಗಿಯಲ್ಲಿ ಹೆಚ್ಚಿನ ಇಳುವರಿ, ಉತ್ಪಾದಕತೆ ಹಾಗೂ ಹೆಚ್ಚಿನ ಲಾಭ: ವೆಚ್ಚದ ಅನುಪಾತವನ್ನು (2.88) ಪಡೆಯಲು ಪ್ರಯೋಜನಕಾರಿಯಾಗಿರುತ್ತದೆ.

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ಕೃಷಿ ವಿಶ್ವವಿದ್ಯಾಲಯ, ಗಾ, ಕೃ, ವಿ, ಕೇ., ಬೆಂಗಳೂರು- 560065

(ಡಾ|| ಪಿ. ಕೆ. ಬಸವರಾಜ)
ಮುಖ್ಯ ಸಲಹೆಗಾರರು

Response of Finger millet to Phosphorus and Potassium Levels in Alfisols of Ramanagara district of Karnataka.

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Introduction

- Finger millet (*Eluesine coracana.*L.) is an important dry land millet crop and ranks third among millets in India after sorghum and pearl millet.
- Finger millet is a staple food crop and good for diabetic patients due to its better nutritional quality. The grains are rich in calcium and iron and known for its slow releasing pattern of sugar in to blood stream, there by it is recommended for diabetic patients.
- Phosphorus plays a key role in energy transfer and is essential for photosynthesis and other chemico-physiological processes in plants and application of phosphorus to soil low in available phosphorus promotes root growth and winter hardiness, stimulates tillering, and often hastens maturity.
- Potassium is required for activation of over 80 enzymes throughout the plant. It is important for plant to withstand extreme cold and hot temperatures, drought, pests and reduces lodging, increases water use efficiency and transforms sugars to starch in the grain-filling process.

Objective

- To study the effect of phosphorus and potassium levels on growth and yield of finger millet.

Material and Methods

The field experiment was conducted in Alfisols having low available phosphorus and potassium fertility under protective irrigation using randomized complete block design (RCBD) with 16 treatments at farmers field, Kodihalli village, Magadi taluk, Ramanagara district.

Experimental details	
Crop	Finger millet
Variety	GPU-28
Plot size	3.9 m X 3.2 m
Spacing	30cm X 10 cm
Season	*Kharif*, 2015

Treatment details	
T_1	100 % RDN + 0 % RDP + 0 % RDK.
T_2	100 % RDN + 0 % RDP + 100 % RDK.
T_3	100 % RDN + 0 % RDP + 125 % RDK.
T_4	100 % RDN + 0 % RDP + 150 % RDK.
T_5	100 % RDN +100 % RDP + 0 % RDK.
T_6	100 % RDN + 100 % RDP +100 % RDK. *(RDF)
T_7	100 % RDN + 100 % RDP + 125 % RDK.
T_8	100 % RDN + 100 % RDP +150 % RDK.
T_9	100 % RDN + 125 % RDP + 0 % RDK.
T_{10}	100 % RDN + 125 % RDP + 100 % RDK.
T_{11}	100 % RDN + 125 % RDP + 125 % RDK.
T_{12}	100 % RDN + 125 % RDP +150 % RDK.
T_{13}	100 % RDN + 150 % RDP + 0 % RDK.
T_{14}	100 % RDN + 150 % RDP + 100 % RDK.
T_{15}	100 % RDN + 150 % RDP + 125 % RDK.
T_{16}	100 % RDN + 150 % RDP + 150 % RDK.

NOTE: *RDF- Recommended dose of fertilizers (100:50:50 kg ha^{-1} N: P_2O_5: K_2O) RDN- Recommended dose of nitrogen, RDP – Recommended dose of phosphorus, RDK- Recommended dose of potassium. All the treatments received nitrogen and farm yard manure as per package of practice.

Initial available phosphorus and potassium content of experimental site.

Available nutrients	kg ha^{-1}	Rating
P_2O_5	16.85	Low
K_2O	108.70	Low

Results

Table 1. Growth parameters of finger millet as influenced by different levels of phosphorus and potassium.

Treatments	Plant height (cm)		No. of leaves hill^{-1}		No. tillers hill^{-1}	
	90 DAS	At harvest	90 DAS	At harvest	90 DAS	At harvest
T_1	87.06	90.67	26.73	25.19	2.93	3.13
T_2	92.77	96.68	30.80	28.70	3.33	3.47
T_3	92.87	98.85	34.07	29.30	3.53	3.53
T_4	92.94	100.17	34.87	30.12	3.60	3.67
T_5	99.21	103.93	42.00	33.99	4.27	4.33
T_6	105.36	105.69	42.87	41.49	4.40	4.60
T_7	106.08	107.24	44.87	42.00	4.47	4.67
T_8	106.26	108.69	45.00	43.80	4.60	5.00
T_9	105.37	107.33	45.40	42.82	4.73	4.87
T_{10}	106.76	108.58	48.47	43.97	5.20	5.47
T_{11}	108.79	110.18	50.25	44.53	5.47	5.60
T_{12}	109.05	112.28	50.10	44.27	5.47	5.60
T_{13}	105.57	109.58	45.07	43.27	4.80	5.33
T_{14}	107.61	113.42	49.93	47.53	5.33	5.60
T_{15}	109.67	116.01	56.66	49.42	5.80	6.00
T_{16}	109.92	116.08	55.34	49.39	5.87	6.07
S. Em±	1.34	1.41	1.66	1.20	0.22	0.25
CD at 5%	4.00	4.22	4.96	3.59	0.66	0.76

- Growth parameters like plant height, number of tillers hill^{-1} recorded significantly higher values in T_{16} at 90 DAS and at harvest over control and RDF (T_6) it was on par with T_{14} and T_{15}. Number of leaves hill^{-1} at 90 DAS and at harvest recorded higher values in T_{15} over control and RDF (T_6) but it was on par with T_{14} and T_{16}.
- Yield attributes *viz*; number of productive tillers hill^{-1} was recorded significantly higher values in T_{15} (4.47) over control (2.42) but it was on par with RDF (T_6), T_{16} and T_{14}. Number of ear heads hill^{-1} (3.83) and ear head weight hill^{-1} (24.10) was recorded higher values in T_{15} over control and RDF (T_6). However, 1000 grain weight was recorded significantly higher value in T_{16} over control and RDF (T_6) but it was on par with T_{15} and T_{14}.
- Significantly the highest grain (52.03 q ha^{-1}) and straw yield (87.57 q ha^{-1}) was recorded in T_{15} over control and RDF (T_6) but it was on par with T_{16}.

Plate 1: General view of experimental plot

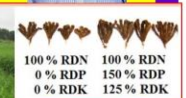

Plate 2: Comparison of ear heads of finger millet between control and superior treatment .

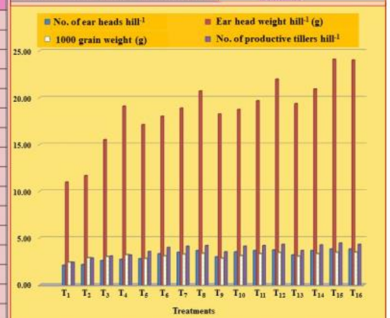

Fig.1: Yield parameters of finger millet as influenced by levels of phosphorus and potassium.

Fig.2: Grain yield and straw yield of finger millet as influenced by levels of phosphorus and potassium.

Discussion

- ✓ Increased levels of phosphorus and potassium significantly influence the growth and yield parameters of finger millet.
- ✓ Yield parameters like number of productive tillers hill^{-1}, number of ear heads hill^{-1} and ear head weight hill^{-1} was recorded significantly higher values in treatment receiving 100 % RDN, 150 % RDP and 125 % RDK (T_{15}). This may be the reason to get higher grain and straw yield in T_{15}.
- ✓ Promotion effect of high P level on growth parameters was due to higher availability of phosphorus, better development of root system, better nutrient and water absorption from large volume of soil.
- ✓ Influence of higher doses of P on yield parameters might be due to better root growth and proliferation resulting in an increase in the uptake of nutrients which produced higher number of productive tillers leading to higher yield.
- ✓ The addition of higher levels of K (125 % RDK and 150 % RDK) than the recommended dose, resulted in vigorous plant growth and higher grain yield in finger millet most probably relates to its stimulating effect on photosynthesis and enhancing the translocation of assimilates as well as enzyme activity and protein synthesis.

Summary

- ✓ Application of 100 % RDN + 150 % RDP + 125 % RDK (T_{15}) recorded the highest grain (52.03 q ha^{-1}) and straw yield (87.57 q ha^{-1}) where as application of potassium at 150 % RDK along with 100 % RDN and 150 % RDP (T_{16}) recorded lower grain (51.25 q ha^{-1}) and straw yield (86.64 q ha^{-1}) compared to T_{15}.
- ✓ Application of 100 % RDN + 150 % RDP + 125 % RDK is best option in enhancing the yield levels of finger millet grown on soils low in available phosphorus and potassium in Alfisols of Ramanagara district of Karnataka.

Advisory committee

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I INTRODUCTION

Productive agriculture is dependent upon sound soil nutrient management practices. Over years of intensive cultivation and imbalanced fertilizer use, Indian soils have become deficient in several nutrients among seventeen nutrients and organic matter which are essential for plants. Yields of various crops have reached a plateau and are on the decline. This is of serious consequence due to increasing population and diminishing per capita land availability. Several methods of nutrient management have been practiced on farms, however, the best option for the farmer is an integration of organic and inorganic approaches to nutrient management. However, current studies across India have shown a gradual and alarming depletion of potassium and phosphorus and also increase in phosphorus fixation leading to sustainability concerns for these two nutrients.

Phosphorus is recognised as an essential nutrient element and is equally important as nitrogen which limits crop growth. Most of the applied phosphorus through fertilizers gets fixed and become unavailable to crops. The use efficiency of phosphorus is as low as 8–20 per cent which is very low as compared to all other fertilizer nutrients. The main reason for the low use efficiency is due to its fixation in the soil. The response to applied P depends on soil properties, the initial available phosphorus, the level of nitrogen applied and management practices. Yield increases brought about by the application of phosphorus have been significant in low and medium level of available phosphorus containing soils. Under these circumstances, the application of phosphatic fertilizers has become assumed much significance to obtain higher crop yields.

The third most important element for plant growth is potassium and its content in the soil varies from low to high. It is referred to as a quality nutrient. The use efficiency of potassium varies from 20–30 per cent and is dictated by the process of erosion, leaching and fixation in the soil. The addition of potassium has always been overlooked and hence there has been potassium mining from the soil by plants leading to deficiency of potassium. Hence, potassium management is of importance specially because potassium influences the uptake of other major nutrients and influences crop quality. In many soils, there has been response to added potassium on soils considered to be high in so called "available potassium", whereas there have been cases where there was no response to added potassium even on low available potassium soils indicating the role of clay mineralogy on K release and fixation.

Alfisols are most abundant soils in semi–arid tropics and cover nearly 16 per cent of tropics and 33 per cent of semi–arid tropics (SAT). These soils are mostly found in south Asia, west and central Africa, and many parts of South America. These soils having a base rich argillic B horizon are probably the largest single soil group of the SAT. These soils are light textured in the surface horizons and may have higher clay content in deeper soil horizons. They occur on flat to rolling topography. They occur mostly in the states of Andhra Pradesh, Karnataka and Tamil Nadu on gneisses, indurated and metamorphosed rocks on undulating to rolling topography. Crusting is one of the primary causes of low yields on *Alfisols* because of this there is a reduction in germination and establishment especially of small-seeded crops such as pearl millet and finger millet. The *Alfisols* are generally low in organic matter, nitrogen, phosphorus, sulphur and zinc, where responses to fertilizers are high. Even potassium which may not be a limiting factor for crop production in the beginning becomes deficient with continuous cropping. The nutrient deficiency and responsiveness to fertilizer application on the farmers' fields is much greater than the soils of research stations. However, in *Alfisols* the synergistic effect of improved cultivar, fertilizer, and soil management is very marked. The *Alfisols* can produce many times more yields with proper soil management, use of fertilizers, high yielding varieties and crop management system. Finger millet is the most commonly grown crop on *Alfisols* of south India.

Finger millet (*Eleusine coracana* L. Gaertn) is a major food crop of the semi-arid tropics of Asia and Africa. It has a wide range of seasonal adaptation and is grown in varying soil and temperature conditions. Finger millet is commonly known as ‘Ragi’ is one of the important food crops and largely grown in southern states of India. In Karnataka, finger millet occupies an area of 1.02 million hectare with a production of 1.875 million tonnes, accounting for 53.95 per cent area and 44.94 per cent production (Anon., 2015). Its cultivation is concentrated mostly in the districts of Bangalore, Ramanagara, Kolar, Tumkur, Chitradurga, Hassan, Mysore, Mandya and Chamarajanagara. However, the yield levels are very low due to poor yielding varieties, poor soil fertility, rainfed farming, lack of improved crop management practices and imbalanced fertilizers application. Most of the soils in the semi-arid tropics, where finger millet is grown, are deficient in major and micronutrients, mainly due to continuous cropping, low use of mineral fertilizer, poor recycling of crop residues, and low rates of organic matter application which can limit yield potential. Therefore, it is important to optimize nutrient management practices and other related factors affecting finger millet cultivation in order to attain better yields under comparatively marginal local growing conditions.

The response of any crop, in general to the application of fertilizers depends upon the amount of available nutrients present in the soil as well as the amount of nutrients required by the crop for its normal potential yield. In attempting to study the behaviour of any crop with respect to varied nutrient regimes, the available nutrient present in the soil should also be considered along with the applied nutrient. Then the quantity of nutrient available to the crop for its growth and development will be the sum of plant available native nutrient as well as the applied one. Therefore, the selection of most appropriate rate of fertilization is a major decision affecting the profitability of crop production.

With regards to soil fertility status of Ramanagara district, among major nutrients available nitrogen status was medium to high, available phosphorus was low to medium and available potassium ranged from low to medium. In Magadi taluk the fertility status with respect to nitrogen, phosphorus and potassium was high, low and low respectively (Anon., 2013).

The farming community generally uses chemical fertilizers in imbalanced quantities, therefore maximium yield could not be obtained. Further it has been observed that farmers generally use only urea as chemical fertilizer without addition of phosphatic and potassic fertilizers. For sustainable agricultural cropping system balanced use of nutrients are essential.

Research information on response of crops to phosphorus and potassium levels have been generated, is very scanty and as such generating further information is very much essential specially in low phosphorus and potassium containing soils to combat the present situation. With this in view, the present study was initiated in low phosphorus and potassium soils to assess the response of finger millet to different levels of phosphorus and potassium fertilizers on *Alfisols* of Ramanagara district of Karnataka, with the following objectives,

1. To study the effect of phosphorus and potassium levels on growth and yield of finger millet.
2. To study the effect of phosphorus and potassium levels on soil properties, nutrient uptake and nutrient use efficiency by finger millet.

II REVIEW OF LITERATURE

Phosphorus and potassium are considered macronutrients and are required by plants in relatively higher amounts compared to other nutrients. Phosphorus is found in many cellular constituents including nucleic acids (DNA, RNA), phospholipids, ATP, and other high-energy compounds in plant cells. These compounds are necessary for photosynthesis, energy transfer, carbohydrate and protein synthesis, and lipid metabolism. Potassium is involved in number of important physiological processes in plants including activation of several enzymes, synthesis and degradation of carbohydrates, synthesis of protein, opening and closing of stomata.

In most of soils, the native as well as added P undergoes various reactions and lead to the formation of different reaction products. The availability of phosphorus in soil mainly depends upon degree and duration to which these reaction products supplies phosphorus for crop uptake. The main problem of potassium in soil is fixation, erosion loss and leaching.

The literature pertinent to the present investigation entitled, "Response of finger millet to phosphorus and potassium levels in *Alfisols* of Ramanagara district of Karnataka" have been reviewed in this chapter under the following headings.

2.1. Influence of phosphorus and potassium levels on growth and yield parameters.

2.2. Effect of phosphorus and potassium levels on soil properties.

2.3. Effect of phosphorus and potassium levels on nutrient uptake and nutrient use efficiency.

2.4. Effect of phosphorus and potassium levels on cost: benefit ratio of crop cultivation**.**

2.1. Influence of phosphorus and potassium levels on growth and yield parameters

2.1.1. Influence of phosphorus levels on growth and yield parameters.

A linear response was noticed by Venkata Rao and Sadashivaiah (1969) in terms of yield of two finger millet varieties (Cv. 9-2-7 and Purna) to super phosphate application up to 320 kg P_2O_5 ha^{-1} with subsequent phosphorus build up in red soils of Mysore.

Application of 70 kg P_2O_5 to two finger millet cultivars (Co-7 and ECW-840) resulted in 10 and 9 per cent higher grain and straw yields respectively over control with no P (Ramaiah *et al*., 1970). Similarly, Badanur and Venkata Rao (1972) reported that ragi recorded 144.2 to 151.0 per cent increase in yield over control at the highest level of P_2O_5 application.

Kumaraswamy and Krishnamoorthy (1974) reported that there was maximum grain and straw yield of finger millet, phosphorus uptake and plant phosphorus content in red, calcareous and non- calcareous soil with increased P application by advancing maturity of finger millet by one week.

Phosphorus application of 17.5 kg ha^{-1} significantly increased the plant height, panicle number, number of functional leaves and nodes, length of panicle, number of fingers in ear, 1000 grain weight and grain yield (Ramaiah and Morachan, 1978)

Kadrekar and Bhosale (1981) reported that the grain yield of rainfed finger millet increased from 1.34 to 1.91 t ha^{-1} and 1.52 to 1.84 t ha^{-1} with increasing N (0-100 kg) and P_2O_5 (0-50 kg) doses respectively. While, Natarajan *et al.* (1983) in their experiment on acid soils using two P sources namely superphosphate and Mussorie rock phosphate found that, addition of these fertilizers (0, 30, 60, 90 kg P_2O_5 ha^{-1}) to finger millet increased yields and had a residual effect on the succeeding crop (*Phaseolus mungo*). However, the increase in yields was only at higher levels of phosphorus addition.

Kalaghatagi *et al*. (1998) carried out a field experiment on response of finger millet to nitrogen and phosphorus under rainfed condition and found a significant increase in grain yield of finger millet with application of 75 kg ha^{-1} of nitrogen and 60 kg of phosphorus ha^{-1} and inferred that the highest grain yield was due to the number of effective tillers $plant^{-1}$ and higher number of fingers per ear head of finger millet.

Application of 60 kg P_2O_5 ha^{-1} through phosphorus compost significantly increased the growth, dry matter and yield of green gram over application of 60 kg P_2O_5 per ha through phosphorus–FYM, phosphorus-vermicompost, phosphorus-poultry manure, phosphorus- pressmud, phosphorus-city compost and single super phosphate (Raundal *et al.*, 1999).

Singh *et al*. (2005) reported that the application of phosphorus at 60 kg P_2O_5 ha^{-1} significantly increased almost all the growth (plant height, number of branches $plant^{-1}$) and yield attributes (number of pods per plant, number of seeds pod^{-1}), resulting in higher grain and biological yields in chickpea. Similarly, application of 5 t FYM ha^{-1} and 17.47 kg P ha^{-1} significantly enhanced the plant height, yield attributes (ear head length and test weight), grain yield, stover yield, protein content of pearl millet grain (Jakhar *et al*., 2006).

Onasanya *et al*. (2009) conducted field experiment to asses growth and yield response of maize (*Zea mays* L.) to different rates of nitrogen and phosphorus fertilizers on soils low in available phosphorus and concluded that application of 120 kg N ha^{-1} + 40 kg P ha^{-1} has significantly enhanced growth and grain yield of maize compared to 120 kg N ha^{-1} + 0 kg P ha^{-1}.

Muhammad Bilal Khan *et al.* (2010) concluded that the growth and yield parameters of wheat viz., plant height, number of tillers per plant, spike length, number of grains per spike, grain and straw yields were significantly improved by application of P at 80 kg P ha^{-1} through single super phosphate (SSP) as compared to triple super phosphate (TSP), nitrophos (NP) and diammonium phosphate (DAP) on phosphorus deficient soil.

Tanweer Mukhtar *et al.* (2011) conducted a field experiment to study the response of maize crop to various NP levels. Six NP rates were tried on two maize hybrids (YH-1898 and YH-1921) for growth and yield. Results revealed that, all fertilizer rates significantly increased the plant height, 1000 grain weight, grain number per ear, grain weight per ear and grain yield of both hybrids over control. NP rate of 250-125 kg gave maximum 1000-grain weight (430.0 g), grain number (658 ear^{-1}), grain weight per ear (281.3 g) and grain yield (8.237 t ha^{-1}), followed by 300-150 kg NP. They concluded that higher nitrogen and phosphorus doses beyond optimum level delayed crop maturity which ultimately reduced the yield.

Mojid *et al*. (2012) reported that most of the growth and yield attributes improved significantly with the increase in P dose up to 20 kg ha^{-1}, beyond which the phosphorus exerted negative, but insignificant, effect on the crop attributes. The omission of nitrogen or phosphorus significantly reduced the yield attributes and yield of wheat.

Mumtaz *et al*. (2014) reported that application of higher dose phosphorus with optimum irrigation has significant effect on growth of wheat. Higher phosphorus application rate compensate the effect of water stress conditions both at vegetative and reproductive stages. Application of phosphorus at higher rate (120 kg ha^{-1}) could compensate drastic effect of water stress. On overall performance, application of phosphorus at the rate of 120 kg ha^{-1} showed better results under water stress conditions as compared to low phosphorus levels.

Sushanta Saha *et al*. (2014) carried out a field experiment to evaluate the fate of different sources of applied P into its nutrition to wheat in calcareous soils and concluded that water soluble sources of phosphatic fertilizers (Single super phosphate, Diammonium phosphate, Urea ammonium phosphate) were found superior over partially water soluble (nitrophosphate) and mineral acid soluble (RP) sources in terms of grain yield. Further, with increasing levels of P from 60 to 120 kg P_2O_5 ha^{-1}, grain yield increased significantly**.**

2.1.2. Influence of potassium levels on growth and yield parameters.

Besides nitrogen and phosphorus, the effect and usefulness of potassium for satisfactory growth of ragi crop has been reported by Govindarajan and Venkata Rao as early as 1952 regarding yield of ragi and its positive relationship with potassium.

Grain yield of finger millet increased up to 100 kg K_2O ha^{-1} but combined harvestable yield were maximum at 7.37 t ha^{-1} of FYM with 50 kg N + 100 kg each P_2O_5 and K_2O (Csatho, 1991). Similarly, Roy *et al.* (1991) found a significant grain and stalk yield of maize with increasing K levels upto 60 kg K_2O ha^{-1}, the per cent response in grain yield being 19.7. Total K uptake by maize also varied considerably and maintained almost similar trend as that of the yield. Whereas, Chaudhary and Roy (1992) observed that the yield of maize grain and straw increased significantly with the increasing levels of K application. Per cent increase in yield over control and response in kg grain per kg K_2O also showed an increase up to 60 kg K_2O ha^{-1}. Further increase in the levels of fertilizer did not make any significant difference in yield.

Thippeswamy (1995) reported that grain and straw yield of ragi increased when 50 kg K_2O ha^{-1} was applied in three splits and the increase in yield was attributed to availability of K at critical stages of plant growth.

Cheema *et al.* (1999) noticed that the application of 150 kg ha^{-1} of potassium resulted in tallest plants (226.5 cm) but it was on par with 50, 75, 100, 125 kg ha^{-1} of potassium. The maize yield improved by the application of potassium, where the highest grain yield of 6.78 t ha^{-1} was noticed in the application of potassium at 125 kg ha^{-1}. The increase in yield was attributed to greater number of grains per cob and 1000 grain weight. Further, the application of potassium at higher level (150 kg ha^{-1}) was found to be uneconomical. Similarly, Nanjundappa (2002) reported that the grain yield of maize increased with increasing dose of potassium and also because of split application of potassium. The increase in yield component may be due to the availability of sufficient potassium which favoured the translocation of assimilates from source to sink, because potassium is directly involved in photosynthetic phosphorylation and also split application of potassium resulted in its availability at various stages of crop growth.

Baque *et al.* (2006) reported that higher levels of potassium (312 kg ha^{-1}) improved the dry matter production in wheat. The yield and yield contributing traits of wheat significantly improved with higher doses of K (312 kg ha^{-1}) compared to low (39 kg ha^{-1}) and medium (156 kg ha^{-1}) doses of potassium.

Muhammad Tariq *et al.* (2011) reported that, the grain yield of maize was significantly increased as the supply of potassium rates increased from both muriate and sulphate of potash sources over control. However, maximum grain yield was recorded in the treatment receiving 150 kg K_2O ha^{-1} from muriate and sulphate of potash in both silty clay loam and silt loam. This is a clear indication that in both the test soils available-K was below the reported critical deficiency limit which showed positive response to applied potassium from either source.

Ali Rahimi (2012) studied the effect of potassium and nitrogen on yield and yield components of dry land wheat and found that the effect of potassium on grain yield was highly significant. Increasing the level of potassium to 100 kg ha^{-1}, increased the grain yield to 4985 kg ha^{-1}. The results also showed that effect of nitrogen on grain yield was highly significant. The grain yield was increased to 4800 kg ha^{-1} by the application of 80 kg ha^{-1} nitrogen. The interaction of potassium and nitrogen on 1000 grain weight and plant height was significant at 1 per cent level. The highest 1000 grain weight (46 g) was obtained with 100 kg ha^{-1} potassium with 80 kg ha^{-1} nitrogen (N_{80} K_{100}).

Mastoi *et al*. (2013) conducted a field experiment to evaluate the response of hybrid maize to integrated use of inorganic and organic K fertilizers where AB-DTPA extractable K is deficient and concluded that the potassium nutrition enhanced various traits of maize *viz.*, plant height (2 to 15 %), fresh biomass (13 to 60 %), cob yield (16 to 76 %), grain yield (22 to 83 %), 1000 grain weight (2 to 30 %), K concentration (150 to 366 %). Further, K application at 60 kg ha^{-1}, by integrating organic and inorganic K fertilizers @ 30 kg ha^{-1} each, potentially improved the growth and biomass production of maize.

Ramachandrappa *et al*. (2014) showed the importance of potassium in finger millet, when applied in conjunction with recommended N (50 kg ha^{-1}) and P (40 kg ha^{-1}). Application of 150 per cent of recommended K (37.5 kg ha^{-1}) to finger millet significantly increased the grain yield (3,857 kg ha^{-1}) and straw yield (8,125 kg ha^{-1}), as compared to the yield obtained with the recommended K (25 kg ha^{-1}) application (3,380 and 7,651 kg ha^{-1} respectively).

Prakash Maurya *et al.* (2014) carried out a field experiment to study the effect of potassium levels on growth and yield of wheat (*Triticum aestivum* L.) varieties. Results revealed that growth characters like number of ear head (391.2 m^{-2}), effective tillers (266.4 m^{-2}) and total number of tillers (317.5 m^{-2}) and yield attributes like length of spike (9.3 cm), no. of spikelets $spike^{-1}$ (19.9), weight spike-^{1} (2.6 g), grains $spike^{-1}$ (46.30) and weight of grains $spike^{-1}$ (1.83 g) were recorded superior values with application of 80 kg K_2O ha^{-1}. Similarly, the highest grain (50.7 q ha^{-1}) and straw yield (70.1q ha^{-1}), were also recorded under 80 kg K_2O ha^{-1} which was on par with 60 kg K_2O ha^{-1}.

2.1.3. Influence of integrated levels of phosphorus and potassium on growth and yield parameters

Shivashankar and Yogesh (1990) reported that, maize grain yield increased to 58.5 q ha^{-1} and 62.1 q ha^{-1} with 135 and 170 per cent increased usage of fertilizer over the yield of 50.9 q ha^{-1} with 150-75-37.5 kg NPK ha^{-1}, the general recommended fertilizer dose for maize in Karnataka under irrigated situation.

Iftikhar Hussain *et al.* (2002) studied the effect of three levels of nitrogen, phosphorus and potassium (35-25-25, 70-50-50 and 105-75-75) on growth, yield and quality of three wheat varieties viz., Inqulab 91, Kharchia and Parwaz-94. They found that the different levels of nitrogen, phosphorus and potassium significantly affected plant height, number of fertile tillers, grain yield and grain protein content of wheat. The highest grain yield of 4.99 t ha^{-1} was recorded in Inqulab 91 with the application of 105-75-75 kg of NPK ha^{-1} due to more fertile tillers, number of grains per spike.

Abida Akram *et al.* (2007) studied the balanced nutrient management for improved and economic production of sorghum. It was grown with phosphorus (80 kg ha^{-1}), potassium (40 kg ha^{-1}) as their sole and combined application along with uniform level of nitrogen (120 kg ha^{-1}). Results indicated that P enhanced the crop growth and yield, and the best results were observed with their combined application. Maximum biological and grain yield of sorghum were 31.7 ha^{-1} and 2.26 t ha^{-1} respectively under integrated dose of phosphorus and potassium.

Arun Kumar *et al.* (2007) observed the highest leaf area index, dry matter yield, number of grains cob^{-1}, cob length (cm), cob girth (cm), fresh cob yield (t ha^{-1}) in treatment which received 100 per cent RDN + 100 per cent RDP + 125 per cent RDK when compared to the treatment which received 50 per cent RDN + 75 per cent RDP + 75 per cent RDK in maize crop.

Nazim Hussain *et al.* (2007) conducted an experiment to assess the influence of different levels of phosphorus and potassium on the yield of maize varieties viz., Azam and Kissan-90. They found that the higher rates of both phosphorous and potassium fertilizers have significantly increased the number of grains per ear, weight per ear and application of 90 kg of phosphorus ha^{-1} and 60 kg of potassium ha^{-1} performed well for getting maximum grain yield of Azam variety compared to Kissan-90. However, Slaton *et al.* (2009) conducted a field studies to evaluate the effect of phosphorus and potassium fertilization rate on yield of wheat and found no significant yield increase from potassium fertilization on the soil with a low soil test K level and the wheat yield respond positively to phosphorous fertilization on the soil with low soil test P level and there would be no yield benefit on the soil having adequate phosphorus availability.

Amanullah and Khan (2010) conducted an experiment to study interactive effect of potassium and phosphorus on phenology and grain yield of sunflower with six levels of K (0, 25, 50, 75, 100, and 125 kg K ha^{-1}) as main plots and four levels of P (0, 45, 90, and 135 kg P ha^{-1}) as sub-plots with three replications on P and K deficient soil. The results revealed that the combined application of 100 kg K and 45 kg P ha^{-1} significantly increased yield components, grain yield, harvest index and shelling percentage of sunflower, suggesting that 100 kg K ha^{-1} in combination with 45 kg P ha^{-1} could maximize productivity of sunflower on the P and K deficient soils. Whereas Qudrat Ullah Khan *et al.* (2014) revealed that the application of P and K at 120 and 60 kg ha^{-1} respectively to the wheat grown on newly developed tube well irrigated soil recorded the maximum plant height (63.60 cm), spike length (10.87 cm), biological yield (2.68 t ha^{-1}) and grain yield (1.50 t ha^{-1}).

Upendra Rao *et al.* (2014) reported that there was significant increase in tiller production by enhancing the doses of P and K by 25 per cent over the recommended doses in *kharif* rice. Further, conspicuous differences in yield attributing characters were also found with incremental doses of N, P and K. The panicle production was significantly different at 50 per cent increment of P and K only. Marked increase in number of filled grains per panicle was recorded due to 25 per cent increase in N and K and 50 per cent increase in P doses. Increase in P and K doses from 100 to 125 per cent did not improve the yield significantly whereas increase in recommended P and K doses from 100 to 150 per cent improved the grain yield significantly.

Dakshina Murthy *et al.* (2015) observed that the growth, yield attributes and yield of rice were significantly influenced by different levels of N, P and K. There was significant increase in tillers as well as dry matter production by enhancing phosphorus and potassium doses by 25per cent over the recommended dose. The panicle production was significantly augmented at 50 per cent increment of P and increase of K dose by 25 per cent and 25 to 50per cent. Increase in P and K doses from 100 to 125 per cent improved grain yield significantly however, further incremental doses of P and K beyond 125 per cent did not result in significant yield improvement.

Mudalagiriyappa *et al*. (2015) conducted an experiment to study the effect of customized fertilizers on the productivity of finger millet. The results revealed that the application of 150 per cent customized fertilizer recorded higher plant height (102.5 cm), number of tillers hill^{-1} (7.11), total dry matter accumulation (100.41 g hill^{-1}), ears hill^{-1} (6.21) and test weight (3.65 g) compared to absolute control, 50, 75, 100 and 125 per cent customized dose. Application of 150 per cent customized fertilizer dose recorded significantly higher grain and straw yield (3279 and 4510 kg ha^{-1}, respectively) compared to other treatments but, it was on par with application of 100 and 125 per cent customized fertilizer application.

Patil *et al*. (2015) carried out a field investigation to study the effect of different levels of fertilizers on growth and yield of finger millet on soils low in available phosphorus and moderately high in available nitrogen and potash. The RDF through briquettes (60:30:00 Kg NPK ha^{-1}) showed significantly higher results regarding different growth attributes like plant height, number of functional leaves plant^{-1}, number of tillers hill^{-1}, leaf area plant^{-1} and dry matter production plant^{-1}. Further, the RDF through briquettes (60:30:00 Kg NPK ha^{-1}) was recorded significantly higher yield attributing characters like number of fingers earhead^{-1} and 1000 grain weight. The higher yield attributing characters resulted into significant increase in grain yield (25.20 q ha^{-1}) and straw yield (32.72 q ha^{-1}) with the application of RDF through briquettes.

Aruna *et al.* (2016) reported that grain and straw yield of aerobic rice differed significantly due to graded nutrient levels and the highest grain and straw yield was recorded in 175 per cent recommended dose of nutrients which was however comparable with 150 per cent recommended dose of nutrients.

2.2. Effect of phosphorus and potassium levels on soil properties.

2.2.1. pH, EC and Organic carbon.

Application of plant nutrients especially through organic and inorganic sources continuously influences soil chemical properties such as pH, electrical conductivity, organic carbon content etc.

