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Influence of Graded Levels of Phosphorus at Different Fertility Gradient on Soil Properties under Finger Millet- Maize Cropping System

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Abstract: The influence of graded levels of phosphorus at different fertility gradient on soil properties was studied at Zonal Agricultural Research Station (ZARS), GKVK, UAS, Bengaluru under finger millet-maize cropping system. Five phosphorus fertility gradients *viz.,* P_0 (Very low), P_1 (Low), P_2 (Medium), P_3 (High) and P_4 (Very high) (< 15, 16-30, 31-45, 46-60 and > 60 kg P_2O_5 ha^{-1}) were imposed. Results indicated that, availability of N, P, K, S, Mg, Mn, Cu content was higher in very high fertility strip, whereas the exchangeable Ca, DTPA-Fe and Zn were significantly higher in medium P fertility gradient strip. Combined application of manures and fertilizers resulted in relatively higher availability of nutrients as compared to inorganics alone. Further, there was a build-up of P in gradient strips with graded levels of P application.

Keywords: *Fertility gradients, graded levels of phosphorus, soil properties, finger millet, and maize*

Introduction

The current agronomic package of practices is recommended uniformly for a zone, irrespective of the soil variability and fertilizer recommendations worked out from experiments conducted on one soil type may not hold good for another soil type. Spatial variation of soil properties decreases the use-efficiency of fertilizers applied uniformly at the field scale (Miller *et al*. 1988). At the same time, there is an increasing pressure to reduce the application of fertilizers in commercial agriculture and minimize non-point sources of pollution of both surface and ground waters. Therefore, application at variable rather than uniform rate of fertilizers has been proposed to avoid application of excess fertilizers where it is not properly utilized by crops (Carr *et al*. 1991 and Mulla *et al.* 1992). There was a selective crop response to nutrients in different soils and the responsiveness varied with soil nutrient status. In acid soils, P deficiency is often accompanied by Al and Mn toxicity, especially when soil pH is below 5.40.

With this background, a field experiment involving graded levels of phosphorus along with different recommended dose of nutrients and FYM was conducted at the Zonal Agricultural Research Station, University of Agricultural Sciences, and GKVK during 2009-2012, their effect on soil properties under finger millet-maize cropping system.

Materials and methods

Experimental site

The experiment was conducted at D-16 Block, Zonal Agricultural Research Station (ZARS), GKVK, UAS, Bengaluru ($12^0$58' N; $75^0$35' E) at an elevation of 930 m above mean sea level.

Soil characteristics of experiment site

Surface soil (0-15 cm) was analyzed for physical and chemical properties by standard procedures. The experimental soil was sandy clay loam (CEC 11.10 [c mol (p^+) kg^{-1}], pH (1:2.5) 5.55, EC 0.26 (dS m^{-1}), organic carbon 0.45%, available N 203.84 (kg ha^{-1}), available P_2O_5 18.4 (kg ha^{-1}), available K_2O 147.1(kg ha^{-1}), exchangeable Ca 6.75 [c mol (p+) kg^{-1}], exchangeable Mg 3.60 [c mol (p+) kg^{-1}], available S 10.82 (kg ha^{-1}),

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DTPA-Fe 55.8 (mg kg^{-1}), DTPA-Mn 59.5 (mg kg^{-1}), DTPA-Cu 2.21 (mg kg^{-1}), DTPA-Zn 2.35 (mg kg^{-1}), B 0.54 (mg kg^{-1})] developed from gneiss.

Creation of fertility gradient strips

Five strips (45 × 8.2 m) of fertility were created *viz.* very low, low, medium, high and very high. Graded doses of P @ 0, 20, 40, 80 and 120 kg ha^{-1} were applied through fertilizer and organics (neem cake), 50 per cent fertilizer and 50% from organics to achieve very low (<15 kg P_2O_5 ha^{-1}), low (16-30 kg P_2O_5 ha^{-1}), medium (31- 45 kg P_2O_5 ha^{-1}), high (46 - 60 kg P_2O_5 ha^{-1}) and very high (> 60 kg P_2O_5 ha^{-1}) P levels in the respective strips. Fodder maize *cv.* South African tall was grown with recommended doses of nitrogen (100 kg ha^{-1}), phosphorus (50 kg P_2O_5 ha^{-1}) and potassium (25 kg K_2O ha^{-1}) and green fodder was harvested at 60 days after sowing. Soils in each strip were analyzed for available nutrients. The available P_2O_5 content in P_0, P_1, P_2, P_3 and P_4, was 14.82, 27.37, 38.76, 52.25, 80.72 kg ha^{-1}, respectively.

