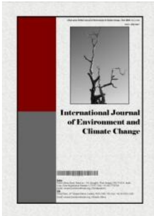

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Effect of Integrated Phosphorus Management on Macro and Micronutrient Status of Soil in *Bt*-Cotton

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Authors' contributions

This work was carried out in collaboration among all authors. Author KVSLRR designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors PPR and PRKP managed the analyses of the study. Author PAK managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aim: To evaluate the impact of integrated use of phosphorus on soil fertility in Bt-Cotton.
Study Design: The experiment was laid out in randomized block design with three replications.
Place of Study: At College Farm, Agricultural College, Bapatla, Guntur district.
Methodology: After the preliminary layout, Tulasi-BG II hybrid of cotton was used as a test crop, with a spacing of 90 cm x 60 cm in the experimental site. Farmyard Manure @ 10 t ha^{-1} was applied 10 days prior to sowing while phosphorus solubilising bacteria @ 5 kg ha^{-1} was applied one day before sowing. Phosphorus was applied as per the treatments basally at sowing whereas, the recommended dose of nitrogen and potassium (120 and 60 kg ha^{-1}, respectively) were applied in four equal splits at 20, 40, 60, and 80.
Results: The treatments showed no significant influence on available nitrogen and potassium but, comparatively higher values of nitrogen and potassium were observed in organic treated plots. The

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available phosphorus content was markedly influenced by level of phosphorus as well as components of integration at all the crop growth stages. Highest available phosphorus was recorded on integration of maximum dose of phosphorus with Phosphorus solubilising bacteria (PSB) and Farmyard manure (FYM). The available micronutrient contents in soil did not show any marked difference among the treatments at all the stages of crop growth.
Conclusion: Application of phosphorus along with Phosphorus solubilising bacteria (PSB) and Farmyard manure (FYM) can reduce the phosphorus requirement to crops as well as improves soil health.

Keywords: Phosphorus; PSB; FYM, Bt-cotton.

1. INTRODUCTION

Crop growth requires nutrient availability and constant supply throughout the growing season. Cotton yield responds positively to the availability of the nutrients, especially Phosphorus [1]. The availability of P in the soil affects the nutrient accumulation and dry matter accumulation in the cotton plant parts [2]. Improving the cotton cultivars with better nutrient management to obtain higher economic yield is of great importance to minimize the environmental impact of inorganic fertilizers. Phosphorus is very important in crop production after nitrogen (N); however, its resources are limited worldwide [3]. The P application improves root architecture by increasing length, width, and diameter of root. Hence, P uptake by the plants is predominantly controlled by the availability and acquisition of P [4]. Therefore, the P deficiency inhibits cotton growth and development by declining the biomass accumulation, leading to lower seed cotton yield [5]. Approximately 15-20 per cent of applied fertilizer phosphorus is utilized by the crops and rest of the gets fixed in the soil and becoming unavailable to crop plants [6]. Efficiency of P fertilizer throughout the world is around 10-25%, phosphatic fertilizers have low efficiency of utilization due to fixation in soil and poor solubility of native soil phosphorus, sometimes there is a build-up of insoluble phosphorus as a result of chemical phosphorus fixation. At present 5% of the Indian soils have adequate available P, 49.3% are under low category, 48.8% under medium and 1.9% under high category. Only 25% to 30% of the applied P is available to crops and remaining P is converted into insoluble P [7].