Formali and Prasad (1979) observed that continuous application of FYM for three years reduced the soil pH from 8.8 to 8.6, whereas application of phosphorus and potassium had no effect on soil pH. However, Singh *et al.* (1980) reported that continuous application of FYM and chemical fertilizers decreased soil pH by about one unit from the initial value could be related to the decomposition and mineralisation of organic matter.

Application of NPK at different combinations through chemical fertilizers has been reported to significantly increase the electrical conductivity of soil (Choudhary *et al.* 1981 and Hifzur Rahman, 1986). Whereas, Kapor *et al.* (1986) reported that continuous application of inorganic fertilizers although brought about a change in soil pH, did not significantly affect the electrical conductivity of the soil.

Singh and Nambiar (1986) found that continuous use of nitrogenous fertilizers resulted in decrease of soil pH. However, NPK in combination with FYM reduced the soil acidity.

Bhandari *et al.* (1992) found that organic carbon content of soil increased significantly with the application of 100 per cent RDF. The conjunctive use of organic manures viz., FYM, green manures with fertilizers further increased the organic carbon content of soil. Similarly, Sudhir and Siddaramappa (1995) reported that organic carbon content of an Alfisol increased 17.8 per cent in plot treated with 100 per cent NPK in the form of fertilizers and by 78.3 per cent in the plots treated with 100 per cent NPK plus FYM.

Addition of FYM along with inorganic fertilizers has been reported to increase the electrical conductivity of soil significantly (Subramanian and Kumaraswamy, 1989), whereas, Santhi *et al.* (1999) observed that the salt content increased slightly due to application of 100 per cent NPK in combination with farmyard manure.

Sudhir *et al.* (1996) reported that continuous use of only chemical fertilizers at different stages significantly decreased the pH of an Alfisol, while application of chemical fertilizers along with FYM maintained the soil pH at initial value. However, Srikanth *et al*. (2000) observed decrease in pH of Alfisol due to either FYM or Vermin compost applied to supplement 50 per cent recommended phosphorus to crop. The soil pH in the treatment receiving recommended dose of inorganic fertilizer was 7.24 which decreased to 7.08 and 7.04 due to the addition of FYM and vermin compost respectively. This was ascribed to the acidifying effect of organic acid released during the decomposition of organic amendments.

Chandra Kumar (2001) observed no significant change in soil pH due to application of various levels of inorganic fertilizers either alone or in combination with organics. However, combined application of organic materials along with inorganic fertilizers recorded comparatively lower soil pH than that with inorganic fertilizers alone.

Jatav *et al.* (2010) reported that the highest soil pH (6.50) was obtained with application of 100 per cent PK from farmyard manure. Likewise, integrated use of 50 per cent PK from inorganic fertilizers and 50 per cent from FYM resulted in highest organic carbon and available P content in soil.

Application of FYM alone or together with mineral fertilizer resulted in a higher C input and consequently built up a higher C stock. After 27 years, higher profile SOC stock (85.7 Mg ha^{-1}), C build up (35.0%), and C sequestration (15.4 Mg C ha^{-1}) was observed with the application of 10 Mg FYM ha^{-1} along with recommended dose of mineral fertilizer and these were positively correlated with cumulative C input and well reflected in sustainable yield index (SYI). (Srinivasarao *et al.,* 2012)

Hemalatha and Chellamuthu *et al.* (2013) studied the effect of continuous fertilization on soil nutrient status after 36 years of cropping cycle on an Inceptisol, and concluded that the soil reaction, as reflected in the pH, soil salinity as measured by EC has not changed significantly due to the different fertilizer schedules adopted over 36 years. The organic carbon content of the soil has increased significantly in all the treatments that received NPK at different levels. The highest value of 6.2 g kg^{-1} was recorded in the treatment receiving 100 per cent NPK + FYM @ 10 t ha^{-1} which was 55 per cent higher than control and also 107 per cent higher than the initial status.

Fayaz Ali *et al.* (2014) reported that the application of P through single super phosphate increased the pH-values initially and later gradually decreased, which resulted significantly negative correlation with one another (r^2 = 0.83). These results indicate that with the application of P as single super phosphate reduced the pH of soil and has favorable effect on the solubility of micronutrients, specifically Fe and Mn in alkaline-calcareous soils.

Hussain *et al.* (2015) conducted an experiment on interaction of diammonium phosphate and potassium sulphate in saline-sodic soil for maize (*Zea mays* L.) crop. Results revealed that increase in the values of EC_e and pH (1:5) in the post-harvest soil was observed when compared with the initial pre-harvest soil test values.

2.2.2. Available nitrogen, phosphorus and potassium

Chaudhary *et al.* (1981) reported that the available nitrogen content of the soil increased significantly with P and K application. The mean increase in available N with P_{30} and P_{60} over P_0 was 10 and 13 ppm, respectively and the mean increase in available N with K_{30} over K_0 was 6 ppm.

Prasad *et al*. (1983) found that application of 150 per cent recommended NPK recorded significantly higher available N (368 kg ha^{-1}), P (60.2 kg ha^{-1}) and K (142 kg ha^{-1}) in soils as compared to 200, 10.1 and 102 kg N, P and K ha^{-1}, respectively under control in red loamy soils of Ranchi. Further, the application of N alone decreased the availability of P and K. Whereas, Singh and Nambiar (1986) reported that application of NPK at 100 to 150 per cent based on initial soil test showed appreciable improvement in available N, P and K in soil. Depletion of P was highest under 100 per cent nitrogen treatment and K under 100 per cent N and P treatment in medium black soils of Coimbatore. Similarly, Thimma Reddy (1988) observed highest available nitrogen content in the soil which received the highest dose of (150 %) NPK fertilizers.

Lokeshwarappa (1997) noticed that application of phosphatic fertilizers continuously at 100 per cent and more than 100 per cent of recommended dosage of P recorded substantial build-up of total P in an Alfisol at Bangalore in finger millet-hybrid maize-cowpea cropping sequence.

Acharya *et al.* (1998) noticed higher available phosphorus content in the surface and subsurface layers due to application of farmyard manure in combination with 100 per cent NPK. Significant build up in available P to the extent of 40.9 per cent was observed when inorganic P was applied in combination with farmyard manure. Similarly, Singh *et al.* (1999) reported higher available K status of soil in NPK + FYM treatment compared to control. Application of FYM at the rate of 5 t ha^{-1} over and above the 40 kg K_2O ha^{-1} had helped to maintain the soil available K status, and in the same way Suresh *et al.* (1999) noticed higher K content in the treatment with FYM + K fertilizer due to addition of K nutrient directly through FYM and K fertilizer to the available soil nutrient pool.

Anon (2006) reported that all the forms of K was relatively higher in plots treated with 150 per cent NPK and 100 per cent NPK + FYM as compared to those treated with lower doses of K and which were not treated with potassic fertilizers.

Jagathjothi *et al.* (2010) recorded higher available nutrients (NPK) in band placement of enriched farm yard manure @ 2 t ha^{-1} + 100 per cent of recommended N and K treatment with values of 164, 13.36 and 353 kg ha^{-1} over recommended dose of fertilizer alone and absolute control in finger millet crop.

Kalaichelvi (2008) reported that the soil available nitrogen and phosphorous was significantly influenced with fertilizer levels after harvest of cotton. Application of fertilizers at the rate of 200:100:100 kg NPK ha^{-1} recorded higher nitrogen and phosphorus availability. However, fertilizer levels had no significant influence on potassium availability. Whereas, Wan-Tai Yu *et al.* (2009) revealed that treatment with N, P and K fertilizers appreciably improved the fertility level of soil, increased the concentration of soil exchangeable K and decreased the non-exchangeable K concentration. In soils under treatment with N, P and K fertilizers and recycled manure, the soil-exchangeable and non-exchangeable K levels in 0-20 cm depth soil layer increased by 34 per cent and 2 per cent, respectively, over the initial levels in soybean-maize rotation.

Hemalatha and Chellamuthu (2011) studied the effect of continuous fertilization on soil inorganic phosphorus (P) fractions after 36 years of cropping cycle on a sandy clay loam soil. Long-term application of 150 per cent NPK increased the soil inorganic P fractions followed by 100 per cent NPK + FYM. But the availability of P is higher in the plots receiving 100 per cent NPK + FYM.

Maruthi Shankar *et al.* (2011) reported that application of FYM at 10 t ha^{-1} + 100 per cent NPK gave significantly higher organic carbon (0.45%), available N (204 kg ha^{-1}), available P (68.6 kg ha^{-1}), and available K (107 kg ha^{-1}) over years. In maize residue block, application of maize residue at 5 t ha^{-1} + 100 per cent NPK gave a significantly higher organic carbon (0.39%), available soil N (190 kg ha^{-1}), available soil P (47.5 kg ha^{-1}), and available soil K (86 kg ha^{-1}).

Meena and Biswas (2014) reported that application of compost material as well as recommended dose of fertilizers either alone or in combination maintained significantly greater available P and application of 100 per cent RDK significantly increased the available potassium content at both 0-15 cm and 15-30 cm depth after wheat harvest compared to the unfertilized control. Similarly, available N, P and K status increased due to 100 per cent NPK+ FYM application and recorded 195, 26.7, 639 kg ha^{-1} respectively. Exclusion of nutrients led to depletion of that nutrient in soil. Generally, there was a reduction in total nutrient content of the soil from the initial level. (Hemalatha and Chellamuthu *et al*., 2013)

Upinder Sharma and Paliyal (2014) studied the effect of long-term use of fertilizers and organics on phosphorus dynamics in rainfed maize-wheat cropping system. Results revealed that Olsen-P increased significantly in all the treatments where P and FYM was applied. The maximum amount of Olsen-P (39.0 kg ha^{-1}) was recorded in 100 per cent NP + FYM followed by 100 per cent NPK treatment (34.20 kg ha^{-1}). The Olsen-P showed a decline from the initial status in the treatments where only N fertilizers were applied either alone or with FYM treatment.

Hussain *et al.* (2015) conducted an experiment on interaction of diammonium phosphate and potassium sulphate in saline-sodic soil for maize (*Zea mays* L.) crop. Results revealed that extractable P increased after P treatments in the soil and application of K significantly decreased Na: K ratios in the soil.

Mazur and Mazur (2015) studied the influence of long-term, annually applied fertilization with manure, slurry, and NPK on the accumulation of total and available forms of phosphorus and potassium. They concluded that the increase in total phosphorus and potassium content under the influence of fertilization was significant when compared to the control and determined it as P-21.8 per cent, K-36.2 per cent in lessive soil and P-24.7 per cent in brown soil.

2.2.3 Available calcium, magnesium and sulphur.

Swarup and Ghosh (1979) studied the change in water soluble sulphur as a result of intensive cropping and manuring. They noticed the maximum available sulphur with the use of FYM and also noticed that NPK level at 150 per cent of the optimum, brought about a significant reduction in the exchangeable Mg, probably due to depressing effect caused by the high rate of K applied. The maximum increase was recorded in the treatment receiving farmyard manure along with 100 per cent NPK.

Yadhuvansi *et al.* (1985) reported that continuous application of NPK fertilizers and FYM would increase the exchangeable calcium and magnesium contents in the soil. They also reported that the continuous use of only chemical fertilizer would cause depletion in calcium and magnesium contents of soil due to release of higher levels of exchangeable H^+ and Al^{3+} ions. Higher levels of NPK would also cause higher crop production and hence depletion in contents of basic cations.

Prasad *et al.* (1996) studied the available nutrient status of a continuously fertilized and cropped acid soil and found that FYM treatments increased the exchangeable calcium and magnesium status of the soils due to biomass incorporation in the soil.

Parashuram Chandravanshi (1998) observed that the use of FYM in combination with inorganic NPK fertilizers significantly increased the available sulphur content of soil. Similarly, Singh *et al.* (1999) reported that application of NPK fertilizers with FYM resulted in significantly higher sulphate-S content than other fertilizer treatments and control. The use of both organic and inorganic fertilizers in combination significantly increased the available sulphur content in the soil after the harvest of crop.

A long term fertilizer experiment with N alone and sulphur free NPK fertilizers for the last 12 years showed a declining trend in available sulphur status of soil. Application of FYM along with 100 per cent NPK plus lime increased the available sulphur content of the soil (Yifter Nega *et al*., 2001)

Hemalatha and Chellamuthu (2013) reported that the available status of Ca (16.89 c mol (p^+) kg^{-1}) and Mg (8.40 c mol (p^+) kg^{-1}) of the soil have increased significantly in all treatments but was recorded highest values in the treatment receiving 100 per cent NPK+ FYM at 10 t ha^{-1}. Similarly, Pushpa *et al*. (2013) reported that where ever single superphosophate, FYM and lime were applied there was higher sulphur content in soil compared to no sulphur applied plots (100 % NPK-S free).

Mazur and Mazur (2015) reported that the increase in magnesium (57.4%) and sulphur (28.5%) content under the influence of fertilization was significant when compared to the control in the experimentation on the influence of long-term, annually applied fertilization with manure, slurry and NPK on the accumulation of total and available forms of magnesium and potassium.

2.2.4 Micronutrients

Biswas *et al.* (1977) observed that high level of available P in soils of the experimental plots reduced the availability of Zn. They concluded that this might be due to the interaction of P and Zn. But K fertilizer application enhanced the uptake of Zn for which they suggested that application of K might overcome the retarding effect of applied P on the translocation of Zn from roots to shoots.

Narasimha Rao *et al*. (1985) reported that application of P depressed the availability of Zn and Fe. This was more pronounced at higher levels of residual P fertilizers. Whereas, Kapur and Rana (1986) observed decreased Zn and Mn content in the soil with the increase in N and P level. This might be due to the crop removal, but K did not show any influence on the Mn content of soil.

Atheefa Munawery (2007) reported from long-term experiment with special reference to micronutrient availability that the application of 100 per cent NPK with FYM and 100 per cent NP and N alone recorded significantly higher available zinc, copper and manganese respectively. While, application of 100 per cent NPK (S-free) recorded higher available iron.

Chandra Deo and Khandelwal (2009) concluded that the available P and DTPA-extractable Zn content of soil increased significantly with increasing levels of P_2O_5 and Zn. The highest available P in soil was found with 60 kg P_2O_5 ha^{-1} and lowest in no-P application. The increase in P_2O_5 content of soil was due to low utilization efficiency of the applied P in soil (25 to 30 % of applied P). The highest content of available Zn was observed in treatment where 10 kg Zn ha^{-1} was applied and lowest with no-Zn application.

Pushpa *et al.* (2013) reported that the higher concentrations of micro nutrients (Fe, Mn, Cu, and Zn) were recorded in 150 per cent recommended fertilizers and FYM applied plots compared to other treatments, whereas Hemalatha and Chellamuthu *et al.* (2013) observed that the micronutrients like iron, zinc, manganese and copper were significantly higher in the treatment receiving 100 per cent NPK + FYM @ 10 t ha^{-1} from the long term field experiment on different doses of graded fertilizers with and without FYM in finger millet – maize cropping sequence at Tamil Nadu Agricultural University, Coimbatore.

Fayaz Ali *et al.* (2014) studied the effect of phosphorus application on the availability of micronutrients in soil and concluded that as the application of phosphorus increases, the concentrations of B, Zn and Cu gradually decreases, which indicate negative interactions, while the concentrations of P, Fe and Mn increases perhaps due to positive interactions with applied phosphorus during incubation period.

2.3. Effect of phosphorus and potassium levels on nutrient uptake and nutrient use efficiency

2.3.1 Nutrient uptake

Almost all the elements in soil are likely to be taken up by the crop plants grown there irrespective of whether they are essential or not for the plants and application of fertilizers to soil is also likely to influence further the nutrients uptake by plants.

Antony Joseph and Danapalan Mosi (1972) observed that K uptake by finger millet was greatest when 120 lbs of ammonical N was applied.

Deosthale *et al.* (1972) while studying the effect of NPK fertilizer on mineral composition of jowar grain noticed that P application (0 to 120 kg ha^{-1}) significantly enhanced the grain mineral composition such as Ca, Mg, P and Fe.

Muthuvel and Krishnamoorthy (1978) found that P content was not much affected by soil moisture in finger millet, but application of 45-135 kg N ha^{-1} decreased it. They also recorded that the P content and uptake were higher in plants grown on red soil than on black soil.

Satyanarayana *et al*. (1978) reported that increasing the levels of N and P increased the uptake of N, P and K by finger millet. The increase in uptake of N at 90 kg N ha^{-1} was about 325 per cent over control. The uptake of P by grain in control was 3.2 kg ha^{-1} whereas with 60 kg P_2O_5 ha^{-1}, the uptake was 6.5 kg ha^{-1}. Whereas, Kavalappa (1989) reported that the application of 100 per cent NPK plus FYM (10 t ha^{-1}) recorded significantly higher uptake of N (62.24 kg ha^{-1}), P (9.23 kg ha^{-1}) and K (30.16 kg ha^{-1}) by finger millet grain and 117.84, 7.16 and 105.01 kg N, P and K ha^{-1} by finger millet straw, respectively at Bangalore. Similarly, Rao *et al.* (1998) revealed that phosphorus uptake by soybean and wheat, available P in the postharvest soil increased significantly with increasing rates of both FYM and fertilizer P.

Shivakumar (1999) reported that application of 50 per cent recommended NPK ha^{-1} through fertilizer along with 50 per cent NPK through FYM recorded higher uptake of N (139.42 kg ha^{-1}), P (82.94 kg ha^{-1}) and K (57.97 kg ha^{-1}) by finger millet at Bangalore. Similarly, Thippeswamy and Shivakumar (2000) reported higher N and K uptake with increasing levels of K application (25, 50, 75 kg ha^{-1}) in finger millet cv. Indaf-9. The N:K ratio decreased due to K application at all stages of crop growth. Basal application of K resulted in the lowest ratio and the highest was recorded at the tillering stage with no basal application of K. The ratio was relatively high in grain compared to straw.

Ray *et al.* (2000) stated that the higher uptake of potassium could be due to interaction effect of higher doses of N, P_2O_5 and primary effect of starter potassium doses in the treated plots which might have caused the release of soil potassium from unavailable to available form, resulting in higher uptake from native soil sources by the jute crop. Whereas, trials conducted at GKVK on finger millet has showed increase in the uptake of N, P, K (102.33, 34.09, 82.93 kg ha^{-1}) with 150 per cent NPK application as compared to 100 per cent NPK (82.74, 26.67, 63.65 kg N, P_2O_5 and K_2O ha^{-1}). (Anon., 2005)

Abida Akram *et al.* (2007) noticed that the nitrogen uptake was improved with P and K application but, the difference between these two was non-significant. Phosphorus uptake with integrated dose of P and K was highest (29.7 kg ha^{-1}) followed by P alone, and both showed significantly higher P uptake as compared with K alone and control. Application of K did not improve P uptake by sorghum significantly. Potassium uptake was highest under combined application of P and K followed by K alone treatment; both having non-significant difference. Application of P alone also increased K uptake over that in control, but their difference was nonsignificant.

Sanjay Kumar *et al.* (2007) reported that the applied doses of P and K gave significantly more P and K uptake by sugarcane than the control. The highest phosphorus uptake of 27.5 kg ha^{-1} was recorded with 120:80 kg of P_2O_5: K_2O ha^{-1}; however, it was statistically similar to 60:40 kg of P_2O_5:K_2O. Increasing doses of potassium increased the potassium uptake by the crop significantly and the uptake with 120:60 and 60:40 kg P_2O_5: K_2O doses was 335.5 and 303.5 kg ha^{-1}, respectively in comparison to 240.3 kg ha^{-1} with control.

Apoorva (2010) recorded that, total major and secondary nutrients uptake by ragi crop was significantly higher in the treatment supplemented with fertilizers and FYM on STCR basis along with dual microbial inoculations compared to all other treatments.

Chandra Deo and Khandelwal (2009) observed that the application of P and Zn significantly increased the P and Zn uptake and oil content of mustard with increasing levels of P and Zn but P uptake decreased at higher level of Zn.

Paramasivan *et al.* (2011) reported that the highest total N uptake (260.60 and 243.44 kg ha^{-1}) by maize in Pilamedu and Palaviduthi series were noticed in the treatment with 250:60:25:10 and 250:76:88:7.4 kg of NPK and Zn ha^{-1}. The application of 200:75:25:10 and 200:95:88:7.4 kg of NPK and Zn ha^{-1} resulted in the highest total P uptake (77.38 and 73.82 kg ha^{-1}, respectively) in both the series. The highest total K uptake (219.47 and 206.50 kg ha^{-1}) was observed for the treatment of 200: 60: 31.25:10 and 200:76:110:7.4 kg of NPK and Zn ha^{-1}. The application of 250:60:25:10 and 250:76:88:7.4 kg of NPK and Zn ha^{-1} resulted in the highest total Zn uptake (1.787 and 1.414 kg ha^{-1}) in Pilamedu and Palaviduthi series respectively.

Nesho Neshev and Ivan Manolov (2015) observed that the fertilization with K_2SO_4 decreased N content in potato tubers from 2.91 per cent at K_{200} level to 2.52 per cent in K_{600} level and increased N content in above ground biomass compared to the control and other levels of K fertilized with KCl. The increased KCl rates led to decreased N content in above ground biomass from 4.03 per cent at K_{200} to 2.34 per cent at potassium level K_{400}. Potassium fertilization did not influence considerably P content in the plant parts. The K content in plant parts fertilized with KCl as potassium source was higher than the plants fertilized with K_2SO_4.

2.3.2 Nutrient use efficiency

Ranganathan *et al*. (1969) indicated that the efficiency factor for added P was an index of responsiveness of the rice crop. Evaluation of site specific recommendation based on these factors, a rate of 86.2 kg N ha^{-1} and 14.4 kg P_2O_5 ha^{-1} was considered optimum for obtaining 87.5 per cent of theoretical maximum yield of 3236 kg ha^{-1} in *kharif* and 111.0 kg N ha^{-1} and 20.8 P_2O_5 kg ha^{-1} for getting 87.5 per cent of theoretical maximum yield of 4375 kg ha^{-1} in *rabi* season respectively.

Sonar *et al.* (1982) reported that for production of one quintal of sorghum grain the nutrient requirement were 3.34 kg N, 0.73 kg P_2O_5 and 3.99 kg K_2O. The efficiency of soil available nutrients was 10.26 per cent from $KMnO_4$ N, 97.26 per cent from Olsen-P and 14.85 per cent NH_4OAC K. Similarly, efficiency of applied nutrients was 82.71 per cent urea N, 26.92 per cent for single super phosphate- P_2O_5 and 104.44 per cent for muriate of potash K_2O.

Reddy *et al.* (1991) mentioned that the nutrient requirement for one quintal groundnut production in different soils ranged from 3.99 to 6.86 kg of N, 1.24 to 2.39 kg of P_2O_5 and 1.74 to 4.39 kg of K_2O. The highest N requirement was in red soil at Bhavanisagar, P requirement in medium black soil at Rahuri and that of K requirement in alluvial soil at Dholi. Soil N efficiency ranged from 17.0-42.8 per cent, P efficiency 38.0-86.7 per cent and that of K efficiency from 30.0 -65.0 per cent. The response ratio ranged from 3.6 to 6.9 kg groundnut kg^{-1} of nutrient applied. The highest being in medium black soil at Rahuri.

Abida Akram *et al.* (2007) observed that the fertilizer use efficiency (FUE) was maximum for K alone (9.65 kg kg^{-1}) followed by P alone treatment (8.45 kg kg^{-1}) with a little difference. Further, each kilogram of P or K nutrient has almost the similar effect towards increasing the grain yield of sorghum. The comparison of combined dose of P and K with P and K alone looks inappropriate, as in the combined treatment two different nutrients were applied.

Ashwini (2007) noticed higher nutrient use efficiency of N, P and K when nutrients were applied as per POP (package of practice) followed by targeted yield of 50 q ha^{-1} for finger millet crop through both organic and inorganic sources of nutrients. Similarly, significantly higher agronomic use efficiency of NPK in maize was recorded with STCR target of 90 q ha^{-1} with IPNS approach (10.86 kg kg^{-1}) as compared to STCR target of 110 q ha^{-1} with purely inorganic fertilizers (3.09 kg kg^{-1}). Among the different fertilizer application approaches, STCR target of 90 q ha^{-1} with IPNS has achieved higher agronomic nutrient use efficiency. (Basavaraja *et al.*, 2014).

Sandana and Pinochet (2014) reported higher phosphorus use efficiency in wheat than in pea. An average, wheat and pea's phosphorus use efficiency was 244 and 147 g yield g^{-1} P available, respectively in experiment 1, while in experiment 2 these values were 146 and 103 g yield g^{-1} P available, respectively.

Srivastava *et al.* (2016) noticed relatively higher apparent utilization (AU) of applied K fertilizer in the rice crop as compared to wheat. In rice crop, the differences in the higher apparent of applied K fertilizer under no Zn application or soil application of 5 kg Zn ha^{-1} were not statistically different. However, the foliar application of 2 kg Zn ha^{-1} resulted in significantly lower AU of K fertilizer at 16.6 kg K ha^{-1} as compared to no Zn application or soil application of 5 kg Zn ha^{-1}. In wheat crop, irrespective of Zn application higher AU of applied K was observed at 24.9 kg K ha^{-1} level.

2.4. Effect of phosphorus and potassium levels on benefit cost (B:C) ratio

Anil Kumar (2000) reported that application of 7.5 tonnes of compost ha^{-1} in conjunction with recommended level of fertilizer recorded highest gross returns (Rs. 28,460 ha^{-1}), net returns and B:C ratio (2.76) in finger millet under Bangalore conditions**.**

Abida Akram *et al.* (2007) observed that the net income and net returns were highest under P+K application followed by P alone treatment. Value cost ratio (VCR) was highest with P fertilizer alone (6.43) but it had a very little difference with K alone (5.86) and P+K treatment (5.40). Relative increase in income was highest (172 %) under P+K followed by P alone (151 %) and lowest with K alone (130 %).

Umesh (2008) recorded higher net income of Rs. 22,374 ha^{-1} and B:C ratio of 2.14 in hybrid maize crop [NAH-2049] due to higher gross returns and grain yield. Among fertility levels, SSNM (34,346 ha^{-1}) and N_{200} P_{100} K_{75} + S + Zn (35,146 kg ha^{-1}) approach recorded 41 and 40 per cent higher net income respectively over RDF. Whereas B: C ratio was higher with application of N_{200} P_{75} K_{50} + S + Zn (3.16) and N_{200} P_{100} K_{75} + S + Zn (2.89) treatments in both the years.

Apoorva *et al.* (2010) reported that the application of fertilizers and FYM on STCR basis along with bio fertilizers was recorded the highest gross returns (Rs. 29,784 ha^{-1}) compared to other tretments. The economic indicators such as VCR, UCP and PI were 1.53, 3.19 and 29.40 with the application of fertilizers and FYM on STCR basis along with dual microbial inoculation.

Venkate Gowda (2012) recorded higher net returns (Rs. 1,13,819 ha^{-1}) and B:C ratio (2.71) in maize-sunflower cropping sequence as compared to all the other treatments. Whereas, soil test based NPK recommendation (+ 25 per cent NPK under medium soil fertility) recorded higher total maize equivalent yield (140.8 q ha^{-1}), net returns (Rs. 84,099 ha^{-1}) and B:C ratio (2.43) in maize groundnut cropping sequence as compared to all the other treatments.

Ramachandrappa *et al.* (2014) carried out an experiment on potassium nutrition on yield and economics of rainfed finger millet in eastern dry zone of Karnataka and recorded the highest B: C ratio of 3.23 with recommended N, P_2O_5 and 150 per cent K_2O compared to lower B: C ratio (3.03) with recommended N, P_2O_5 and 100 per cent K_2O.

Mudalagiriyappa *et al.* (2015) reported that the application of 125 per cent customized fertilizer dose recorded higher net returns (25635 Rs. ha^{-1}) and B: C ratio (2.53) compared to others.

III MATERIAL AND METHODS

In order to achieve the various objectives of the research work, investigation was carried out by field experiment and employing laboratory estimations during the year 2015-16. The details of materials used, procedures followed and methodologies adopted are presented in this chapter.

3.1 Selection of the experimental site

Initially 22 soil samples were collected from in and around Magadi taluk of Ramanagara district. Based on the analytical soil data, the soil low in available phosphorus and potassium was selected for the experiment. The location, farmer's details, available phosphorus and potassium content and other relevant information on the sampled location are given in Table 1.

3.2 Climatic conditions

The climatic conditions with respect to rainfall and temperature for Solur hobli which covers experimental village Kodihalli during the year 2015 are presented in Table 2.

3.3 Details of field experiment

3.3.1 Location of the experimental site

The field experiment was conducted at farmer's field which was low in available phosphorus and potassium at Kodihalli village, Magadi taluk, Ramanagara district where available phosphorus and potassium content was low. It is located in Eastern Dry Zone of Karnataka at 13° 01′ 42.4″ N latitude, 77° 17′ 49.3″ E longitude with an altitude of 868 meters above Mean Sea Level (MSL).

3.3.2 Soil characteristics of experimental site

A composite soil sample was drawn from the experimental site by collecting samples from 0-15cm depth before initiation of experiment. The soil was air-dried, powdered and then passed through 2 mm sieve and was analysed for physical and chemical properties. The analytical techniques followed for the estimation of physical and chemical properties of soil and the results are presented in Table 3.

Soil of the experimental site was sandy loam in texture and slightly acidic in reaction (pH 6.28). Electrical conductivity was 0.068 dS m^{-1}, and organic carbon content was 5.80 g kg^{-1}. Available nitrogen was 261.38 kg N ha^{-1}, available phosphorus was low (16.85 kg P_2O_5 ha^{-1}) and available potassium was low (108.70 kg K_2O ha^{-1}).

Table 1: Details of soil samples collected from selected villages in Magadi taluk of Ramanagara district

Sl. No.	Farmers name	Village	Taluk	Co-ordinates	pH	EC (d Sm^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})
1	Maheshappa	Basavenahalli	Magadi	13° 02′ 18.5″ N 77° 18′ 57.0″ E	7.43	0.086	14.79	339.60
2	Gangaiah	Basavenahalli	Magadi	13° 02′ 18.1″ N 77° 18′ 55.8″ E	7.42	0.126	246.34	706.80
3	Maregowda	Marenahalli	Magadi	13° 00′ 45.3″ N 77° 18′ 42.3″ E	6.60	0.084	410.35	279.60
4	M. G. Revanna	Gollahalli	Magadi	13° 05′ 40.0″ N 77° 09′ 38.7″ E	7.77	0.095	158.86	606.00
5	Nagaraju	Navagrama	Magadi	13° 05′ 40.0″ N 77° 09′ 38.7″ E	7.86	0.058	23.80	110.40
6	Somashekar	Byalakere	Magadi	12° 58′ 43.4″ N 77° 14′ 18.9″ E	7.91	0.112	212.25	696.00
7	Nanjappa	Hosahalli	Magadi	12° 58′ 06.1″ N 77° 13′ 12.5″ E	7.39	0.094	75.89	387.60
8	Muninarasaiah	Madbal	Magadi	12° 54′ 45.3″ N 77° 13′ 50.6″ E	7.30	0.119	28.94	362.40
9	Narasimhaiah	Motagondanahalli	Magadi	13° 00′ 14.7″ N 77° 18′ 14.2″ E	6.25	0.060	190.38	142.80
10	Ramachandraiah	Motagondanahalli	Magadi	13° 00′ 18.2″ N 77° 18′ 21.7″ E	6.45	0.051	149.86	182.40
11	Rajanna	Belagumba	Magadi	12° 59′ 38.3″ N 77° 14′ 56.2″ E	6.32	0.073	259.84	222.00
12	Shivalingappa	Mummenahalli	Magadi	12° 58′ 32.2″ N 77° 19′ 17.5″ E	7.65	0.097	286.21	480.00
13	Somanna	Chikkasoluru	Magadi	13° 03′ 17.8″ N 77° 14′ 54.1″ E	7.27	0.101	125.42	348.00
14	Chikanna	Naganahalli	Magadi	13° 01′ 46.0″ N 77° 17′ 18.8″ E	5.98	0.048	30.87	74.40
15	Sanjeevaiah	Naganahalli	Magadi	13° 01′ 46.6″ N 77° 17′ 15.7″ E	5.87	0.057	75.89	140.40
16	Govindaiah	Thirumalapura	Magadi	13° 00′ 57.5″ N 77° 17′ 22.5″ E	5.92	0.044	73.97	130.80
17	Rajanna	Gudemaaranahalli	Magadi	13° 03′ 15.6″ N 77° 16′ 10.2″ E	7.12	0.066	42.45	436.80
18	Anjinappa	Hakkinalu	Magadi	13° 02′ 11.7″ N 77° 16′ 56.1″ E	6.81	0.100	93.90	79.20
19	Lokesh	Pemmanahalli	Magadi	13° 00′ 58.2″ N 77° 18′ 17.3″ E	6.17	0.109	71.39	266.40
20	Timmanna	Bommanahalli	Magadi	13° 00′ 09.3″ N 77° 18′ 04.4″ E	6.41	0.082	120.27	301.20
21	Ramaiah H	Kodihalli	Magadi	13° 01′ 42.4″ N 77° 17′ 49.3″ E	6.22	0.065	15.90	105.80
22	Veerabhadraiah	Kodihalli	Magadi	13° 01′ 34.9″ N 77° 17′ 55.3″ E	5.81	0.071	173.01	213.60

Table 2: Monthly rainfall distribution pattern and temperature of Solur hobli during 2015

Month	Normal weighed Avg. (mm)	Actual weighed Avg. (mm)	% Departure	Temperature (^{0}C)			
				Max		Min	
				N	A	N	A
January	2	0	-100	28.60	28.60	14.50	14.80
February	6	0	-100	30.10	29.50	15.40	16.60
March	9	23	156	32.30	32.90	18.10	18.50
April	53	109	106	34.10	34.60	20.80	21.40
May	122	208	71	34.20	34.30	20.70	21.20
June	76	99	31	30.30	30.80	19.70	20.40
July	96	69	-28	28.20	28.10	19.10	19.80
August	141	110	-22	28.00	28.60	19.20	19.70
September	211	234	11	28.80	28.60	19.40	19.80
October	195	115	-41	28.10	28.10	18.80	19.20
November	53	230	330	28.90	28.90	16.80	16.60
December	14	5	-65	28.80	28.80	15.10	16.10
Total	978	1202	349				

Note: Weighed average rainfall is computed using Thiessen Polygon method
A: Actual for the year 2015
N: Normal for previous 38 years (1975-2014)
Max: Maximum, Min: Minimum

Table 3: Initial physico-chemical characteristics of the experimental site

Sl. No.	Particulars	Values	Method followed
I	Physical properties of soil		
1	Sand (%)	52.65	International pipette method (Piper, 1966)
2	Silt (%)	29.85	
3	Clay (%)	12.50	
4	Texture	Sandy loam	
5	Bulk Density (Mg m^{-3})	1.34	Keen Raezkowski cup method (Piper, 1966)
6	Particle Density (Mg m^{-3})	2.51	Keen Raezkowski cup method (Piper, 1966)
7	Maximum water holding capacity (%)	42.18	Keen Raezkowski cup method (Piper, 1966)
II	Chemical properties of soil		
1	pH (1:2.5)	6.29	Potentiometry (Jackson, 1967)
2	Electrical conductivity (dS m^{-1})	0.068	Conductometry (Jackson, 1973)
3	Organic carbon (g kg^{-1})	5.80	Wet oxidation method (Walkley and Black, 1934)
4	Cation exchange capacity (c mol (p^{+}) kg^{-1})	14.13	Kjeldhal distillation method (Jackson, 1973)
5	Available N (kg ha^{-1})	261.38	Alkaline peramanganate method (Subbiah and Asija, 1956)
6	Available P_2O_5 (kg ha^{-1})	16.85	Bray's method (Jackson, 1973)
7	Available K_2O (kg ha^{-1})	108.70	Flame photometry method (page, 1982)
8	Available S (mg kg^{-1})	20.27	Turbidometry method (Jackson, 1973)
9	Exchangable calcium [c mol (P^{+}) kg^{-1}]	4.00	Versenate titration method (Jackson, 1973)
10	Exchangable magnesium [c mol (p^{+}) kg^{-1}]	1.75	Versenate titration method (Jackson, 1973)
11	Available boron (mg kg^{-1})	0.51	Hot water extraction and colorimetry using Azomethane-H (Berger and Truog, 1939)
12	Available zinc (mg kg^{-1})	0.78	DTPA extraction method (Lindsay and Norvell, 1978)
13	Available iron (mg kg^{-1})	6.97	
14	Available copper (mg kg^{-1})	0.75	
15	Available manganese (mg kg^{-1})	16.62	

3.3.3 Design and layout

The experiment was laid out in randomized complete block design (RCBD) having sixteen treatment combinations and replicated thrice on a net plot size of 3.9 m × 3.2 m. The plan of layout of the experiment is shown in Fig. 1.