Soil properties in fertility gradient strips with application of graded levels of P fertilizer

After harvest of maize crop, each strip was divided into three replications and each replication was sub divided into seven treatment plots. Finger millet *cv* GPU-28 was grown at the spacing of 20 x 10 cm during summer followed by maize *cv* Nithyashree Hybrid was grown at the spacing of 60 x 30 cm during kharif 2011. There were seven treatments comprising of T_1 Absolute control; T_2 Package of practice (NPK+FYM); T_3 100 % Recommended N, P &K only (no FYM); T_4 75 % Recommended P + Recommended dose of N&K (no FYM); T_5 75 % Rec. P + Recommended dose of N&K only+ Recommended FYM; T_6 125 % Recommended P + Recommended dose of N&K (no FYM); T_7 125 % Recommended P + Recommended dose of N&K + Recommended FYM following factorial RCBD design.

Recommended dose of fertilizer for finger millet was 50:40:25 kg ha^{-1} of N: P_2O_5: K_2O whereas for maize it was 100:50:25 kg ha^{-1} of N: P_2O_5:K_2O. Recommended dose of FYM was applied (7.5 t ha^{-1}) to both the crops.

Soil sampling

The representative soil samples were collected at 0-15 cm depth from all the plots separately at harvest of finger millet as well as maize crop and were analyzed for pH, EC, organic carbon and available nutrients by standard procedures.

Statistical analysis

The analysis and interpretation of the data was done using Fisher's method of analysis and variance technique. The field experiment data was 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

Soil properties after harvest of finger millet

The pH of the soil at harvest of finger-millet did not differ significantly. Very high fertility gradient strip (P_4) and treatment T_7 had significantly higher electrical conductivity of soil (Table 1). Santhy *et al.* (1999) observed that the salt content of soil increased slightly due to application of 100% NPK with FYM.

Increase in organic carbon of soil (Table 1) was observed with increase in P fertility gradient might be due to the mineralization of neem cake and FYM. Pattar *et al*. (1998) also reported that the application of FYM @ 10 t ha^{-1} resulted in higher organic carbon content. Badole and More (2000) reported that organic carbon content was relatively higher when organic sources were added (FYM and neem cake). Among treatments, both T_7 and T_2 treatments recorded higher organic carbon content.

The P_4 fertility gradient strip recorded significantly higher available nitrogen and sulphur (Fig. 1: A & C) followed by high fertility gradient strip. Treatment T_7 recorded significantly higher available N (Fig. 2A) and S (Fig. 2C) compared to chemical fertilizer alone. Ramesh *et al*. (2008) reported that application of organic manures such as FYM; vermi-compost and poultry manure increased the available NPK and organic carbon content of soil as compared to chemical fertilizer after the harvest of crops in a three year cropping sequence. Absolute control (T_1) recorded lower available N and S content which may be due to uptake of native soil N and S by the crop.

Table 1. Changes in pH, EC and organic carbon (OC) content of soil after harvest 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/	pH (1:2:3)					EC (dS m-1)						OC (per cent)					
Treatments	P0	P1	P2	P3	P4	P0	P1	P2	P3	P4	Mean	P0	P1	P2	P3	P4	Mean
T1	5.53	5.54	5.59	5.56	5.54	0.20	0.22	0.24	0.25	0.26	0.24	0.40	0.60	0.62	0.66	0.71	0.60
T2	5.65	5.65	5.69	5.57	5.73	0.26	0.27	0.28	0.29	0.30	0.28	0.49	0.71	0.74	0.77	0.81	0.71
T3	5.52	5.53	5.66	5.62	5.67	0.24	0.27	0.27	0.28	0.29	0.27	0.44	0.64	0.67	0.71	0.75	0.64
T4	5.51	5.56	5.62	5.59	5.63	0.23	0.27	0.24	0.26	0.27	0.25	0.43	0.61	0.64	0.67	0.71	0.61
T5	5.77	5.78	5.75	5.65	5.80	0.25	0.26	0.26	0.29	0.30	0.27	0.45	0.67	0.71	0.74	0.77	0.67
T6	5.52	5.61	5.67	5.65	5.71	0.24	0.25	0.27	0.28	0.28	0.26	0.47	0.66	0.69	0.73	0.76	0.66
T7	5.80	5.79	5.75	5.68	5.74	0.27	0.29	0.30	0.31	0.32	0.30	0.49	0.71	0.76	0.78	0.82	0.71
Mean	**5.61**	**5.64**	**5.68**	**5.62**	**5.69**	**0.24**	**0.26**	**0.27**	**0.28**	**0.29**	**0.27**	**0.45**	**0.66**	**0.69**	**0.72**	**0.76**	**0.66**
Initial (after harvest of F exhaust crop)	4.72	4.81	4.83	4.89	4.82	0.26	0.27	0.28	0.29	0.29	0.42	0.53	0.61	0.62	0.71		
S.Em±	CD (p=0.05)		F	S.Em±	CD (p=0.05)		CV	F	S.Em±	CD (p=0.05)		CV					
P	NS	0.06	-	S	0.003	0.007	4.54	S	0.01	0.02	4.38						
T	NS	0.07	-	S	0.003	0.009		S	0.01	0.02							
P x T	NS	0.15	-	NS	0.01	-		NS	0.02	-							

