

Original Research Article

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Effect of Application of Graded Level of Phosphorus to Finger Millet - Maize Cropping System in Soils of Different P Fertility

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ABSTRACT

Fertilizers are one of the costly inputs but continue to exert significant contribution to produce additional food grains. To realize maximum benefits and reduce nutrient losses from fertilizers, they must be applied in the right quantity, source and combination at the right time using the right method. An investigation on requirement of P for finger millet and maize in EDZ of Karnataka was taken at UAS, Bangalore. Response of finger millet and maize to graded levels of P was studied in the field by creating five phosphorus fertility gradients viz., P₀ (Very low), P₁ (Low), P₂ (Medium), P₃ (High) and P₄ (Very high) (< 15: 16-30: 31-45: 46-60: > 60 kg P₂O₅ ha⁻¹, respectively). Results revealed that, application of 125% RDP with rec. NK&FYM recorded higher finger millet (31.66 and 55.32 q ha⁻¹ grain and straw, respectively) and maize (78.26 q ha⁻¹ grain) yield in high P strip. Grain yield and harvest index of cropping system as a whole improved significantly in FYM supplied plots. Phosphorus use efficiency in maize was higher than finger millet. The higher use efficiency was recorded in very low gradient strip. Higher PUE among treatments was obtained when P was applied at the rate of 75 % of recommended dose along with rec. N&K. Application of 75 % rec. P + rec. N&K recorded higher B: C ratio in both the crops and was the best and optimum P prescription for these crops as the P use efficiency was also higher.

Keywords

Graded level of phosphorus, Finger millet, Maize, Cropping system, Soils.

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Introduction

The soil test ratings of low, medium and high fertility classes for nutrients are currently adopted by the soil testing laboratories need a fresh look as significant responses to applied nutrients have been recorded in soils with high fertility status in many crops. Phosphorus responses decrease with improvement in soil P-status, as expected. In

Punjab, responses were obtained upto 60-90 kg P₂O₅ ha⁻¹ in low-P soils, upto 60 kg P₂O₅ ha⁻¹ in medium-P soil and there was little response to P in high-P soils. In alluvial soils of U.P., even on soils classified as high in available P, 60 kg P₂O₅ ha⁻¹ increased the wheat yield by 653 kg ha⁻¹ or 10.9 kg grain per kg P₂O₅.

Even at the current high price of P_2O_5 , this underscores the need to revise soil fertility limits (Tiwari, 2002). If the initial soil phosphorus level is high, then maintenance application will be enough (Anonymous, 2012).

Finger millet [*Eleusine coracana* (L.) Gaertn.] [F: Poaceae] also known as Ragi or African millet ranks fourth in importance among millets in the world after sorghum (*Sorghum bicolor*), pearl millet (*Pennisetum glaucum*) and foxtail millet (*Setaria italica*). Of the total area of 2.7 mha under millets, Ragi alone accounts for 1.6 mha of the area and 75 per cent of total production in the country. India is the world's largest producer with annual production of 2.1 mt and productivity of around 1300 kg ha⁻¹. In India, ragi ranks fourth among the grain crops in productivity after wheat, rice and maize. Under irrigated conditions, the crop has a yield potential of 3-4 t ha⁻¹ (Anonymous, 2009).

Maize (*Zea mays* L.) is one of the important cereals cultivated in India and it ranks fourth after rice, wheat and sorghum. Maize area in Karnataka was insignificant during the pre-green revolution years. The yield levels were also low in the range of 700 – 900 kg ha⁻¹. The maize area in the state increased steadily because of the steady high yield levels and assured market prices. The present area under cultivation in the state is 10.7 lakh ha with a production of 30.3 lakh tons and a productivity of 2833 kg ha⁻¹ in 2008 – 09.

In the light of the above facts, a field experiment involving gradient creation followed by response of crops with graded levels of phosphorus along with other recommended dose of nutrients and FYM as organic source was conducted at the Zonal Agricultural Research Station, University of Agricultural Sciences, GKVK during 2009-2012, with the objective is to study the effect

of application of graded levels of phosphorus applied to soils with different fertility gradient on growth of finger millet and maize.

Materials and Methods

The field experiment comprised of two stages. Fertility gradient creation was the preparatory step as per the procedure of Ramamoorthy *et al.*, (1967) followed by finger millet-maize cropping system in the subsequent seasons. The experiment was conducted at D-16 Block, Zonal Agricultural Research Station (ZARS), GKVK, UAS, Bengaluru which is located in Eastern Dry Zone of Karnataka. Surface soil (0-15 cm) was analyzed for physical and chemical properties by adopting standard procedures. The soil of experimental site was red sandy clay loam in texture, acidic in reaction, low in available nitrogen (203.84 kg ha⁻¹) and phosphorus (18.42 kg ha⁻¹) and medium in available potassium (147.12 kg ha⁻¹) content.