Crop	Finger millet
Variety	GPU-28
Season	*Kharif* -2015
Recommended dose of fertilizer (NPK kg ha^{-1})	100:50:50
Gross plot	3.9 m X 3.2 m = 12.48 m^2
Net plot	3.3 m X 2.8 m = 9.24 m^2
Spacing	30 cm × 10 cm
Date of sowing	04-08-2015
Date of harvest	29-11-2015
Source of nutrients	Urea, single super phosphate and muriate of potash

3.3.4 Treatment details

T_1 – 100 % RDN + 0 % RDP + 0 % RDK.
T_2 – 100 % RDN + 0 % RDP + 100 % RDK.
T_3 – 100 % RDN + 0 % RDP + 125 % RDK.
T_4 – 100 % RDN + 0 % RDP + 150 % RDK.
T_5 – 100 % RDN + 100 % RDP + 0 % RDK.
T_6 – 100 % RDN + 100 % RDP + 100 % RDK. (RDF*)
T_7 – 100 % RDN + 100 % RDP + 125 % RDK.
T_8 – 100 % RDN + 100 % RDP + 150 % RDK.
T_9 – 100 % RDN + 125 % RDP + 0 % RDK.
T_{10} – 100 % RDN + 125 % RDP + 100 % RDK.
T_{11} – 100 % RDN + 125 % RDP + 125 % RDK.
T_{12} – 100 % RDN + 125 % RDP + 150 % RDK.
T_{13} – 100 % RDN + 150 % RDP + 0 % RDK.
T_{14} – 100 % RDN + 150 % RDP + 100 % RDK
T_{15} – 100 % RDN + 150 % RDP + 125 % RDK.
T_{16} – 100 % RDN + 150 % RDP + 150 % RDK.

Note

*RDN- Recommended dose of nitrogen, RDP – Recommended dose of phosphorus,
RDK- Recommended dose of potassium, RDF- Recommended dose of fertilizers.
All the treatments received nitrogen and farm yard manure as per package of practice.

3.4 Methodology adopted for the field experiment

3.4.1 Cropping history of the experimental site

Before taking up the finger millet crop during *kharif*- 2015 (August, 2015 to December, 2015), in the same plot, castor was grown during *kharif*- 2014.

3.4.2 Land preparation

The land was ploughed once by disc plough which was followed by passing cultivator twice. Afterwards the plots were laid out and levelled. Small bunds were constructed on all the four sides of the plot and provision was made for removing excess water, irrigation channel was laid and treatments were allotted at random as per the design (plate1and 2).

3.4.3 Sowing and fertilizer application

After the preparation of land, plots were laid out as shown in the Fig.1. Farmyard manure was incorporated into the soil two weeks before sowing (Line sowing of seeds was followed). Fertilizers were added to the soil on the day of sowing of seeds as per the treatment. Nitrogen was applied as urea, phosphorus as single super phosphate and potassium as muriate of potash and fertilizers were mixed with soil and then top dressing with 50 per cent N was followed one month after sowing of finger millet.

3.4.4 Aftercare

After 12 days of sowing, thinning was carried out to remove excess seedlings and gap filling was done to maintain optimum plant population. The crop was irrigated whenever necessary to maintain good soil moisture. The plots were hand weeded twice to keep them free from weeds and earthed up after each weeding to loose the top soil. The crop was harvested at full maturity of ear heads.

3.4.5 Harvesting and threshing

The crop was harvested at physiological maturity by cutting the ear heads separately from each plot. The ear heads were dried under sun for 15 days, threshed by beating with stick, cleaned and weighed. The straw was also harvested separately from each plot after the harvest of ear heads, sun dried for 15 days and weight was recorded.

3.5 Observations recorded

For recording various observations as detailed below, five plants in each plot were selected at random and labelled. Periodical observations were taken on these plants.

3.5.1 Growth parameters

3.5.1.1 Plant height

The plant height was measured at 30 DAS, 60 DAS, 90 DAS and at harvest stage, from the ground level up to the base of node of fully opened first leaf from the top and the mean plant height was worked out and expressed in centimetre (cm).

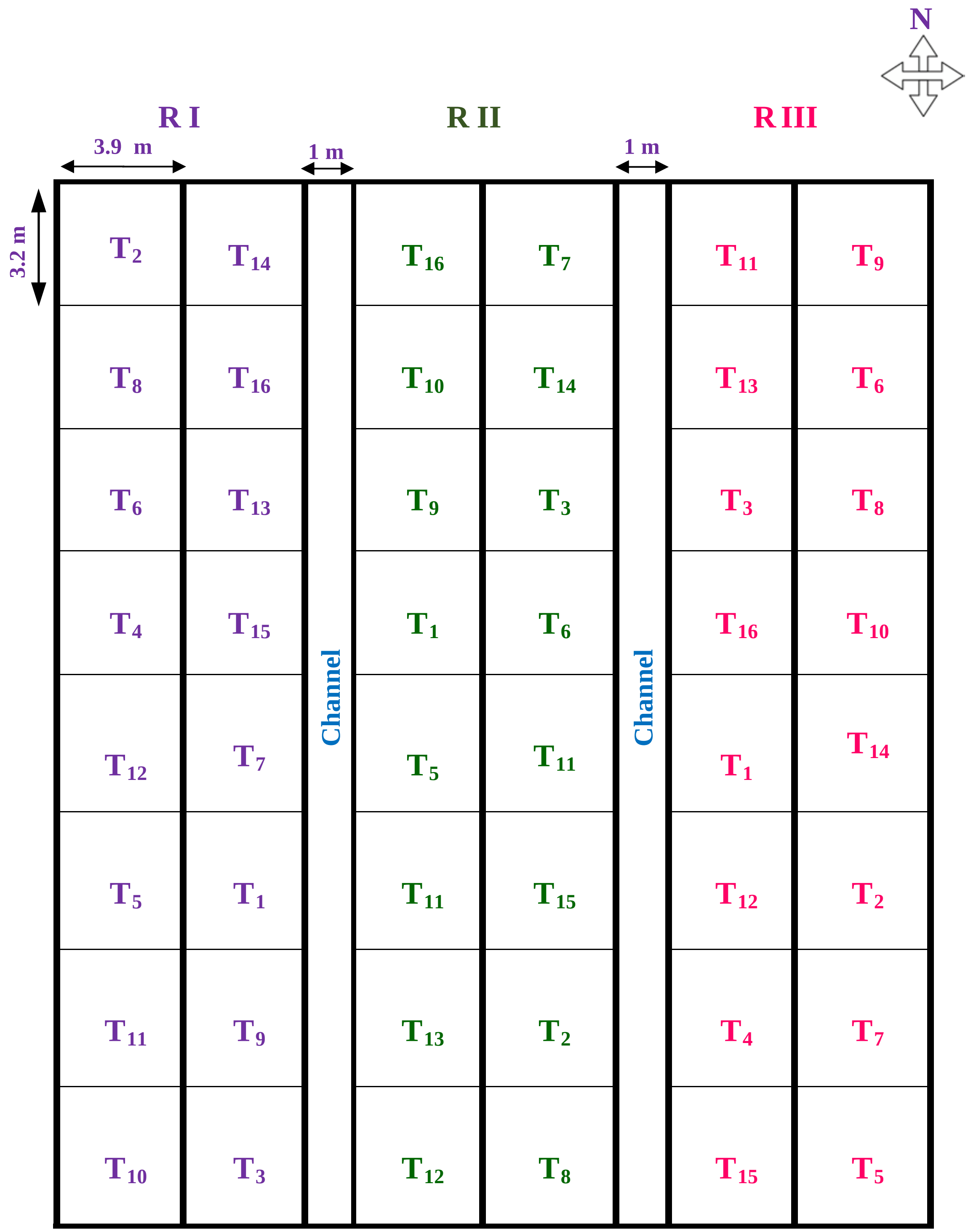

Fig. 1: **Plan of layout of experimental site at Kodihalli village, Solur (H), Magadi (Tq), Ramanagara (D)**

Plate 1: General view of the experimental plot at Kodihalli village, Ramanagara district

Plate 2: Effect of different levels of phosphorus and potassium on finger millet

3.5.1.2 Number of leaves

From the five random plants was selected from each plot, number of leaves per plant was counted at 30 DAS, 60 DAS, 90 DAS and at harvest and they were pooled and expressed as average number of leaves.

3.5.1.3 Number of tillers hill^{-1}

From the randomly selected five plants, number of tillers per plant was counted before harvest of the crop and they were pooled and average number of tillers per hill was recorded.

3.5.2 Yield parameters

3.5.2.1 Number of productive tillers hill^{-1}

Number of productive tillers from randomly selected five plants was counted and expressed as mean value of productive tillers per hill.

3.5.2.2 Ear head length

Ear head length was measured from all the ear heads of randomly selected five plants and mean value was computed and expressed as centimetre.

3.5.2.3 Ear head weight

Ear head weighed was taken from all the ear heads of randomly selected five plants and mean value was computed and expressed as gram.

3.5.2.4 Number of fingers per ear head

Number of fingers per ear head was counted from randomly selected five plants and mean value was computed.

3.5.2.5 1000 grain weight

After drying and threshing the grains, 1000 grains were selected from the grain pool of each plot, weighed on electronic balance and expressed in grams.

3.5.2.6 Grain yield

The ear heads were harvested separately from each plots and dried under sun in the threshing yard for 15 days. The ear heads were threshed, winnowed, cleaned and weight was recorded. Grain yield ha^{-1} was worked out and expressed in q ha^{-1}.

3.5.2.7 Straw yield

The straw was harvested separately from each plots and dried under sun in the threshing yard for 15 days. The dry weight of the straw was recorded and expressed in q ha^{-1}.

3.6 Chemical analysis of soil and plant samples

3.6.1 Analysis of soil samples

Soil samples (0-15 cm) collected from each plot after harvest were processed and subjected for analysis of various chemical properties. The materials used and the methods followed during the estimation are presented in this chapter.

3.6.1.1 Soil reaction and Electrical conductivity

Soil pH was measured in 1:2.5 soil: water suspension, using pH meter (Jackson, 1973). The clear supernatant solution of the above soil - water suspension was taken out and electrical conductivity was measured using conductivity bridge (Jackson, 1973) and expressed as dS m^{-1}.

3.6.1.2 Soil organic carbon

Soil organic carbon was estimated by Walkley and Black wet oxidation method as described by Jackson (1973) and expressed as g kg^{-1}.

3.6.1.3 Available nitrogen

Five gram of soil was distilled with 50 ml of 0.32 % $KMnO_4$ in the presence of 50 ml of 2.5 per cent NaOH. The ammonia released during distillation was trapped in two per cent boric acid containing mixed indicator and titrated against standard H_2SO_4 and available nitrogen was expressed in kg ha^{-1} (Subbaiah and Asija, 1956).

3.6.1.4 Available phosphorus

The available phosphorus in the soil was extracted with Bray's reagent. The extracted phosphorus was then estimated by ascorbic acid blue colour method. The intensity of blue colour was read in spectrophotometer at a wavelength of 660 nm (Jackson, 1973).

3.6.1.5 Available potassium

Available potassium was extracted from the soil with neutral normal ammonium acetate solution and potassium present in the extractant was estimated using flame photometer as described by Page *et al*. (1982).

3.6.1.6 Exchangeable calcium and magnesium

Exchangeable calcium and magnesium was estimated from neutral normal ammonium acetate extract of the soil by titration with standard versenate solution using murexide and EBT indicators respectively for calcium and calcium plus magnesium. The difference between the value of calcium plus magnesium and calcium gives the amount of exchangeable magnesium (Jackson, 1973).

3.6.1.7 Available sulphur

Ten gram of soil was treated with 0.15 per cent $CaCl_2$ solution. A known volume of the aliquot was treated with 1 ml of sulphur "seed solution" and 0.5 g of barium chloride followed with gum acacia as stabilizing agent. The light transmitted through the turbid solution was read at 420 nm wave length using spectrophotometer (Jackson, 1973).

3.6.1.8 Available micronutrients

The available soil iron, zinc, manganese and copper was determined by shaking the soil with DTPA extractant solution (0.005 M DTPA + 0.01 M $CaCl_2$. $2H_2O$ + 0.1 M TEA, pH > 7.3) at 1:2 soil: extractant ratio followed by filtering and feeding to an Atomic Absorption Spectrophotometer (AAS) under appropriate instrument conditions as prescribed for the respective element (Lindsay and Norwell, 1978).

3.6.1.9 Hot water soluble boron

Hot water soluble boron in the soil sample was determined by Azomethine-H method using spectrophotometer (Berger and Truog, 1939).

3.7 Analysis of plant samples

3.7.1 Collection and preparation of plant samples

During the harvesting of crop, five plants from each plot which were randomly selected, labelled and collected by pulling out the entire plant carefully. All the plant samples were first washed with tap water and finally with distilled water to remove the adhering soil and dusts. Then, they were sun dried for a week. Then samples were powdered with wiley milling machine and stored in polythene bags. These samples were analysed for nitrogen, phosphorus, potassium, calcium, magnesium, sulphur, iron, zinc, manganese, boron and copper.

3.7.2 Nitrogen

Nitrogen was determined by Kjeldahl's method using digestion mixture consisting of copper sulphate, potassium sulphate and selenium catalytic mixture. One gram of plant sample was digested in digestion flasks in macro Kjeldahl's unit using sulphuric acid and digestion mixture. After complete digestion, the digested materials were distilled in alkaline medium and the liberated ammonia was trapped in four per cent boric acid solution containing mixed indicator. The trapped ammonia was titrated against standard sulphuric acid (Jackson, 1973). Nitrogen was calculated by using titre value.

3.7.3 Digestion of plant samples

One gram of plant sample (grain and straw) was pre-digested with 5 ml nitric acid and digested with diacid mixture of nitric acid and perchloric acid (9:4). The clean digested material was made up to 50 ml volume with double distilled water and was used for the analysis of all elements except nitrogen.

3.7.4 Phosphorus

Phosphorus content in the digested plant sample was estimated by vanado-molybdo phosphoric yellow colour method in nitric acid medium and the colour intensity was measured at 460 nm wave length as given by Jackson (1973).

3.7.5 Potassium

Potassium in the digested plant sample was estimated by atomizing the diluted acid extract in a flame photometer as described by Jackson (1973).

3.7.6 Calcium and magnesium

Calcium and magnesium in the plant sample digest were estimated by titrating against standard versenate solution using murexide and EBT indicators respectively for calcium and calcium plus magnesium, whereas magnesium was determined by difference between concentration of calcium plus magnesium and calcium (Jackson, 1973).

3.7.7 Sulphur

Sulphur content of the plant sample was estimated by using an aliquot of digested plant extract by turbidimetric method by using barium chloride as outlined by Black (1965).

3.7.8 DTPA extractable micronutrients (Fe, Zn, Mn and Cu)

After making suitable dilution of di-acid extract, the samples were fed to the atomic absorption spectrophotometer using appropriate hallow cathode lamp and Fe, Zn, Mn and Cu content of the plant sample was estimated (Lindsay and Norwell, 1978).

3.7.9 Boron

Boron in the di-acid digested plant materials was determined by Colorimetry using Azomethane-H reagent (Page *et al.,* 1982).

3.8 Uptake of Nutrients

Nutrient uptake for all the major, secondary and micronutrients was calculated by the formula mentioned below.

$$\text{Uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient concentration (\%) x Biomass (kg ha}^{-1}\text{)}}{100}$$

3.9 Nutrient use efficiency

Nutrient use efficiency of phosphorus and potassium was calculated using this formula.

$$\text{NUE (\%)} = \frac{\text{Total nutrient uptake in treated plots - Total nutrient uptake in control plot}}{\text{Nutrients applied}} \text{ x100}$$

3.10 Nutrient requirement

The efficiency of the finger millet crop can be calculated in the form of NPK nutrient required (NR) to produce a quintal of grain by using the following formula.

$$\text{NR (kg q}^{-1}\text{)} = \frac{\text{Uptake of N/P/K by grain (kg ha}^{-1}\text{)}}{\text{Grain yield in q ha}^{-1}}$$

3.11 Agronomic nutrient use efficiency

$$\text{ANU (kg kg}^{-1}\text{)} = \frac{\text{Grain yield in treated plot – Grain yield in control plot}}{\text{Nutrient added}}$$

3.12 Response yard stick (RYS)

Response yardstick indicates how efficiently the applied nutrients in total are utilized by the crop to get maximum economic yield. ie. by application of one kg of NPK nutrient in the ratio mentioned in each treatment, the economic yield obtained will be worked out. The higher RYS, will give an indication about the maximum yield obtained per kg of NPK nutrients applied in total.

Response yard stick is the ratio of yield response (kg ha^{-1}) to total amount of N, P_2O_5 and K_2O fertilizer nutrients applied (kg ha^{-1}).

$$\text{RYS (kg kg}^{-1}\text{)} = \frac{\text{Yield response (kg ha}^{-1}\text{)}}{\text{Total fertilizer applied (kg N, } P_2O_5 \text{ and } K_2O \text{ ha}^{-1}\text{)}}$$

3.13 Economic analysis

The cost of inputs that were prevailing at the time of their use was considered for working out the economics of various treatment combinations. A net return ha^{-1} was calculated by deducting the cost of cultivation from gross income per hectare. Benefit cost ratio was calculated by using the following formula.

$$\text{Benefit cost ratio (B: C ratio)} = \frac{\text{Gross returns (Rs.)}}{\text{Cost of cultivation (Rs.)}}$$

3.14 Statistical analysis of data

Experimental data obtained were subjected to statistical analysis adopting Fisher’s method of analysis of variance as out lined by Gomez and Gomez (1984). The level of significance used in ‘F’ test was given at 5 per cent. Critical difference (CD) values are given in the table at 5 per cent level of significance, wherever the ‘F’ test was found significant at 5 per cent level.

IV EXPERIMENTAL RESULTS

The results of the field experiment conducted in farmers's field at Kodihalli village, Magadi taluk, Ramanagara district during *kharif* -2015 entitled "Response of finger millet to phosphorus and potassium levels in *Alfisols* of Ramanagara district of Karnataka", are presented in this chapter.

4.1 Effect of phosphorus and potassium levels on growth and yield of finger millet.

Average data of five plants on growth and yield parameters of finger millet *viz.*, plant height, number of leaves hill^{-1}, number of tillers hill^{-1}, number of productive tillers hill^{-1}, ear head length, ear head weight hill^{-1}, number of fingers ear head^{-1}, 1000 grain weight as influenced by different levels of phosphorus and potassium application in low phosphorus and low potassium soils are presented below.

4.1.1 Growth parameters

4.1.1.1 Plant height

The data on plant height (cm) of finger millet as influenced by different levels of phosphorus and potassium at different growth stages are presented in Table 4. Plant height differed significantly at all the growth stages with different treatments. Plant height increased progressively with increase in age of the crop up to 90 days after sowing and thereafter increase was slightly lower.

At 30 DAS

Significantly higher plant height (14.76 cm) was recorded in T_{16} which received 100 per cent N + 150 per cent P + 150 per cent RDK compared to 100 per cent RDF (T_6) applied treatment (12.79 cm) and also with 100 per cent RDN (T_1) with no P and K application (8.92 cm). However, it was on par with 100 per cent RDN (T_{12}) with 125 per cent RDP and 150 per cent RDK (14.05 cm) and also with T_{15} where 100 per cent RDN was applied with 150 per cent RDP and 125 per cent RDK.

At 60 DAS

The plant height varied significantly with different treatment combinations of phosphorus and potassium at 60 DAS. Application of 150 per cent RDP + 150 per cent RDK along with 100 per cent RDN (T_{16}) recorded significantly higher plant height (57.25 cm). However, it was on par with T_6 which received 100 per cent RDF (52.29 cm) and also with all the treatments from T_5 to T_{15}. But was found to be significantly superior over the T_1 (31.76 cm) which received 100 per cent RDN + 0 per cent RDP + 0 per cent RDK.

At 90 DAS

Significantly higher plant height was noticed in T_{16} which received 150 per cent RDP + 150 per cent RDK along with 100 per cent RDN (109.92 cm) compared to T_6 (105.36 cm) which received 100 per cent RDF and T_1 (87.06 cm) which received 100 per cent RDN with no phosphorus and potassium fertilizers. However, it was on par with T_{15} (109.67 cm) followed by T_{12} (109.05cm) which received 100 per cent RDN + 150 per

Table 4: Influence of different levels of phosphorus and potassium on plant height (cm) of finger millet

Treatment details	Plant height (cm)			
	30 DAS	60 DAS	90 DAS	At harvest
T_1 : 100 % RDN + 0 % RDP + 0 % RDK.	8.92	31.76	87.06	90.67
T_2 : 100 % RDN + 0 % RDP +100 % RDK.	9.71	35.62	92.77	96.68
T_3 : 100 % RDN + 0 % RDP + 125 % RDK.	10.01	37.71	92.87	98.85
T_4 : 100 % RDN + 0 % RDP + 150 % RDK.	11.17	41.06	92.94	100.17
T_5 : 100 % RDN + 100 % RDP + 0 % RDK.	12.08	51.81	99.21	103.93
T_6 : 100 % RDN + 100 % RDP + 100 % RDK *(RDF)	12.79	52.29	105.36	105.69
T_7 : 100 % RDN + 100 RDP + 125 % RDK.	13.03	53.35	106.08	107.24
T_8 : 100 % RDN +100 % RDP +150 % RDK.	14.02	56.72	106.26	108.69
T_9 : 100 % RDN +125 % RDP + 0 % RDK	13.21	52.52	105.37	107.33
T_{10} : 100 % RDN + 125 % RDP + 100 % RDK.	13.75	55.01	106.76	108.58
T_{11} : 100 % RDN + 125 % RDP + 125 % RDK.	14.01	56.55	108.79	110.18
T_{12} : 100 % RDN + 125 % RDP + 150 % RDK.	14.09	57.02	109.05	112.28
T_{13} : 100 % RDN + 150 % RDP + 0 % RDK.	13.31	55.38	105.57	109.58
T_{14} : 100 % RDN + 150 % RDP+100%RDK.	13.90	56.96	107.61	113.42
T_{15} : 100% RDN + 150% RDP + 125 % RDK.	14.05	57.15	109.67	116.01
T_{16}: 100 % RDN +150 % RDP + 150 % RDK.	14.76	57.25	109.92	116.08
S.Em. ±	**0.42**	**1.97**	**1.34**	**1.41**
CD (*P = 0.05*)	**1.26**	**5.92**	**4.00**	**4.22**

DAS – Days after sowing, RDN – Recommended dose of nitrogen, RDP- Recommended dose of phosphorus, RDK – Recommended dose of potassium, RDF- Recommended dose of fertilizers (100: 50: 50 kg NPK ha^{-1}).

cent RDP + 125 per cent RDK and 100 per cent RDN + 125 per cent RDP + 150 per cent RDK respectively. It was very clearly evident from the data that wherever either phosphorus or potassium was not applied, or both are not applied, plant height was significantly reduced compared to T_{16} which received 150 per cent RDP and RDK along with 100 per cent RDN.

At harvest

Plant height at harvest was significantly higher (116.08 cm) in T_{16} treatment in which 100 per cent RDN was applied along with 150 per cent of RDP and RDK compared to all other treatments except T_{15} where 100 per cent RDN was applied along with 150 per cent RDP and 125 per cent RDK (116.01 cm).

4.1.1.2 Number of leaves hill^{-1}

The data on number of leaves hill^{-1} of finger millet as influenced by different levels of phosphorus and potassium at different growth stages are presented in Table 5. The number of leaves hill^{-1} differed significantly at all growth stages with different treatment combinations of phosphorus and potassium.

At 30 DAS

Significantly higher number of leaves hill^{-1} was recorded in T_{16} (22.27) which received 150 per cent RDP + 150 per cent RDK along with 100 per cent RDN over T_1 (10.07) which received 100 per cent RDN with no phosphorus and potassium application. But it was found to be statistically on par with T_6 (19.47), where 100 per cent RDF was applied. Similarly it was on par with T_{15} (22.07) which received 150 per cent RDP and 125 per cent RDK along with 100 per cent RDN followed by T_{12} (22.15) which received 100 per cent RDN + 125 per cent RDP + 150 per cent RDK.

At 60 DAS

Treatment which received 150 per cent RDP + 150 per cent RDK along with 100 per cent RDN (T_{16}) recorded significantly higher number of leaves hill^{-1} (50.47) compared to T_1 (26.27) which received 100 per cent RDN without phosphorus and potassium fertilizers . However, it was found to be on par with T_6 (42.10) which received 100 per cent RDF. Further, it was also on par with T_{15} (49.92) followed by T_{12} (47.30) which received 150 per cent RDP and 125 per cent RDK along with 100 per cent RDN and 125 per cent RDP + 150 per cent RDK along with 100 per cent RDN respectively.

At 90 DAS

Significantly higher number of leaves hill^{-1} was recorded in T_{15} which received 150 per cent RDP + 125 per cent RDK along with 100 per cent RDN (56.66) compared to all other treatments except T_{16} in which 150 per cent of phosphorus and potassium was applied along with 100 per cent RDN (55.34). However, significantly lower number of leaves hill^{-1} was noticed in T_1 (26.73) which received 100 per cent RDN without phosphorus and potassium fertilizers.

Table 5: Influence of different levels of phosphorus and potassium on number of leaves hill $^{-1}$ in finger millet

Treatment details	Number of leaves hill^{-1}			
	30 DAS	**60 DAS**	**90 DAS**	**At harvest**
T_1 : 100 % RDN + 0 % RDP + 0 % RDK.	10.07	26.27	26.73	25.19
T_2 : 100 % RDN + 0 % RDP +100 % RDK.	13.15	30.00	30.80	28.70
T_3 : 100 % RDN + 0 % RDP + 125 % RDK.	14.53	33.60	34.07	29.30
T_4 : 100 % RDN + 0 % RDP + 150 % RDK.	17.07	34.40	34.87	30.12
T_5 : 100 % RDN + 100 % RDP + 0 % RDK.	17.33	41.70	42.00	33.99
T_6 : 100 % RDN + 100 % RDP + 100 %RDK.*(RDF)	19.47	42.10	42.87	41.49
T_7 : 100 % RDN + 100 RDP + 125 % RDK.	20.77	43.80	44.87	42.00
T_8 : 100 % RDN +100 % RDP +150 % RDK.	20.80	44.38	45.00	43.80
T_9 : 100 % RDN +125 % RDP + 0 % RDK	21.00	41.80	45.40	42.82
T_{10} : 100 % RDN + 125 % RDP + 100 % RDK.	21.53	43.40	48.47	43.97
T_{11} : 100 % RDN + 125 % RDP + 125 % RDK.	21.90	44.25	50.25	44.53
T_{12} : 100 % RDN + 125 % RDP + 150 % RDK.	22.05	47.30	50.10	44.27
T_{13} : 100 % RDN + 150 % RDP + 0 % RDK.	21.07	44.13	45.07	43.27
T_{14} : 100 % RDN + 150 % RDP+100%RDK.	21.87	45.73	49.93	47.53
T_{15} : 100% RDN + 150% RDP + 125 % RDK.	22.07	49.92	56.66	49.42
T_{16}: 100 % RDN + 150 % RDP + 150 % RDK.	22.27	50.47	55.34	49.39
S.Em. ±	**0.96**	**2.84**	**1.66**	**1.20**
CD (*P = 0.05*)	**2.87**	**8.51**	**4.96**	**3.59**

DAS – Days after sowing, RDN – Recommended dose of nitrogen, RDP- Recommended dose of phosphorus, RDK – Recommended dose of potassium, RDF- Recommended dose of fertilizers (100: 50: 50 kg NPK ha^{-1})

At harvest

Number of leaves hill^{-1} at harvest was significantly higher in T_{15} (49.42) which received 100 per cent RDN + 150 per cent RDP + 125 per cent RDK compared to all other treatments except T_{16} (49.42) and T_{14} (47.53) which received 100 per cent RDN + 150 per cent RDP + 150 per cent RDK and 100 per cent RDN + 150 per cent RDP + 100 per cent RDK respectively. However, decrease in number of leaves hill^{-1} was noticed at harvest in all the treatments compared to 90 days after sowing.

4.1.1.3. Number of tillers hill^{-1}

The data on number of tillers hill^{-1} in finger millet at different growth stages as influenced by different levels of phosphorus and potassium are presented in Table 6.

At 30 DAS

Application of 100 per cent RDN + 150 per cent RDP + 150 per cent RDK (T_{16}) followed by T_{12} which received 100 per cent + 125 per cent RDP + 150 per cent RDK (3.45) has recorded significantly higher number of tillers hill^{-1} compared to T_1 (2.40) which received 100 per cent RDN without phosphorus and potassium fertilizers. However, it was found to be on par with T_6 (3.27) which received 100 per cent RDF and also with T_{15} (3.40) and T_{14} (3.40) which received 100 per cent RDN + 150 per cent RDN + 125 per cent RDK and 100 per cent RDN + 150 per cent RDN + 100 per cent RDK respectively.

At 60 DAS

Treatments which received 100 per cent RDN + 150 per cent RDP + 150 per cent RDK (T_{16}) and 100 per cent RDN + 150 per cent RDP + 125 per cent RDK (T_{15}) have recorded significantly higher number of tillers hill^{-1} (4.73) compared to T_1 (2.73) which received 100 per cent RDN without phosphorus and potassium fertilizers. However, it was found to be on par with T_6 (4.13) which received 100 per cent RDF and also with T_{14} (4.60) which received 100 per cent RDN + 150 per cent RDP + 100 per cent RDK.

At 90 DAS

Application of 150 per cent RDP + 150 per cent RDK along with 100 per cent RDN (T_{16}) has recorded significantly higher number of tillers hill^{-1}(5.87) compared to T_6 (4.40) which received 100 per cent RDF and T_1 (2.93) which received 100 per cent RDN without phosphorus and potassium fertilizers. However, it was found to be on par with T_{15} (5.80) which received 100 per cent RDN + 150 per cent RDP + 125 per cent RDK followed by T_{12} (5.47) and T_{11} (5.47) which received 100 per cent RDN + 125 per cent RDP + 150 per cent RDK and 100 per cent RDN + 125 per cent RDP + 125 per cent RDK respectively.