pH: Initial- 5.55 EC: Initial- 0.26 dS m^{-1} OC: Initial- 0.45 per cent

T_1: Absolute control
Phosphorus fertility strip
T_2: Package of Practice (rec.NPK+FYM)
fertility strip
T_3: 100 per cent rec. N, P & K (no FYM)
Phosphorus fertility strip
T_4: 75 per cent rec. P + rec. N&K (no FYM)
fertility strip
T_5: 75 per cent rec. P + rec. N&K+ rec. FYM
Phosphorus fertility strip
T_6: 125 per cent rec. P + rec. N&K (no FYM)
T_7: 125 per cent rec. P + rec. N&K + rec. FY

P_0: Very low
P_1: Low Phosphorus
P_2: Medium
P_3: High Phosphorus
P_4: Very high

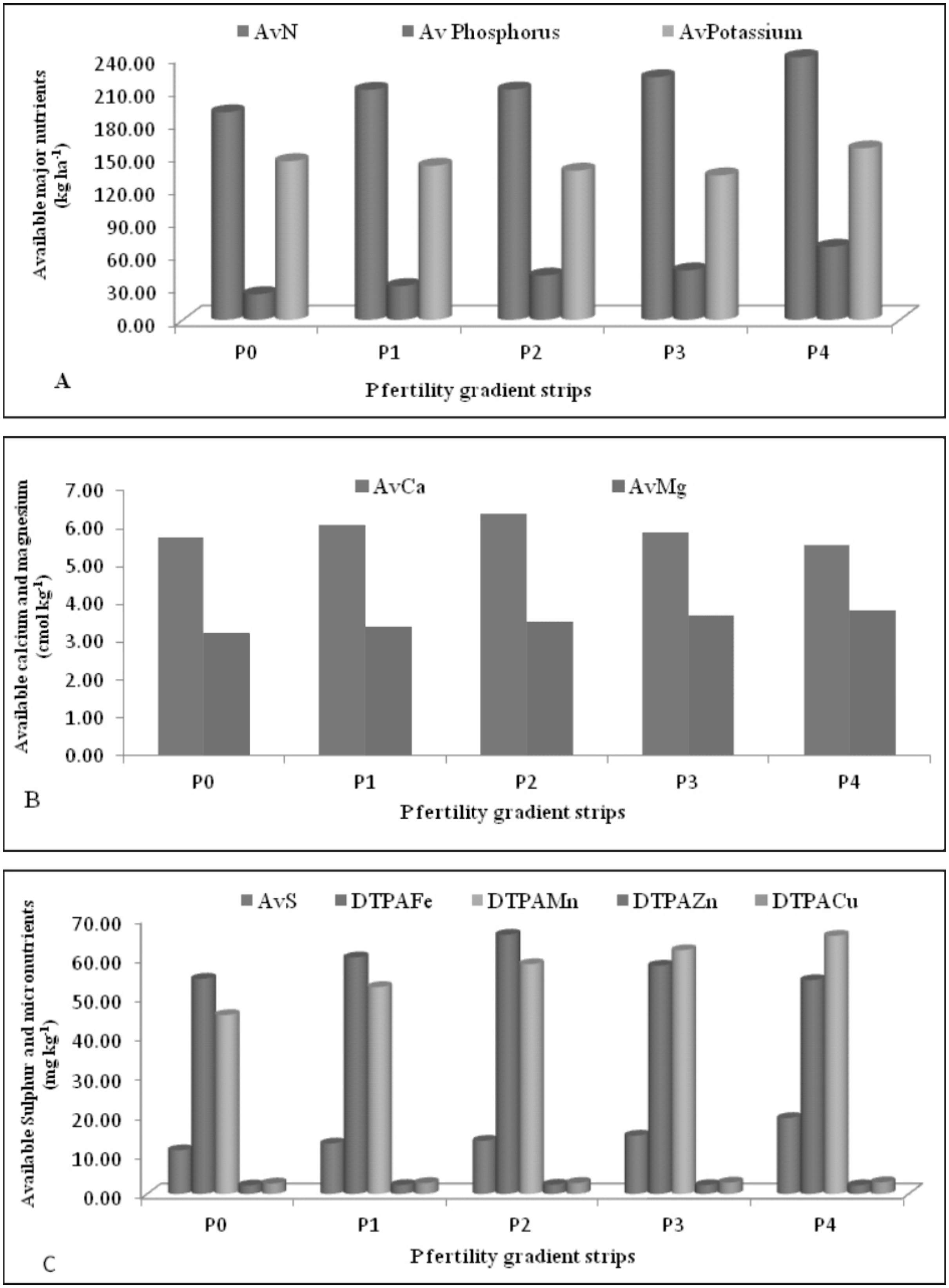


Fig. 1: A. Available major nutrients, B. Available calcium and magnesium, C. Available sulphur and micronutrients in soil after harvest of finger millet in different P fertility gradient strips