The role of organic manure is well recognized and considered as balance manures which supplies macro and micro nutrients essential to plants. Farm yard manure (FYM) is one of the important organic manures, which supplies a suitable mineral balance and improves nutrient availability by enzymes. The Phosphorus biofertilizers like PSB and VAM enhances the availability of phosphorus to the plant by converting insoluble phosphorus from the soil in to soluble form. The PSB like *Pseudomonas striata* bacterial inoculation was found as equivalent to supply 50 kg P_2O_5 /ha through single super phosphate [8]. Phosphorus fertilizer use efficiency was enhanced by combined application of P mineral fertilizers with organic P sources and mainly affected by soil type, pH, crops growth pattern, management practices and climatic conditions of an area [9]. Integration of organic materials with inorganic sources of nutrients has an extra benefit over the application of inorganic nutrients alone [10]. Organic matter directly influences the factors that control fixation and release of P in soils. The use of chemical fertilizers does not necessarily lead to better farming; however, the combined use of chemical and organic fertilizers leads to better farming and sustainable production [11]. Thus, availability of phosphorus is the major problems in productivity of crops concerning not only its actual deficiency in soil but also its availability to crop plants. For increasing phosphorus availability, integrated phosphorus management (IPM) is the only viable strategy. The IPM helps to restore and sustain soil fertility, crop productivity and is also economic [12]. The aim of current study was to develop a well balanced and integrated nutrient management plan that utilizes bio fertilizers of P in conjunction with organic sources and mineral fertilizers. Keeping in view, the experiment was planned to study the effect of integrated phosphorus management in Bt cotton for sustaining yield and soil fertility.

2. MATERIALS AND METHODS

The experiment was carried out at the Agricultural College Farm, Bapatla, Guntur district, Andhra pradesh, in *kharif* season with 10 treatments replicated thrice in a randomized block design in *Bt* cotton. The treatments comprised of T_1 = RDP *i.e.,* Recommended dose of phosphorus (60 kg P_2O_5 ha^{-1}); T_2 = RDP+PSB (Phosphorus solubilising bacteria); T_3 = 50% RDP+PSB; T_4 = PSB; T_5 = RDP+FYM (Farmyard manure) ; T_6 = 50% RDP+FYM; T_7 = FYM; T_8 = RDP+PSB+FYM; T_9 = 50% RDP+FYM and T_{10} = PSB + FYM. FYM and PSB were applied @10 t ha^{-1} and 5 kg ha^{-1}, respectively. The mean values of various weather parameters pertaining to the crop growth period of previous 20 years and current season were recorded from the India Meteorological Department Observatory, Bapatla, to arrive at a general distribution of different weather parameters over the years and their deviation in current crop growing season. During experimentation the study area experienced average maximum and minimum temperatures of 32.24 ^oC and 21.90 ^oC, respectively with a total rainfall of 627.8 mm over 30 rainy days. The experimental soil was clay loam in texture, with slightly alkaline in reaction (pH 7.8), non saline (EC 0.39 dS m^{-1}) and medium (5.5 g kg^{-1}) organic carbon content. The bulk density was 1.39 Mg m^{-3}. The soil was low in nitrogen (203 kg ha^{-1}), medium in phosphorus (32.18 kg ha^{-1}) and high in potassium (750 kg ha^{-1}). Standard procedures were followed to analyze available nutrient status in soil at different growth stages and Fisher's method of analysis of variance was followed for analysis and interpretation of the data as suggested by Panse and Sukhatme [13].

3. RESULTS AND DISCUSSION

3.1 Soil Available Nutrients

3.1.1 Nitrogen

The data related to the nutrient status of the soil represented by Table.1 and Fig.1 indicated that the treatmental effect at different stages on available N was non-significant. However at all stages the treatments received FYM recorded higher nitrogen values than other treatments. The N values ranged between 239 and 279 kg ha^{-1} at 45 DAS. The values varied from 254 to 288 and 194 to 222 kg ha^{-1} at 90 DAS and harvest respectively. At all stages highest and lowest values were recorded by T_8 and T_4 treatments, respectively.