At harvest

During harvest maximum number of tillers hill^{-1} was noticed in T_{16} (6.07) due to application of 150 per cent RDP + 150 per cent RDK along with 100 per cent RDN compared to T_6 (4.60) which received 100 per cent RDF and T_1 (3.13) which received

Table 6: Influence of different levels of phosphorus and potassium on number of tillers hill $^{-1}$ in finger millet

Treatment details	30 DAS	60 DAS	90 DAS	At harvest
T_1 : 100 % RDN + 0 % RDP + 0 % RDK.	2.40	2.73	2.93	3.13
T_2 : 100 % RDN + 0 % RDP +100 % RDK.	2.80	3.07	3.33	3.47
T_3 : 100 % RDN + 0 % RDP + 125 % RDK.	2.93	3.20	3.53	3.53
T_4 : 100 % RDN + 0 % RDP + 150 % RDK.	2.93	3.33	3.60	3.67
T_5 : 100 % RDN + 100 % RDP + 0 % RDK.	2.87	4.07	4.27	4.33
T_6 : 100 % RDN + 100 % RDP + 100 %RDK.*(RDF)	3.27	4.13	4.40	4.60
T_7 : 100 % RDN + 100 RDP + 125 % RDK.	3.27	4.20	4.47	4.67
T_8 : 100 % RDN +100 % RDP +150 % RDK.	3.40	4.20	4.60	5.00
T_9 : 100 % RDN +125 % RDP + 0 % RDK	3.20	4.13	4.73	4.87
T_{10} : 100 % RDN + 125 % RDP + 100 % RDK.	3.33	4.20	5.20	5.47
T_{11} : 100 % RDN + 125 % RDP + 125 % RDK.	3.40	4.27	5.47	5.60
T_{12} : 100 % RDN + 125 % RDP + 150 % RDK.	3.45	4.40	5.47	5.60
T_{13} : 100 % RDN + 150 % RDP + 0 % RDK.	3.33	4.20	4.80	5.33
T_{14} : 100 % RDN + 150 % RDP+100%RDK.	3.40	4.60	5.33	5.60
T_{15} : 100% RDN + 150% RDP + 125 % RDK.	3.40	4.73	5.80	6.00
T_{16}: 100 % RDN + 150 % RDP + 150 % RDK.	3.47	4.73	5.87	6.07
S.Em. ±	**0.19**	**0.26**	**0.22**	**0.25**
CD (*P = 0.05*)	**0.58**	**0.76**	**0.66**	**0.76**

DAS – Days after sowing, RDN – Recommended dose of nitrogen, RDP- Recommended dose of phosphorus, RDK – Recommended dose of potassium, RDF- Recommended dose of fertilizers (100: 50: 50 kg NPK ha^{-1})

100 per cent RDN without phosphorus and potassium fertilizers. However, it was found to be on par with T_{15} (6.00) which received 100 per cent RDN + 150 per cent RDP + 125 per cent RDK.

4.1.2 Yield and yield parameters

The data pertaining to yield and yield parameters as influenced by the levels of phosphorus and potassium are presented in Table 7 and Table 8.

4.1.2.1 Number of productive tillers hill^{-1}

Number of productive tillers hill^{-1} differed significantly due to application of different levels of phosphorus and potassium in low phosphorus and potassium soil. Application of 100 per cent RDN + 150 per cent RDP + 125 per cent RDK (T_{15}) recorded higher number of productive tillers hill^{-1}(4.47) compared to T_1 (2.42) which received 100 per cent RDN without phosphorus and potassium fertilizers. However, it was on par with T_6 (4.00) which received 100 per cent RDF and also with T_{16} (4.33) which received 100 per cent RDN and 150 per cent of RDP and RDK followed by T_{14} (4.33) which received 100 per cent RDN + 150 per cent RDP + 100 per cent RDK.

4.1.2.2 Ear head length

There was no significant difference between the treatments with respect to ear head length. However, numerically higher value of ear head length (7.52 cm) was observed in T_{16} (100 % RDN + 150% RDP + 150 % RDK) followed by T_{15} (7.49 cm) which received 100 per cent RDN + 150 per cent RDP + 125 per cent RDK and T_{12} (7.47 cm) which received 100 per cent RDN + 125 per cent RDP + 150 per cent RDK. The lowest ear head length was noticed in T_1 (6.48) which received100 per cent RDN + 0 per cent RDP + 0 per cent RDK.

4.1.2.3 Ear head weight hill^{-1}

Significantly higher ear head weight hill^{-1} was observed in T_{15} (24.10 g) which received 100 per cent RDN + 150 per cent RDP + 125 per cent RDK compared to T_6 (18.01 g) which received 100 per cent RDF and T_1 (10.98 g) which received 100 per cent RDN without phosphorus and potassium fertilizers. However, it was found to be on par with T_{16} (24.01 g) in which 100 per cent RDN was applied along with 150 per cent of RDP and RDK followed by T_{12} (21.97 g) which received 100 per cent RDN + 125 per cent RDP + 150 per cent RDK.

4.1.2.4 Number of fingers ear head^{-1}

Number of fingers ear head^{-1} varied significantly due to different levels of phosphorus and potassium application in low phosphorus and potassium soil. Both T_{16} and T_{15} treatments, which received 100 per cent RDN + 150 per cent RDP + 150 per cent RDK and 100 per cent RDN + 150 per cent RDP + 125 per cent RDP respectively, recorded higher number of fingers ear head^{-1}(7.73) compared to T_6 (6.53) which received 100 per cent RDF and T_1 (6.22) which received 100 per cent RDN without any phosphorus and potassium fertilizers. However, it was found to be on par with T_{11} (7.53)

Table 7: Influence of different levels of phosphorus and potassium on yield attributes of finger millet

Treatment details	No. of productive tillers hill^{-1}	Ear head length (cm)	Ear head weight hill^{-1} (g)	No. of fingers ear head^{-1}	1000 grain weight (g)
T_1 : 100 % RDN + 0 % RDP + 0 % RDK.	2.42	6.48	10.98	6.22	2.44
T_2 : 100 % RDN + 0 % RDP +100 % RDK.	2.87	6.84	11.67	6.47	2.91
T_3 : 100 % RDN + 0 % RDP + 125 % RDK.	3.09	6.88	15.51	6.50	3.05
T_4 : 100 % RDN + 0 % RDP + 150 % RDK.	3.19	6.98	19.09	6.53	3.23
T_5 : 100 % RDN + 100 % RDP + 0 % RDK.	3.57	7.07	17.11	6.47	2.83
T_6 : 100 % RDN + 100 % RDP + 100 %RDK.*(RDF)	4.00	7.23	18.01	6.53	3.11
T_7 : 100 % RDN + 100 RDP + 125 % RDK.	4.13	7.40	18.87	6.88	3.30
T_8 : 100 % RDN +100 % RDP +150 % RDK.	4.20	7.38	20.71	7.16	3.39
T_9 : 100 % RDN +125 % RDP + 0 % RDK	3.53	7.20	18.25	6.60	2.86
T_{10}: 100 % RDN + 125 % RDP + 100 % RDK.	4.13	7.31	18.73	7.20	3.14
T_{11}: 100 % RDN + 125 % RDP + 125 % RDK.	4.20	7.43	19.67	7.53	3.35
T_{12}: 100 % RDN + 125 % RDP + 150 % RDK.	4.27	7.47	21.97	7.53	3.39
T_{13}: 100 % RDN + 150 % RDP + 0 % RDK.	3.67	7.23	19.36	7.00	3.07
T_{14}: 100 % RDN + 150 % RDP+100%RDK.	4.33	7.46	20.92	7.28	3.44
T_{15}:100% RDN + 150% RDP + 125 % RDK.	4.47	7.49	24.10	7.73	3.49
T_{16}:100 % RDN + 150 % RDP + 150 % RDK.	4.33	7.52	24.01	7.73	3.51
S.Em. ±	**0.22**	**0.26**	**1.79**	**0.25**	**0.12**
CD ($P = 0.05$)	**0.65**	**NS**	**5.35**	**0.76**	**0.35**

RDN – Recommended dose of nitrogen, RDP- Recommended dose of phosphorus, RDK – Recommended dose of potassium, RDF- Recommended dose of fertilizers (100: 50: 50 kg NPK ha^{-1}).

and T_{12} (7.53) which received 100 per cent RDN along with 125 per cent RDP + 125 per cent RDK and 100 per cent RDN + 125 per cent RDP + 150 per cent RDK respectively.

4.1.2.5 1000 grain weight

Application of 150 per cent RDP + 150 per cent RDK along with 100 per cent RDN (T_{16}) was recorded significantly higher 1000 grain weight (3.51 g) compared to T_6 (3.11 g) which received 100 per cent RDF and T_1 (2.44 g) which received 100 per cent RDN without any phosphorus and potassium fertilizers. However, which was found to be on par with T_{15} which received 100 per cent RDN + 150 per cent RDP + 125 per cent RDK (3.49 g) followed by T_{14} which received 150 per cent RDP + 100 per cent RDK along with 100 per cent RDN (3.44 g). The data on test weight of finger millet grain clearly indicated that wherever P or K, or both were not applied the test weight was significantly reduced compared to $T_{16.}$

4.1.2.6 Grain yield

The application of different levels of phosphorus and potassium significantly influenced the grain yield of finger millet in low phosphorus and low potassium soils of Ramanagara district. Significantly higher grain yield was recorded in T_{15} (52.03 q ha^{-1}) where 100 per cent RDN was applied with 150 per cent RDP + 125 per cent RDK compared to all other treatments except T_{16} (51.25 q ha^{-1}) and T_{14} (50.37 q ha^{-1}) which received 100 per cent RDN + 150 per cent RDP + 150 per cent RDK and 100 per cent RDN +150 per cent RDP + 100 per cent RDK respectively. However, significantly lowest grain yield (25.24 q ha^{-1}) was noticed in T_1 where 100 per cent RDN was applied without phosphorus and potassium and rest of the treatments are intermediate. Application of either 25 per cent or 50 per cent of higher doses of phosphorus and or potassium along with 100 per cent RDN has given slightly higher grain yield, compared to no phosphorus and potassium, and also to 100 per cent P or K application in the absence of the other nutrient. However, this increased yield was not noticed when either of these nutrients was not applied.

4.1.2.7 Straw yield

Straw yield differed significantly due to application of phosphorus and potassium at different doses. Application of 100 per cent RDN + 150 per cent RDP + 125 per cent RDK (T_{15}) has recorded significantly the highest straw yield (87.57 q ha^{-1}) compared to all other treatments except T_{16} (86.64 q ha^{-1}) and T_{14} (81.62 q ha^{-1}) which received 100 per cent RDN + 150 per cent RDP + 150 per cent RDK and 100 per cent RDN +150 per cent RDP + 100 per cent RDK respectively. However, significantly lowest straw yield was noticed in T_1 (46.20 q ha^{-1}) in which 100 per cent RDN was applied without phosphorus and potassium fertilizers and rest of the treatments are intermediate in straw yield.

Table 8: Grain and straw yield of finger millet as influenced by application of different levels of phosphorus and potassium

Treatment details	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})
T_1 : 100 % RDN + 0 % RDP + 0 % RDK.	25.24	46.20
T_2 : 100 % RDN + 0 % RDP +100 % RDK.	28.55	50.96
T_3 : 100 % RDN + 0 % RDP + 125 % RDK.	33.51	53.33
T_4 : 100 % RDN + 0 % RDP + 150 % RDK.	34.97	54.87
T_5 : 100 % RDN + 100 % RDP + 0 % RDK.	33.81	56.99
T_6 : 100 % RDN + 100 % RDP + 100 %RDK.*(RDF)	39.76	58.78
T_7 : 100 % RDN + 100 RDP + 125 % RDK.	40.24	64.07
T_8 : 100 % RDN +100 % RDP +150 % RDK.	41.28	65.38
T_9 : 100 % RDN +125 % RDP + 0 % RDK	35.14	59.05
T_{10}: 100 % RDN + 125 % RDP + 100 % RDK.	40.91	63.54
T_{11}: 100 % RDN + 125 % RDP + 125 % RDK.	42.11	73.39
T_{12}: 100 % RDN + 125 % RDP + 150 % RDK.	43.85	75.00
T_{13}: 100 % RDN + 150 % RDP + 0 % RDK.	37.76	61.93
T_{14}: 100 % RDN + 150 % RDP+100%RDK.	50.37	81.62
T_{15}:100% RDN + 150% RDP + 125 % RDK.	52.03	87.57
T_{16}:100 % RDN + 150 % RDP + 150 % RDK.	51.25	86.64
S.Em. ±	**1.37**	**2.40**
CD (*P = 0.05*)	**4.11**	**7.18**

RDN – Recommended dose of nitrogen, RDP- Recommended dose of phosphorus, RDK – Recommended dose of potassium, RDF- Recommended dose of fertilizer (100: 50: 50 kg NPK ha^{-1})

4.2 Chemical parameters of soil

4.2.1 Soil pH

Data in Table 9 indicated that, there was slight increase in soil pH value in all the treatments as compared to initial (6.29) pH value except in the T_1 treatment (6.25), where there was slight decrease in the pH was noticed, which received only 100 per cent RDN through urea without phosphorus and potassium fertilizers in addition to FYM (10 t ha^{-1}) as per package of practice. However, no significant differences were observed with respect to post harvest soil pH among the treatments. Numerically higher pH value (6.60) was recorded with the application of 100 per cent RDN along with 150 per cent RDP and 125 per cent RDK (T_{15}).

4.2.2 Soil electrical conductivity (EC)

The electrical conductivity (EC) data in Table 9, showed that there was significant difference among the treatments with respect to soil EC after harvest. Significantly higher EC (0.098 dS m^{-1}) was recorded in treatment receiving 150 per cent of RDP and RDK along with 100 per cent RDN (T_{16}) compared to 100 per cent RDF treatment (T_6) which recorded the EC value of 0.074 dS m^{-1} and T_1 (0.058 dS m^{-1}) which received 100 per cent RDN without phosphorus and potassium fertilizers. However, it was on par with T_{12} (0.093 dS m^{-1}) which received 100 per cent RDN + 125 per cent RDP + 150 per cent RDK and also with Treatment T_{15} (0.092 dS m^{-1}) which received 150 per cent RDP + 125 per cent RDK along with 100 per cent RDN. Further, decrease in EC from the initial value of 0.068 dSm^{-1} was noticed in treatment T_1 (0.058 dSm^{-1}) which received 100 per cent RDN without phosphorus and potassium fertilizers.

4.2.3 Soil organic carbon

Perusal of the data with respect to organic carbon in Table 9 indicated that there was no significant difference with respect to organic carbon content of soil among the different treatments after harvest of finger millet. The organic carbon content of soil after harvest of finger millet ranged from 5.50 to 6.43 g kg^{-1}. The organic carbon increased from initial level (5.80 g kg^{-1}) in all the treatments except in T_1 (5.50 g kg^{-1}) which received 100 per cent RDN and FYM (10 t ha^{-1}) without P and K and T_9 (5.60 g kg^{-1}) which received 100 per cent RDN along with FYM (10 t ha^{-1}) + 125 per cent RDP without K, where a slight decrease in soil organic carbon was noticed. However, numerically higher mean value of organic carbon was observed in T_{12} (6.43 g kg^{-1}) in which 100 per cent RDN was applied along with 125 per cent RDP + 150 per cent RDK and FYM (10 t ha^{-1}).

4.3 Nutrient status of the soil

The nutrient status like available N, P_2O_5, K_2O and S, exchangeable Ca and Mg and DTPA extractable Zn, Cu, Mn, Fe and hot water soluble boron of the soil after harvest of finger millet was analyzed and the results are showed in Table 10, 11 and 12.

Table 9: Effect of different levels of phosphorus and potassium application on physico chemical properties of soil after harvest of finger millet crop

Treatment details	pH	EC (dS m^{-1})	OC (g kg^{-1})
	1:2.5 (soil: water)		
T_1 : 100 % RDN + 0 % RDP + 0 % RDK.	6.25	0.058	5.50
T_2 : 100 % RDN + 0 % RDP +100 % RDK.	6.29	0.065	5.90
T_3 : 100 % RDN + 0 % RDP + 125 % RDK.	6.32	0.064	5.80
T_4 : 100 % RDN + 0 % RDP + 150 % RDK.	6.35	0.066	5.87
T_5 : 100 % RDN + 100 % RDP + 0 % RDK.	6.48	0.064	6.10
T_6 : 100 % RDN + 100 % RDP + 100 % RDK. *(RDF)	6.44	0.074	6.20
T_7 : 100 % RDN + 100 RDP + 125 % RDK.	6.38	0.084	6.23
T_8 : 100 % RDN +100 % RDP +150 % RDK.	6.38	0.086	6.26
T_9 : 100 % RDN +125 % RDP + 0 % RDK	6.35	0.070	5.83
T_{10} : 100 % RDN + 125 % RDP + 100 % RDK.	6.54	0.075	5.85
T_{11} : 100 % RDN + 125 % RDP + 125 % RDK.	6.55	0.090	6.30
T_{12} : 100 % RDN + 125 % RDP + 150 % RDK.	6.41	0.093	6.43
T_{13} : 100 % RDN + 150 % RDP + 0 % RDK.	6.42	0.088	6.17
T_{14} : 100 % RDN + 150 % RDP+100%RDK.	6.52	0.090	6.20
T_{15} : 100% RDN + 150% RDP + 125 % RDK.	6.60	0.092	6.27
T_{16}: 100 % RDN + 150 % RDP + 150 % RDK.	6.42	0.098	6.30
S.Em. ±	**0.17**	**0.007**	**0.36**
CD ($P = 0.05$)	**NS**	**0.021**	**NS**
Initial	6.29	0.068	5.80

RDN – Recommended dose of nitrogen, RDP- Recommended dose of phosphorus, RDK – Recommended dose of potassium, RDF- Recommended dose of fertilizer (100: 50: 50 kg NPK ha^{-1})

4.3.1 Available nitrogen

Available nitrogen content in soil after the harvest of finger millet crop has significantly differed due to different levels of P and K application (Table 10). Significantly higher (290.94 kg ha^{-1}) available nitrogen was recorded in T_{16} where 100 per cent RDN with 150 per cent of RDP and RDK were applied compared to RDF (T_6) plot where 100 per cent NPK were applied (271.00 kg ha^{-1}) and T_1 where 100 per cent RDN was applied without phosphorus and potassium fertilizer (259.85 kg ha^{-1}). However, it was on par with all the treatments (T_{13} to T_{15}) which recorded 150 per cent RDP irrespective of the levels of potassium application. Similarly there was slightly increase in available nitrogen was noticed as the levels of P or K were increased, irrespective of the levels of the other nutrient.

4.3.2 Available phosphorus

The available phosphorus content in soil after harvest of finger millet significantly differed among the treatments imposed (Table 10). Significantly higher available phosphorus content in soil was observed in T_{15} treatment (48.38 kg ha^{-1}) which received 100 per cent RDN along with 150 per cent RDP and 125 per cent RDK compared to T_6 treatment (37.15 kg ha^{-1}) which received 100 per cent RDF as per package of practice and T_1 (17.21 kg ha^{-1}) which received 100 per cent RDN without P and K fertilizers. However, it was on par with T_{16} (47.44 kg ha^{-1}) which received 100 per cent RDN along with 150 per cent of RDP and RDK followed by T_{14} (42.98 kg ha^{-1}) which received 150 per cent RDP and 100 per cent RDK along with 100 per cent RDN.

4.3.3 Available potassium

Available potassium content in soil increased significantly due to different levels of P and K application (Table 10). Application of 125 per cent RDP + 150 per cent RDK along with 100 per cent RDN (T_{12}) significantly recorded higher available potassium (300.66 kg ha^{-1}) as compared to T_6 (256.34 kg ha^{-1}) which received 100 per cent RDF and T_1 (118.03 kg ha^{-1}) which received 100 per cent RDN without P and K fertilizers. However, it was found to be on par with T_8 (290.48 kg ha^{-1}) which received 100 per cent of RDN and RDP along with 150 per cent RDK followed by T_{11} (287.57 kg ha^{-1}) which received 125 per cent of RDP and RDK along with 100 per cent RDN. Significantly very low available potassium was recorded in all the treatments (T_1, T_5, T_9 and T_{13}) where no potassium was applied, irrespective of the levels of P applied.

4.3.4 Exchangeable calcium

Exchangeable calcium content in soil was found to be significantly higher from the initial value (4.00 c mol (p+) kg^{-1}) due to application of different levels of phosphorus and potassium (Table 11). Significantly higher exchangeable calcium content was recorded in T_{16} (6.47 c mol (p^+) kg^{-1}) which received 150 per cent of RDP and RDK along with 100 per cent RDN compared to no phosphorus and potassium fertilizers applied treatment (T_1) which recorded 4.18 cmol (p^+) kg^{-1} of calcium. However, it was found to be on par with T_6 (5.97 c mol (p^+) kg^{-1}) which received 100 per cent RDF as per package of practice and also with T_{15} (100 % RDN + 150 % RDP + 125 % RDK) and T_{14} (100 % RDN + 150 % RDP + 100 % RDK) which recorded the same value of

Table 10: Effect of different levels of phosphorus and potassium on available major nutrient status of soil after harvest of finger millet crop

Treatment details	N	P_2O_5	K_2O
	(kg ha^{-1})		
T_1 : 100 % RDN + 0 % RDP + 0 % RDK.	259.85	17.21	118.03
T_2 : 100 % RDN + 0 % RDP +100 % RDK.	262.96	20.08	200.93
T_3 : 100 % RDN + 0 % RDP + 125 % RDK.	268.48	20.75	221.43
T_4 : 100 % RDN + 0 % RDP + 150 % RDK.	275.73	22.50	244.27
T_5 : 100 % RDN + 100 % RDP + 0 % RDK.	256.42	35.34	123.55
T_6 : 100 % RDN + 100 % RDP + 100 % RDK. *(RDF)	271.00	37.15	256.34
T_7 : 100 % RDN + 100 RDP + 125 % RDK.	277.21	34.09	280.56
T_8 : 100 % RDN +100 % RDP +150 % RDK.	282.60	34.23	290.48
T_9 : 100 % RDN +125 % RDP + 0 % RDK	244.97	40.25	124.23
T_{10} : 100 % RDN + 125 % RDP + 100 % RDK.	251.67	38.37	236.54
T_{11} : 100 % RDN + 125 % RDP + 125 % RDK.	267.61	40.15	287.52
T_{12} : 100 % RDN + 125 % RDP + 150 % RDK.	272.63	38.46	300.66
T_{13} : 100 % RDN + 150 % RDP + 0 % RDK.	282.90	40.89	125.64
T_{14} : 100 % RDN + 150 % RDP+100%RDK.	284.33	42.98	250.77
T_{15} : 100% RDN + 150% RDP + 125 % RDK.	287.78	48.38	257.74
T_{16}: 100 % RDN + 150 % RDP + 150 % RDK.	290.94	47.44	283.57
S.Em. ±	**2.80**	**3.05**	**10.66**
CD (*P = 0.05*)	**8.33**	**9.14**	**31.95**
Initial	**254.26**	**16.85**	**108.70**

RDN – Recommended dose of nitrogen, RDP- Recommended dose of phosphorus, RDK – Recommended dose of potassium, RDF- Recommended dose of fertilizer (100: 50: 50 kg NPK ha^{-1})

exchangeable calcium (6.40 c mol (p^+) kg^{-1}). It was also clearly noticed that where 150 per cent RDP was applied higher levels Ca was recorded irrespective of the levels of K applied.

4.3.5 Exchangeable magnesium

The data on exchangeable magnesium did not show any significant difference between treatments due to application of different levels of phosphorus and potassium in low phosphorus and potassium soils (Table 11). However, numerically higher value of exchangeable magnesium in soil [3.43 cmol (p^+) kg^{-1}] was found in T_{12} treatment which received 100 per cent RDN along with 125 per cent of RDP and 150 per cent RDK. The numerically lower value of exchangeable magnesium (2.07 cmol (p^+) kg^{-1}) was observed in T_9 which received 100 per cent RDN along with 125 per cent RDP and 0 per cent RDK.

4.3.6 Available sulphur

Available sulphur content was found to be significantly varying between the treatments in soil due to the application of different levels of phosphorus and potassium in low phosphorus and potassium soils (Table 11). Significantly higher value of available sulphur was recorded in T_{15} (25.06 mg kg^{-1}) which received 100 per cent RDN along with 150 per cent RDP and 125 per cent RDK compared to T_6 (17.00 mg kg^{-1}) which received 100 per cent RDF as per package of practice and T_1 (12.66 mg kg^{-1}) which received 100 per cent RDN without P and K fertilizers. However, it was on par with all the treatments (T_9 to T_{16}) which received either 125 per cent or 150 per cent RDP irrespective of the levels of K applied. Further, there was decrease in available sulphur content was noticed in the treatments where no P or 100 per cent RDP was applied irrespective of levels potassium applied as compared to 125 per cent and 150 per cent RDP applied plots.

4.3.7 DTPA extractable iron

The data in Table 12, on iron content of postharvest soil did not show any significant difference due to different levels of phosphorus and potassium application. However, the numerically higher value of Fe (8.76 mg kg^{-1}) was observed in T_{15} which received 100 per cent RDN and 150 per cent RDP along 125 per cent RDK without phosphorus fertilizers, followed by T_2 (8.74 mg ka^{-1}) which received 100 per cent RDN along with 0 per cent RDP and 100 per cent RDK. The lower value (6.40 mg kg^{-1}) was found in T_{11} which received 100 per cent RDN along with 125 per cent of RDP and RDK.

4.3.8 DTPA extractable manganese

The manganese content of postharvest soil did not differ significantly due to application of different levels of phosphorus and potassium (Table 12). The numerically higher value of Mn (16.45 mg kg^{-1}) was found where 100 per cent of RDN and RDP were applied along with 125 per cent RDK (T_7) followed by T_3 (16.00 mg kg^{-1}) where 100 per cent RDN and 125 per cent RDK was applied without phosphorus fertilizer. Significantly lower manganese content (12.36 mg kg^{-1}) was found in treatment which received 100 per cent of RDN and 100 per cent RDK along with 125 per cent RDP (T_{10}).

Table 11: Effect of Sdifferent levels of phosphorus and potassium on exchangeable secondary nutrients status of soil after harvest of finger millet crop

Treatment details	Ca	Mg	S
	(cmol (p^+) kg^{-1})		(mg kg^{-1})
T_1 : 100 % RDN + 0 % RDP + 0 % RDK.	4.18	2.50	12.66
T_2 : 100 % RDN + 0 % RDP +100 % RDK.	5.34	3.00	13.38
T_3 : 100 % RDN + 0 % RDP + 125 % RDK.	5.93	2.50	13.42
T_4 : 100 % RDN + 0 % RDP + 150 % RDK.	5.43	2.57	13.11
T_5 : 100 % RDN + 100 % RDP + 0 % RDK.	5.83	2.87	15.62
T_6 : 100 % RDN + 100 % RDP + 100 % RDK. *(RDF)	5.97	2.33	17.00
T_7 : 100 % RDN + 100 RDP + 125 % RDK.	6.07	2.70	16.79
T_8 : 100 % RDN +100 % RDP +150 % RDK.	5.93	2.70	15.36
T_9 : 100 % RDN +125 % RDP + 0 % RDK	6.17	2.07	22.09
T_{10} : 100 % RDN + 125 % RDP + 100 % RDK.	6.27	2.30	22.99
T_{11} : 100 % RDN + 125 % RDP + 125 % RDK.	6.17	2.80	21.29
T_{12} : 100 % RDN + 125 % RDP + 150 % RDK.	6.20	3.43	23.14
T_{13} : 100 % RDN + 150 % RDP + 0 % RDK.	6.36	2.60	24.57
T_{14} : 100 % RDN + 150 % RDP+100%RDK.	6.40	2.83	23.64
T_{15} : 100% RDN + 150% RDP + 125 % RDK.	6.40	2.40	25.06
T_{16}: 100 % RDN + 150 % RDP + 150 % RDK.	6.47	2.47	23.37
S.Em. ±	**0.35**	**0.29**	**1.98**
CD (*P = 0.05*)	**1.05**	**NS**	**5.94**
Initial	4.00	2.26	20.27

RDN – Recommended dose of nitrogen, RDP- Recommended dose of phosphorus, RDK – Recommended dose of potassium, RDF- Recommended dose of fertilizer (100: 50: 50 kg NPK ha^{-1})

Table 12: Effect of different levels of phosphorus and potassium on DTPA extractable micronutrients (Fe, Mn, Zn and Cu) and hot water soluble boron of soil after harvest of finger millet crop

Treatment details	**Fe**	**Mn**	**Zn**	**Cu**	**B**
	(mg kg^{-1})				
T_1 : 100 % RDN + 0 % RDP + 0 % RDK.	8.73	14.98	1.01	0.77	0.33
T_2 : 100 % RDN + 0 % RDP +100 % RDK.	8.74	13.40	1.02	0.73	0.41
T_3 : 100 % RDN + 0 % RDP + 125 % RDK.	8.64	16.00	1.01	0.74	0.51
T_4 : 100 % RDN + 0 % RDP + 150 % RDK.	8.74	13.44	1.08	0.69	0.48
T_5 : 100 % RDN + 100 % RDP + 0 % RDK.	7.63	13.69	1.19	0.70	0.47
T_6 : 100 % RDN + 100 % RDP + 100 % RDK. *(RDF)	7.14	13.30	1.16	0.69	0.33
T_7 : 100 % RDN + 100 RDP + 125 % RDK.	7.26	16.45	1.25	0.81	0.53
T_8 : 100 % RDN +100 % RDP +150 % RDK.	7.35	14.50	1.17	0.80	0.52
T_9 : 100 % RDN +125 % RDP + 0 % RDK	6.80	15.75	1.28	0.75	0.53
T_{10} : 100 % RDN + 125 % RDP + 100 % RDK.	6.47	12.36	1.29	0.67	0.40
T_{11} : 100 % RDN + 125 % RDP + 125 % RDK.	6.40	12.90	1.32	0.66	0.39
T_{12} : 100 % RDN + 125 % RDP + 150 % RDK.	7.37	14.34	1.25	0.70	0.45
T_{13} : 100 % RDN + 150 % RDP + 0 % RDK.	6.67	14.46	1.30	0.79	0.44
T_{14} : 100 % RDN + 150 % RDP+100%RDK.	7.55	15.14	1.33	0.83	0.42
T_{15} : 100% RDN + 150% RDP + 125 % RDK.	8.76	14.28	1.34	0.76	0.55
T_{16}: 100 % RDN + 150 % RDP + 150 % RDK.	7.81	15.15	1.32	0.80	0.42
S.Em. ±	**0.80**	**1.44**	**0.15**	**0.07**	**0.04**
CD (*P = 0.05*)	**NS**	**NS**	**NS**	**NS**	**0.13**
Initial	**6.97**	**16.62**	**0.78**	**0.75**	**0.51**

RDN – Recommended dose of nitrogen, RDP- Recommended dose of phosphorus, RDK – Recommended dose of potassium, RDF- Recommended dose of fertilizer (100: 50: 50 kg NPK ha^{-1})

4.3.9 DTPA extractable zinc

The perusal of the data on micronutrient status of soil indicated that no significant difference was found with respect to zinc content in soil after harvest of finger millet due to different treatments imposed (Table 12). However, numerically higher DTPA extractable zinc content (1.34 mg kg^{-1}) was found in treatment receiving 100 per cent of RDN and RDP along with 125 per cent RDK (T_7) followed by the treatment (T_{15}) which received 100 per cent RDN along with 150 per cent RDP and 100 per cent RDK (T_{12}). The numerically lower zinc content (1.01 mg kg^{-1}) was found in control plot where 100 per cent RDN was applied without phosphorus and potassium fertilizer (T_1) and also in T_3 which received 100 per cent RDN along with 125 per cent RDK without phosphorus fertilizer.

4.3.10 DTPA extractable copper

The DTPA extractable copper did not vary significantly due to the application of different levels of phosphorus and potassium (Table 12). Numerically the higher DTPA extractable copper content (0.83 mg kg^{-1}) was found in the treatment which received 150 per cent RDP and 100 per cent RDK along with 100 per cent RDN (T_{14}) followed by T_7 which received 100 per cent of RDN and RDP along with 125 per cent RDK (0.81 mg kg^{-1}). The numerically lower content of copper (0.66 mg kg^{-1}) was noticed in treatment which received 125 per cent of RDP and RDK along with 100 per cent RDN (T_{11}).

4.3.11 Hot water soluble boron

There was significant variation in the hot water soluble boron in the postharvest soil due to application of different levels of phosphorus and potassium fertilizers (Table 12). Significantly higher boron content was noticed in T_{15} (0.55 mg kg^{-1}) which received 150 per cent RDP and 125 per cent RDK along with 100 per cent RDN compared to T_6 which received 100 per cent RDF and T_1 which received 100 % RDN along with FYM at 10 t ha^{-1} without phosphorus and potassium fertilizers. But it was found to be on par with T_{15} which received 100 per cent RDN and 150 per cent of RDP and RDK along with FYM at 10 t ha^{-1}.

4.4 Macronutrient concentration in finger millet straw

The data on macro nutrient concentration in finger millet straw viz; N, P, K, Ca, Mg and S are presented in Table 13. The perusal of the data indicates that Ca, Mg and S content of straw was higher compared to grain, whereas N and P were slightly higher in grain.

4.4.1 Nitrogen concentration in straw

The nitrogen concentration in straw did not differ significantly among the treatments. The numerically higher N concentration of 1.18 per cent was recorded in T_{12} which received 100 per cent RDN + 125 per cent RDP + 150 per cent RDK. However, lower N concentration of 0.98 per cent was observed in T_1 which received 100 per cent RDN without phosphorus and potassium fertilizers and rest of the treatments are intermediate between these treatments.

4.4.2 Phosphorus concentration in straw

The phosphorus concentration in straw did not differ significantly among the treatments. The numerically higher concentration of 0.19 per cent was found in T_{15}, T_{14} T_{12} and T_{11} which received 100 per cent RDN + 150 per cent RDP + 125 per cent RDK, 100 per cent RDN + 150 per cent RDP + 100 per cent RDK, 100 per cent RDN + 125 per cent RDP + 150 per cent RDK and 100 per cent RDN +125 per cent of RDP and RDK respectively. However, lower P concentration of 0.16 per cent was noticed in T_1, T_2 and T_4 which received 100 per cent RDN without phosphorus and potassium fertilizers, 100 per cent of RDN and RDK without phosphorus fertilizers and 100 per cent RDN + 150 per cent RDK without phosphorus fertilizers.

4.4.3. Potassium concentration in straw

The potassium concentration in straw differed significantly among the treatments. Significantly higher K concentration of 0.80 per cent was found in T_{15} which received 100 per cent RDN + 150 per cent RDP + 125 per cent RDK followed by the T_{16} (0.78 %) which received 100 per cent RDN + 150 per cent RDP + 100 per cent RDK compared to T_1 (0.50 %) which received 100 per cent RDN without phosphorus and potassium fertilizers. However, it was on par with T_6 (0.68 %) which received 100 per cent RDF as per package of practice and also with T_{16} (0.78 %) and T_{14} (0.77 %) which received 100 per cent RDN + 150 per cent RDP + 150 per cent RDK and 100 per cent RDN + 150 per cent RDP + 100 per cent RDK respectively.