Significantly higher available mean P_2O_5 (Fig. 1A) was noticed in very high P fertility gradient strip (P_4) compared to other gradient strips. This could be due to the addition of P fertilizer at the rate of 120 P_2O_5 kg ha^{-1} as well as application of graded levels of P fertilizer to finger millet crop. Continuous use of phosphatic fertilizers in excess of crop requirement results in a gradual increase in available phosphorus status of the soil (Rashid 2012). Manjunatha Hebara (2003) also observed that irrespective of N and K application, available phosphorus of soil at harvest of *kharif* rice increased with increased level of P application from P1 (75 kg ha^{-1}) to P3 (125 kg ha^{-1}).

Treatment T_7 recorded significantly higher available P_2O_5 content in soil (Fig. 2A) followed T_2. Treatment T_5 and T_7 125 % rec. P + rec. N&K (T_6) were at par with each other as the uptake and P utilization by crop was almost similar. Absolute control recorded lower available P_2O_5 owing to decrease in native soil solution P.

The available potassium content of soil was significantly higher in very high P gradient strip (Fig. 1A) over rest of the P fertility gradient strips. This may be due to release from the initially applied neem cake as it contained 1.5% of K. Lower available potassium was recorded in very low P (P_0) strip due to better uptake of added potassium (25 kg ha^{-1}). Among treatments, T_5 (75 % rec. P + rec. N&K + rec. FYM) recorded higher available K_2O (Fig. 2A) which was significantly higher over other treatments which may be due to better uptake of K by the crop in other treatments which received higher rate of P resulting in good crop growth and uptake.

The exchangeable calcium content of soil was significantly higher in medium P fertility strip (Fig. 1B) followed by low P strip. Very high P strip (P_4) had lower exchangeable Ca due to its fixation with P. Treatment T_7 recorded higher Ca content (Fig. 2B) and lower value was observed in absolute control (T_1). Exchangeable magnesium in soil was significantly higher in P_4 fertility strip and the lower value in very low (P_0) gradient strip (Fig. 1B). Among treatments, T_5 recorded higher exchangeable magnesium content (Fig. 2B) and lower value was recorded in treatment T_4.

Medium fertility strip had significantly higher available iron and zinc in soil (Fig. 1C). Very low and very high fertility strips recorded lower contents. Among treatments, T_7 recorded higher iron and zinc (Fig. 2C) content in soil and the values were lower in absolute control. Higher availability may be due to balanced supply of the nutrients through organics as well as inorganics and also lower fixation of Fe and Zn with P. In absolute control of very low gradient strip, the reduced availability of zinc and iron may be due to their uptakes by crop.

There was a reduction in available P, K and DTPA-Zn in the plots which did not receive these nutrients initially either through fertilizer or manure. Singh *et al.* (1999) also observed increase in the DTPA-Cu, Mn, Fe and available B in the plots treated with single super phosphate and or FYM.

Medium fertility strip had significantly higher available iron and zinc in soil (Fig. 1C). Very low and very high fertility strips recorded lower contents. Among treatments, T_7 recorded higher iron and zinc (Fig. 2C) content in soil and the values were lower in absolute control. Higher availability may be due to balanced supply of the nutrients through organics as well as inorganics and also lower fixation of Fe and Zn with P. In absolute control of very low gradient strip, the reduced availability of zinc and iron may be due to their uptake by crop. There was a reduction in available P, K and DTPA-Zn in the plots which did not receive these nutrients initially either through fertilizer or manure. Singh *et al.* (1999) also observed increase in the DTPA-Cu, Mn, Fe and available B in the plots treated with single super phosphate and or FYM.

Available manganese and copper in soil were higher (Fig. 1C) in very high P strip (P_4) and the values were lower in very low P strip (P_0). Treatment T_7 recorded significantly higher DTPA-Mn and Cu and absolute control had lower contents (Fig. 2C). Walia and Kler (2010) observed significant increase in major (NPK) and micronutrients (Fe, Mn, Zn and Cu) status in soil after the harvest of maize in maize- wheat system under recommended dose of chemical fertilizer with green manuring as compared to recommended dose of chemical fertilizer.

Soil properties after the harvest of maize

Soil pH after harvest of maize (Table 2) did not differ significantly among the P gradient strips.