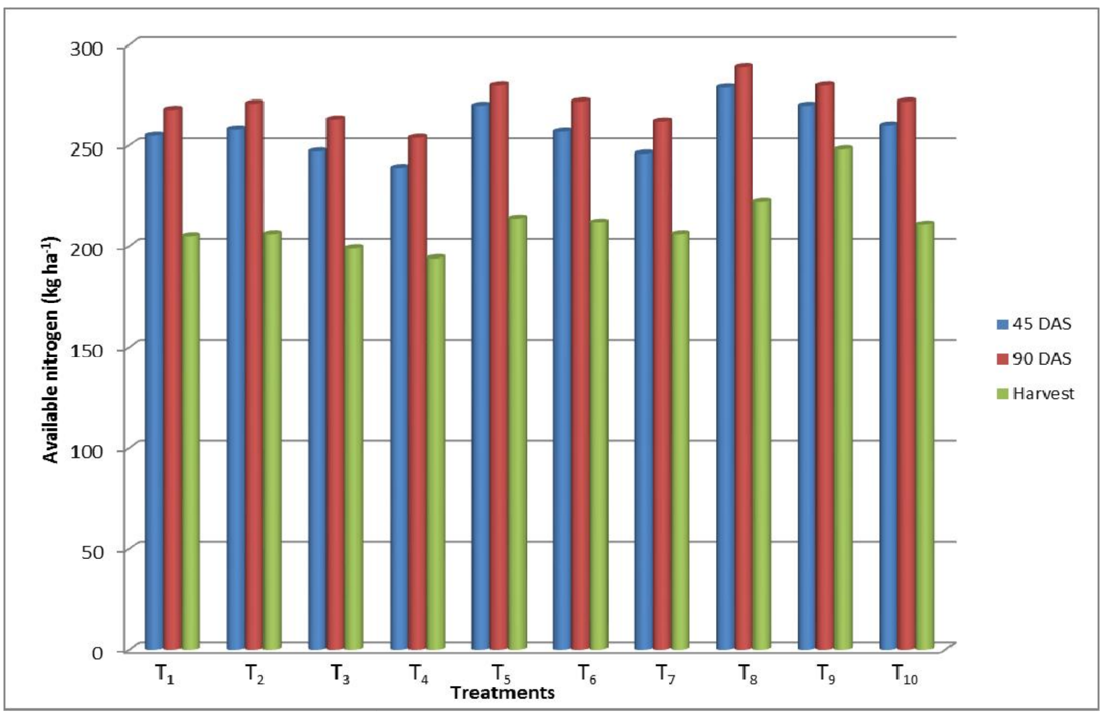

Fig. 1. Available nitrogen status in soils

Table 1. Effect of Phosphorus levels, PSB and FYM on available macronutrients in soil

Treatments	Nitrogen			Phosphorus (P_2O_5) (kg ha^{-1})			Potassium (K_2O)		
	45 DAS	90 DAS	Harvest	45 DAS	90 DAS	Harvest	45 DAS	90 DAS	Harvest
T_1-60 kg P_2O_5 ha^{-1}	255	268	205	59.33	52.32	38.98	1030	1221	997
T_2-60 kg P_2O_5 ha^{-1} +PSB	258	271	206	61.90	54.37	41.72	1153	1187	874
T_3-30 kg P_2O_5 ha^{-1} +PSB	247	263	199	49.93	44.11	32.32	1130	1165	784
T_4-PSB	239	254	194	40.18	36.59	28.38	1143	1120	795
T_5-60 kg P_2O_5 ha^{-1} +FYM	270	280	214	63.61	56.43	44.11	1143	1333	941
T_6-30 kg P_2O_5 ha^{-1} +FYM	257	272	212	51.64	46.68	34.71	1176	1221	840
T_7-FYM	246	262	206	42.58	39.16	31.12	1108	1232	896
T_8-60 kg P_2O_5 ha^{-1} +PSB+FYM	279	288	222	65.83	59.33	47.53	1153	1198	784
T_9-30 kg P_2O_5 ha^{-1} +PSB+FYM	270	280	218	55.91	49.93	37.96	1164	1243	829
T_{10}-PSB+FYM	260	272	211	44.97	42.06	33.86	1120	1322	896
SEM$\pm$	6	6	5	1.40	1.50	1.20	61	76	63
CD@0.05	NS	NS	NS	4.15	4.44	3.60	NS	NS	NS
CV	3.84	3.75	4.11	4.52	5.38	5.70	9.41	10.73	12.67