4.4.4 Calcium concentration in straw

Calcium concentration in straw did not differ significantly among the treatments. The numerically higher concentration of Ca (0.94 %) was found in T_7 which received 100 per cent of RDN and RDK along with 125 per cent RDP. However, lower Ca concentration of 0.74 per cent was noticed in T_1 which received 100 per cent RDN without phosphorus and potassium fertilizers.

4.4.5 Magnesium concentration in straw

The magnesium concentration in straw did not differ significantly among the treatments. However, the numerically higher Mg content of 0.70 per cent was found in treatments T_6 and T_7 which received 100 per cent RDF and 100 per cent RDN + 100 per cent RDP +125 per cent RDK respectively. However, the lowest Mg concentration was observed in treatment T_2 (0.33 %) which received 100 per cent of RDN and RDK without phosphorus fertilizer.

4.4.6 Sulphur concentration in straw

The sulphur concentration of straw did not vary significantly due to different levels of phosphorus and potassium. Numerically higher value of 0.20 per cent was noticed in T_{15}, T_{14} and T_6 which received 100 per cent RDN + 150 per cent RDP + 125 per cent RDK, 100 per cent RDN + 150 per cent RDP + 100 per cent RDK and 100 per cent RDF as per package of practice respectively. However, the lowest concentration of S (0.13 %) was observed in T_1, T_2 and T_4 which received 100 per cent RDN without

Table 13: Effect of different levels of phosphorus and potassium on concentration of major and secondary nutrients of finger millet straw

Treatment details	Nitrogen (%)	Phosphorus (%)	Potassium (%)	Calcium (%)	Magnesium (%)	Sulphur (%)
T_1 : 100 % RDN + 0 % RDP + 0 % RDK.	0.98	0.16	0.50	0.74	0.34	0.13
T_2 : 100 % RDN + 0 % RDP +100 % RDK.	1.03	0.16	0.65	0.80	0.33	0.13
T_3 : 100 % RDN + 0 % RDP + 125 % RDK.	1.06	0.17	0.68	0.79	0.34	0.14
T_4 : 100 % RDN + 0 % RDP + 150 % RDK.	1.09	0.16	0.68	0.82	0.35	0.13
T_5 : 100 % RDN + 100 % RDP + 0 % RDK.	1.05	0.18	0.54	0.92	0.34	0.19
T_6 : 100 % RDN + 100 % RDP + 100 % RDK.	1.12	0.18	0.68	0.90	0.70	0.20
T_7 : 100 % RDN + 100 RDP + 125 % RDK.	1.13	0.18	0.65	0.94	0.70	0.18
T_8 : 100 % RDN +100 % RDP +150 % RDK.	1.15	0.18	0.64	0.92	0.63	0.19
T_9 : 100 % RDN +125 % RDP + 0 % RDK	1.06	0.18	0.62	0.93	0.68	0.18
T_{10} : 100 % RDN + 125 % RDP + 100 % RDK.	1.09	0.18	0.73	0.92	0.65	0.18
T_{11} : 100 % RDN + 125 % RDP + 125 % RDK.	1.13	0.19	0.74	0.93	0.69	0.18
T_{12} : 100 % RDN + 125 % RDP + 150 % RDK.	1.18	0.19	0.78	0.92	0.65	0.18
T_{13} : 100 % RDN + 150 % RDP + 0 % RDK.	1.08	0.18	0.58	0.79	0.66	0.19
T_{14} : 100 % RDN + 150 % RDP+100%RDK.	1.07	0.19	0.77	0.83	0.67	0.20
T_{15} : 100% RDN + 150% RDP + 125 % RDK.	1.08	0.19	0.80	0.79	0.67	0.20
T_{16}: 100 % RDN + 150 % RDP + 150 % RDK.	1.08	0.18	0.78	0.78	0.64	0.18
S.Em. ±	**0.10**	**0.01**	**0.05**	**0.09**	**0.07**	**0.02**
CD (*P = 0.05*)	**NS**	**NS**	**0.16**	**NS**	**NS**	**NS**

RDN – Recommended dose of nitrogen, RDP- Recommended dose of phosphorus, RDK – Recommended dose of potassium, RDF- Recommended dose of fertilizer (100: 50: 50 kg NPK ha^{-1})

phosphorus and potassium fertlizers and 100 per cent of RDN and RDK without phosphorus fertilizer and 100 per cent RDN and 150 per cent RDK without P respectively.

4.4.7. Micronutrients concentration in straw (Fe, Mn, Zn, Cu and B)

The data on micronutrients concentration like Fe, Mn, Zn, Cu and B in finger millet straw were presented in Table 14.

Perusal of the data indicated that there was no significant difference in the micronutrients (Fe, Zn, Cu and B) content in straw due to different levels of phosphorus and potassium except Mn.

The concentration of Fe was in the range of 55.18 mg kg^{-1} to 65.62 mg kg^{-1}. The numerically higher value (65.62 mg kg^{-1}) was noticed in T_{11} (100 % RDN + 125 % RDP + 125 % RDK) and lower value (55.18 mg kg^{-1}) was observed in T_2 (100 % RDN + 0 % RDP + 100 % RDK) and rest of the treatments were intermediate between these values.

The Mn concentration in straw varied significantly due to different treatment combinations of phosphorus and potassium. Significantly higher Mn content was observed in T_{16} (220.53 mg kg^{-1}) which received 100 per cent RDN along with 150 per cent of RDP and RDK as compared to T_6 (163.10 mg kg^{-1}) which received 100 per cent RDF as per package of practice and T_1 (133.50 mg kg^{-1}) which received 100 per cent RDN without phosphorus and potassium fertilizers. However, it was found to be on par with treatments T_{15} (218.75 mg kg^{-1}) and T_{14} (208.05 mg kg^{-1}) which received 100 per cent RDN + 150 per cent RDP + 125 per cent RDK and 100 per cent RDN + 150 per cent RDP + 100 per cent RDK respectively.

The zinc content in straw ranged from 29.38 mg kg^{-1} in T_1 (100 % RDN without phosphorus and potassium fertilizers) to 36.38 mg kg^{-1} in T_{16} (100 % RDN + 150 % RDP + 150 % RDK) and rest of the treatments are with in this range.

The Cu content in the finger millet straw ranged from 4.52 mg kg^{-1} in T_1 (100 % RDN without phosphorus and potassium fertilizers) to 7.10 mg kg^{-1} in T_{11} which received 100 % RDN along with 125 % of RDP and RDK) and rest of the treatments are between these values.

The B concentration was in the range of 2.78 mg kg^{-1} in T_1 (100 % RDN without phosphorus and potassium fertilizers) to 5.65 mg kg^{-1} in T_{12} (100 % RDN + 125 % RDP + 150 % RDK) and rest of the treatments are between these values.

Table 14 : Effect of different levels of phosphorus and potassium on micronutrients concentration of finger millet straw

Treatment details	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Zn (mg kg^{-1})	Cu (mg kg^{-1})	B (mg kg^{-1})
T_1 : 100 % RDN + 0 % RDP + 0 % RDK.	59.90	133.50	29.38	4.52	2.78
T_2 : 100 % RDN + 0 % RDP +100 % RDK.	55.18	142.38	30.57	5.40	3.10
T_3 : 100 % RDN + 0 % RDP + 125 % RDK.	62.10	135.07	30.68	5.53	3.25
T_4 : 100 % RDN + 0 % RDP + 150 % RDK.	63.00	152.78	34.43	5.32	3.58
T_5 : 100 % RDN + 100 % RDP + 0 % RDK.	63.70	169.25	29.58	4.83	3.25
T_6 : 100 % RDN + 100 % RDP + 100 % RDK.	59.46	163.10	30.07	5.78	3.58
T_7 : 100 % RDN + 100 RDP + 125 % RDK.	62.65	167.17	30.63	5.53	4.03
T_8 : 100 % RDN +100 % RDP +150 % RDK.	56.09	187.32	31.18	5.82	5.12
T_9 : 100 % RDN +125 % RDP + 0 % RDK	55.72	164.65	30.28	5.27	5.10
T_{10} : 100 % RDN + 125 % RDP + 100 % RDK.	64.62	170.72	29.67	6.67	5.38
T_{11} : 100 % RDN + 125 % RDP + 125 % RDK.	65.62	175.62	32.40	7.10	5.49
T_{12} : 100 % RDN + 125 % RDP + 150 % RDK.	59.62	187.63	33.83	7.05	5.65
T_{13} : 100 % RDN + 150 % RDP + 0 % RDK.	55.82	197.35	34.28	5.36	5.25
T_{14} : 100 % RDN + 150 % RDP+100%RDK.	63.52	208.05	35.05	6.57	5.49
T_{15} : 100% RDN + 150% RDP + 125 % RDK.	60.92	218.75	35.44	6.45	5.60
T_{16}: 100 % RDN + 150 % RDP + 150 % RDK.	59.38	220.53	36.38	5.64	5.60
S.Em. ±	**7.58**	**14.41**	**3.17**	**0.80**	**0.96**
CD (*P = 0.05*)	**NS**	**43.21**	**NS**	**NS**	**NS**

RDN – Recommended dose of nitrogen, RDP- Recommended dose of phosphorus, RDK – Recommended dose of potassium, RDF- Recommended dose of fertilizer (100: 50: 50 kg NPK ha^{-1})

4.5 Macro nutrient concentration in finger millet grain

The data on macronutrient concentration like N, P, K, Ca, Mg and S are presented in Table 15.

4.5.1 Nitrogen concentration in grain

The nitrogen concentration in grain did not differ significantly among the treatments. However, numerically higher N concentration of 1.65 per cent was recorded in treatments T_{15}, T_{14} and T_{12} which received 100 per cent RDN + 150 per cent RDP + 125 per cent RDK, 100 per cent RDN + 150 per cent RDP + 100 per cent RDK and 100 per cent RDN + 125 per cent RDP + 150 per cent RDK respectively. The lower N concentration of 1.45 per cent was observed in T_1 which received 100 per cent RDN without phosphorus and potassium fertilizers and rest of the treatments are intermediate.

4.5.2 Phosphorus concentration in grain

The phosphorus concentration in grain did not differ significantly among the treatments. The numerically higher concentration of 0.24 per cent was noticed in T_{15} which received 100 per cent RDN + 150 per cent RDP + 125 per cent RDK, However, lower P concentration of 0.18 per cent was observed in T_1 which received 100 per cent RDN without phosphorus and potassium fertilizers and same values were recorded in T_9 and T_{13} where no K was applied irrespective of levels of P applied.

4.5.3 Potassium concentration in grain

The potassium concentration in grain did not differ significantly among the treatments. However, numerically higher K concentration of 0.37 per cent was found in T_{12} which received 100 per cent RDN + 125 per cent RDP + 150 per cent RDK followed by the treatments (0.36 per cent) $T_{15,}$ T_{16}, T_6 and T_4. The lower K concentration of 0.27 per cent was recorded in T_1 which received 100 per cent RDN without phosphorus and potassium fertilizers.

4.5.4 Calcium concentration in grain

The calcium concentration in grain did not differ significantly among the treatments. The numerically higher concentration of Ca (0.28 %) was found in T_{10} which received 100 per cent RDN + 125 per cent RDP + 100 per cent RDK and also in the treatments T_4 (100 % RDN + 0 % RDP + 150 % RDK) and T_5 (100 % RDN + 100 % RDP + 0 % RDK). However, the lower Ca concentration of 0.24 per cent was recorded in T_1 which received 100 per cent RDN without phosphorus and potassium fertilizers.

4.5.5 Magnesium concentration in grain

The magnesium concentration in grain did not differ significantly among the treatments. However, the numerically higher Mg content of 0.33 per cent was found in treatments T_{14} and T_{15} which received 100 per cent of RDN and RDK along with 150 per cent RDP and 100 per cent RDN + 150 per cent RDP +125 per cent RDK respectively. However, the lower Mg concentration was observed in treatment T_1 (0.23 %) which received 100 per cent of RDN without phosphorus and potassium fertilizers.

Table 15: Effect of different levels of phosphorus and potassium on concentration of major and secondary nutrients of finger millet grain

Treatment details	Nitrogen (%)	Phosphorus (%)	Potassium (%)	Calcium (%)	Magnesium (%)	Sulphur (%)
T_1 : 100 % RDN + 0 % RDP + 0 % RDK.	1.45	0.18	0.27	0.24	0.23	0.09
T_2 : 100 % RDN + 0 % RDP +100 % RDK.	1.53	0.20	0.33	0.26	0.26	0.11
T_3 : 100 % RDN + 0 % RDP + 125 % RDK.	1.51	0.20	0.34	0.26	0.26	0.11
T_4 : 100 % RDN + 0 % RDP + 150 % RDK.	1.53	0.22	0.35	0.28	0.27	0.11
T_5 : 100 % RDN + 100 % RDP + 0 % RDK.	1.51	0.19	0.35	0.28	0.24	0.09
T_6 : 100 % RDN + 100 % RDP + 100 % RDK.	1.58	0.19	0.36	0.27	0.25	0.11
T_7 : 100 % RDN + 100 RDP + 125 % RDK.	1.58	0.19	0.36	0.26	0.28	0.12
T_8 : 100 % RDN +100 % RDP +150 % RDK.	1.59	0.22	0.35	0.26	0.32	0.12
T_9 : 100 % RDN +125 % RDP + 0 % RDK	1.52	0.18	0.34	0.27	0.25	0.10
T_{10} : 100 % RDN + 125 % RDP + 100 % RDK.	1.59	0.22	0.34	0.28	0.28	0.10
T_{11} : 100 % RDN + 125 % RDP + 125 % RDK.	1.60	0.23	0.36	0.27	0.28	0.12
T_{12} : 100 % RDN + 125 % RDP + 150 % RDK.	1.65	0.23	0.37	0.25	0.30	0.11
T_{13} : 100 % RDN + 150 % RDP + 0 % RDK.	1.62	0.18	0.33	0.26	0.27	0.09
T_{14} : 100 % RDN + 150 % RDP+100%RDK.	1.65	0.23	0.35	0.26	0.33	0.11
T_{15} : 100% RDN + 150% RDP + 125 % RDK.	1.65	0.24	0.36	0.27	0.33	0.11
T_{16}: 100 % RDN + 150 % RDP + 150 % RDK.	1.60	0.23	0.36	0.26	0.32	0.11
S.Em. ±	**0.10**	**0.03**	**0.04**	**0.06**	**0.04**	**0.01**
CD (*P = 0.05*)	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

RDN – Recommended dose of nitrogen, RDP- Recommended dose of phosphorus, RDK – Recommended dose of potassium, RDF- Recommended dose of fertilizer (100: 50: 50 kg NPK ha^{-1})

4.5.6 Sulphur concentration in grain

The sulphur concentration of finger millet grain did not vary significantly due to different levels of phosphorus and potassium. Sulphur concentration in grain was ranging from 0.09 per cent (T_1, T_5 and T_{13}) to 0.12 per cent (T_7, T_8 and T_{11}). However, lower concentration of sulphur (0.09 %) was recorded in T_1 where 100 per cent RDN was applied without phosphorus and potassium fertilizers.

4.6 Micronutrients concentration in finger millet grain (Fe, Mn, Zn, Cu and B)

The data on micronutrient concentration of like Fe, Mn, Zn, Cu and B in finger millet grains are presented in Table 16.

There was no significant difference in micronutrients content in grains due to different levels of phosphorus and potassium.

The concentration of Fe was in the range of 145.78 mg kg^{-1} to 166.22 mg kg^{-1}. The numerically higher Fe content (166.22 mg kg^{-1}) was noticed in T_{13} (100 % RDN + 150 % RDP + 0 % RDK) and lower value (145.78 mg kg^{-1}) was observed in T_1 (100 % RDN + 0 % RDP + 0 % RDK) and rest of the values were intermediate between these two treatments.

The numerically higher Mn (116.97 mg kg^{-1}) was noticed in T_{15} which received 100 per cent RDN + 150 per cent RDP + 125 per cent RDK and lower value (97.73 mg kg^{-1}) was recorded in 100 per cent RDN applied plots without phosphorus and potassium fertilizers (T_1).

The zinc content in grain ranged from 20.72 mg kg^{-1} in T_1 (100 % RDN without phosphorus and potassium fertilizers) to 25.65 mg kg^{-1} in T_8 (100 % RDN + 100 % RDP + 150 % RDP) and rest of the treatments are intermediate between these treatments.

Similarly Cu content in the finger millet grain ranged from 4.32 mg kg^{-1} in T_1 (100 % RDN without phosphorus and potassium fertilizers) to 6.25 mg kg^{-1} in T_4 (100 % RDN and 150 % RDK without phosphorus fertilizers) and rest of the treatments are with in this range.

The B concentration was in the range of 4.87 mg kg^{-1} in T_1 (100 % RDN without phosphorus and potassium fertilizers) to 7.75 mg kg^{-1} in T_{15} (100 % RDN + 150 % RDP + 125 % RDK) and rest of the treatments are between these range.

4.7 Major nutrients (N, P and K) uptake by finger millet

The uptake of N, P and K by straw, grain and total uptake by finger millet crop (grain and straw) are presented in Table 17.

4.7.1 Nitrogen uptake by straw

The nitrogen uptake by finger millet straw differed significantly due to different levels of phosphorus and potassium application in low phosphorus and low potassium

Table 16: Effect of different levels of phosphorus and potassium on micronutrients concentration of fingermillet grain

Treatment details	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Zn (mg kg^{-1})	Cu (mg kg^{-1})	B (mg kg^{-1})
T_1 : 100 % RDN + 0 % RDP + 0 % RDK.	145.78	97.73	20.72	4.32	4.87
T_2 : 100 % RDN + 0 % RDP +100 % RDK.	153.25	107.58	23.02	5.57	5.87
T_3 : 100 % RDN + 0 % RDP + 125 % RDK.	150.48	107.87	23.32	5.68	5.53
T_4 : 100 % RDN + 0 % RDP + 150 % RDK.	157.93	110.47	24.65	6.25	5.70
T_5 : 100 % RDN + 100 % RDP + 0 % RDK.	152.63	113.46	23.40	5.98	5.32
T_6 : 100 % RDN + 100 % RDP + 100 % RDK.	150.95	110.30	23.55	5.92	5.23
T_7 : 100 % RDN + 100 RDP + 125 % RDK.	157.05	115.92	24.33	5.67	5.39
T_8 : 100 % RDN +100 % RDP +150 % RDK.	154.30	107.90	25.67	5.53	5.19
T_9 : 100 % RDN +125 % RDP + 0 % RDK	160.88	107.82	20.90	5.50	5.94
T_{10} : 100 % RDN + 125 % RDP + 100 % RDK.	165.12	110.68	21.83	5.67	6.51
T_{11} : 100 % RDN + 125 % RDP + 125 % RDK.	162.32	112.70	23.78	5.62	6.64
T_{12} : 100 % RDN + 125 % RDP + 150 % RDK.	164.20	112.75	24.23	5.80	7.01
T_{13} : 100 % RDN + 150 % RDP + 0 % RDK.	166.22	111.37	22.87	5.38	6.52
T_{14} : 100 % RDN + 150 % RDP+100%RDK.	162.60	115.03	24.00	5.58	7.51
T_{15} : 100% RDN + 150% RDP + 125 % RDK.	160.83	116.97	24.20	5.60	7.75
T_{16}: 100 % RDN + 150 % RDP + 150 % RDK.	159.23	115.43	23.68	5.58	7.61
S.Em. ±	**25.52**	**7.55**	**1.59**	**0.65**	**1.18**
CD (*P = 0.05*)	**NS**	**NS**	**NS**	**NS**	**NS**

RDN – Recommended dose of nitrogen, RDP- Recommended dose of phosphorus, RDK – Recommended dose of potassium, RDF- Recommended dose of fertilizer (100: 50: 50 kg NPK ha^{-1})

soils of Ramanagara district (Table 17). Significantly higher nitrogen uptake (93.17 kg ha^{-1}) by straw was recorded in T_{16}, where 100 per cent RDN along with 125 per cent RDP and 150 per cent RDK was applied compared to T_6 (65.62 kg ha^{-1}) which received 100 per cent RDF and T_1 (45.91 kg ha^{-1}) which received 100 per cent RDN without phosphorus and potassium fertilizers. However, it was found to be on par with T_{15} (93.11 kg ha^{-1}) which received 150 per cent RDP and 125 per cent RDK along with 100 per cent RDN followed by T_{14} (88.91 kg ha^{-1}) which received 100 per cent RDN + 150 per cent RDP + 100 per cent RDK and T_{12} (88.67 kg ha^{-1}) which received 100 per cent RDN + 125 per cent RDP + 150 per cent RDK.

4.7.2 Nitrogen uptake by grain

The perusal of the data in Table 17 showed that nitrogen uptake by finger millet grain differed significantly due to different levels of phosphorus and potassium in low phosphorus and low potassium soils of Ramanagara district. Significantly higher nitrogen uptake (86.09 kg ha^{-1}) by grain was recorded in treatment receiving 100 per cent RDN + 150 per cent RDN + 125 per cent RDK (T_{15}) compared to T_6 which received 100 per cent RDF (62.49 kg ha^{-1}) and T_1 (36.74 kg ha^{-1}) where 100 per cent RDN was applied without phosphorus and potassium fertilizers. However, it was found to be on par with T_{14} (82.90 kg ha^{-1}) which received 100 per cent RDN along with 150 per cent RDP and 100 per cent RDK followed by T_{16} (82.30 kg ha^{-1}) which received 150 per cent of RDP and RDK along with 100 per cent RDN and T_{12} (72.04 kg ha^{-1}) which received 100 per cent RDN + 125 per cent RDP + 150 per cent RDK.

4.7.3 Total uptake of nitrogen by finger millet crop

The total nitrogen uptake by finger millet crop differed significantly due to different levels of phosphorus and potassium application through fertilizers (Table 17). Significantly higher total nitrogen uptake was noticed in T_{15} (179.20 kg ha^{-1}) which received 150 per cent RDP + 125 per cent RDK along with 100 per cent RDN compared to T_6 (128.11 kg ha^{-1}) where 100 per cent RDF was applied and T_1 (82.65 kg ha^{-1}) where 100 per cent RDN was applied without phosphorus and potassium fertilizers. However, it was found to be on par with T_{16} (175.47 kg ha^{-1}) which received 150 per cent of RDP and RDK along with 100 per cent RDN followed by T_{14} (171.81 kg ha^{-1}) which received 100 per cent of RDN and RDK along with 150 per cent RDP and T_{12} (160.71 kg ha^{-1}) which received 100 per cent RDN +125 per cent RDP + 150 per cent RDK.

4.7.4 Phosphorus uptake by straw

Perusal of the data in Table 17 indicated that the uptake of phosphorus by straw was found to be significantly differing among the treatments. The significantly higher uptake (16.77 kg ha^{-1}) was found in 100 per cent RDN + 150 per cent RDP + 125 per cent RDK (T_{15}) compared to T_6 which received 100 per cent RDF (10.81 kg ha^{-1}) and T_1 (7.48 kg ha^{-1}) which received 100 per cent RDN without phosphorus and potassium fertilizers. However, it was on par with T_{14} (16.00 kg ha^{-1}) which received 100 per cent of RDN and RDK along with 150 per cent RDP followed by T_{16} (15.63 kg ha^{-1}) which received 150 per cent of RDP and RDK along with 100 per cent RDN and T_{12} (14.09 kg ha^{-1}) which received 100 per cent RDN + 125 per cent RDP + 150 per cent RDK.

4.7.5 Phosphorus uptake by grain

The data in Table 17 indicated that the phosphorus uptake by finger millet grain differed significantly due to different levels of phosphorus and potassium application. Significantly higher phosphorus uptake (12.79 kg ha^{-1}) was noticed in treatment receiving 150 per cent RDP and 125 per cent RDK along with 100 per cent RDN as compared to T_6 (7.63 kg ha^{-1}) where 100 per cent RDF was applied and T_1 (4.50 kg ha^{-1}) which received 100 per cent RDN without phosphorus and potassium fertilizers. However, it was found to be on par with T_{16} (12.06 kg ha^{-1}) which received 150 per cent of RDP and RDK along with 100 per cent RDN followed by T_{14} (11.57 kg ha^{-1}) where 100 per cent of RDN and RDP was applied along with 150 per cent RDP. The lowest uptake of P by grain was noticed in T_1 (4.50 kg ha^{-1}) which received 100 per cent RDN without phosphorus and potassium fertilizers.

4.7.6 Total uptake of phosphorus by finger millet crop

There was a significant difference in total phosphorus uptake by finger millet due to different levels of phosphorus and potassium application. The significantly higher total uptake of phosphorus (29.56 kg of P ha^{-1}) found in treatment (T_{15}) receiving 150 per cent RDP and 125 per cent RDK along with 100 per cent RDN compared to all treatments except T_{16} (27.69 kg ha^{-1}) and T_{14} (27.57 kg ha^{-1}) which received 150 per cent RDP + 150 per cent RDK along with 100 per cent RDN and 100 per cent of RDN and RDK along with 150 per cent RDP respectively. However, lower uptake was noticed in T_1 (11.98 kg ha^{-1}) which received 100 per cent RDN without phosphorus and potassium fertilizers.

4.7.7 Potassium uptake by straw

The data on potassium uptake by straw showed a significant difference among treatments due to different treatments imposed (Table 17). The significantly higher potassium uptake by straw (70.69 kg ha^{-1}) was recorded in T_{15} which received 150 per cent RDP + 125 per cent RDK along with 100 per cent RDN as compared to 100 per cent RDF receiving treatment (T_6) which recorded the K uptake 40.31 kg ha^{-1} and T_1 (22.56 kg ha^{-1}) where 100 per cent RDN was applied without phosphorus and potassium fertilizers. However, it was found to be on par with T_{16} (67.80 kg ha^{-1}) which received 100 per cent RDN + 150 per cent RDP +150 per cent RDK and T_{14} (50.10 kg ha^{-1}) which received 100 per cent RDN + 150 per cent RDP +100 per cent RDK.

4.7.8 Potassium uptake by grain

Perusal of the potassium uptake data in Table 17 indicated that the significant difference was found among treatments in K uptake by grains due to different levels of phosphorus and potassium fertilizer application. Significantly higher K uptake (18.59 kg ha^{-1}) was noticed in T_{15} which received 150 per cent RDP and 125 per cent RDK along with100 per cent RDN compared to T_1 (6.93 kg ha^{-1}) which received 100 per cent RDF without P and K fertilizers. However, it was found to be on par with T_6 (14.49 kg ha^{-1}) which received 100 per cent RDF as per package of practice and also with treatments T_{16} (18.49 kg ha^{-1}) and T_{14} (17.72 kg ha^{-1}) which received 150 per cent of RDP and RDK along with 100 per cent RDN and 100 per cent of RDN and RDK along with 150 per cent RDP respectively.

Table 17: Uptake of major nutrients by grain and straw of finger millet as influenced by different levels of phosphorus and potassium application

Treatment details	Nitrogen (kg ha^{-1})			Phosphorus (kg ha^{-1})			Potassium (kg ha^{-1})		
	Straw	**Grain**	**Total uptake**	**Straw**	**Grain**	**Total uptake**	**Straw**	**Grain**	**Total uptake**
T_1 : 100 % RDN + 0 % RDP + 0 % RDK.	45.91	36.74	82.65	7.48	4.50	11.98	22.56	6.93	29.50
T_2 : 100 % RDN + 0 % RDP +100 % RDK.	53.59	43.86	97.45	7.98	5.77	13.75	33.58	9.53	43.11
T_3 : 100 % RDN + 0 % RDP + 125 % RDK.	59.79	50.17	109.97	9.22	6.74	15.96	37.19	11.81	49.00
T_4 : 100 % RDN + 0 % RDP + 150 % RDK.	64.08	53.14	117.22	9.02	7.76	16.77	36.90	12.47	49.36
T_5 : 100 % RDN + 100 % RDP + 0 % RDK.	61.52	51.18	112.70	10.39	6.80	17.20	30.82	12.02	42.84
T_6 : 100 % RDN + 100 % RDP + 100 % RDK. *(RDF)	65.62	62.49	128.11	10.81	7.63	18.44	40.31	14.49	54.80
T_7 : 100 % RDN + 100 RDP + 125 % RDK.	72.35	63.11	135.46	11.79	7.66	19.45	41.83	15.00	56.83
T_8 : 100 % RDN +100 % RDP +150 % RDK.	74.97	65.03	140.00	12.05	9.16	21.21	41.46	14.58	56.03
T_9 : 100 % RDN +125 % RDP + 0 % RDK	62.75	53.50	116.25	10.61	6.27	16.88	38.74	11.94	50.67
T_{10} : 100 % RDN + 125 % RDP + 100 % RDK.	69.27	64.71	133.97	11.48	8.73	20.21	46.38	14.03	60.41
T_{11} : 100 % RDN + 125 % RDP + 125 % RDK.	83.69	67.23	150.92	13.83	9.69	23.52	54.66	15.07	69.73
T_{12} : 100 % RDN + 125 % RDP + 150 % RDK.	96.75	72.04	168.79	14.09	10.07	24.17	58.66	16.43	75.09
T_{13} : 100 % RDN + 150 % RDP + 0 % RDK.	68.05	61.16	129.21	11.38	6.94	18.32	35.72	12.42	48.14
T_{14} : 100 % RDN + 150 % RDP+100%RDK.	88.91	82.90	171.81	16.00	11.57	27.57	63.18	17.72	80.90
T_{15}: 100% RDN + 150% RDP + 125 % RDK.	93.11	86.09	179.21	16.77	12.79	29.57	70.69	18.59	89.28
T_{16}: 100 % RDN + 150 % RDP + 150 % RDK.	93.17	82.30	175.48	15.63	12.06	27.69	67.80	18.49	86.29
S.Em. ±	**6.77**	**5.00**	**8.27**	**0.94**	**1.27**	**1.58**	**5.82**	**1.53**	**5.97**
CD(*P=0.05*)	**20.31**	**14.98**	**24.79**	**2.83**	**3.80**	**4.74**	**17.46**	**4.58**	**17.89**

RDN – Recommended dose of nitrogen, RDP- Recommended dose of phosphorus, RDK – Recommended dose of potassium, RDF- Recommended dose of fertilizer (100: 50: 50 kg NPK ha^{-1})

4.7.9 Total uptake of potassium by finger millet crop

The significant difference was noticed among the treatments in total K uptake by finger millet crop due to different levels of phosphorus and potassium fertilizer application. Significantly higher total potassium uptake (89.28 kg ha^{-1}) was found in T_{15} which received 100 per cent RDN + 150 per cent RDP +125 per cent RDK compared to T_6 (54.80 kg ha^{-1}) which received 100 per cent RDF as per package of practice and T_1 (29.50 kg ha^{-1}) which received 100 per cent RDF without P and K fertilizers. However, it was on par with T_{16} (86.29 kg ha^{-1}) which received 150 per cent of RDP and RDK along with 100 per cent RDN followed by T_{14} (80.90 kg ha^{-1}) which received 100 per cent RDN + 150 per cent RDP +100 per cent RDK and T_{12} (75.09 kg ha^{-1}) where 125 per cent RDP and 150 per cent RDK was applied along with 100 per cent RDN.

4.8 Uptake of secondary nutrients (Ca, Mg and S) by finger millet crop

The uptake of secondary nutrients like calcium, magnesium and sulphur by finger millet straw, grain and total uptake is presented in the Table 18

4.8.1 Calcium uptake by straw

Significant difference was found among the treatments in calcium uptake by straw due to different treatments imposed (Table 18). Significantly higher uptake of calcium (69.98 kg ha^{-1}) was found where 100 per cent RDN was applied along with 150 per cent RDP and 125 per cent RDK (T_{15}) compared to T_1 (34.05 kg ha^{-1}) where 100 per cent RDN was applied without phosphorus and potassium fertilizers and also with all treatments (T_2, T_3 and T_4) which did not receive phosphorus fertilizers irrespective of levels of K applied. However, it was found to be on par with treatment (T_6) receiving 100 per cent RDF (52.92 kg ha^{-1}) and also with T_{16} (67.87 kg ha^{-1}) which received 150 per cent of RDP and RDK along with 100 per cent RDN and T_{14} (68.09 kg ha^{-1}) where it received 100 per cent of RDN and RDK along with 150 per cent RDP.

4.8.2 Calcium uptake by grain

Calcium uptake by grain did not vary significantly among the treatments due to application of different levels of phosphorus and potassium. However, numerically higher uptake of calcium was noticed in T_{15} (14.27 kg ha^{-1}) which received 100 per cent RDN + 150 per cent RDP + 125 per cent RDK followed by T_{16} (13.48 kg ha^{-1}) where it received 150 per cent of RDP and RDK along with 100 per cent RDN. Further, numerically lower uptake was observed in T_1 (6.05 kg ha^{-1}) which receives 100 per cent RDF without P and K fertilizers and rest of the treatments are intermediate between these values.

4.8.3 Total uptake of calcium by finger millet crop

The data on total uptake of calcium by finger millet crop was found to be significant due to application of different levels of phosphorus and potassium fertilizers. Significantly higher total uptake of calcium (84.25 kg ha^{-1}) was found where 100 per cent RDN was applied along with 150 per cent RDP and 125 per cent RDK (T_{15}) compared to T_1 (40.50 kg ha^{-1}) where 100 per cent RDN was applied without phosphorus and potassium fertilizers and also with all treatments (T_2, T_3 and T_4) which did not receive phosphorus fertilizers irrespective of levels of K applied. However, it was found to be on par with treatment (T_6) receiving 100 per cent RDF (63.89 kg ha^{-1}) and also with T_{16} (81.35 kg ha^{-1}) which received 150 per cent of RDP and RDK along with 100 per cent RDN and also with all the other treatments which received P and K fertilizers.