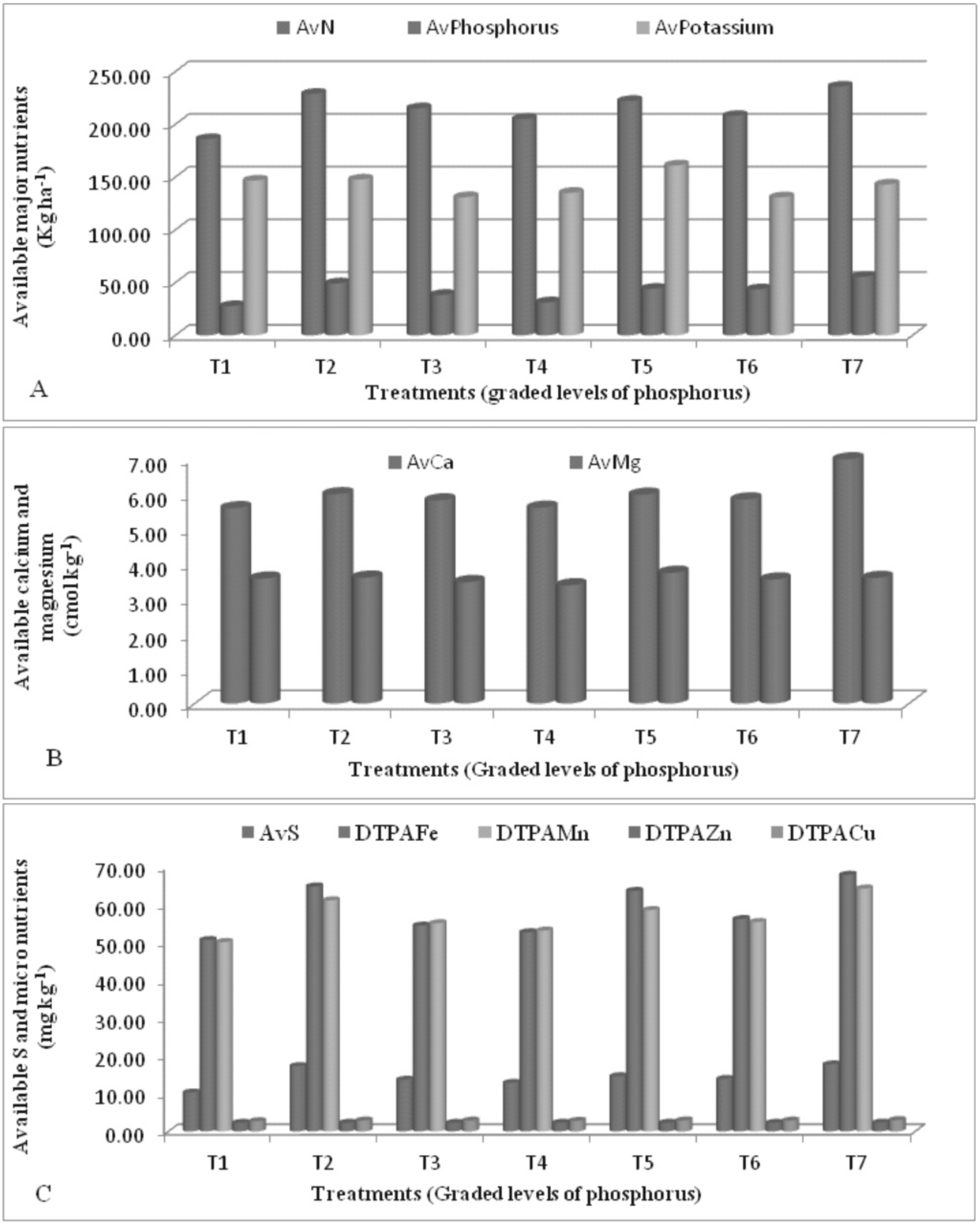


Fig. 2: A. Available major nutrients, B. Available calcium and magnesium, C. Available sulphur and micronutrients in soil after harvest of finger millet in different P fertility gradient strips as influenced by graded levels of phosphorus

Table 2. Changes in pH, EC and organic carbon (OC) content of soil after harvest 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	pH (1:2:5)					EC (dS m^{-1})						OC (per cent)					
	P_0	P_1	P_2	P_3	P_4	P_0	P_1	P_2	P_3	P_4	Mean	P_0	P_1	P_2	P_3	P_4	Mean
T_1	5.39	5.47	5.55	5.44	5.38	0.24	0.25	0.26	0.29	0.30	**0.27**	0.30	0.50	0.52	0.56	0.61	**0.50**
T_2	5.65	5.77	5.83	5.66	5.82	0.27	0.28	0.31	0.32	0.34	**0.31**	0.39	0.61	0.64	0.67	0.71	**0.61**
T_3	5.41	5.58	5.54	5.55	5.56	0.27	0.29	0.31	0.33	0.37	**0.31**	0.34	0.54	0.57	0.61	0.65	**0.54**
T_4	5.42	5.48	5.50	5.50	5.62	0.22	0.24	0.27	0.30	0.34	**0.28**	0.33	0.51	0.54	0.57	0.61	**0.51**
T_5	5.69	5.74	5.68	5.72	5.69	0.26	0.28	0.28	0.33	0.35	**0.30**	0.35	0.57	0.61	0.64	0.67	**0.57**
T_6	5.39	5.52	5.37	5.32	5.59	0.22	0.27	0.32	0.34	0.31	**0.29**	0.37	0.56	0.59	0.63	0.66	**0.56**
T_7	5.79	5.77	5.77	5.75	5.73	0.27	0.30	0.33	0.36	0.38	**0.33**	0.39	0.61	0.66	0.68	0.72	**0.61**
Mean	**5.54**	**5.62**	**5.60**	**5.56**	**5.62**	**0.25**	**0.27**	**0.30**	**0.32**	**0.34**	0.30	**0.35**	**0.56**	**0.59**	**0.62**	**0.66**	0.56