Five equal strips (45 × 8.2 m²) were created in one and the same field and named very low (VL), low (L), medium (M), high (H) and very high (VH) gradient strips as P₀, P₁, P₂, P₃ and P₄, respectively. Graded doses of phosphorus *viz.* 0, 20, 40, 80 and 120 kg ha⁻¹ was applied through fertilizer and organics 50 per cent each so as to achieve Very low (<15 kg P₂O₅ ha⁻¹), Low (16-30 kg P₂O₅ ha⁻¹), Medium (31- 45 kg P₂O₅ ha⁻¹), High (46 - 60 kg P₂O₅ ha⁻¹) and Very high (> 60 kg P₂O₅ ha⁻¹) P levels in the respective strips. Exhaustive crop fodder maize was grown and green fodder was harvested at 60 days after sowing. Soils in each strip analyzed for available nutrients status. Available P₂O₅ content obtained in P₀, P₁, P₂, P₃ and P₄, was 14.82, 27.37, 38.76, 52.25, 80.72 kg ha⁻¹, respectively.

Finger millet (GPU-28) was grown during summer followed by maize was grown during

kharif 2011 by imposing treatments in a factorial RCBD design. Treatment details as follows; T₁: Absolute control; T₂: Package of Practice (NPK+FYM); T₃: 100 % Rec. N, P &K only (no FYM); T₄: 75 % Rec. P + rec. dose of N&K (no FYM); T₅: 75 % Rec. P + Rec. dose of N&K only+ Rec. FYM; T₆: 125 % Rec. P + Rec. dose of N&K (no FYM); T₇: 125 % Rec. P + Rec. dose of N&K + Rec. FYM.

The ragi ear heads harvested from each plot were sun dried and threshing was done to separate out the grains. Grain weight was recorded and grain yield in quintal per ha was calculated. For maize, the net plot was marked, cobs were harvested separately and total dried cob yield from each net plot was recorded. After threshing, grains were separated, cleaned and grain weight was recorded in quintal per ha. Finger millet straw was hand reaped from each plot, sun dried and dry weight was recorded and was calculated in quintal per hectare. Maize stover yield per net plot was recorded for each treatment. Later the stover yield per net plot was computed on hectare basis and then it was converted in to quintal per ha.

Phosphorus Use Efficiency (PUE) defined as 'yield per unit of nutrient supplied (from the soil and or fertilizer)' which was determined by using the formula of Moll *et al.*, (1982). The harvest index (HI) was calculated as the ratio of grain weight to total above ground crop dry weight as per Terao *et al.*, (2011). Cost of cultivation was calculated based on the prices of inputs that were prevailing in the market at the time of their use. The selling price for the produce was obtained from APMC market, Bangalore. The net returns per hectare was calculated by deducting the cost of cultivation from gross income and expressed in rupees per hectare (Rs. ha⁻¹).

The analysis and interpretation of the data were done using the Fisher's method of

analysis and variance technique. For field experiment data were analyzed using ANOVA (Two-Way) with interaction effect. Critical differences among P fertility gradient strips, treatments and interactions were estimated at 5 % probability level of significance (Panse and Sukhatme, 1985).

Results and Discussion

The results of the investigation on performance of crops on different phosphorus fertility gradient strips applied with graded levels of phosphorus to finger millet-maize cropping system are presented in this chapter under the following sub headings.

Response of finger millet yield

Finger millet grain and straw yield (Table 1) were significantly increased due to application of graded levels of phosphorus to different P fertility gradient strips. Yields increased as the P fertility gradient increased to high P fertility strips and then declined. Among the P fertility gradient strips, P₃ (high P) strip recorded significantly higher mean grain and straw yield followed by medium fertility gradient strip compared to other fertility gradient strips. Low P gradient strip recorded significantly higher yields over very low strip and was on par with very high P fertility strip. However, very low gradient strip recorded lower grain and straw yield which may be due to the contribution of initial soil fertility and residual effect of organic manure (neem cake).

Higher yield in high P strip soils could be due to better bioavailability of P and adequate as well as balanced supply of all the essential nutrients. The magnitude of response to applied P decreased sharply with increase in soil available P status and also with increase in applied P levels. Dhillon *et al.*, (1987) obtained similar results. In high P soils, the decrease in yield response per unit increase in

applied P could possibly be attributed to higher P concentration in soil-plant system leading to antagonistic effect on availability of Zn to plants and also to the imbalance in nutrients availability and uptake. Lu Ru-Kun (1981) reported a positive response to P application and observed 17.0- 40.9 kg increase in rice yield per kg of P applied on P deficient soils of China. Hanumanthappa and Shivaraj (2003) observed that application of neem cake at 750 kg ha⁻¹ recorded the higher seed yield and stalk yield of sesamum which was significantly higher compared to plots not involving organic manures.