*PSB @ 5 kg ha^{-1}; FYM @ 10 t ha^{-1}

Data also indicated that available nitrogen was more at 90 DAS and later it decreased at harvest which could be due to more utilization by plants and other losses. The increase in availability of nitrogen in FYM applied plots may be due to additional amount of nitrogen added through FYM, increased mineralization, increase in proliferation of microbes in the soil which results in enhanced nitrogen fixation by mainly non-symbiotic microorganisms. The increase in availability of nitrogen in the plots where PSB was applied could be due to positive relation between the added and native microorganisms in the soil that mineralized the organic matter [14]. Similar increase in availability of nitrogen was reported by Das et al. [15]. The decrease in availability of nitrogen in the plots receiving 50 percent and no phosphorus may be due to poor mineralization at lower levels of phosphorus.

3.1.2 Phosphorus

The availability of phosphorus increased significantly with increase in phosphorus dose up to 60 kgha^{-1} of P_2O_5 with PSB or FYM or their combination Table.1 & Fig .2. Among all the treatments the treatment that received combined application of PSB+FYM recorded higher availability of phosphorus than individual application of FYM or PSB at same level of phosphorus.

This might be due to higher quantity of phosphorus application and bio fertilizer viz. PSB, resulted in buildup of nutrients in the soil. Similar results were also reported by Dekhane et al. [16]. This might be due to higher quantity of FYM along with bio fertilizers viz. PSB resulted in buildup of nutrients in the soil. Similar results were also reported by Chaudhari et al. [17] and Khan et al. [18] revealed that phosphorus management improved the residual soil fertility and the gain in available P_2O_5 over the initial soil nutrient content. The role of PSB is very important, as it helps in dephosphorylation of phosphorus bearing organic compounds. Release of phosphorus by PSB from insoluble and fixed/adsorbed forms is an important aspect regarding phosphorus availability in soils [19].

Availability at 45 DAS was maximum in treatment T_8 (65.83 kg ha^{-1}), which was on a par with $T_5$and T_2 (63.61 and 61.90 kg ha^{-1}, respectively) and significantly superior over all other treatments. T_2 and T_9 (61.90 and 55.91 kg ha^{-1}) were at par with T_1 recording slightly higher and lower values, respectively. The treatment T_4 recorded lowest value (40.18 kg ha^{-1}) of available phosphorus.