	F	*S.Em±*	CD (*p=0.05*)	F	*S.Em±*	CD (*p=0.05*)	CV	F	*S.Em±*	CD (*p=0.05*)	CV
P	NS	-	-	S	0.004	0.011	6.16	S	0.002	0.007	2.11
T	S	0.04	0.13	S	0.005	0.013		S	0.003	0.008	
P x T	NS	-	-	S	0.011	0.03		S	0.007	0.018	

T_1: Absolute control
T_2: Package of Practice (rec. NPK+FYM)
T_3: 100 per cent rec. N, P & K (no FYM)
T_4: 75 per cent rec. P + rec. N&K (no FYM)
T_5: 75 per cent rec. P + rec. N&K+ rec. FYM
T_6: 125 per cent rec. P + rec. N&K (no FYM)
T_7: 125 per cent rec. P + rec. N&K + rec. FYM

P_0: Very low Phosphorus fertility strip
P_1: Low Phosphorus fertility strip
P_2: Medium Phosphorus fertility strip
P_3: High Phosphorus fertility strip
P_4: Very high Phosphorus fertility strip

The electrical conductivity and organic carbon content of soil after harvest of maize (Table 2) was significantly higher in very high P gradient strip followed by high fertility gradient strip and lowest contents were observed in very low strip (P_0). Treatment T_7 recorded significantly higher EC and OC contents followed by T_2. Bhardwaj and Omanwar (1994) observed that continuous cropping without fertilization of NPK led to depletion of organic carbon, whereas continuous fertilization of NPK had beneficial effect on the build-up of organic carbon in the soil. Louduraj and Rajagopal (2000) reported that the higher rates of manure (FYM) application increased organic carbon content of soil.

The available nitrogen content of soil after the harvest of maize was significantly higher in very low P strip (Fig. 3A) followed by low strip due to lower uptake of N by the crop in very low strip as compared to other gradient strips. High P fertility strip had lower available N owing to higher uptake of N, and/or N losses through leaching or volatilization. Application of FYM along with fertilizer recorded higher available N over treatments which did not receive FYM.

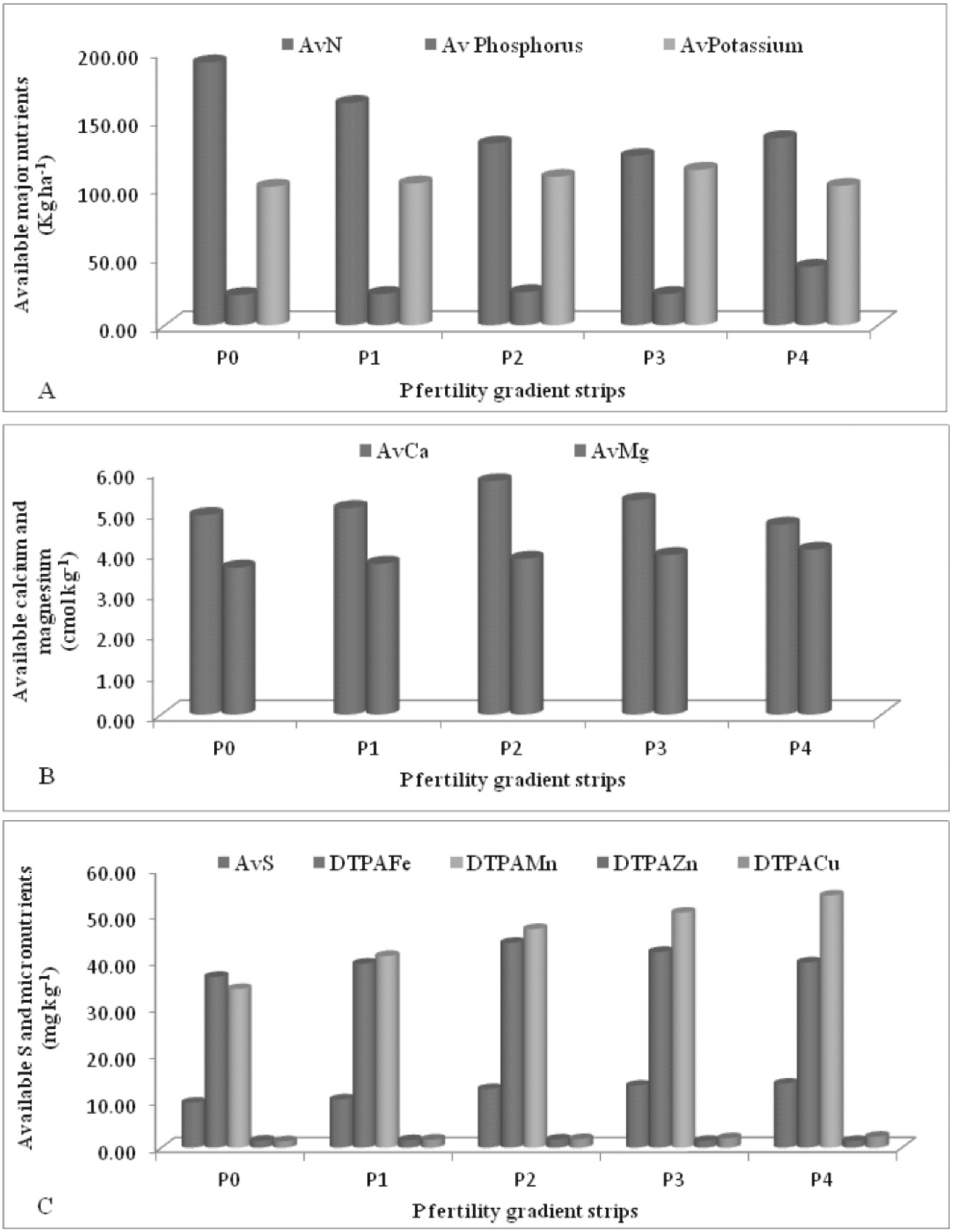
The application of nutrients as per package of practice (T_2) recorded significantly higher available N (Fig. 4A) followed by treatment T_5 and lowest available N content was recorded in absolute control. This may be due to application of fertilizers and FYM at higher rates. In a similar study, Tolanur and Badanur (2003) reported increased organic carbon content and available N, P and K status of the soil in pearl millet- pigeon pea cropping system.