4.8.4 Magnesium uptake by straw

Magnesium uptake by finger millet straw did not differ significantly among the treatments due to application of different levels of phosphorus and potassium application. However, numerically higher uptake of magnesium was noticed in T_{15} (43.88 kg ha^{-1}) which received 100 per cent RDN + 150 per cent RDP + 125 per cent RDK followed by T_{14} (39.59 kg ha^{-1}) where it receives 100 per cent of RDN and RDK along with 150 per cent RDP. Further, numerically lower uptake of Mg was observed in T_1 (15.67 kg ha^{-1}) which received 100 per cent RDF without P and K fertilizers and rest of the treatments are intermediate between these values.

4.8.5 Magnesium uptake by grain

The perusal of the data in Table 18 indicated that the uptake of magnesium by finger millet grain differed significantly among the treatments. Significantly higher magnesium uptake (17.33kg ha^{-1}) was found in T_{15} which received 100 per cent RDN + 150 per cent RDP +125 per cent RDK compared to T_6 (9.87 kg ha^{-1}) where 100 per cent of RDF was applied as per package of practice and T_1 (5.83 kg ha^{-1}) which receives 100 per cent RDF without P and K fertilizers. However, it was found to be on par with T_{16} (16.60 kg ha^{-1}) which received 150 per cent of RDP and RDK along with 100 per cent RDN followed by T_{14} (16.71kg ha^{-1}) where it received 100 per cent of RDN and RDK along with 150 per cent RDP.

4.8.6 Total uptake of magnesium by finger millet crop

The data on total uptake of magnesium by finger millet crop was found to be significant due to application of different levels of phosphorus and potassium fertilizers in low phosphorus and potassium soils of Ramanagara district. Significantly higher total uptake of magnesium (61.21 kg ha^{-1}) was found where 100 per cent RDN was applied along with 150 per cent RDP and 125 per cent RDK (T_{15}) compared to T_1 (21.50 kg ha^{-1}) where 100 per cent RDN was applied without phosphorus and potassium fertilizers. However, it was found to be on par with treatment (T_6) receiving 100 per cent RDF (50.51 kg ha^{-1}) and also with all other treatments which received different levels of phosphorus irrespective of the K levels applied.

4.8.7 Sulphur uptake by straw

Significant difference was found among the treatments with respect to sulphur uptake by straw due to different treatments imposed (Table 18). Significantly higher uptake of sulphur by straw (17.89 kg ha^{-1}) was noticed in T_{15} which received 100 per cent RDN + 150 per cent RDP + 125 per cent RDK compared to treatment (T_6) receiving 100 per cent RDF as per package of practice (11.55 kg ha^{-1}) and T_1 (6.26 kg ha^{-1}) which received 100 per cent RDN without P and K fertilizers. However, it was found to be on par with T_{16} (17.04 kg ha^{-1}) which received 150 per cent of RDP and RDK along with

Table 18: Uptake of secondary nutrients by grain and straw of finger millet as influenced by different levels of phosphorus and potassium application

Treatment details	Calcium (kg ha^{-1})			Magnesium (kg ha^{-1})			Sulphur (kg ha^{-1})		
	Straw	**Grain**	**Total uptake**	**Straw**	**Grain**	**Total uptake**	**Straw**	**Grain**	**Total uptake**
T_1 : 100 % RDN + 0 % RDP + 0 % RDK.	34.05	6.45	40.50	15.67	5.83	21.50	6.26	2.30	8.56
T_2 : 100 % RDN + 0 % RDP +100 % RDK.	40.33	7.33	47.66	17.52	7.31	24.83	6.90	3.09	9.99
T_3 : 100 % RDN + 0 % RDP + 125 % RDK.	41.89	8.95	50.84	18.83	8.72	27.55	7.45	3.76	11.21
T_4 : 100 % RDN + 0 % RDP + 150 % RDK.	44.08	9.75	53.83	20.27	9.26	29.53	7.55	4.23	11.78
T_5 : 100 % RDN + 100 % RDP + 0 % RDK.	51.52	9.31	60.83	20.75	8.17	28.92	10.30	3.22	13.52
T_6 : 100 % RDN + 100 % RDP + 100 % RDK. *(RDF)	52.92	10.97	63.89	40.64	9.87	50.51	11.55	4.30	15.85
T_7 : 100 % RDN + 100 RDP + 125 % RDK.	60.21	10.84	71.05	49.29	10.83	60.12	11.85	5.11	16.96
T_8 : 100 % RDN +100 % RDP +150 % RDK.	60.32	11.30	71.62	40.87	14.78	55.65	12.21	5.30	17.51
T_9 : 100 % RDN +125 % RDP + 0 % RDK	54.79	9.34	64.13	37.61	8.67	46.28	10.61	3.53	14.14
T_{10} : 100 % RDN + 125 % RDP + 100 % RDK.	58.95	11.44	70.39	39.64	11.46	51.10	11.69	4.32	16.01
T_{11} : 100 % RDN + 125 % RDP + 125 % RDK.	68.97	11.39	80.36	29.25	11.73	40.98	13.17	5.10	18.27
T_{12} : 100 % RDN + 125 % RDP + 150 % RDK.	69.49	11.39	80.88	32.09	13.17	45.26	13.29	4.99	18.28
T_{13} : 100 % RDN + 150 % RDP + 0 % RDK.	49.73	9.01	58.74	31.54	10.17	43.10	11.94	3.48	15.42
T_{14} : 100 % RDN + 150 % RDP+100%RDK.	68.09	12.85	80.94	39.57	16.71	56.28	16.83	5.41	22.24
T_{15} : 100% RDN + 150% RDP + 125 % RDK.	69.98	14.27	84.25	43.88	17.33	61.21	17.89	5.87	23.76
T_{16}: 100 % RDN + 150 % RDP + 150 % RDK.	67.87	13.48	81.35	36.77	16.60	53.37	17.04	5.49	22.53
S.Em. ±	**6.12**	**2.92**	**8.09**	**7.90**	**1.49**	**8.46**	**1.89**	**0.57**	**2.17**
CD(*P=0.05*)	**18.35**	**NS**	**24.27**	**NS**	**4.47**	**25.36**	**5.68**	**1.71**	**6.51**

RDN – Recommended dose of nitrogen, RDP- Recommended dose of phosphorus, RDK – Recommended dose of potassium, RDF- Recommended dose of fertilizers (100: 50: 50 kg NPK ha^{-1})

100 per cent RDN followed by T_{14} (16.83 kg ha^{-1}) where it received 100 per cent of RDN and RDK along with 150 per cent RDP.

4.8.8 Sulphur uptake by grain

Uptake of sulphur by finger millet grain showed significant difference among the treatments (Table 18). Significantly higher value of sulphur uptake by finger millet grain was found in T_{15} which received 100 per cent RDN + 150 per cent RDP + 125 per cent RDK (5.87 kg ha^{-1}) compared to T_1 (2.30 kg ha^{-1}) which received 100 per cent RDN without P and K fertilizers and also with all the treatments (T_2, T_3 and T_4) which did not received P fertilizer irrespective of the K levels and treatments (T_5, T_9 and T_{13}) which did not receive K fertilizer irrespective of the P levels applied. However, it was found to be on par with treatment (T_6) receiving 100 per cent RDF as per package of practice (4.30 kg ha^{-1}) and also with all other treatments.

4.8.9 Total uptake of sulphur by finger millet crop

The perusal of the data in Table 18 indicated that the total uptake of sulphur by finger millet grain differed significantly among the treatments. Significantly higher sulphur uptake (23.76 kg ha^{-1}) was found in T_{15} which received 100 per cent RDN + 150 per cent RDP +125 per cent RDK compared T_6 which received 100 per cent RDF as per package of practice (15.85 kg ha^{-1}) and also withal the treatments (T_2, T_3 and T_4) which did not received P and treatments (T_5, T_9 and T_{13}) which did not receive K, irrespective of levels of K and P applied respectively. However, it was found to be on par with T_{16} (22.53 kg ha^{-1}) which received 150 per cent of RDP and RDK along with 100 per cent RDN followed by T_{14} (22.24 kg ha^{-1}) where it received 100 per cent of RDN and RDK along with 150 per cent RDP.

4.9 Uptake of micronutrients (Fe, Mn, Zn, Cu and B) by finger millet crop

The uptake of micronutrients by straw, grain and total uptake by finger millet crop was shown in Table 19 and 20.

4.9.1 Uptake of iron by straw

The data in Table 19 on uptake of Fe by finger millet straw showed significant difference among the treatments due to different treatments imposed. Significantly higher uptake (539.70 g ha^{-1}) of iron was noticed in T_{15} in which 150 per cent RDP and 125 per cent RDK was applied along with 100 per cent RDN compared to 100 per cent RDF receiving treatment (T_6) which recorded the uptake of 352.86 g ha^{-1} and T_1 (273.77 g ha^{-1}) which received 100 per cent RDN without P and K fertilizers. However, it was found to be on par with T_{14} (527.82 g ha^{-1}) where it received 100 per cent of RDN and RDK along with 150 per cent RDP followed by T_{16} (517.05 g ha^{-1}) which received 150 per cent of RDP and RDK along with 100 per cent RDN.

4.9.2 Uptake of iron by finger millet grain

Uptake of Fe by finger millet grain did not show the significant difference due to different levels of phosphorus and potassium fertilizer application. However, numerically higher uptake of Fe (84.09 g ha^{-1}) by grain was noticed in T_{15} which received 100 per cent RDN + 150 per cent RDP + 125 per cent RDK followed by T_{16} (82.35 g ha^{-1}) which received 150 per cent of RDP and RDK along with 100 per cent RDN. Numerically lower uptake of Fe (36.62 g ha^{-1}) by grain was observed in T_1 which received 100 per cent RDN without P and K fertilizers.

4.9.3 Total uptake of iron by finger millet crop

Perusal of the data in table 18 indicated a significant difference in total uptake of Fe by finger millet crop due to different levels of phosphorus and potassium application through fertilizers. The significantly higher total uptake of Fe (623.79 g Fe ha^{-1}) was recorded in treatment receiving 150 per cent RDP and 125 per cent RDK along with 100 per cent RDN (T_{15}) compared to 100 per cent RDF receiving treatment (T_6) which recorded the Fe uptake of 412.55 g kg^{-1} and T_1 (310.39 g ha^{-1}) which received 100 per cent RDN without P and K fertilizers. However, it was found to be on par with T_{14} (609.69 g ha^{-1}) where it received 100 per cent of RDN and RDK along with 150 per cent RDP followed by T_{16} (599.40 g ha^{-1}) which received 150 per cent of RDP and RDK along with 100 per cent RDN.

4.9.4 Uptake of manganese by straw

The data on uptake of Mn by finger millet straw showed a significant difference among the treatments (Table 19). Significantly higher uptake (220.53 g ha^{-1}) of Mn noticed in treatment where 150 per cent of RDP and RDK was applied along with 100 per cent RDN compared to T_6 (163.10 g ha^{-1}) where 100 per cent RDF was applied and T_1 (133.50 g ha^{-1}) where 100 per cent RDN was applied without phosphorus and potassium fertilizers. However, it was on par with T_{15} (218.75 g ha^{-1}) which received 150 per cent RDP and 125 per cent RDK along with 100 per cent RDN followed by T_{14} (208.05 g ha^{-1}) which received 100 per cent of RDN and RDK along with 150 per cent RDP.

4.9.5 Uptake of manganese by finger millet grain

Uptake of Mn by finger millet grain showed significant difference between the different treatments imposed (Table 19). The significantly higher uptake of manganese (61.03 g ha^{-1}) was recorded in treatment receiving 150 per cent RDP and 125 per cent RDK along with 100 per cent RDN compared to T_6 (44.22 g ha^{-1}) where 100 per cent RDF was applied and all the treatments (T_1, T_2, T_3 and T_4) which did not receive P irrespective of the K levels applied and also the treatments (T_5, T_9 and T_{13}) which did not receive K, irrespective of the P levels applied. However, it was found to be on par with T_{16} (59.39 g ha^{-1}) which received 150 per cent of RDP and RDK along with 100 per cent RDN followed by T_{14} (58.32 g ha^{-1}) where it received 100 per cent of RDN and RDK along with 150 per cent RDP.

4.9.6 Total uptake of manganese by finger millet crop

Total uptake of Mn by finger millet showed a significant difference among the treatments (Table 19). Significantly higher total uptake (279.92 g ha^{-1}) of Mn was noticed in treatment where 150 per cent of RDP and RDK was applied along with 100 per cent RDN (T_{16}) compared to T_6 (207.32 g ha^{-1}) where 100 per cent RDF was applied and T_1

Table 19: Uptake of micronutrients (Fe, Mn and Zn) by grain and straw of finger millet crop as influenced by different level of phosphorus and potassium application

Treatment details	Fe (g ha^{-1})			Mn (g ha^{-1})			Zn (g ha^{-1})		
	Straw	**Grain**	**Total uptake**	**Straw**	**Grain**	**Total uptake**	**Straw**	**Grain**	**Total uptake**
T_1 : 100 % RDN + 0 % RDP + 0 % RDK.	273.77	36.62	310.39	133.50	24.78	158.28	136.68	5.22	141.90
T_2 : 100 % RDN + 0 % RDP +100 % RDK.	276.39	42.82	319.21	142.38	30.92	173.30	156.53	6.58	163.11
T_3 : 100 % RDN + 0 % RDP + 125 % RDK.	328.17	49.38	377.55	135.07	36.35	171.42	164.55	7.81	172.36
T_4 : 100 % RDN + 0 % RDP + 150 % RDK.	344.47	54.61	399.08	152.78	39.09	191.87	188.57	8.59	197.16
T_5 : 100 % RDN + 100 % RDP + 0 % RDK.	354.51	50.34	404.85	169.25	38.60	207.85	163.37	7.90	171.27
T_6 : 100 % RDN + 100 % RDP + 100 % RDK. *(RDF)	352.86	59.69	412.55	163.10	44.22	207.32	174.20	9.34	183.54
T_7 : 100 % RDN + 100 RDP + 125 % RDK.	402.40	63.90	466.30	167.17	46.30	213.47	196.55	9.77	206.32
T_8 : 100 % RDN +100 % RDP +150 % RDK.	369.72	64.07	433.79	187.32	44.88	232.20	204.69	10.24	214.93
T_9 : 100 % RDN +125 % RDP + 0 % RDK	330.97	56.96	387.93	164.65	37.74	202.39	178.49	7.34	185.83
T_{10} : 100 % RDN + 125 % RDP + 100 % RDK.	409.66	68.52	478.18	170.72	44.66	215.38	189.14	8.99	198.13
T_{11} : 100 % RDN + 125 % RDP + 125 % RDK.	488.23	68.41	556.64	175.62	47.39	223.01	238.57	10.01	248.58
T_{12} : 100 % RDN + 125 % RDP + 150 % RDK.	454.54	71.76	526.30	187.63	49.46	237.09	254.85	10.62	265.47
T_{13} : 100 % RDN + 150 % RDP + 0 % RDK.	345.79	62.93	408.72	197.35	42.13	239.48	212.04	8.64	220.68
T_{14} : 100 % RDN + 150 % RDP+100%RDK.	527.82	81.87	609.69	208.05	58.32	266.37	288.76	12.13	300.89
T_{15} : 100% RDN + 150% RDP + 125 % RDK.	539.70	84.09	623.79	218.75	61.03	279.78	312.85	12.63	325.48
T_{16}: 100 % RDN + 150 % RDP + 150 % RDK.	517.05	82.35	599.40	220.53	59.39	279.92	322.08	12.19	334.27
S.Em. ±	**54.19**	**11.06**	**58.15**	**14.41**	**3.94**	**32.80**	**25.32**	**0.81**	**25.81**
CD(*P=0.05*)	**162.48**	**NS**	**174.35**	**43.21**	**11.82**	**98.31**	**75.91**	**2.43**	**77.39**

RDN – Recommended dose of nitrogen, RDP- Recommended dose of phosphorus, RDK – Recommended dose of potassium, RDF- Recommended dose of fertilizers (100: 50: 50 kg NPK ha^{-1})

(158.28 g ha^{-1}) where 100 per cent RDN was applied without phosphorus and potassium fertilizers. However, it was on par with T_{15} (279.78 g ha^{-1}) which received 150 per cent RDP and 125 per cent RDK along with 100 per cent RDN followed by T_{14} (266.37 g ha^{-1}) which received 100 per cent of RDN and RDK along with 150 per cent RDP.

4.9.7 Uptake of zinc by straw

Uptake of zinc by finger millet straw showed a significant difference in between the treatments (Table 19) Significantly higher uptake of zinc (322.08 g Zn ha^{-1}) by finger millet straw was found in treatment receiving 150 per cent RDP and RDK along with 100 per cent RDN (T_{16}) compared to T_6 (174.20 g Zn ha^{-1}) which received 100 per cent RDF as per package of practice and T_1 (136.68 g Zn ha^{-1}) which received 100 per cent RDF. However, it was on par with T_{15} (312.85 g Zn ha^{-1}) which received 150 per cent RDP and 125 per cent RDK along with 100 per cent RDN followed by T_{14} (288.76 g Zn ha^{-1}) which received 100 per cent of RDN and RDK along with 150 per cent RDP.

4.9.8 Uptake of zinc by grain

Perusal of the data in Table 19 indicated that the uptake of zinc by finger millet grain showed significant difference between the treatments. The significantly higher zinc uptake by finger millet grain was (12.63 g ha^{-1}) found in (T_{15}) treatment receiving 150 per cent RDP and 125 per cent RDK along with 100 per cent RDN compared to 100 per cent RDF receiving treatment (T_6) as per package of practice (9.34 g ha^{-1}) and T_1 (5.22 g ha^{-1}) which received 100 per cent RDN without P and K fertilizers. However, it was found to be on par with T_{16} (12.19 g ha^{-1}) which received 150 per cent of RDP and RDK along with 100 per cent RDN followed by T_{14} (12.13 g ha^{-1}) which it received 100 per cent of RDN and RDK along with 150 per cent RDP.

4.9.9 Total uptake of zinc by finger millet crop

The data in Table 19 indicated that the total uptake of zinc by finger millet crop showed significant difference between treatments due to different levels of phosphorus and potassium fertilizer application Significantly higher total uptake (334.27 g ha^{-1}) of zinc was found where 150 per cent of RDP and RDK was applied (T_{16}) along with 100 per cent RDN over 100 per cent RDF treatment (T_6) which recorded the value of 183.54 g Zn ha^{-1} and T_1 (141.90 g ha^{-1}) which received 100 per cent RDF without phosphorus and potassium fertilizers. However, it was on par with T_{15} (325.48 g ha^{-1}) which received 150 per cent RDP and 125 per cent RDK along with 100 per cent RDN followed by T_{14} (300.89 g ha^{-1}) which received 100 per cent of RDN and RDK along with 150 per cent RDP.

4.9.10 Uptake of copper by straw

Uptake of Cu by finger millet straw showed significant difference between the treatments due to different treatments imposed (Table 20). Significantly higher uptake (57.04 g ha^{-1}) was found in the treatment receiving 150 per cent of RDP and 125 per cent RDK was applied along with 100 per cent RDN (T_{15}) as compared to T_6 (33.50 g ha^{-1}) where 100 per cent RDF was applied and T_1 (21.12 g ha^{-1}) where 100 per cent RDN was applied without phosphorus and potassium fertilizers. However, it was found to be on par with T_{14} (54.11 g ha^{-1}))and T_{16} (49.61 g ha^{-1}) which received 100 per cent of RDN and RDK along with 150 per cent RDP and 150 per cent of RDP and RDK were applied along with 100 per cent RDN respectively.

4.9.11 Uptake of copper by finger millet grain

The data on Cu uptake (Table 20) by finger millet was found to be significantly different among the treatments due to different levels of phosphorus and potassium fertilizer application. The higher uptake of copper (2.92 g ha^{-1}) by grain was observed where 150 per cent of RDP and 125 per cent RDK was applied along with 100 per cent RDN compared to T_1 (1.08 g ha^{-1}) which received 100 per cent RDN without phosphorus and potassium fertilizers. However, it was found to be on par with 100 per cent RDF treatment (T_6) which recorded the value of 2.39 g ha^{-1} and also with T_{16} (2.87 g ha^{-1}) and T_{14} (2.81 g ha^{-1}) which received 150 per cent of RDP and RDK along with 100 per cent RDN and 100 per cent of RDN and RDK along with 150 per cent RDP respectively.

4.9.12 Total uptake of copper by finger millet crop

Perusal of the data in Table 20 indicated a significant difference in total Cu uptake by finger millet crop. Significantly higher total Cu uptake (59.96 g ha^{-1}) was noticed in treatment receiving 150 per cent of RDP and 125 per cent RDK was applied along with 100 per cent RDN (T_{15}) as compared to T_6 (35.89 g ha^{-1}) where 100 per cent RDF was applied and T_1 (22.20 g ha^{-1}) where 100 per cent RDN was applied without phosphorus and potassium fertilizers. However, it was found to be on par with T_{14} (56.92 g ha^{-1}) and T_{16} (52.48 g ha^{-1}) which received 100 per cent of RDN and RDK along with 150 per cent RDP and 150 per cent of RDP and RDK along with 100 per cent RDN respectively.

4.9.13 Uptake of boron by finger millet straw

The data on uptake of B by finger millet straw showed a significant difference among the treatments (Table 20). Significantly higher uptake (48.32 g ha^{-1}) of B noticed in treatment (T_{16}) where 150 per cent of RDP and RDK was applied along with 100 per cent RDN compared to T_6 (21.20 g ha^{-1}) where 100 per cent RDF was applied and T_1 (12.67 g ha^{-1}) where 100 per cent RDN was applied without phosphorus and potassium fertilizers. However, it was found to be on par with T_{15} (47.82 g ha^{-1}) which received 150 per cent RDP and 125 per cent RDK along with 100 per cent RDN, T_{14} (43.79 g ha^{-1}) where it received 100 per cent of RDN and RDK along with 150 per cent of RDP.

4.9.14 Uptake of boron by finger millet grain

Perusal of the data in Table 20 indicated that the uptake of boron by finger millet grain differed significantly between the treatments. The significantly higher boron uptake by finger millet grain was (4.03 g ha^{-1}) found in (T_{15}) treatment receiving 150 per cent RDP and 125 per cent RDK along with 100 per cent RDN compared to 100 per cent RDF receiving treatment (T_6) as per package of practice (2.11 g ha^{-1}) and T_1 (1.23 g ha^{-1}) which received 100 per cent RDN without P and K fertilizers. However, it was found to be on par with T_{16} (3.89 g ha^{-1}) which received 150 per cent of RDP and RDK along with

Table 20: Uptake of micronutrients (Cu and B) by grain and straw of finger millet crop as influenced by different level of phosphorus and potassium application

Treatment details	Cu (g ha^{-1})			B (g ha^{-1})		
	Straw	**Grain**	**Total uptake**	**Straw**	**Grain**	**Total uptake**
T_1 : 100 % RDN + 0 % RDP + 0 % RDK.	21.12	1.08	22.20	12.67	1.23	13.90
T_2 : 100 % RDN + 0 % RDP +100 % RDK.	27.12	1.57	28.69	16.05	1.67	17.72
T_3 : 100 % RDN + 0 % RDP + 125 % RDK.	29.86	1.90	31.76	17.44	1.84	19.28
T_4 : 100 % RDN + 0 % RDP + 150 % RDK.	28.40	2.17	30.57	19.08	2.00	21.08
T_5 : 100 % RDN + 100 % RDP + 0 % RDK.	28.45	2.01	30.46	18.54	1.75	20.29
T_6 : 100 % RDN + 100 % RDP + 100 % RDK. *(RDF)	33.50	2.39	35.89	21.20	2.11	23.31
T_7 : 100 % RDN + 100 RDP + 125 % RDK.	35.31	2.30	37.61	25.70	2.18	27.88
T_8 : 100 % RDN +100 % RDP +150 % RDK.	38.24	2.35	40.59	33.57	2.10	35.67
T_9 : 100 % RDN +125 % RDP + 0 % RDK	31.16	1.93	33.09	30.08	2.09	32.17
T_{10} : 100 % RDN + 125 % RDP + 100 % RDK.	42.45	2.30	44.75	33.74	2.65	36.39
T_{11} : 100 % RDN + 125 % RDP + 125 % RDK.	53.06	2.36	55.42	40.75	2.79	43.54
T_{12} : 100 % RDN + 125 % RDP + 150 % RDK.	52.50	2.54	55.04	44.35	3.00	47.35
T_{13} : 100 % RDN + 150 % RDP + 0 % RDK.	33.18	2.03	35.21	32.91	2.47	35.38
T_{14} : 100 % RDN + 150 % RDP+100%RDK.	54.11	2.81	56.92	43.79	3.75	47.54
T_{15} : 100% RDN + 150% RDP + 125 % RDK.	57.04	2.92	59.96	47.82	4.03	51.85
T_{16}: 100 % RDN + 150 % RDP + 150 % RDK.	49.61	2.87	52.48	48.32	3.89	52.21
S.Em. ±	**5.77**	**0.29**	**5.84**	**6.90**	**0.50**	**8.64**
CD(*P=0.05*)	**17.29**	**0.86**	**17.50**	**20.69**	**1.49**	**25.91**

RDN – Recommended dose of nitrogen, RDP- Recommended dose of phosphorus, RDK – Recommended dose of potassium, RDF- Recommended dose of fertilizers (100: 50: 50 kg NPK ha^{-1})

100 per cent RDN followed by T_{14} (3.75 g ha^{-1}) where it received 100 per cent of RDN and RDK along with 150 per cent RDP.

4.9.15 Total uptake of boron by finger millet crop

Total uptake of B by finger millet showed a significant difference among the treatments (Table 20). Significantly higher total uptake of boron (52.21 g ha^{-1}) noticed in treatment where 150 per cent RDP and 125 per cent RDK was applied along with 100 per cent RDN (T_{15}) compared to T_6 (23.31 g ha^{-1}) where 100 per cent RDF was applied and T_1 (13.90 g ha^{-1}) where 100 per cent RDN was applied without phosphorus and potassium fertilizers. However, it was on par with T_{15} (51.85 g ha^{-1}) which received 150 per cent of RDP and RDK along with 100 per cent RDN, T_{14} (63.34 g ha^{-1}) which received 100 per cent of RDN and RDK along with 150 per cent RDP. This data clearly indicates that significantly lower uptake of B was recorded wherever P was not applied, irrespective of the K levels applied

4.10 Nutrient requirement by finger millet crop

The individual nutrient required (kg) to produce a quintal of grain (NR) is the indirect method of calculating the nutrient use efficiency (NUE) by a crop. NPK nutrient required to produce a quintal of finger millet grain was presented in Table 21.

4.10.1 Nitrogen requirement

Nitrogen requirement by finger millet grain did not show any significant difference between the treatments imposed due to different levels of phosphorus and potassium fertilizers application (Table 21). However, the numerically higher N requirement (1.65 kg q^{-1}) for grain production was recorded in treatments T_{15}, T_{14} and T_{12} which received 100 per cent RDN along with 150 per cent RDP and 125 per cent RDK, 100 per cent of RDN and RDK along with150 per cent RDP and 100 per cent RDN along with 125 per cent RDP and 150 per cent RDK respectively. Numerically lower nitrogen requirement (1.45 kg q^{-1}) was recorded in T_1 which received 100 per cent RDN without phosphorus and potassium fertilizer.

4.10.2 Phosphorus requirement

The data in Table 21 indicated that the phosphorus requirement by finger millet grain did not show significant difference due to different treatments imposed. However, numerically higher P requirement (0.24 kg q^{-1}) for finger millet grain production was recorded in T_{15} which received 100 per cent RDN along with 150 per cent RDP and 125 per cent RDK. Similarly, numerically lower P requirement (0.18 kg q^{-1}) was recorded in T_1, T_9 and T_{13} which received 100 per cent RDN without P and K fertilizers, 100 per cent RDN along with 125 per cent RDP without K fertilizers, 100 per cent RDN along with 150 per cent RDP without potassium.

Table 21: **Nutrient requirement and Response yard stick as influenced by the levels of phosphorus and potassium**

Treatment details	NR_N	NR_P	NR_K	RYS
	(kg q^{-1})			(kg ha^{-1})
T_1 : 100 % RDN + 0 % RDP + 0 % RDK.	1.45	0.18	0.27	0.00
T_2 : 100 % RDN + 0 % RDP +100 % RDK.	1.53	0.20	0.33	2.21
T_3 : 100 % RDN + 0 % RDP + 125 % RDK.	1.51	0.20	0.34	5.09
T_4 : 100 % RDN + 0 % RDP + 150 % RDK.	1.53	0.22	0.35	5.56
T_5 : 100 % RDN + 100 % RDP + 0 % RDK.	1.51	0.20	0.35	5.71
T_6 : 100 % RDN + 100 % RDP + 100 % RDK. *(RDF)	1.58	0.19	0.36	7.26
T_7 : 100 % RDN + 100 RDP + 125 % RDK.	1.58	0.19	0.36	7.06
T_8 : 100 % RDN +100 % RDP +150 % RDK.	1.59	0.22	0.35	7.13
T_9 : 100 % RDN +125 % RDP + 0 % RDK	1.52	0.18	0.34	6.10
T_{10} : 100 % RDN + 125 % RDP + 100 % RDK.	1.59	0.22	0.34	7.38
T_{11} : 100 % RDN + 125 % RDP + 125 % RDK.	1.60	0.23	0.36	7.50
T_{12} : 100 % RDN + 125 % RDP + 150 % RDK.	1.65	0.23	0.36	7.84
T_{13} : 100 % RDN + 150 % RDP + 0 % RDK.	1.62	0.18	0.33	7.16
T_{14} : 100 % RDN + 150 % RDP+100%RDK.	1.65	0.23	0.35	11.17
T_{15} : 100% RDN + 150% RDP + 125 % RDK.	1.65	0.24	0.36	11.28
T_{16}: 100 % RDN + 150 % RDP + 150 % RDK.	1.60	0.23	0.36	10.41
S.Em. ±	**0.21**	**0.04**	**1.17**	**-**
CD at 5 %	**NS**	**NS**	**NS**	**-**

RDN – Recommended dose of nitrogen, RDP- Recommended dose of phosphorus, RDK – Recommended dose of potassium, RDF- Recommended dose of fertilizers (100: 50: 50 kg NPK ha^{-1}), NR_N –Nitrogen requirement, NR_P – Phosphorus requirement, NR_K- Potassium requirement, RYS- Response yard stick.

4.10.3 Potassium requirement

Perusal of the data in Table 21 showed that the potassium requirement for finger millet grain production did not differ significantly due to different treatments imposed. However, numerically higher potassium requirement (0.36 kg q^{-1}) for finger millet grain production was noticed in treatments T_{15}, T_{16} as well as T_6 and T_4 both 100 per cent RDN along with 150 per cent RDP and 125 per cent RDK (T_{15}) and 150 per cent of RDP and RDK along with 100 per cent RDN (T_{16}). However, numerically lower K requirement was observed in treatment T_1 which received 100 per cent RDN without P and K fertilizers followed by T_2 and T_{13} which recorded the same value of 0.33 kg q^{-1}.

4.11 Response yard stick

Response yard stick gives the information on the quantity of yield (kgs) produced by a kg of nutrients (NPK) used in the ratio shown in each treatment.

The higher response yard stick was recorded (11.28 kg kg^{-1}) where 100 per cent RDN was applied along with 150 per cent RDP and 125 per cent RDK (T_{15}) followed by T_{14} (11.17 kg kg^{-1}) where 100 per cent RDN and RDK was applied along with 150 per cent RDP and T_{16} (10.41 kg kg^{-1}) which received 150 per cent of RDP and RDK along with 100 per cent RDN. The treatment receiving 100 per cent RDN along with 100 per cent RDK without phosphorus fertilizer application (T_2) recorded lower response yard stick (2.21 kg kg^{-1}).

4.12 Nutrient use efficiency

A plant may be considered efficient in nutrient utilization, if it uses the applied nutrients efficiently to produce the maximum quantity of economic yield which will be measured as percent nutrient use efficiency with respect to phosphorus and potassium. The data related to P and K use efficiency are presented in Table 22

4.12.1 Phosphorus use efficiency

Highest phosphorus use efficiency (PUE) of 18.43 per cent was recorded in treatment T_{14} which received 100 per cent RDN + 150 per cent RDP + 100 per cent RDK followed by treatment T_{15} (18.15 %) where 100 per cent RDN was applied along with 150 per cent RDP and 125 per cent RDK. However, the lower PUE of 6.97 per cent was recorded in treatment T_7 which received 100 per cent RDN + 100 per cent RDP + 125 per cent RDK followed by T_9 (7.84%) which received 100 per cent RDN and 125 per cent RDP without potassium.

4.12.2 Potassium use efficiency

Highest potassium use efficiency (KUE) was recorded in treatment T_{15} (65.82 %) which received 100 per cent RDN along with 150 per cent RDP and 125 per cent RDK followed by application 100 per cent of RDN and RDK along with 150 per cent RDP (T_{14}). which recorded the KUE of 65.52 per cent and T_{16} (50.87 %) which received 100 per cent RDN along with 150 per cent of RDP and RDK. However, the lower potassium use efficiency was observed in T_8 (17.59 %) which received 100 per cent RDN +100 per

Table 22: **Phosphorus and potassium use efficiency, agronomic phosphorus and potassium use efficiency as influenced by the levels of phosphorus and potassium**

Treatment details	Nutrient use efficiency (%)		Agronomic nutrient use efficiency (kg kg^{-1})	
	PUE (%)	KUE (%)	APUE (kg kg^{-1})	AKUE (kg kg^{-1})
T_1 : 100 % RDN + 0 % RDP + 0 % RDK.	-	-	-	-
T_2 : 100 % RDN + 0 % RDP +100 % RDK.	-	27.21	-	6.62
T_3 : 100 % RDN + 0 % RDP + 125 % RDK.	-	31.21	-	13.24
T_4 : 100 % RDN + 0 % RDP + 150 % RDK.	-	26.48	-	12.97
T_5 : 100 % RDN + 100 % RDP + 0 % RDK.	10.43	-	17.14	-
T_6 : 100 % RDN + 100 % RDP + 100 % RDK. *(RDF)	9.40	23.93	22.43	11.91
T_7 : 100 % RDN + 100 RDP + 125 % RDK.	6.97	22.38	13.46	10.30
T_8 : 100 % RDN +100 % RDP +150 % RDK.	8.87	17.59	12.62	9.96
T_9 : 100 % RDN +125 % RDP + 0 % RDK	7.84	-	15.85	-
T_{10} : 100 % RDN + 125 % RDP + 100 % RDK.	10.35	19.47	19.79	11.54
T_{11} : 100 % RDN + 125 % RDP + 125 % RDK.	12.11	30.49	13.76	11.15
T_{12} : 100 % RDN + 125 % RDP + 150 % RDK.	11.83	32.56	14.21	11.61
T_{13} : 100 % RDN + 150 % RDP + 0 % RDK.	8.45	-	16.70	-
T_{14} : 100 % RDN + 150 % RDP+100%RDK.	18.43	65.52	29.09	25.21
T_{15} : 100% RDN + 150% RDP + 125 % RDK.	18.15	65.82	24.68	22.83
T_{16}: 100 % RDN + 150 % RDP + 150 % RDK.	14.56	50.87	21.71	17.99

RDN – Recommended dose of nitrogen, RDP- Recommended dose of phosphorus, RDK – Recommended dose of potassium, RDF- Recommended dose of fertilizers (100: 50: 50 kg NPK ha^{-1}), PUE- Phosphorus use efficiency, KUE- Potassium use efficiency, APUE- Agronomic phosphorus use efficiency, AKUE – Agronomic potassium use efficiency.

cent RDP +150 per cent RDK followed by the treatment T_{10} (19.47 %) which received 100 per cent RDN and RDK along with 125 per cent RDP.