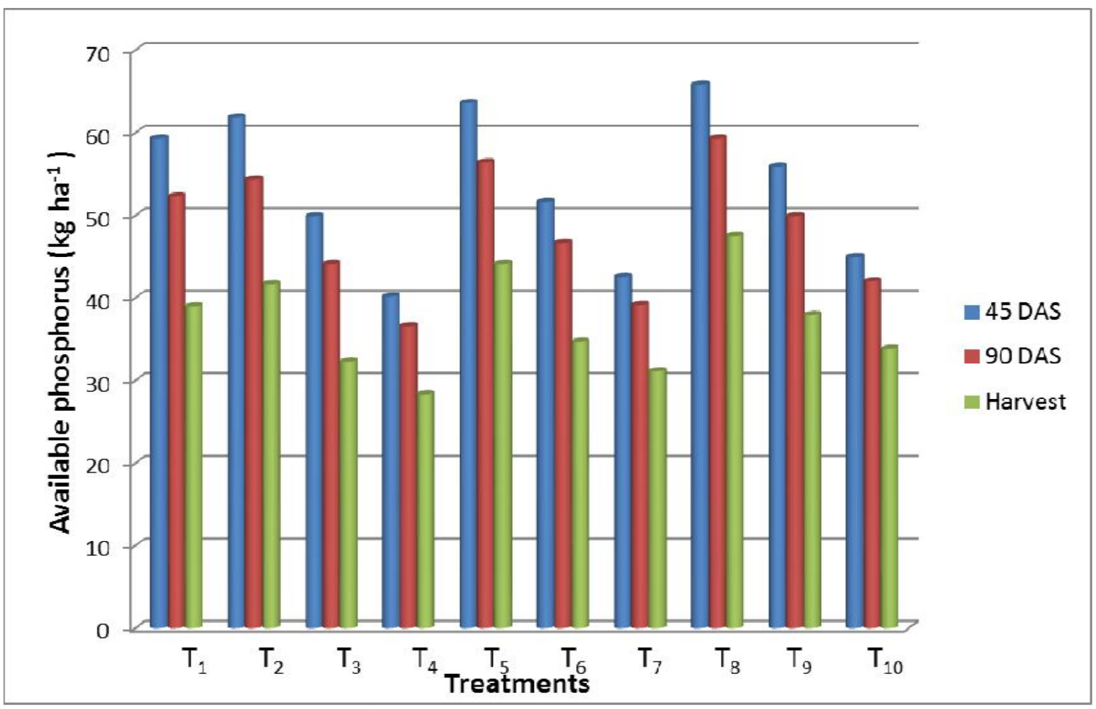

Fig. 2. Available phosphorus in soils

At 90 DAS, the highest (59.33 kg ha^{-1}) phosphorus availability was recorded by treatment T_8, which was on a par with T_5 (56.43 kg ha^{-1}) and significantly superior over others. T_1 and T_2 were on a par with each other and superior than remaining treatments except T_9 which was numerically inferior but on a par with T_1. At harvest stage T_8 and T_5 were significantly superior over application of only 60 kg P_2O_5 ha^{-1} (T_1) which was on a par with T_2 and T_9. The highest (47.53 kg ha^{-1}) was recorded in T_8 and lowest value (28.38 kg ha^{-1}) was recorded in T_4 (PSB @ 5 kg ha^{-1}).

Critical observation of the data revealed that available P content followed a decreasing trend with maturity of the crop. This low level of P at harvest could be due to utilization of available phosphorus by increased biomass with time. The increase in available phosphorus content of soil with increase in level of P application might be due to the fact that major proportions of applied P were left in available pool of soil. The lesser fixation of P coupled with the increase in kinetic factor could have resulted in an increase in available P inspite of enhanced P absorption by the plants at higher levels.

Available phosphorus content of the soil increased significantly with FYM application. This might be due to solubilisation of insoluble forms of phosphorus in the soil through release of various organic acids, and also due to reduced phosphorus fixation by organic acids through their chelation with metals like iron, which otherwise form insoluble phosphorus compounds with applied phosphorus [20]. The efficiency of FYM in increasing the phosphorus availability can also be attributed to its power to chelate phosphate fixing capacity (Fe^{+3}, Al^{+3}) and reduce phosphate sorption with low bonding energy and exchange of adsorbed PO_4^{3-} by organic anions [21] reported that organic acids produced during decomposition of crop residues converted insoluble Ca, Fe, and Al bound phosphorus into soluble and available phosphorus.

Improved nutritional status in plant parts under FYM application primarily seems to be on account of enrichment of these nutrients in soil, secondly it can be attributed to their efficient extraction per translocation in the plant system due to enhanced activities of roots on account of pivotal role of FYM on maintenance of better physico-chemical and biological properties of the soils. Similar results were also reported by Shankar et al. [22] and Kokani et al. [23]

It is imperative that the increase in soil nutrient content and enhancing physico-chemical as well as biological properties of the soil due to addition of 10 t/ha FYM. It is imperative that the increase in soil nutrient content was due to addition of 10 t/ha FYM. These results were in line with the results reported by Ghanshyam et al. [24] and Subbarayappa et al. [25].

3.1.3 Potassium

The available potassium content was not significantly influenced by the treatments Table.1 and Fig. 3. The available potassium content in the soil increased up to 90 DAS and later decreased at harvest. Highest available potassium at 45 DAS was recorded in T_6 (1176 kg ha^{-1}) and the lowest was recorded in T_1 (1030 kg ha^{-1}). At 90 DAS the highest available potassium was recorded in T_5 (1333 kg ha^{-1}) treatment and lowest was recorded in T_4 (1120 kg ha^{-1}) and at harvest highest available potassium was recorded in T_1 (997 kg ha^{-1}) treatment and lowest was recorded in T_8 and T_3 (784 kg ha^{-1}). The higher values of potassium in the initial stages of crop growth could be due to the release of native potassium as well as split application of potassic fertilizers upto 80 days after sowing.