The available phosphorus content in soil (Fig. 3A) was significantly higher in very high gradient strip (P_4) compared to the other strips which may be attributed to lower uptake of P in very high gradient strip. Treatment T_7 recorded significantly higher available P_2O_5 (Fig. 4A) followed by application of nutrients as per package of practice. Absolute control recorded lower available phosphorus content indicating the need to apply sufficient P to meet crop requirement and also to maintain available P status in soil. Manjunatha Hebara (2003) observed higher available P in soil after harvest of rice crop due to increased P application from P1 (75 kg ha^{-1}) to P3 (125 kg ha^{-1}) irrespective of N and K application. Further, higher soil P at harvest was due to application of 125 kg ha^{-1} (P3). However, the non phosphorous receiving plots fertilizer during continuous cropping recorded low P values. Mann *et al*. (2006) also obtained higher P content in soil due to application of NPK and farm yard manure than only NPK.

Available potassium content in soil (Fig. 4A) was significantly higher in high P strip followed by medium P strip and lowest value was recorded in very low (P_0) gradient strip. Treatments T_7 and T_5 had higher available K (Fig. 4A) and lower value was observed in absolute control. Available K content in soil decreased at harvest of maize as compared to initial as the application was limited to recommended dose. Further potassium supplied by neem cake might have utilized by the previous finger-millet crop. These results are in accordance with Manjunatha Hebara (2003) who reported higher soil K under high level of P application (P3 -125 kg ha^{-1}) compared to lower level (P1-75 kg ha^{-1}).

There was an increase in available sulphur, manganese, copper (Fig. 3C) and exchangeable magnesium (Fig. 3B) in soil as P content increased in the gradient strips. Addition of FYM along with inorganic nutrients also recorded higher available sulphur, manganese, copper (Fig. 4C) and exchangeable magnesium (Fig. 4B) in soil. Chaudhary and Narwal (2005) reported linear relationship between organic carbon (OC) and DTPA extractable Zn, Fe, Mn, and Cu and total contents.

The exchangeable calcium (Fig. 3B), available iron and zinc (Fig. 3C) contents of soil were significantly higher in medium P fertility gradient strip (P_2) but decreased as the gradient increased. Available iron content in soil was lower in very low gradient strip as this gradient did not receive neem cake. Among treatments, T_5 recorded significantly higher exchangeable calcium, available iron and zinc (Fig. 4: B&C) contents followed by T_2 and T_7. These treatments had higher P due to interaction effect between P_2 strips with the application of FYM along with inorganic. Farm Yard Manure might have complex with Ca, Fe and Zn in soil thereby reducing the fixation resulting in higher availability of these nutrients. Mann *et al*. (2006) also observed higher DTPA- extractable micronutrients content compared to initial value due to application of NPK with farm yard manure.