4.13 Agronomic nutrient use efficiency

Agronomic nutrient use efficiency (ANU) is calculated in units of yield increase per unit of nutrient applied. This will more closely reflects the direct production impact of an applied fertilizer and relates directly to economic return.

4.13.1 Agronomic phosphorus use efficiency

Higher agronomic phosphorus use efficiency (APUE) was noticed in T_{14} (29.09 kg kg^{-1}) which received 100 per cent RDN + 150 per cent RDP + 100 per cent RDK followed by treatment T_{15} (24.68 kg kg^{-1}) which received 100 per cent RDN + 150 per cent RDP + 125 per cent RDK. Further, the lower agronomic phosphorus use efficiency was noticed in 100 per cent RDN + 100 per cent RDP +150 per cent RDK (T_8) which recorded the APUE of 12.62 kg kg^{-1} followed by T_7 (13.46 kg kg^{-1}) which received 100 per cent RDN + 100 RDP + 125 per cent RDK (Table 22).

4.13.2 Agronomic potassium use efficiency

The treatment which received 100 per cent RDN + 150 per cent RDP+100 per cent RDK (T_{14}) has recorded the higher agronomic potassium use efficiency of 25.21 kg kg^{-1} followed by treatment T_{15} (22.83 kg kg^{-1}) which received 100 per cent RDN + 150 per cent RDP + 125 per cent RDK. However, the lower agronomic potassium use efficiency was noticed in T_2 (6.62 kg kg^{-1}) which received 100 per cent of RDN and RDK without phosphorus followed by T_8 (9.96 kg kg^{-1}) which received 100 per cent of RDN and RDP along with 150 per cent RDK (Table 22).

4.14 Economics of finger millet production

Economics of irrigated finger millet production as influenced by different levels of phosphorus and potassium application in low P and K soils are presented in Table 23.

The benefit cost ratio has been calculated to evaluate the economics of irrigated finger millet production under different treatments imposed. The higher gross returns (Table 23) was recorded (Rs. 1, 00,757) in treatment (T_{15}) receiving 100 per cent N + 150 per cent RDP + 125 per cent RDK followed by T_{16} (Rs. 99,328) which received 150 per cent of RDP and RDK along with 100 per cent RDN. The least gross returns were recorded in T_1 (Rs.49, 619) which received 100 per cent RDN without P and K fertilizer application followed by T_2 (Rs. 55,866) which received 100 per cent of RDN and RDK without P fertilizer.

The higher net returns were recorded (Rs.65, 740) in treatment T_{15} which received 100 per cent RDN + 150 per cent RDP + 125 per cent RDK followed by T_{16} (Rs. 63,978) which received 150 per cent of RDP and RDK along with 100 per cent RDN. The least net returns were recorded (Rs.19, 751) in T_1 which received 100 per cent RDN without P and K fertilizer application.

Table 23: **Cost of cultivation, gross returns, net returns and benefit cost ratio as influenced by the levels of phosphorus and potassium application**

Treatment Details	Total cost of cultivation (Rs. ha^{-1})	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B: C
T_{1} : 100 % N + 0 % RDP + 0% RDK	29868	49619	19752	1.66
T_{2} : 100 % N + 0 % RDP + 100 % RDK	31201	55866	24665	1.79
T_{3} : 100 % N + 0 % RDP + 125 % RDK	31534	64288	32754	2.04
T_{4} : 100 % N + 0 % RDP + 150% RDK	31867	66921	35053	2.10
T_{5} : 100 % N + 100 % RDP + 0% RDK	32189	65489	33300	2.03
T_{6} : 100 % N + 100 % RDP + 100% RDK	33523	75378	41855	2.25
T_{7} : 100 % N +100 % RDP + 125 % RDK	33856	77203	43347	2.28
T_{8} : 100 % N + 100 % RDP + 150 % RDK	34189	79118	44929	2.31
T_{9} : 100 % N + 125 % RDP + 0% RDK	32770	68039	35269	2.08
T_{10} : 100 % N + 125 % RDP + 100% RDK	34103	78169	44065	2.29
T_{11} : 100 % N + 125 % RDP + 125 % RDK	34436	82060	47624	2.38
T_{12} : 100 % N + 125 % RDP + 150 % RDK	34770	85159	50390	2.45
T_{13} : 100 % N + 150 % RDP + 0% RDK	33350	72803	39452	2.18
T_{14} : 100 % N + 150 % RDP + 100% RDK	34684	96910	62226	2.79
T_{15} : 100 % N + 150 % RDP + 125 % RDK	35017	100757	65740	2.88
T_{16} : 100 % N + 150 % RDP + 150 % RDK	35350	99328	63978	2.81

RDN – Recommended dose of nitrogen, RDP- Recommended dose of phosphorus, RDK – Recommended dose of potassium, RDF- Recommended dose of fertilizers (100: 50: 50 kg NPK ha^{-1})

The higher B: C ratio of 2.88 was recorded in treatment T_{15} which received 100 per cent RDN along with 150 per cent RDP and 125 per cent RDK and it was followed by treatment (T_{16}) receiving 150 per cent of RDP and RDK along with 100 per cent RDN (2.01) Whereas the least B:C ratio (1.66) was observed in the treatment (T_1) which received 100 per cent RDN without P and K fertilizers when compared to the recommended dose (T_6) of fertilizers applied plot where 100 : 50 : 50 kg NPK were applied (2.25).

V DISCUSSION

The results of research entitled "Response of finger millet to phosphorus and potassium levels in *Alfisols* of Ramanagara district", conducted in farmer's field at Kodihalli village presented in previous chapter are discussed here in the light of the studies conducted elsewhere as available from the literature. Discussion is made in below mentioned sub divisions *viz,*

5.1 Weather and crop growth.

5.2 Influence of different levels of phosphorus and potassium on growth and yield of finger millet.

5.3 Influence of different levels of phosphorus and potassium on soil properties.

5.4 Influence of different levels of phosphorus and potassium on nutrient concentration, nutrient uptake and nutrient use efficiency by finger millet.

5.5 Economics of finger millet as influenced by different levels of phosphorus and potassium.

5.1 Weather and crop growth

The prevailing weather conditions during the crop growth period favored the normal growth and development of crop (Table 2). The total rainfall (1202 mm) was slightly more during the period of experimentation as compared to normal rainfall (978 mm). However, actual rainfall during cropping period was 689 mm. The rainfall was well distributed from sowing to till harvest which favored normal growth and development of crop. During the crop growth period, the highest monthly rainfall was recorded in September (234 mm) and the lowest was in August (110 mm).The average maximum temperature during the period of experimentation was 28.90^0C in November 2015. The mean minimum temperature was more than the normal for most of the months. The crop was not suffered from any of the prevailing weather parameters.

5.2 Influence of different levels of phosphorus and potassium on growth and yield of finger millet

The grain yield depends on the synthesis and accumulation of photosynthates and their distribution among various plant parts. The synthesis, accumulation and translocation of photosynthates depends upon the efficient photosynthetic structure as well as the extent of translocation into sink (grains) and also on plant growth and development during early stages of crop growth. The production and translocation of synthesized photosynthates depends upon mineral nutrition supplied by soil. Most of the photosynthetic pathways are dependent on enzymes and coenzymes which are synthesized from mineral elements such as nitrogen, phosphorus and potassium and micro nutrients.

5.2.1 Growth of finger millet

Significantly higher plant height was observed at 30 DAS (14.76 cm), 60 DAS (57.25 cm), 90 DAS (109.92 cm) and at harvest stage (116.08 cm) due to application of

100 per cent RDN (100 kg N ha^{-1})+ 150 per cent RDP (75 kg P_2O_5 ha^{-1}) + 150 per cent RDK (75 kg K_2O ha^{-1}) (T_{16}) compared to 100 per cent RDF (T_6) and T_1 where 100 per cent RDN was applied without phosphorus and potassium fertilizers except at 60 DAS and on par with T_{15} (100 % RDN + 150 % RDP + 125 % RDK) at all the growth intervals. Significantly lower plant height was noticed in T_1 at all the growth stages which received 100 per cent RDN without phosphorus and potassium fertilizers which clearly indicated the role phosphorus and potassium in enhancing the crop growth due to better root growth and translocation of photosynthates resulting in vigorous plant growth. The similar findings also reported by Prakash Maurya *et al*. (2014) and Muhammad Bilal Khan *et al.* (2010) in case of wheat crop.

Number of leaves $hill^{-1}$ was significantly differed due to application of varied levels of phosphorus and potassium at all growth stages. Significantly higher number of leaves was noticed in T_{16} at 30 DAS (22.27) and 60 DAS (50.47) compared to 100 per cent RDF (T_6) and T_1 where 100 per cent RDN was applied without P and K fertilizers. But at 90 DAS and at harvest significantly higher number of leaves $hill^{-1}$ was observed in T_{15} which received 100 per cent RDN + 150 per cent RDP + 125 per cent RDK. The lower number of leaves was observed at harvest compared to 90 DAS due to translocation of photosynthates from older leaves to grain at harvest subsequently the older leaves dried and fall out.

The number of tillers $hill^{-1}$significantly differed in all the treatments at all the growth stages (30 DAS to till harvest). At all the growth stages application of 100 per cent RDN + 150 per cent of RDP and RDK (T_{16}) has recorded higher number of tillers $hill^{-1}$. However, at harvest minimum of 3.13 tillers $hill^{-1}$ was recorded in control (T_1) where no phosphorus and potassium fertilizers was applied except 100 per cent RDN, which significantly increased to 6.07 tillers $hill^{-1}$ (T_{16}) due to application of different levels of phosphorus and potassium fertilizers. There was improvement in growth parameters of finger millet due to integrated application phosphorus and potassium fertilizer along with FYM compared to no P or K application or both. In turn this may be attributed to the increased supply of phosphorus and potassium for better crop uptake. The similar findings were reported by Muhammad Bilal Khan *et al.* (2010) in case of wheat crop and Dakshina Murthy *et al.* (2014) in rice crop.

Significant increase in growth parameters like plant height, number of leaves $hill^{-1}$, number of tillers $hill^{-1}$of finger millet was due to application of increased levels of phosphorus and potassium at 25 per cent, 50 per cent more than the recommended dose. This was due to important role of phosphorus and potassium in nutrient and sugar translocation in plant and turgor pressure of plant cells. Also potassium activates numerous enzyme systems involved in formation of organic substances and buildup of compounds such as carbohydrates. Its role in mainly cell development and in triggering young tissues or be due to that potassium is involved in plant mersitematic growth (Prakash Maurya *et al*., 2014). Also due to maximum availability of phosphorus which established more root establishments. This fact would ultimately maximized availability of mineral nutrients for optimum cell growth, more uptake, reproduction, photosynthesis and transformation of sugars and starches.

5.2.2 Yield attributes

The yield attributes of finger millet like number of productive tillers hill^{-1}, ear head weight hill^{-1}, number of fingers ear head^{-1} and 1000 grain weight are significantly enhanced by the application of different levels of phosphorus and potassium fertilizers (Fig.2).

The number of productive tillers hill^{-1} recorded significantly higher value in the T_{15} which received 100 per cent RDN + 150 per cent RDP + 125 per cent RDK (4.47) compared to T_1 (2.42) where 100 per cent RDN was applied along with FYM without phosphorus and potassium fertilizers. However, it was found to be on par with T_{16} (4.33) and T_{14} (4.33) which received 100 per cent RDN along with 150 per cent of RDP and RDK and 100 per cent RDN + 150 per cent RDP + 100 per cent RDK.

Ear head length was not significantly differed due to the application of different levels of phosphorus and potassium fertilizers. However, numerically higher ear head length was observed in T_{16} (7.52 cm) where 150 per cent of RDP and RDK was applied along with 100 per cent RDN over T_1 which recorded numerically lower ear head length of 6.48 cm.

Ear head weight hill^{-1} has recorded significantly recorded higher values of 24.10 g in T_{15} where 150 per cent RDP and 125 per cent RDK was applied along with 100 per cent RDN compared to T_6 (18.01 g) where 100 per cent RDF was applied and T_1 (10.98 g) which received 100 per cent RDN without P and K fertilizers.

Number of fingers ear head^{-1} was recorded significantly higher value of 7.73 in both T_{15} and T_{16} where 150 per cent RDP was applied along with 125 per cent RDK and 100 per cent RDN and 150 per cent of RDP and RDK was applied along with 100 per cent RDN compared to T_1 (100 % RDN without P and K fertilizers) which recorded the lowest value of 6.22 finger ear head^{-1}.

Treatment which received 150 per cent of RDP and RDK along with 100 per cent RDN (T_{16}) was recorded significantly higher 1000 grain weight (3.51 g) compared to T_6 (3.11g) where 100 per cent RDN was applied and T_1 (2.44g) where 100 per cent RDN was applied without phosphorus and potassium fertilizers. Significant increase in test weight was attributed to better grain filling due to improved supply of potassium. Because potassium regulates enzyme activities and translocation of photosynthates. Similar findings were reported by Anil Kumar (2000) in finger millet.

Data in Table 7 reveals that application of phosphorus and potassium at 25 per cent and 50 per cent more than the recommended dose increased the yield parameters of finger millet. The increase in number of fingers, ear head length, number of fingers ear head^{-1} due to efficient utilization of the applied nutrients by the finger crop.

This was due to increase in phosphorus application which resulting in better root growth and increased photosynthetic activity along with optimum irrigation at critical growth stages showed increase in number of tillers hill^{-1} and also other yield parameters (Muhammad Zahid Mumtaz *et al.,* 2014).

5.2.3 Grain yield and straw yield

Application of 100 per cent RDN + 150 per cent RDP + 125 per cent RDK recorded more grain (52.03 q ha^{-1}) and straw (87.57 q ha^{-1}) yield compared to 100 per cent RDF as per package of practice T_6 which recorded 39.76 q ha^{-1} of grain and 58.78 q ha^{-1} of straw yield (Fig.3). This clearly indicates that the response of finger millet with respect to grain and straw yield is more due to application of phosphorus at 150 per cent RDP and potassium at 125 per cent RDK long with 100 per cent RDN compared to application of phosphorus and potassium both at 150 per cent of their recommended dose (T_{16}) along with 100 per cent RDN. The lowest grain (25.24 q ha^{-1}) and straw (46.20 q ha^{-1}) yield were recorded in treatments where 100 per cent RDN applied without P and K (T_1).This data clearly indicated that the blanket recommendation of 100 per cent RDF of finger millet crop is of no use in enhancing the yield specially in low P and K soils, where modification in the RDF is required through soil test and LMH approach. These results are in conformity with Cheema *et al.* (1999) in maize and Dakshina Murthy *et al.* (2015) in rice.

Increase in grain yield in T_{15} (100 % RDN + 150 % RDP + 125 RDK) was due to more number of productive tillers hill^{-1}, ear head weight hill^{-1} and number of fingers ear head^{-1}. This might be due to the rate of production and number of tillers in finger millet are dependent upon nutrient supply. Finger millet has considerable capacity to produce more number of tillers per hill under adequate phosphorus and potassium fertilization specially in low P and K soils. Number of tillers per hill increased with increase in the fertilizer level most probably phosphorus and potassium in the present investigation.

Increased grain yield associated with added phosphorus and potassium fertilizers levels along with nitrogen have enhanced the cumulative effect of increased translocation of photosynthates to sink resulting in enhanced level of yield components. These results corroborated the findings of Rao *et al.* (2004).

In the present investigation application of phosphorus at 150 per cent RDP (75 kg P_2O_5 ha^{-1}) increased the yield of finger millet irrespective of potassium application. Because P is involved in several energy transformation and biochemical reactions for plant growth and development and also for early flowering. Because P supply increases cytokinins synthesis and supply of photosynthates for flower formation. Ultimately it might have increases the grain yield of finger millet.

5.3 Influence of different levels of phosphorus and potassium on soil properties.

The different levels of phosphorus and potassium fertilizer application have resulted in the changes of properties of soil after harvest of finger millet crop (Table 9).

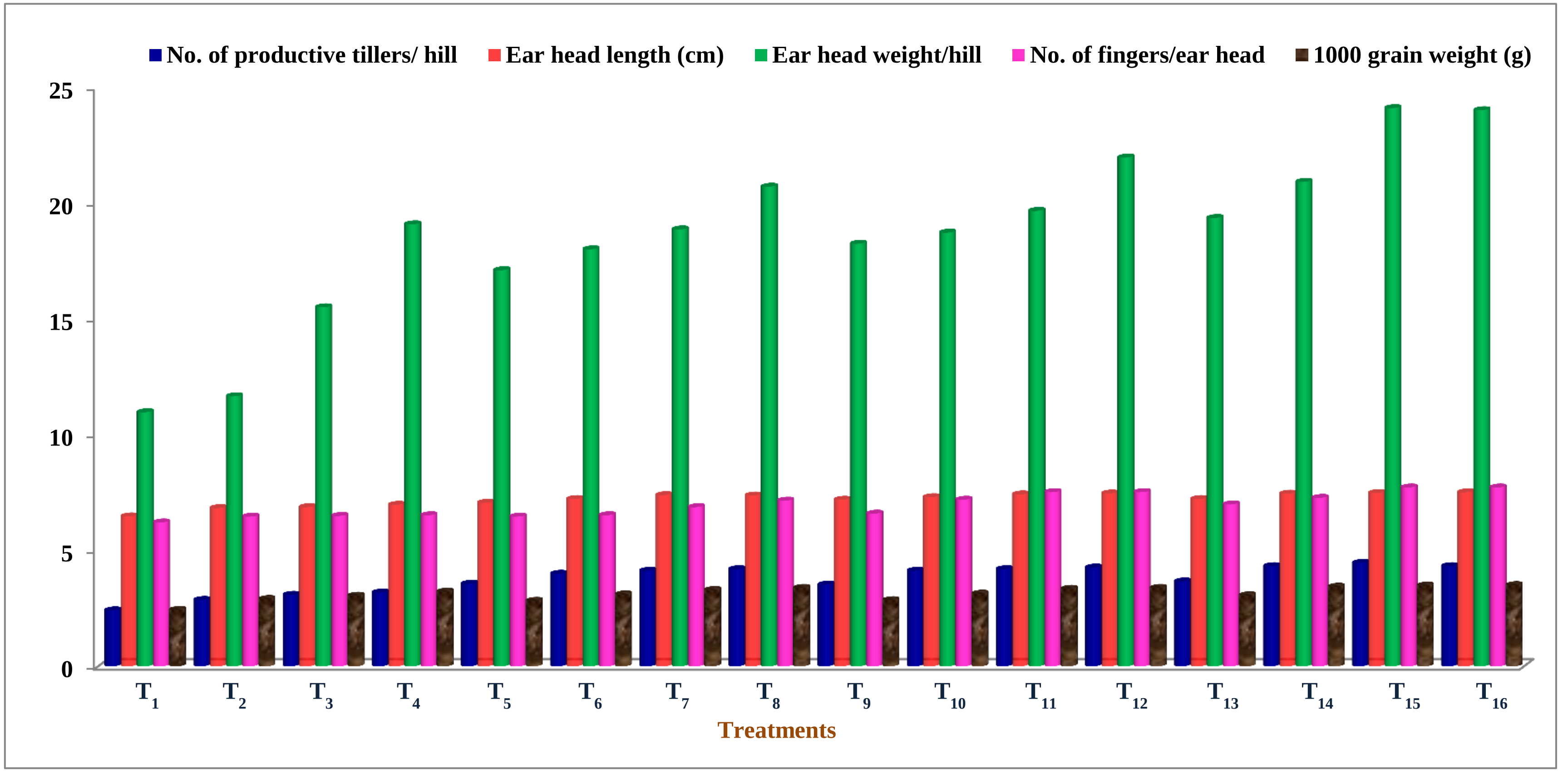

Fig. 2: Influence of different levels of phosphorus and potassium on yield attributes of finger millet

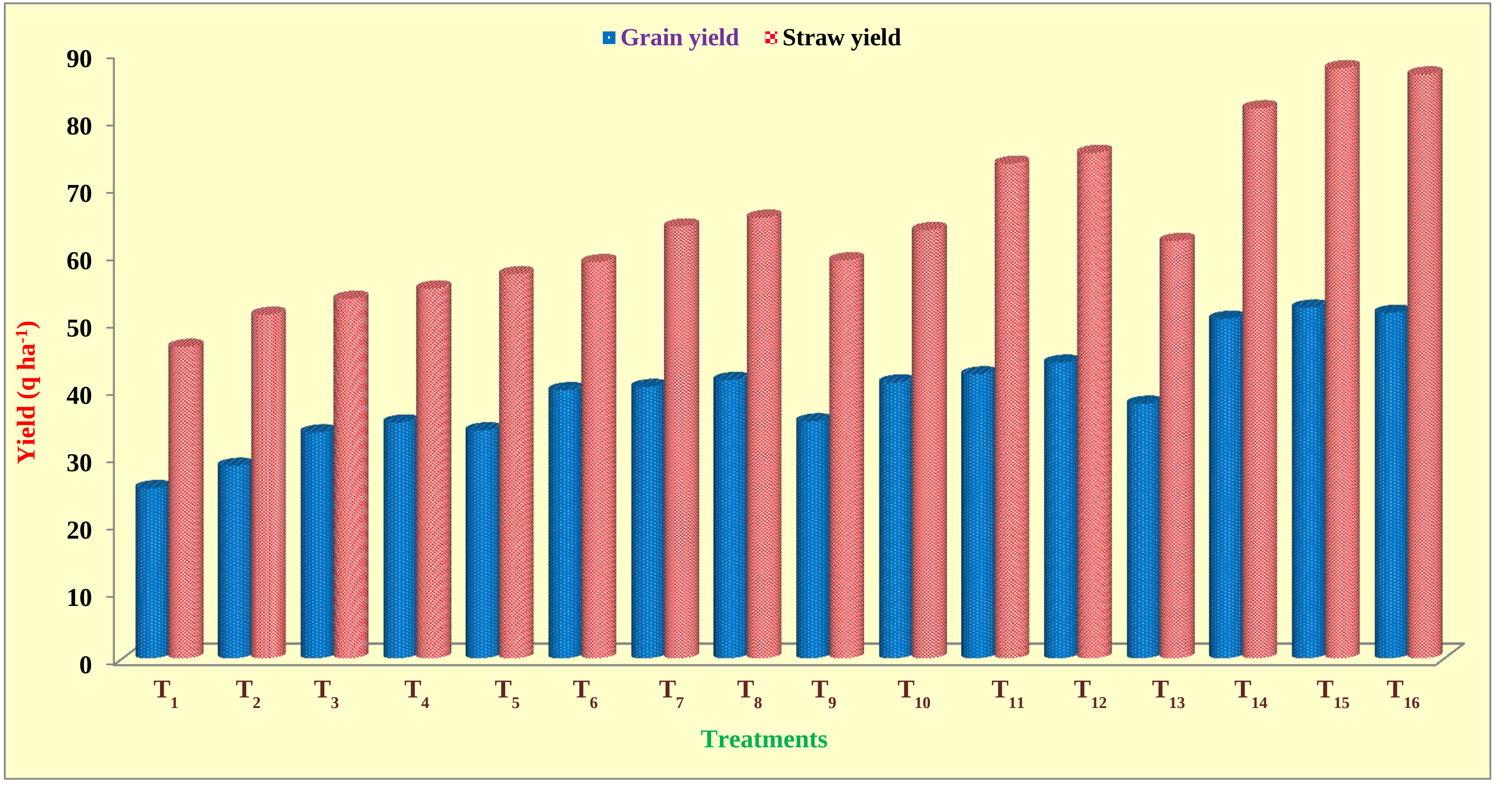

Fig. 3: Grain and straw yield of finger millet as influenced by application of different levels of phosphorus and potassium

5.3.1 Soil pH, electrical conductivity and soil organic carbon

There was no significant difference observed with respect to post harvest soil pH among the treatments. However, the pH values was slightly higher in the plots which received either phosphorus or potassium or both along with the nitrogen through urea and FYM compared to initial pH value of 6.29 and also in plots (T_1) where nitrogen through urea was added along with the FYM without phosphorus and potassium fertilizers. The reason for this could be attributed to the release of basic cations from organic matter on its decomposition. This was in conformity with the reports of Das *et al.* (1991). The pH value was relatively lower (6.25) in 100 per cent RDN through urea treated plots (T_1) due to the acidifying effect of N fertilizers (Chawla and Chhabra, 1991) and also due to decomposition of organic matter has been known to release of organic and inorganic acids with concomitant increases in soil acidity (Agbede, 2009).

A significant difference in EC of soil was observed due to application of different levels of phosphorus and potassium fertilizers. The plots which received 150 per cent of RDP and RDK along with 100 per cent RDN had relatively higher EC values than the 100 per cent RDN treated plots without P and K fertilizers. This was due to the application of muriate of potash at 75 kg ha^{-1} (150 % of RDK) resulted in increasing the salt concentration in the soil. Similar findings were reported by Shaaban *et al.*, 2011 in clay loam soil. And also release of soluble salts from FYM upon decomposition might also cause higher EC values. These findings are in accordance with that of Chawla and Chhabra (1991).

No significant difference was observed with respect to soil organic carbon among the treatments due to application of different levels of phosphorus and potassium fertilizers. However, in general application of either phosphorous or potassium or both along with nitrogen and FYM increased the organic carbon content of the soil compared to 100 per cent RDN and FYM applied plots (T_1). Due to increased crop growth and addition of biomass to the soil by roots and crop residues and also due to incorporation of FYM into the soil. This is in conformity with the reports of Anand Swarup and Yaduvanshi (2000).

5.3.2 Available nitrogen, phosphorus and potassium

Available nitrogen, phosphorus and potassium after harvest of finger millet was found to be significantly varied with respect to different levels of phosphorus and potassium fertilizers. (Table 10)

Significant difference was noticed with respect to available nitrogen due to application of different levels of phosphorus and potassium fertilizers. Among the treatments, the treatment (T_{16}) which received 100 per cent RDN + 150 per cent RDP + 150 per cent RDK (100, 75 and 75 kg NPK ha^{-1}) recorded the higher available nitrogen (290.94 kg ha^{-1}) followed by T_{15} (287.78 kg ha^{-1}) The reason for relatively higher amounts of available nitrogen by these treatments could be ascribed to the increased organic matter content of the soil caused by the combined application of FYM and N fertilizers (Bandyopadhay and Puste, 2002; Prakash *et al.*, 2002).

Significantly higher available phosphorus was recorded in T_{15} (48.38 kg ha^{-1}) where 150 per cent of RDP was applied along with125 per cent RDK and 100 per cent RDN followed by T_{16} (47.44 kg ha^{-1}) compared to treatment (T_6) which received 100 per cent RDF (37.15 kg P_2O_5 ha^{-1}). In general application of 150 per cent RDP plots have recorded higher available phosphorus irrespective of potassium application compared to 100 per cent RDP and 125 per cent RDP applied plots. However, lower availability of phosphorus was noticed where no phosphorus was applied irrespective of levels of potassium application (Table 10). It was also evident that available P was slightly lower in treatments where no K was applied irrespective of levels of P applied. This was due to solubilization of soil P by organic acids produced during decomposition or mineralization of added FYM. And also due to synergetic effect of K on availability of P in soils after harvest of finger millet (Ramachandrappa *et al.,* 2014).

Significantly higher available potassium (Table 10) was recorded in T_{12} where 150 per cent of RDK and 125 per cent RDP was applied along with 100 per cent RDN (300.66 kg ha^{-1}) followed by T_{16} where 150 per cent of RDK and RDP was applied along with 100 per cent RDN (283.57 kg ha^{-1}). Further, the application of potassium at 150 per cent RDK irrespective of phosphorus application significantly recorded the higher available potassium as compared to the rest of the treatments. This might be due to release of nonexchangeable K could have resulted in the increased available K. (Ramachandrappa *et al.,* 2014)

The increase in the K content after harvest of finger millet might be due to the direct contribution of potassium to the pool of available K in soil due to addition of FYM and high dose of potassium (Apoorva, 2008).

5.3.3 Exchangeable calcium, magnesium and available sulphur content of soil

The available calcium content in soil was significantly higher [6.47 cmol (p+) kg^{-1}] calcium content was recorded in treatment (T_{16}) receiving 100 per cent RDN + 150 per cent RDP + 150 per cent RDK fertilizers, whereas the lower calcium content [4.18 cmol (p+) kg^{-1}] was recorded in treatment (T_1) which received 100 per cent RDN without phosphorus and potassium fertilizers (Table 11). Higher calcium due to application of phosphorus and potassium fertilizers could be due to addition of Ca through SSP which contains 18 per cent of Ca resulting in increased soil calcium. Similarly, addition of FYM in these treatments has increased the Ca content of soil, similar results were noticed by Santhosha (2013). Release of calcium during mineralization process and retention of calcium due to addition of organic matter might have also increased Ca content of soil (Shashi, 2003).

The exchangeable magnesium did not show significant difference between treatments due to application of different levels of phosphorus and potassium in low phosphorus and potassium soils (Table 11). The numerically higher value of exchangeable magnesium in soil [3.43 cmol (p^+) kg^{-1}] was found in T_{12} treatment which received 100 per cent RDN along with 125 per cent of RDP and 150 per cent RDK. However, there was a slight increase in magnesium content was noticed in all the treatments compared to the initial value (2.26 cmol (p^+) kg^{-1}). This was due to the behavior of magnesium much similar to that of calcium. The increase in magnesium content might be due to addition of FYM, which resulted in release of magnesium during mineralization process (Shashi, 2003).

The sulphur content of soil after harvest of the finger millet crop increased significantly due to application of different levels of phosphorus and potassium fertilizers (Table 11). Significantly higher values of available sulphur was recorded in T_{15} (25.06 mg kg^{-1}) which received 100 per cent RDN along with 150 per cent RDP and 125 per cent RDK compared to T_6 (17.00 mg kg^{-1}) which received 100 per cent RDF as per package of practice and T_1 (12.66 mg kg^{-1}) which received 100 per cent RDN without P and K fertilizers. From the data it can be inferred that the plots which received the phosphorus at 125 per cent RDP and 150 per cent RDP has recorded higher values of available sulphur due to the fact that P was applied through SSP which contains 12 per cent sulphur that helped in enhancing sulphur content of soil compared to the plots where no P or 100 per cent RDP was added (T_1 to T_8). It was also noticed that the available sulphur was decreased from the initial values (20.27 mg kg^{-1}) in the plots where no P was added irrespective of levels of potassium application.

The increase in available sulphur content in soil after harvest of finger millet due to addition of S through SSP which was used as a phosphatic fertilizer in the study. Similar results were reported by Sunitha (2008). In addition, the synergistic relationship of phosphorus and sulphur had also resulted in increased sulphur content with increased dose of NPK fertilizers (Thiyagarajan, 1998). The treatment receiving of 25 per cent extra NPK fertilizers along with FYM recorded highest available sulphur, where FYM application directly added sulphur to the soil available pool. Similar type of results was confirmed by Trivedi *et al*. (2000), Intidia and Sahu (1999) and Poongothai *et al*. (1999).

5.3.4 DTPA extractable micronutrients

The available micronutrients like iron, manganese zinc, copper and boron, in the soil did not show any significant variation after the harvest of finger millet (Table 12).

No definite trend was observed with respect to available micro nutrients after harvest of the finger millet. However, there was slight decrease and same concentration as that of initial concentration was maintained for all the micronutrients in the soil after harvest of the crop except zinc. The zinc content increased in all the plots irrespective of the treatments due to the fact that all the treatments have received 12.5 kg ha^{-1} of $ZnSO_4$ as per RDF. Numerically, the higher content of zinc was noticed in treatment (T_{15}) where 150 per cent RDP and 125 per cent RDK was applied along with 100 per cent RDN and FYM. This is because, the zinc sulphate at the rate of 12.5 kg ha^{-1} was applied to all the treatments in addition to FYM as per package of practice where in addition to $ZnSO_4$ FYM has added some amount of Zn to the soil, which might have caused higher Zn in postharvest soil.

Similarly hot water soluble boron was found to be significantly higher (0.55 mg kg^{-1} in T_{15} where higher levels of P or K were applied along with FYM, as compared to T_1, where no P or K was applied except nitrogen. This increased boron content at higher doses of P or K due to addition of boron through FYM as well as through root residues where higher plant growth and yield were recorded. Similar findings were reported by Mohamed Saqueebulla, (2014) who noticed highly significant positive correlation between organic matter and hot water soluble boron.

5.4 Influence of different levels of phosphorus and potassium on nutrient concentration, nutrient uptake and nutrient use efficiency in finger millet.

5.4.1 Nutrient concentration in finger millet grain and straw.

The nutrient concentration in finger millet straw and grain did not differ significantly among the different levels of phosphorus and potassium in low P and K soils, except potassium and manganese in finger millet straw.