Yield reduction in very high fertility gradient strip may be attributed to excessive addition of P that predisposed the crop to pest and disease incidences which in turn affected the crop growth and productivity. Decrease in yield of crop might be due to lower uptake of all the essential nutrients and to imbalanced supply of nutrients through fixation and antagonism effect of P with Ca, Fe and Zn, respectively. Thus, once the soil test P level reached the optimum for crop yield, it was recommended that P fertilizer application be restricted or stopped to minimize negative effects. Field survey data of Zhang Xiao-Sheng *et al.*, (2007) reported similar findings.

Among treatments, mean grain and straw yield were increased with the increased rate of phosphorus application along with FYM. Treatment involving 125 % rec. P + rec. N&K + rec. FYM (T₇) recorded significantly higher grain and straw yield followed by nutrient application as per package of practice (T₂). Treatments T₅ (75 % rec. P + rec. N&K + rec. FYM) and T₆ were significantly higher over T₄ (75 % rec. P + rec. N&K) and absolute control (T₁). Lower yield (11.38 and 25.09 q ha⁻¹, respectively) was recorded in absolute control (T₁). Phosphorus, being primary essential nutrient, has prime importance in crop nutrition. It is involved in almost all the biochemical pathways as a component of

energy carrier compounds ATP and ADP. Hence, these results emphasize the importance of applying adequate P for consistently high yields. Khalil and Jan (2003) and Guo Jianhua *et al.*, (2000) also got similar results.

Application of FYM along with 100 per cent recommended NPK recorded significantly higher mean finger millet grain yield compared to recommend NPK which may be due to buildup of soil phosphorus due to FYM application which also lowered the phosphorus fixation in *Alfisols*, thus making higher proportion of applied phosphorus available for crop utilization. Similar findings were reported by Thimma Reddy (1987) and Anon. (2000). Lower level of P application yielded the lower grain yield, whereas the higher fertilizer P treatment produced maximum yield. The grain yield increased significantly upto 62 kg P₂O₅ ha⁻¹ in very low, low and medium P strip soil as compared to very high strip soils. There was a significant response to applied P in very low, low and medium P strips. However, application of higher rate of P in very high P strip showed only marginal increase in yield. Dhillon *et al.*, (1987) reported similar responses for P application.

Application of 75 % rec. P + Rec. N&K recorded significantly higher yield over absolute control and was on par with 100 percent RDF which could be due to better P utilization in these two treatments. Ghanshyam *et al.*, (2010), Niazi *et al.*, (1990) and Khan *et al.*, (2000) reported increased grain yield due to P application over control. More and Agale (1993) noticed increased seed cotton and dry matter yield with increasing level of P upto 50 kg P₂O₅ ha⁻¹. Ananda (2009) reported significantly higher grain and straw yield of finger millet over control with application of 100 per cent NPK + FYM in finger millet-soybean cropping system.

Application of RDF 100 % + FYM recorded significantly higher yield over 125 % rec. P + rec. N&K. Similar findings were reported by Virupakshi (1988). However, 100 % RDF + FYM also recorded significantly higher yield over 100 % RDF due to considerable increase in the organic carbon content and a marginal increase in cation exchange capacity of soil (Anon., 1996). Nimje and Seth (1988) reported higher yield of soybean with increasing rates of P₂O₅ (0, 40 and 80 kg ha⁻¹) along with farmyard manure. Subramanian and Kumaraswamy (1989) recorded higher dry matter production of finger millet under 100 per cent NPK + FYM @ 10 t per ha under finger millet-cowpea-maize cropping sequence.

Judicious use of chemical fertilizers and organic manure would lead to efficient use of fertilizer and integrated nutrient management supply system and management holds a great promise in reducing the fertilizer dose for crop production. Higher yield can be produced by distributing fertilizer based on initial soil test values. These findings are in accordance with Prasad and Prasad (1994) and Prasad *et al.*, (1984). Balasubramaniyan (2005) reported that combined application of FYM with P fertilizer resulted in higher rice grain yield.

Interaction effect showed significantly higher finger millet grain and straw yield in high P strip (P₃) with treatment T₇ which received 125 % rec. P + rec. N&K + rec. FYM followed by treatment T₂ (Pop). Lower yield was recorded in very low P gradient strip with absolute control.