AvN
Av Phosphorus
AvPotassium
Available major nutrients (Kg ha-1)
200.00
150.00
100.00
50.00
0.00
P0
P1
P2
P3
P4
A
P fertility gradient strips
AvCa
AvMg
Available calcium and magnesium (cmol kg-1)
6.00
5.00
4.00
3.00
2.00
1.00
0.00
B
AvS
DTPAFe
DTPAMn
DTPAZn
DTPACu
Available S and micronutrients (mg kg-1)
60.00
50.00
40.00
30.00
20.00
10.00
0.00
C

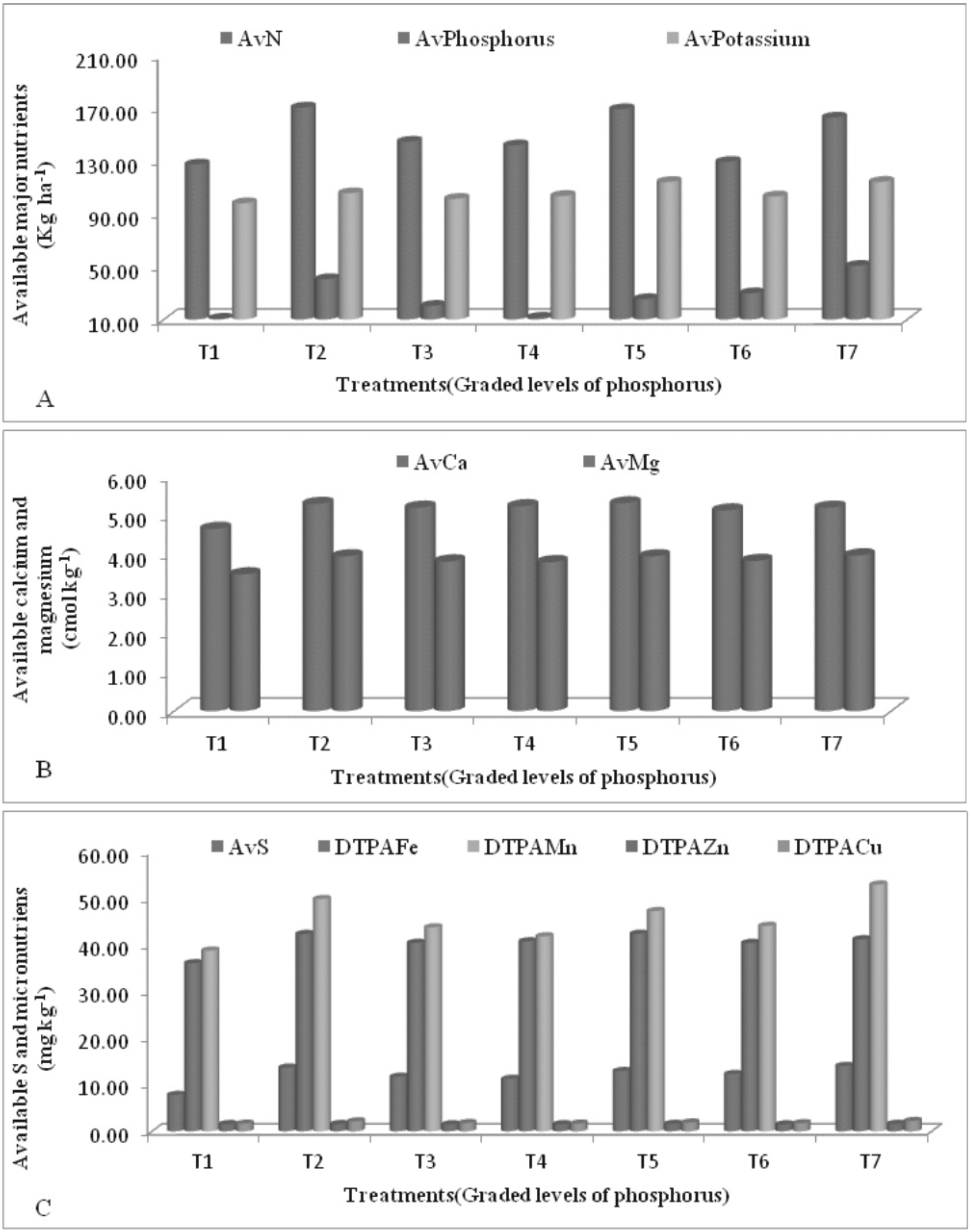


Fig. 4 : A. Available major nutrients, B. Available calcium and magnesium, C. Available sulphur and micronutrients in soil after harvest of maize in different P fertility gradient strips as influenced by graded levels of phosphorus

Conclusions

It can be concluded that, there was variance in a build up of P in soil applied with graded levels of P. Application of organics improved the pH, EC, OC and nutrient status of soil after the harvest of both finger millet and maize crop. Application of organics to very high P fertility soils is essential to maintain soil health and productivity.

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