The potassium concentration in finger millet straw differed significantly among the treatments. Significantly higher K concentration of 0.80 per cent was found in T_{15} which received 100 per cent RDN + 150 per cent RDP + 125 per cent RDK followed by T_{16} (0.78 %) which received 100 per cent RDN + 150 per cent RDP + 100 per cent RDK. Significantly higher concentration of manganese (220.53 mg kg^{-1}) by finger millet straw was recorded in treatment (T_{16}) receiving 150 per cent RDP and RDK along with 100 per cent RDN. The higher level phosphorus and potassium along with nitrogen is conducive for extensive root proliferation, to explore a greater volume of soil and absorb larger quantities of nutrients that often tend to correlate positively with dry matter production and concentration of nutrients in the plant under higher level of nutrient supply. Similar findings were recorded by Upendra Rao *et al.* (2014).

5.4.2 Effect of different levels of phosphorus and potassium fertilizers on uptake of nutrients by finger millet.

5.4.2.1 Uptake of N, P and K nutrients by finger millet

Uptake of nitrogen by finger millet straw (93.17 kg N ha^{-1}) was higher in treatment T_{16} receiving 100 per cent RDN + 150 per cent RDP + 150 per cent RDK and grain (86.09 kg N ha^{-1}) was higher in treatment T_{15} which received 150 per cent RDP and 125 per cent RDK along with 100 per cent RDN (Fig. 4). Whereas, the higher total nitrogen uptake was noticed in T_{15} (179.21 kg N ha^{-1}). This increased uptake of nitrogen might be due to higher grain and straw yield in that treatment (T_{15}). This may be due to improved utilization of applied nitrogen in the presence of sufficient potassium and FYM. Similar positive interaction between N and K was also reported by Thippeswamy (1995) who reported that the uptake of N and K was found to increase significantly with the levels and split application of K in finger millet. Similarly FYM enhanced available N, through mineralization process and also increases efficiency of applied N.

In the present investigation the nitrogen uptake was improved by the application of phosphorus and potassium more than the recommended doses (25 %, 50 % more than the recommended doses) in soils where P and K was deficient. The reason for higher uptake of nitrogen under high doses of phosphorus and potassium was due to application of K, which released the fixed NH_4^+ ion from soil and helped the crop for better uptake of nitrogen. Similar findings were reported by Abida Akram *et al.* (2007) who reported that

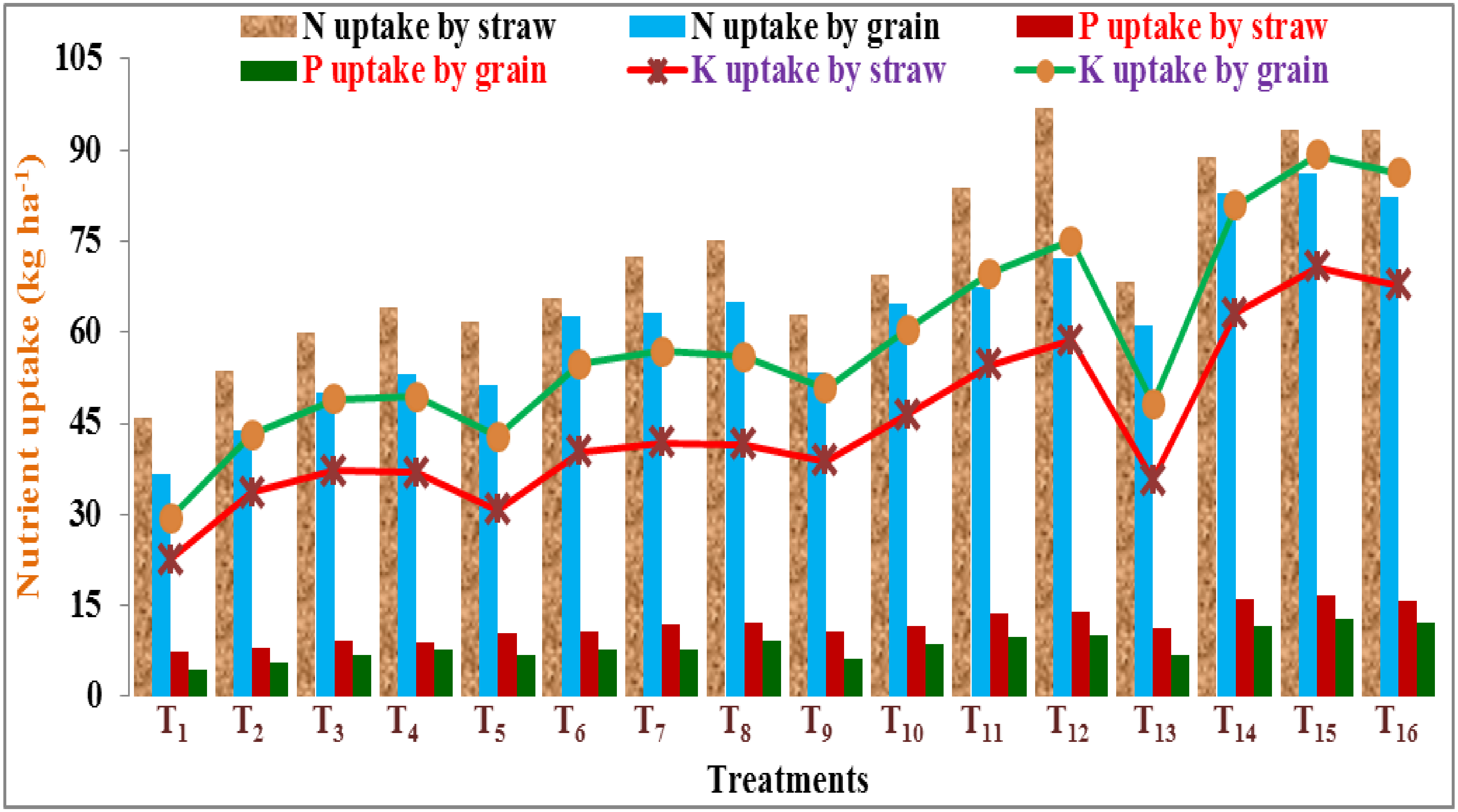

Fig. 4: **Uptake of major nutrients by grain and straw of finger millet as influenced by different levels of phosphorus and potassium application**

nitrogen uptake was improved with P and K application compared to their sole application. Application of higher doses of phosphorus increased root proliferation due to increased levels of P resulted in the better utilization of nitrogen by the finger millet. Similar findings were reported by Jagathjothi *et al*. (2010).

Uptake of phosphorus by finger millet straw (16.77 kg ha^{-1}) and grain (12.79 kg ha^{-1}) total uptake (29.57 kg ha^{-1}) was higher in treatment receiving 150 per cent RDP and 125 per cent RDK along with 100 per cent RDN (Table 17). The uptake of phosphorus was slightly higher in all the treatments except in the plots where no P was applied irrespective of levels of K applied (Table 17). Higher uptake of phosphorus might be due to higher grain and straw yield in these treatments.

In the present study higher phosphorus was due to application of phosphorus and potassium fertilizers which influenced the higher 'P' uptake. Higher uptake of phosphorus was also due to application of higher doses of phosphorus (125 % RDP and 150 % RDP). This trend might be explained on the basis of availability of P and solubility of fertilizer in the soil system. Water soluble P fertilizer (SSP) added at higher doses maintain higher available P levels in the soil system are able to maintain effective concentration of P in soil solution which might ultimately lead to its uptake by plants. These findings are in line with Sushanta Saha *et al*., (2014) who reported that the P uptake increased with the use of water soluble fertilizers over partially water soluble and mineral acid soluble sources of phosphorus.

Higher uptake of potassium by finger millet straw (70.69 kg ha^{-1}) and grain (18.59 kg ha^{-1}) and total uptake (89.28 kg ha^{-1}) was observed in treatment T_{15} which received 150 per cent RDP and 125 per cent RDK along with 100 per cent RDN (Table 17). The higher uptake in T_{15} was because of higher biomass production in that treatment. This may also be due to increased availability of K at different critical stages of crop growth. This is in conformity with the findings of Thippeswamy (1995) who reported that availability of potassium at critical stages of crop growth resulted in higher uptake of potassium.

In the present study application of phosphorus at 150 per cent of recommended dose (75 kg ha^{-1}) along with potassium at 125 per cent (75 kg ha^{-1}) and 100 per cent nitrogen increased the K uptake by finger millet. This was because SSP contains 18 to 21 per cent of calcium, which might have helped in opening the edges of the clay minerals encouraging release of previously trapped lattice K (Koria *et al.*, 1988) and also due to application of 25 per cent more K than the recommended dose increased its availability.

The lower uptake of K was noticed in treatments where there was no addition of K. This implies that inadequate supply or absence of any one major nutrient to the crop would result in imbalance in the supply of nutrient elements and consequent reduction in yield, nutrient use efficiency and uptake. These results are in conformity with the findings of Anon. (2006).

5.4.2.2 Uptake of Ca, Mg and S nutrients by finger millet

The total uptake of calcium (84.25 kg ha^{-1}) and magnesium (61.21 kg ha^{-1}) by finger millet was recorded higher in treatment receiving 100 per cent RDN + 150 per cent RDP + 125 per cent RDK (Fig. 5). Increase in uptake of calcium and magnesium in this treatment might be due to higher biomass production. Similarly, this might also be due to application of SSP which contains calcium helped in increasing the calcium uptake. Due to higher biomass production, uptake of Ca and Mg was increased. These results are in accordance with Shaymaa *et al*. (2009) and Santhosha (2013).

Increased uptake of calcium was noticed in treatment which received 125 per cent RDK + 100 per cent RDN + 150 per cent RDP (T_{15}) as compared to T_{16} which received 150 per cent RDK + 100 per cent RDN + 150 per cent RDP was due to antagonisitic interaction between Ca and K since they are complementary cations (Lavanya, 2007).

The total uptake of sulphur (23.76 kg ha^{-1}) by finger millet was higher in the treatment (T_{15}) receiving 100 per cent RDN + 150 per cent RDP + 125 per cent RDK. Higher uptake of sulphur was noticed in plots treated with 150 per cent RDP along with 100 per cent RDN irrespective of potassium application. This might be due to addition of sulphur through SSP. Higher grain and straw yield in these treatments (T_{14} and T_{16}) also resulted in higher uptake. This might also be due to synergistic interaction between sulphur and potassium (Bansal, 1991). Lowest uptake of S was noticed where nitrogen was applied without phosphorus and potassium fertilizers. Similar observation was also recorded by Anon. (2006) who reported that content and uptake of sulphur in DAP applied treatment was significantly lower to that of equivalent quantity of phosphorus applied in the form of sulphur containing fertilizer (SSP).

5.4.2.3 Uptake of micronutrients by finger millet

The total uptake of micronutrients *viz*., Fe, Mn, Zn, Cu and B by finger millet grain and straw varied significantly due to different levels of phosphorus and potassium fertilizers. Higher total uptake of Fe (623.79 g ha^{-1}) and Cu (59.96 g ha^{-1}) by finger millet was recorded in the treatment (T_{15}) which received 100 per cent RDN + 150 per cent RDP + 125 per cent RDK, whereas higher total uptake of Mn (279.92 g ha^{-1}), Zn (334.27 g ha^{-1}) and B (52.21 g ha^{-}1) were recorded T16 100 per cent RDN + 150 per cent RDP + 150 per cent RDK. Higher uptake of these micronutrients was due to higher biomass production which was recorded due to higher doses of phosphorus and potassium. The iron concentration in plant is directly influenced by nitrogen and sulphur containing fertilizers. These results are in accordance with Santhosha (2013). The higher uptake of micronutrients due to addition of FYM along with fertilizers was noticed by several scientists (Shashi. 2003; Manasa. 2013). Atheefa (2007) also revealed that FYM application enhanced uptake of micronutrients through greater availability of micronutrients by forming soluble complexes.

Addition of FYM along with inorganic nutrients might have enhanced the microbial activity in the soil and the consequent release of complex organic substances would have prevented micronutrients from precipitation, fixation, oxidation and leaching, thereby enhanced the leaching (Sushma, 2005).

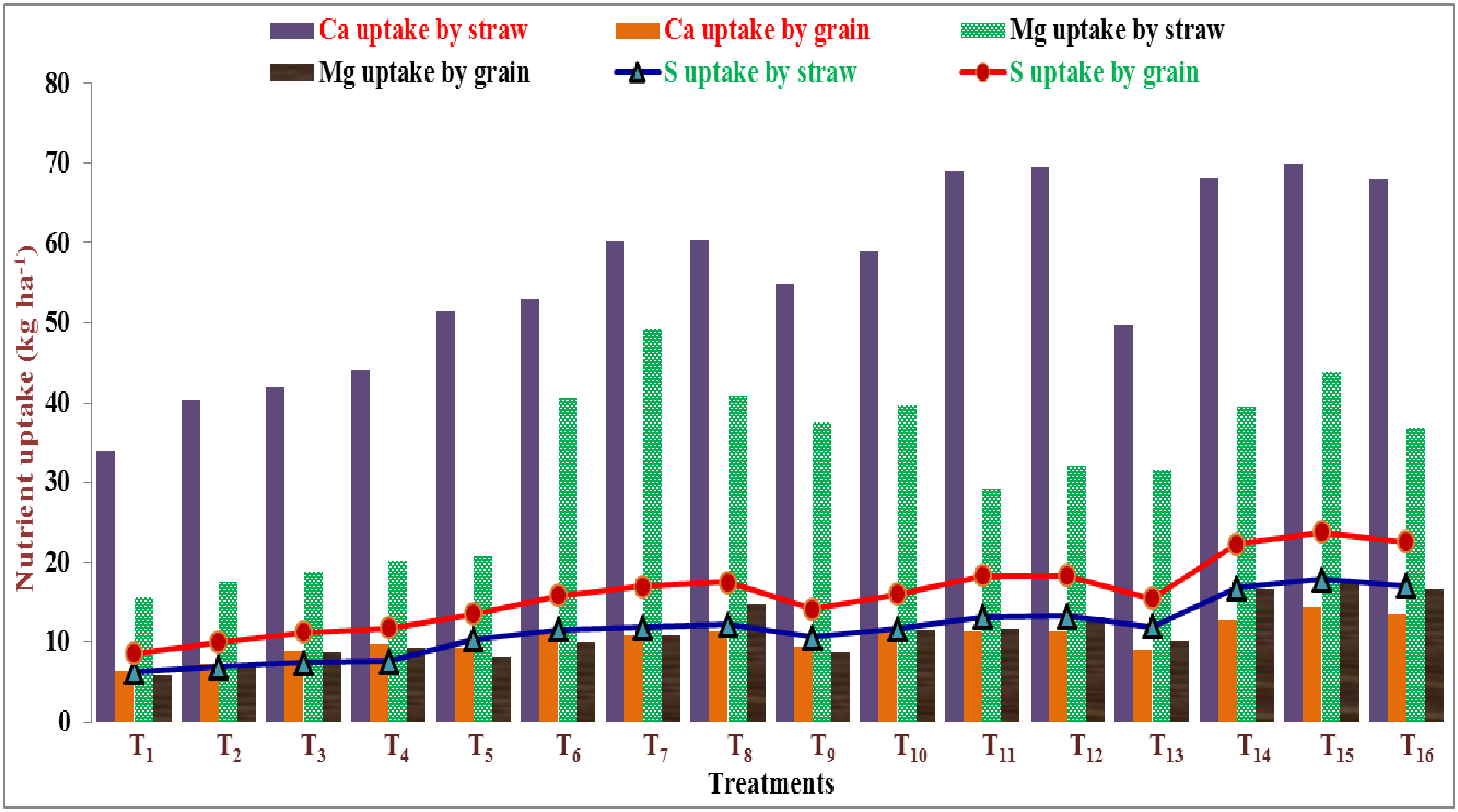

Fig. 5: **Uptake of secondary nutrients by grain and straw of finger millet as influenced by different levels of phosphorus and potassium application**

5.5 Nutrient use efficiency by finger millet as influenced by the levels of phosphors and potassium application.

5.5.1 Phosphorus and potassium use efficiency

Higher phosphorus use efficiency (PUE) of 18.43 per cent was recorded in treatment T_{14} which received 100 per cent RDN + 150 per cent RDP + 100 per cent RDK followed by treatment T_{15} (18.15 %) where 100 per cent RDN was applied along with 150 per cent RDP and 125 per cent RDK. whereas higher potassium use efficiency (KUE) was recorded in treatment T_{15} (65.82 %) which received 100 per cent RDN along with 150 per cent RDP and 125 per cent RDK followed by application 100 per cent of RDN and RDK along with 150 per cent RDP (T_{14}).

Phosphorus use efficiency or utilization efficiency showed that greater proportion of P applied at 150 per cent RDP (75 kg ha^{-1}) has been utilized more than that of 125 per cent RDP (62.5 kg) and 100 per cent RDP (50 kg ha^{-1}). This corroborate with the findings of Mugwira *et al*. (1997), who reported that PUE was mostly determined by the P uptake under P deficient condition. At higher P rates the availability of added P was more compared to other doses (100 % RDP and 125 % RDP). So there was greater proliferation of root system there by root surface exposes to high soil volume there by greater uptake of nutrients, which resulted in high PUE was noticed in treatment receiving 100 per cent RDN + 150 per cent RDP + 100 per cent RDK (T_{14}).

Potassium use efficiency was more in T_{15} compared to T_{16} and T_{14}, This might be due to higher uptake of potassium by the root at 100 per cent RDK along with 150 per cent RDP and 100 per cent RDN. Under higher phosphorus dose there was better root growth there by it exposes to more soil volume so uptake of applied potassium was higher at 125 per cent RDK (62.5 kg K_2O ha^{-1}). Whereas at higher potassium dose [150 % RDK (75 kg K_2O ha^{-1})] after meeting the demand of the crop to complete its life cycle, other part of potassium might have been converted to nonexchangeable and lattice K. (Shehu, 2014).

5.5.3 Agronomic phosphorus and potassium use efficiency

The higher agronomic phosphorus use efficiency (APUE) and potassium use efficiency (AKUE) was noticed in T_{14} (29.09 kg kg^{-1} and 25.21 kg kg^{-1} respectively) which received 100 per cent RDN + 150 per cent RDP + 100 per cent RDK followed by treatment T_{15} (24.68 kg kg^{-1} and 22.83 kg kg^{-1} respectively) which received 100 per cent RDN + 150 per cent RDP + 125 per cent RDK.

Agronomic efficiency of P and K progressively increased with incremental doses of P and K respectively i.e. increase in P levels from 100 per cent to 150 per cent RDP and RDK respectively. However, incremental doses of phosphorus at 100 per cent RDP, 125 per cent RDP and 150 per cent RDP showed increase in agronomic use efficiency of K. This suggests that at 150 per cent RDP there is better utilization of K even at 100 per cent RDK. Further, addition of K decreases the agronomic use efficiency of that nutrient especially at higher dose (150 % K). This may be due to better availability of nutrients and concomitant utilization by the crop with incremental levels P and K. This is an indication of the fact that recovery efficiency of the incremental doses is good at initial increments and showed the scope for increased levels of respective nutrients. These results are in close agreement with those of Dakshina Murthy *et al*. (2015).

5.5.4 Nutrient requirement by finger millet of N, P and K as influenced by application of different levels of phosphorus and potassium fertilizers.

Nutrient use efficiency by a crop can be decided by working out the NR (Nutrient requirement). Nutrient requirement is the amount of NPK nutrients required (kgs) individually to produce a quintal of finger millet grain. The efficiency of the nutrient is considered when it produces the maximum quantity of the plant biomass including economic yield with minimum quantity of nutrient (Table 21).

Nitrogen requirement by finger millet grain did not show any significant difference between the treatments imposed due to different levels of phosphorus and potassium fertilizers application (Table 21). The numerically higher N requirement (1.65 kg q^{-1}) for grain production was recorded in treatments T_{15}, T_{14} and T_{12} which received 100 per cent RDN along with 150 per cent RDP and 125 per cent RDK, 100 per cent of RDN and RDK along with150 per cent RDP and 100 per cent RDN along with 125 per cent RDP and 150 per cent RDK respectively. This might be due to more utilization of nutrients by the crop for higher yield due to application of higher doses in low phosphorus and potassium soils in study area compared to 100 per cent RDF, because of easy availability of nutrients at higher doses. Similar results were supported with those of Santhosha (2013) and Praveen *et al.* (2013) who observed higher hybrid maize and cotton yield might be due to higher requirement of nutrient based on STCR approach.

The phosphorus requirement by finger millet grain did not show significant difference due to different treatments imposed. However, numerically higher P requirement (0.24 kg q^{-1}) for finger millet grain production was recorded in T_{15} which received 100 per cent RDN along with 150 per cent RDP and 125 per cent RDK. This increased NR of P might be due to high available P in the soil upon addition of higher doses of phosphorus along with FYM in P deficient soils.

The potassium requirement for finger millet grain production also did not differ significantly due to different treatments imposed. However, numerically higher potassium requirement (0.36 kg q^{-1}) for finger millet grain production was noticed in treatments where higher dose of K was applied ($T_{11,}$ $T_{12,}$ T_{15} and T_{16}). This may be attributed to better utilization of nutrients by the crop by the application of higher doses of phosphorus and potassium in low P and K soils along with FYM.

5.5.5 Response yard stick

Response yardstick indicates how efficiently the applied nutrients in total are utilized by the crop to get maximum economic yield. The higher response yard stick was recorded (11.28 kg kg^{-1}) where 100 per cent RDN was applied along with 150 per cent RDP and 125 per cent RDK (T_{15}). Higher response yardstick was recorded in this treatment may be due to effective utilization of NPK nutrients by the crop through better root establishments, uptake of nutrients, increased photosynthetic ability and uniform maturation of crops due to application of phosphorus and potassium more than recommended dose at 150 per cent RDP and 125 per cent RDK respectively along with 100 per cent RDN and FYM. Basavaraja *et al*. (2014) who reported that application of NPK fertilizers were effectively utilized by the crop under STCR approach compared to other approaches in maize crop.

5.5 Economics of finger millet as influenced by different levels of phosphorus and potassium

The benefit cost ratio has been calculated to evaluate the economics of irrigated finger millet production under different treatments imposed. The higher gross returns (Table 23) were recorded (Rs. 1, 00,757) in treatment (T_{15}) receiving 100 per cent N + 150 per cent RDP + 125 per cent RDK followed by T_{16} (Rs.99, 328) which received 150 per cent of RDP and RDK along with 100 per cent RDN. The least gross returns were recorded in T_1 (Rs. 49,619) which received 100 per cent RDN without P and K fertilizers (Table 23).

The higher B: C ratio of 2.88 was recorded in treatment T_{15} which received 100 per cent RDN along with 150 per cent RDP and 125 per cent RDK and it was followed by treatment (T_{16}) receiving 150 per cent of RDP and RDK along with 100 per cent RDN (2.81).

Highest B: C ratio (2.88) observed in T_{15} was due to more grain (52.03 q ha^{-1}) and straw yield (87.57 q ha^{-1}) in that treatment due to application of phosphorus and potassium at 50 per cent and 25 per cent more than the recommended doses along with 100 per cent RDN and FYM. The highest gross and net income was also recorded in the same treatment. This was due to the fact that crop has not experienced nutrient stress at any growth stages, even though soil was low in available P and K because of balanced nutrition due to higher doses of P and K, improved vegetative growth and increased number of productive tillers which resulted in good grain and straw yield. These results are in line with Mudalagiriyappa *et al*. (2015) who reported that application of 125 per cent customized fertilizer dose recorded higher net returns and B: C ratio.

Even though treatment T_{16} received 150 per cent RDP and RDK along with 100 per cent RDN and FYM has recorded a slightly lower B: C ratio (2.81) compared to T_{15}. It clearly indicated that the application of 50 per cent more (75 kg ha^{-1}) K than the recommended dose of potassium (50 kg ha^{-1}) was uneconomical due to higher cost and lower net returns compared to $T_{15.}$ Therefore on the basis of these results it could be concluded that application of 100 per cent RDN + 150 per cent RDP + 125 per cent RDK is the best dose of nitrogen, phosphorus and potassium in enhancing yield levels of finger millet grown on low P and K soils of the Ramanagara district.

VI SUMMARY

A field experiment entitled "Response of finger millet to phosphorus and potassium levels on *Alfisols* of Ramanagara district of Karnataka" was conducted in farmers's field where available phosphorus and potassium was low, at Kodihalli village, Magadi taluk, Ramanagara district during *kharif* -2015 to evaluate the different levels of phosphorus and potassium on finger millet growth and yield attributes, yield, post – harvest soil properties, nutrient uptake, nutrient requirement and benefit : cost ratio in finger millet production under irrigated condition in low phosphorus and potassium soils.

The results of the present investigation related to response of finger millet to different levels of phosphorus and potassium on finger millet growth, yield, soil properties, nutrient uptake and economics are summarized in this chapter.

- Significantly higher plant height and number of tillers hill^{-1} was observed in T_{16} at 30 DAS, 60 DAS and 90 DAS and at harvest stage due to application of 100 per cent RDN + 150 per cent RDP + 150 per cent RDK (100: 75:75 kg NPK ha^{-1}). Significantly higher number of leaves was noticed in T_{16} (100:75:75 kg NPK ha^{-1}) at 30 DAS and 60 DAS. Whereas, at 90 DAS and at harvest significantly higher number of leaves hill^{-1} was observed in T_{15} which received 100 per cent RDN + 150 per cent RDP + 125 per cent RDK (100:75:62.5 kg NPK ha^{-1}).
- The number of productive tillers hill^{-1} and ear head weight recorded significantly higher value in the T_{15} (100:75:62.5 kg NPK ha^{-1}). Number of fingers ear head^{-1} was recorded significantly higher value in both T_{15} and T_{16}. Significantly higher 1000 grain weight was recorded in $T_{16.}$
- Application of 100:75:62.5 kg NPK ha^{-1} (T_{15}) recorded significantly higher grain (52.03 q ha^{-1}) and straw (87.57 q ha^{-1}) yield compared to T_6 (100:50:50 kg NPK ha^{-1}) which received nutrients as per package of practice which recorded 39.76 q ha^{-1} of grain and 58.78 q ha^{-1} of straw yield.
- There was no significant change in post- harvest soil pH and soil organic carbon among the treatments. However, significantly higher EC was noticed in T_{16} treated plots. Among the treatments, T_{16} (100:75:75 kg NPK ha^{-1}) recorded significantly higher available nitrogen (290.94 kg N ha^{-1}). Significantly higher (48.38 kg ha^{-1}) available phosphorus was recorded in T_{15}. Whereas, higher available potassium was recorded in T_{12} (100:62.5:75 kg NPK ha^{-1}).
- Significantly higher [6.47 cmol (p$^+$) kg^{-1}] calcium content was recorded in treatment (T_{16}), whereas the lower calcium content [4.18 cmol (p$^+$) kg^{-1}] was recorded in treatment T_1 without phosphorus and potassium fertilizers (100:0:0 kg NPK ha^{-1}). The exchangeable magnesium did not show significant difference between treatments due to application of different levels of phosphorus and potassium. Significantly higher available sulphur was recorded in T_{15} (25.06 mg kg^{-1}) The DTPA extractable micronutrients *viz;* iron, manganese, zinc and copper did not show significant variation in soil after harvest of finger millet. Whereas hot water soluble boron significantly recorded higher values in T_{15} (100:75:62.50 kg NPK ha^{-1}).

- The significantly higher total NPK (179.20 kg N ha^{-1}, 29.56 kg P_2O_5 ha^{-1} and 70.89 kg K_2O ha^{-1} respectively) and secondary nutrients (84.25 kg Ca ha^{-1}, 61.21 kg Mg ha^{-1} and 23.76 kg S ha^{-1}) uptake was noticed in T_{15} which received 150 per cent RDP and 125 per cent RDK along with 100 per cent RDN (100:75:62.5 kg NPK ha^{-1}).

- The total uptake of micronutrients viz., Fe, Mn, Zn, Cu and B by finger millet varied significantly due to different levels of phosphorus and potassium fertilizers. Higher total uptake of Fe (623.79 g ha^{-1}) and Cu (59.96 g ha^{-1}) by finger millet was recorded in the treatment T_{15}. Whereas, higher total uptake of Mn (279.92 g ha^{-1}), Zn (334.27 g ha^{-1}) and B (52.21 g ha^{-1}) was recorded in T_{16}.

- Higher phosphorus use efficiency (PUE) of 18.43 per cent was recorded in treatment T_{14} (100:75:50 kg NPK ha^{-1}) followed by T_{15} (18.15 %).Whereas, higher potassium use efficiency (KUE) was recorded in treatment T_{15} (65.82 %) followed by T_{14}.

- The higher agronomic phosphorus use efficiency (29.09 kg kg^{-1}) and potassium use efficiency (25.21 kg kg^{-1}) was noticed in T_{14} followed by treatment T_{15} (24.68 kg kg^{-1} P and 22.83 kg kg^{-1} K). The higher B : C ratio of 2.88 was recorded in treatment T_{15} and it was followed by T_{16} (2.81). Whereas the least B : C ratio (1.66) was observed in the treatment (T_1) which received 100 per cent RDN without P and K fertilizers (100:0:0 kg NPK ha^{-1}).

Based on the summary, it is concluded that application of 100 per cent RDN + 150 per cent RDP + 125 per cent RDK (100:75:62.5 kg NPK ha^{-1}) is helpful for getting higher yield of finger millet as well as higher benefit cost ratio (2.88) as compared to the present RDF (100:50:50 kg NPK ha^{-1}) in low phosphorus and potassium soils of Ramanagara district of Karnataka.

Future line of work

- The best levels of phosphorus and potassium along with nitrogen (100:75:62.5 kg NPK ha^{-1}) which out yielded other levels in the present experiment needs to be validated in different locations where available phosphorus and potassium was low in soils.

- Experiments need to be conducted to determine the appropriate fertilizer dose for other major crops under low phosphorus and potassium soils.

- STCR approach of fertilizer recommendation needs to be tested in the study area where available phosphorus and potassium was low in soils considering the benefit cost ratio.

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APPENDIX-1

List of abbreviation

AKUE	Agronomic potassium use efficiency
ANU	Agronomic nutrient use efficiency
APUE	Agronomic phosphorus use efficiency
AU	Apparent utilization
B : C	Benefit cost ratio
DAS	Days after sowing
FYM	Farm yard manure
GPU-28	Germ plasm unit 28
K	Potassium
KUE	Potassium use efficiency
N	Nitrogen
NR_K	Potassium requirement
NR_N	Nitrogen requirement
NR_P	Phosphorus requirement
P	Phosphorus
PI	Productivity Index
PUE	Phosphorus use efficiency
RDF	Recommended dose of fertilizers
RDK	Recommended dose of potassium
RDN	Recommended dose of nitrogen
RDP	Recommended dose of phosphorus
RYS	Response yard stick
STCR	Soil test crop response
UCP	Unit Cost of Production
VCR	Value cost ratio

APPENDIX-II

Amount of NPK kg ha^{-1} added according to treatments

Treatments	NPK (kg ha^{-1})
T_1 – 100 % RDN + 0 % RDP + 0 % RDK.	100: 0: 0
T_2 – 100 % RDN + 0 % RDP + 100 % RDK.	100: 0: 50
T_3 – 100 % RDN + 0 % RDP + 125 % RDK.	100: 0: 62.50
T_4 – 100 % RDN + 0 % RDP + 150 % RDK.	100: 0: 75
T_5 – 100 % RDN + 100 % RDP + 0 % RDK.	100: 50: 0
T_6 – 100 % RDN + 100 % RDP + 100 % RDK. (RDF*)	100: 50: 50
T_7 – 100 % RDN + 100 % RDP + 125 % RDK.	100: 50: 62.50
T_8 – 100 % RDN + 100 % RDP + 150 % RDK.	100: 50: 75
T_9 – 100 % RDN + 125 % RDP + 0 % RDK.	100: 62.50: 0
T_{10} – 100 % RDN + 125 % RDP + 100 % RDK.	100: 62.50: 50
T_{11} –100 % RDN + 125 % RDP + 125 % RDK.	100: 62.50: 62.50
T_{12} – 100 % RDN + 125 % RDP + 150 % RDK.	100: 62.50: 75
T_{13} – 100 % RDN + 150 % RDP + 0 % RDK.	100: 75: 0
T_{14} – 100 % RDN + 150 % RDP + 100 % RDK	100: 75: 50
T_{15} – 100 % RDN + 150 % RDP + 125 % RDK.	100: 75: 62.50
T_{16} – 100 % RDN + 150 % RDP + 150 % RDK.	100: 75: 75

APPENDIX-III

Cost of cultivation of irrigated ragi

Particulars	Quantity	Per unit cost	Cost (₹)
Variable cost			
Human labour (Mandays)	60.20	200	12,040.00
Bullock labour (BP days)	4.25	500	2,125.00
Machine labour (hours)	10	600	6,000.00
Seed (kgs)	10	25	250.00
FYM (tractor load)	2	1,900.00	3,800.00
Fertilizer cost			
a. Nitrogen	217.40	5.56	1,208.70
b. zinc sulphate	12.50	32.50	418.75
Irrigation (acre inches)			1800
Interest on working capital @ 8 per cent			2537.56
Total variable cost			29867.55
Returns per product			
Grain yield	1 q	1600 Rs.	
Straw	1q	200 Rs.	

P and K sources	Doses	P and K (kg ha^{-1})	P and K through fertilizers (kg ha^{-1})	Cost (₹ kg^{-1})	Total cost (₹)
SSP					
	100 % RDP	50.00 kg P_2O_5	312.50	7.43	2,321.88
	125 % RDP	62.50 kg P_2O_5	390.63	7.43	2,902.34
	150 % RDP	75.00 kg P_2O_5	468.75	7.43	3,482.81
MOP					
	100 % RDK	50.00 kg K_2O	83.33	16.00	1,333.33
	125 % RDK	62.50 kg K_2O	104.16	16.00	1,666.60
	150 % RDK	75.00 kg K_2O	125.00	16.00	1,999.92