The response to applied P was more pronounced on soils low in available phosphorus than in other soils. In general, the response to P was very sharp in soils having low extractable P. Gradual increase in yield was observed in very low, low, medium and

high available P soils at all the P levels and was found to be statistically significant. These findings are confirming the result of Ali and Rahman (2011) and Muralidharudu *et al.*, (2003).

Response of maize yield

Numerous studies have shown that maize crop responded to fertility levels under various edapho-climatic conditions. Response to added fertilizer is dependent upon the variety, initial fertility status of soil and climatic conditions. With the advent of high yielding varieties and hybrids and pressing demand to increase the quality, adequate application of fertilizers is becoming increasingly important.

Maize grain and stover yields were increased with the increased P gradients from very low (P₀) to high P (P₃) gradient strip and were decreased as the gradient increased to very high (Table 2). High P gradient strip recorded significantly higher yield followed by medium fertility gradient strip which could be due to better root growth and development with P fertilization encouraged the higher uptake of nutrients resulting in better grain formation and also due to residual effect of organics and inorganics applied to previous finger millet crop. Low, medium, high and very high strips were on par with each other with respect to stover yield.

This may be due to better utilization of nutrients in all the gradient strips. Very low strip (P₀) recorded lower yield which may be due to inadequate supply of nutrients as the maize is an exhaustive crop. Hence, properly managed FYM and NP fertilizers could be used for maize production. In areas of marginal P deficiency, application of P fertilizers is essential to marginal higher yields under intensive cropping. Datta and Gomez (1975) reported the similar findings.

Table.1 Grain and straw yield (q ha⁻¹) of finger millet grown on different phosphorus fertility gradient strips as influenced by graded levels of applied phosphorus to finger millet-maize cropping system

P levels/ Treatments	Grain						Straw					
	P ₀	P ₁	P ₂	P ₃	P ₄	Mean	P ₀	P ₁	P ₂	P ₃	P ₄	Mean
T ₁	8.51	9.81	10.73	12.88	14.97	11.38	21.68	23.80	25.89	26.92	27.14	25.09
T ₂	25.70	26.32	28.86	29.53	24.88	27.06	49.02	51.32	53.67	54.33	47.26	51.12
T ₃	22.55	25.21	26.35	26.79	24.28	25.04	45.55	49.51	49.89	50.13	48.28	48.67
T ₄	20.89	24.20	25.54	25.88	24.06	24.12	43.56	47.53	49.29	48.88	48.06	47.47
T ₅	23.60	25.27	28.29	29.31	24.17	26.13	46.93	48.32	51.95	52.95	47.42	49.52
T ₆	24.68	24.77	27.10	27.87	23.80	25.65	48.15	47.78	50.60	51.21	48.80	49.31
T ₇	26.66	28.29	30.08	31.66	24.05	28.15	50.32	52.29	51.08	55.32	47.39	51.28
Mean	21.80	23.41	25.28	26.28	22.89	23.93	43.60	45.79	47.48	48.54	44.91	46.06
	F	<i>S.Em</i> ±	CD (p=0.05)		CV		F	<i>S.Em</i> ±	CD (p=0.05)		CV	
P	S	0.31	0.86		5.85		S	0.399	1.13		5.98	
T	S	0.36	1.02				S	0.47	1.34			
P x T	S	0.81	2.28				S	1.06	2.98			

T₁: Absolute control
 T₂: Package of Practice (rec. NPK+FYM)
 T₃: 100 per cent rec. N, P & K (no FYM)
 T₄: 75 per cent rec. P + rec. N&K (no FYM)
 T₅: 75 per cent rec. P + rec. N&K+ rec. FYM
 T₆: 125 per cent rec. P + rec. N&K (no FYM)
 T₇: 125 per cent rec. P + rec. N&K + rec. FYM

P₀: Very low Phosphorus fertility strip
 P₁: Low Phosphorus fertility strip
 P₂: Medium Phosphorus fertility strip
 P₃: High Phosphorus fertility strip
 P₄: Very high Phosphorus fertility strip

Table.2 Grain and stover yield (q ha⁻¹) of maize grown on different phosphorus fertility gradient strips as influenced by graded levels of applied phosphorus to finger millet-maize cropping system

P levels/ Treatments	Grain						Stover					
	P ₀	P ₁	P ₂	P ₃	P ₄	Mean	P ₀	P ₁	P ₂	P ₃	P ₄	Mean
T ₁	15.00	22.65	27.22	28.78	30.67	24.86	27.93	40.08	46.78	48.06	47.41	42.05
T ₂	63.72	70.66	74.48	76.43	71.80	71.42	104.28	109.73	109.83	115.13	109.21	109.64
T ₃	54.74	65.15	69.03	70.33	66.92	65.23	91.76	110.77	111.80	114.63	108.80	107.55
T ₄	51.97	63.33	68.24	69.27	68.56	64.28	89.97	110.21	111.08	113.19	112.47	107.38
T ₅	59.33	67.40	72.96	73.31	70.19	68.64	100.63	111.08	115.40	115.08	108.09	110.06
T ₆	59.72	66.85	70.58	71.57	62.63	66.27	95.52	111.66	109.54	110.51	105.66	106.58
T ₇	67.93	73.06	75.95	78.26	71.40	73.32	100.50	113.52	107.88	108.39	116.49	109.36
Mean	53.20	61.30	65.49	66.85	63.17	62.00	87.23	101.01	101.76	103.57	101.16	98.95
	F	<i>S.Em</i> ±		<i>CD (p=0.05)</i>		CV	F	<i>S.Em</i> ±		<i>CD (p=0.05)</i>		CV
P	S	0.37		1.04		2.74	S	0.92		2.59		4.25
T	S	0.44		1.24			S	1.09		3.06		
P x T	S	0.98		2.76			S	2.43		6.85		

T₁: Absolute control
 T₂: Package of Practice (rec. NPK+FYM)
 T₃: 100 per cent rec. N, P & K (no FYM)
 T₄: 75 per cent rec. P + rec. N&K (no FYM)
 T₅: 75 per cent rec. P + rec. N&K+ rec. FYM
 T₆: 125 per cent rec. P + rec. N&K (no FYM)
 T₇: 125 per cent rec. P + rec. N&K + rec. FYM

P₀: Very low Phosphorus fertility strip
 P₁: Low Phosphorus fertility strip
 P₂: Medium Phosphorus fertility strip
 P₃: High Phosphorus fertility strip
 P₄: Very high Phosphorus fertility strip

Table.3 Harvest index for finger millet and maize as influenced by different phosphorus fertility gradient strips applied with graded levels of phosphorus to finger millet-maize cropping system

P levels/ Treatments	Finger millet						Maize					
	P ₀	P ₁	P ₂	P ₃	P ₄	Mean	P ₀	P ₁	P ₂	P ₃	P ₄	Mean
T ₁	0.28	0.29	0.29	0.32	0.36	0.31	0.35	0.36	0.37	0.37	0.39	0.37
T ₂	0.34	0.34	0.35	0.35	0.35	0.35	0.38	0.39	0.40	0.40	0.40	0.39
T ₃	0.33	0.34	0.35	0.35	0.33	0.34	0.37	0.37	0.38	0.38	0.38	0.38
T ₄	0.32	0.34	0.34	0.35	0.33	0.34	0.37	0.36	0.38	0.38	0.38	0.37
T ₅	0.33	0.34	0.35	0.36	0.34	0.34	0.37	0.38	0.39	0.39	0.39	0.38
T ₆	0.34	0.34	0.35	0.35	0.33	0.34	0.39	0.37	0.39	0.39	0.37	0.38
T ₇	0.35	0.35	0.37	0.36	0.34	0.35	0.40	0.39	0.41	0.42	0.38	0.40
Mean	0.33	0.33	0.34	0.35	0.34	0.34	0.38	0.38	0.39	0.39	0.38	0.38
	F	<i>S.Em</i> ±		CD (p=0.05)		CV	F	<i>S.Em</i> ±		CD (p=0.05)		CV
P	S	0.003		0.007		3.49	S	0.002		0.006		2.72
T	S	0.003		0.009			S	0.003		0.008		
P x T	S	0.007		0.019			S	0.006		0.017		

T₁: Absolute control
 T₂: Package of Practice (rec. NPK+FYM)
 T₃: 100 per cent rec. N, P & K (no FYM)
 T₄: 75 per cent rec. P + rec. N&K (no FYM)
 T₅: 75 per cent rec. P + rec. N&K+ rec. FYM
 T₆: 125 per cent rec. P + rec. N&K (no FYM)
 T₇: 125 per cent rec. P + rec. N&K + rec. FYM

P₀: Very low Phosphorus fertility strip
 P₁: Low Phosphorus fertility strip
 P₂: Medium Phosphorus fertility strip
 P₃: High Phosphorus fertility strip
 P₄: Very high Phosphorus fertility strip

Table.4 PUEP (Phosphorus Use Efficiency Per cent) by finger millet and maize grown on different phosphorus fertility gradient strips applied with graded levels of phosphorus to finger millet-maize cropping system

P levels/ Treatments	Finger millet						Maize					
	P ₀	P ₁	P ₂	P ₃	P ₄	Mean	P ₀	P ₁	P ₂	P ₃	P ₄	Mean
T₁	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
T₂	31.24	28.25	27.36	24.11	15.85	25.36	38.40	38.89	39.13	42.85	38.00	39.45
T₃	31.56	30.95	26.51	24.09	15.41	25.70	36.93	42.88	40.16	44.86	38.29	40.62
T₄	33.74	30.00	27.79	24.18	17.49	26.64	37.55	44.30	43.61	48.20	44.35	43.60
T₅	31.75	28.12	28.00	24.68	16.18	25.75	36.93	42.36	43.92	45.08	40.43	41.74
T₆	36.55	29.86	27.40	23.65	15.77	26.65	38.99	44.36	42.29	43.53	34.55	40.74
T₇	31.48	29.56	26.55	25.97	15.44	25.80	36.83	39.54	39.37	39.30	35.59	38.13
Mean	32.72	29.46	27.27	24.44	16.02	25.98	37.61	42.05	41.41	43.97	38.53	40.72

T₁: Absolute control

T₂: Package of Practice (rec. NPK+FYM)

T₃: 100 per cent rec. N, P & K (no FYM)

T₄: 75 per cent rec. P + rec. N&K (no FYM)

T₅: 75 per cent rec. P + rec. N&K+ rec. FYM

T₆: 125 per cent rec. P + rec. N&K (no FYM)

T₇: 125 per cent rec. P + rec. N&K + rec. FYM

P₀: Very low Phosphorus fertility strip

P₁: Low Phosphorus fertility strip

P₂: Medium Phosphorus fertility strip

P₃: High Phosphorus fertility strip

P₄: Very high Phosphorus fertility strip

Table.5 Benefit cost analysis (B: C) of crops grown on different phosphorus fertility gradient strips applied with graded levels of phosphorus to finger millet-maize cropping system

P levels/ Treatments	Finger millet						Maize					
	P ₀	P ₁	P ₂	P ₃	P ₄	Mean	P ₀	P ₁	P ₂	P ₃	P ₄	Mean
T₁	1.88	2.14	2.34	2.73	3.09	1.88	1.59	2.38	2.85	3.01	3.18	2.60
T₂	1.96	2.01	2.19	2.24	1.89	1.96	2.86	3.16	3.31	3.41	3.20	3.19
T₃	3.42	3.80	3.95	4.01	3.67	3.42	3.84	4.58	4.83	4.92	4.68	4.57
T₄	3.33	3.81	4.01	4.05	3.80	3.33	3.77	4.60	4.93	5.00	4.95	4.65
T₅	1.85	1.97	2.19	2.26	1.89	1.85	2.73	3.09	3.33	3.34	3.20	3.14
T₆	3.56	3.57	3.88	3.98	3.47	3.56	4.05	4.55	4.77	4.83	4.26	4.49
T₇	1.98	2.10	2.20	2.32	1.80	1.98	2.96	3.20	3.30	3.39	3.14	3.20
Mean	1.88	2.14	2.34	2.73	3.09	1.88	3.11	3.65	3.90	3.99	3.80	3.69

T₁: Absolute control

T₂: Package of Practice (rec. NPK+FYM)

T₃: 100 per cent rec. N, P & K (no FYM)

T₄: 75 per cent rec. P + rec. N&K (no FYM)

T₅: 75 per cent rec. P + rec. N&K+ rec. FYM

T₆: 125 per cent rec. P + rec. N&K (no FYM)

T₇: 125 per cent rec. P + rec. N&K + rec. FYM

P₀: Very low Phosphorus fertility strip

P₁: Low Phosphorus fertility strip

P₂: Medium Phosphorus fertility strip

P₃: High Phosphorus fertility strip

P₄: Very high Phosphorus fertility strip

Continuous application of different organic and inorganic sources of nutrients profoundly influences many chemical properties of soil such as organic carbon content, pH, electrical conductivity etc. Increase in organic matter in soil increases the exchange capacity and cation retention, reduces phosphorus fixation and acts as a source and sink of trace elements resulting in higher availability of nutrients may help in enhancing higher yields. Muralidharudu *et al.*, (2003), Niazi *et al.*, (1990) and Khan *et al.*, (2000) reported increased grain yield due to P application. Guo Jianhua *et al.*, (2000) observed the residual effects of P application to wheat increased the succeeding corn yield with 150 kg P₂O₅ ha⁻¹ compared to no P, which confirms the importance of P. Wakene Negassa *et al.*, (2005) observed significant residual effects of FYM and NP fertilizers on maize grain yields due to considerable amounts of macronutrients and small amounts of micronutrients which were supplied by FYM.

Among the treatments, application of 125 % rec. P + rec. N&K + rec. FYM (T₇) recorded significantly higher grain yield. Stover yield was higher due to application of 75 % rec. P + rec. N&K + rec. FYM (T₅) followed by nutrients applied as per package of practice which may be due to the improved physico-chemical properties of soil and created an ideal rhizospheric environment which resulted in congenial soil-water relations for better nutrient release and availability besides supplying major and micronutrients.

Sankaran *et al.*, (2005) observed similar results. Interaction effects were higher in P₃ strip applied with 125 % rec. P + rec. N&K + rec. FYM (T₇) in grain and P₄ strip applied with T₇ in straw which may be ascribed to the adequate availability of nutrients in P₃ strip and this facilitated greater partitioning of photosynthates to the ear.

The positive interaction may be due to the beneficial effect of FYM application on the availability of phosphorus to the plants. In addition to phosphorus, which was mineralised from the organic matter and became available to plants, organic matter also acts as chelating agents, thereby preventing the formation of insoluble phosphates. Furthermore, the application of organic matter to soil not only supplies phosphorus, but on decomposition provides acidic compounds which increase the availability of mineral forms of phosphorus (*i.e.*, extra CO₂ speeded up the solubility of phosphatic compounds) in the soil. Saad Abdel Rahman Sulieman and Tag El-Din Hagoin (2007) reported the similar findings. Lower yield obtained in very low gradient strip with absolute control (T₁) may be due to supply of lower quantity of nutrients. Kogbe and Adediran (2003) reported the optimum rate of P for maize grown in the derived savanna was 40 kg ha⁻¹.

The literature on FYM application to crops clearly indicates that application of FYM increases the microbial activity in soil and resulted in improving the physical properties of soil (*viz.*, structural status, water retention, bulk density of soil) which are reflected on getting higher grain, straw and biomass yields. This could be due to higher availability of nutrients over no FYM application. Combined application of FYM with inorganic fertilizers further enhanced the yield and improved the soil fertility status which resulted in higher crop yield. Sajid Ali *et al.*, (2008) observed increase in maize grain yield with the increase in levels of P application (60 kg ha⁻¹, 90 kg ha⁻¹ and 120 kg ha⁻¹) as compared to control and P dose of 60 kg ha⁻¹ resulted in maximum increase in grain yield. Sawargaonkar *et al.*, (2008) reported that recommended dose of fertilizer at the rate of 100 and 125 per cent recorded similar mean yield of maize grain and were

significantly higher over 75 per cent RDF in maize-maize sequence. Venkatesh *et al.*, (2002) noticed that application of P levels upto 60 kg ha⁻¹ increased grain as well as stover yield of maize significantly as compared to control and 30 kg P₂O₅ ha⁻¹.

Similar yields were obtained with the application of 100 and 125 per cent recommended dose of P₂O₅ ha⁻¹. Similar responses were noticed when FYM was applied with different levels of phosphorus. Suryavanshi *et al.*, (2008) noticed that the maize crop responded quadratically to the inputs of nitrogen and phosphorus. Sahoo and Panda (2001) reported the similar results. Balai *et al.*, (2011) obtained maximum grain and stover yield of maize by conjoint application of FYM with recommended dose of NPK over unfertilized control. Damodar Reddy *et al.*, (1999) reported that the integrated use of manure and fertilizer P is a promising strategy to improve soil P fertility status and to obtain higher and sustained productivity of the soybean-wheat cropping system.

Harvest Index (HI)

Harvest index across the P strips and treatments showed almost similar values except absolute control (Table 3). This could be due to similarity in biological yield though there was a difference in grain and straw/stover yield. Higher grain yield in comparison to stover yield of maize in high gradient strip recorded higher harvest index among the gradient strips. Higher value recorded in medium gradient with the treatment T₇ which received 125 % rec. P + rec. N&K + rec. FYM followed by high gradient strip with T₇ may be due to higher grain yield. Very low gradient with absolute control showed lower HI could be due to lower grain as well as biomass yield. Grain yield and harvest index of cropping system as

a whole improved significantly in FYM supplied plots. Anil Choudhary *et al.*, (2007) observed significant improvement in harvest index of wheat and rice crops with increase in chemical fertilizer levels from 50 to 150 per cent of recommended NPK.

The HI was decreased significantly with increased P fertility gradient strips as well as P levels and was unstable across P levels may be due to genotypic stability for HI was maintained. Reddy *et al.*, (2004) reported similar results. Ti-Da Ge *et al.*, (2012) observed HI for maize was ranging from 0.20 to 0.40. Dustin *et al.*, (2012) reported harvest index for maize averaged across treatments was 0.49 and none of the treatments were significantly different compared to the control.

P Use Efficiency (PUE)

Phosphorus use efficiency in maize was higher than finger millet (Table 4) since the maize was known to be exhaustive in nature and also due to residual effect of manures and fertilizers. Generally, lower the P application rate better was the use efficiency. PUE decreased as the fertility gradient increased from very low to very high in finger millet. The higher use efficiency was recorded in very low gradient strip. This may be due to higher response of finger millet to applied P in very low and low P gradient strip resulted in to better utilization of native as well as applied P. In case of maize, PUE was higher in high gradient strip followed by medium and low gradient strips due to higher growth of crop and better uptake of P in high gradient strip. Reduction in PUE in very high gradient strip shows the inefficiency of crop to utilize P due to adverse effect of higher amount of P application which affected the crop growth and development which has reduced movement and uptake of nutrients resulting in lower fertilizer P use efficiency.

Higher PUE among treatments was obtained when P was applied at the rate of 75 % of recommended dose along with rec. N&K. This could be due to maximum utilization and uptake of added P and further application beyond this level was non beneficial and was also non economical to farmers as the PUE by the crops were only 20-40 per cent in general, the remaining amount was fixed in the soil. Application of P upto 50 kg P₂O₅ ha⁻¹ with or without FYM was increased phosphorus use efficiency thereafter it significantly reduced indicating PUE decreases at higher doses of P due to the fact that plants grown in extremely P deficient soil exhibit greater P sorption at lower doses of P. In areas of marginal P deficiency, application of P fertilizers is essential to marginal higher yields under intensive cropping. Nutrient use efficiency and productive efficiency decreased with increasing doses of P application. Venkatesh *et al.*, (2002) reported similar results.

Bisht and Chandel (1991) noticed the higher photosynthetic rate and physiological efficiency of nitrogen was obtained with the application of 80 kg P₂O₅ + 10 t FYM per ha. Majumdar *et al.*, (2007) observed the higher P use efficiency at lower doses of applied P and maximum was 21.30 per cent recorded with SSP @ 30 kg P₂O₅ ha⁻¹ + FYM. Dhillon *et al.*, (1987) reported that the P use efficiency by pearl millet was maximum in low P soils and decreased with increase in available P status. Further, the increasing level of applied P also resulted in low P utilization and hence, fertilizer efficiency decreased. Datta and Gomez (1975) reported an increase in P use efficiency with successive cropping's. Muralidharudu *et al.*, (2003) obtained relatively higher NUE and PE in low and high available P soils due to application of 30 kg P₂O₅ ha⁻¹. Apparent P recovery declined with increasing rates of P application.

B: C ratio

Higher B: C ratio in finger millet and maize were recorded in very high and high P fertility gradient strip could be due to higher yield obtained due to residual as well as added fertilizer effect (Table 5). Application of FYM along with inorganics recorded lower B: C ratio due to higher cost of FYM purchase resulting higher cost of cultivation and lower B: C ratio. If the manure produced by the farmer the cost of cultivation reduces and sustains B: C ratio. In case of maize there was a slight decrease in B: C ratio in very high gradient could be due to lower yield resulting in lower gross and net income. Among treatments, application of 125 % rec. P + rec. N&K (T₆) and 75 % rec. P + rec. N&K (T₄) noticed higher B: C ratio may be due to better yield and lower cost of inputs as the non-addition of manure.

Application of 75 % rec. P + rec. N&K recorded higher B: C ratio in both the crops and was the best and optimum P prescription for these crops as the P use efficiency was also higher. Application of higher dose of P fertilize has no beneficial effect in high and very high P fertility strips. Very low gradient with absolute control showed lower benefit cost ratio which indicates that application of sufficient amount of nutrients was very much essential in order to achieve better crop yields and income. There was an increased B: C ratio in absolute control with increased P fertility gradients there was increase in yield which shows the role and importance of phosphorus for crop production. Similar findings were reported by Vinodkumar (2008), Rajput *et al.*, (1995), Singh *et al.*, (1999), Singh and Verma (2002) and Balasubramanian (2005).

It was concluded that, application of fertilizer P @ 125 % RDP with rec. NK&FYM in very low, low and medium fertility soils recorded

higher grain and straw/stover yield of finger millet and maize. 100 % or 75 % RDP with rec. NK&FYM were optimum though there was an increase in yield at higher rate of P application in high P fertility soils. PUE was higher at lower levels of P application.

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