Available potassium content of the soil didn't vary significantly with the level of phosphorus applied, FYM and PSB either individually or in combination, which might be due to the buffering capacity of the soil for potassium and was also due to high native potassium status of the experimental soil.

3.1.4 Micronutrients

The data in Table.2 revealed that the availability of zinc Fig. 4 was markedly influenced only at harvest while copper Fig. 5 was significantly influenced up to 90 DAS. Significant influence on manganese Fig. 6 was observed only at 90 DAS whereas, the impact was non-significant with iron Fig. 7 at all stages. Different levels of phosphorus didn't show any significant effect on the available micronutrient contents. Even though micronutrients at different stages were found to be significant, it can't be completely ascribed to treatmental effect as they were not following any specific trend. The contents of all the micronutrients decreased at harvest except manganese which recorded more or less same values at all stages.

The reason for higher micronutrient content in soil may be due to improved activity of microorganisms leading to greater mineralization of applied and inherent micronutrients through transformation of solid to soluble metal complex. Similar findings have been reported by Narendra et al. [26].

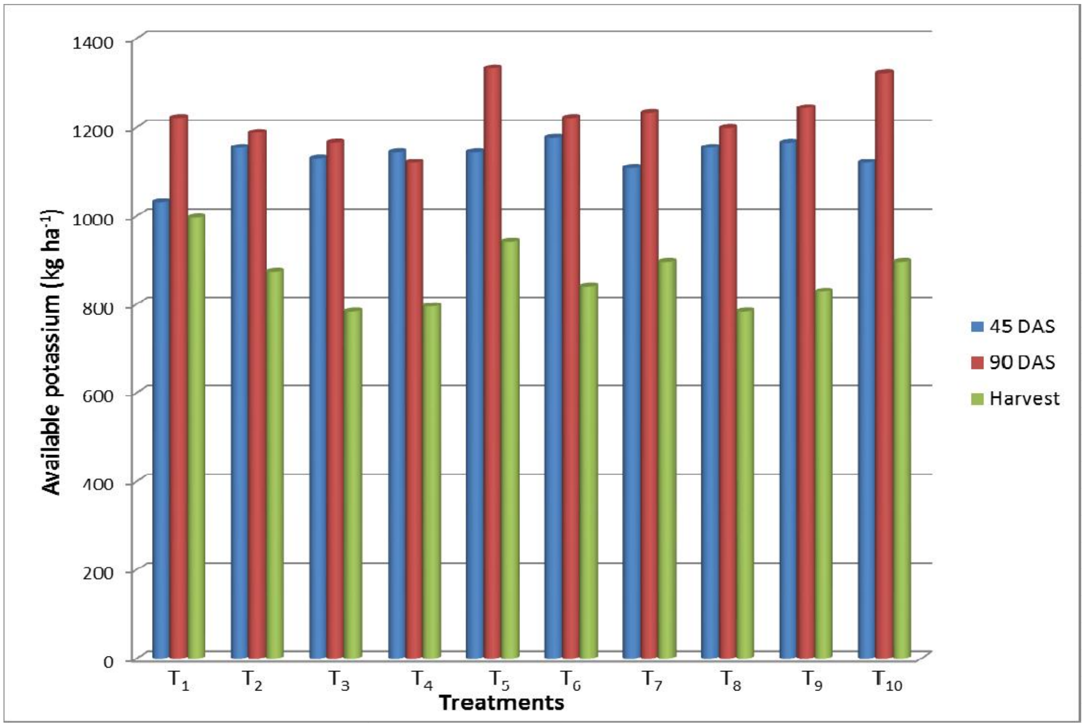

Fig. 3. Available potassium in soils

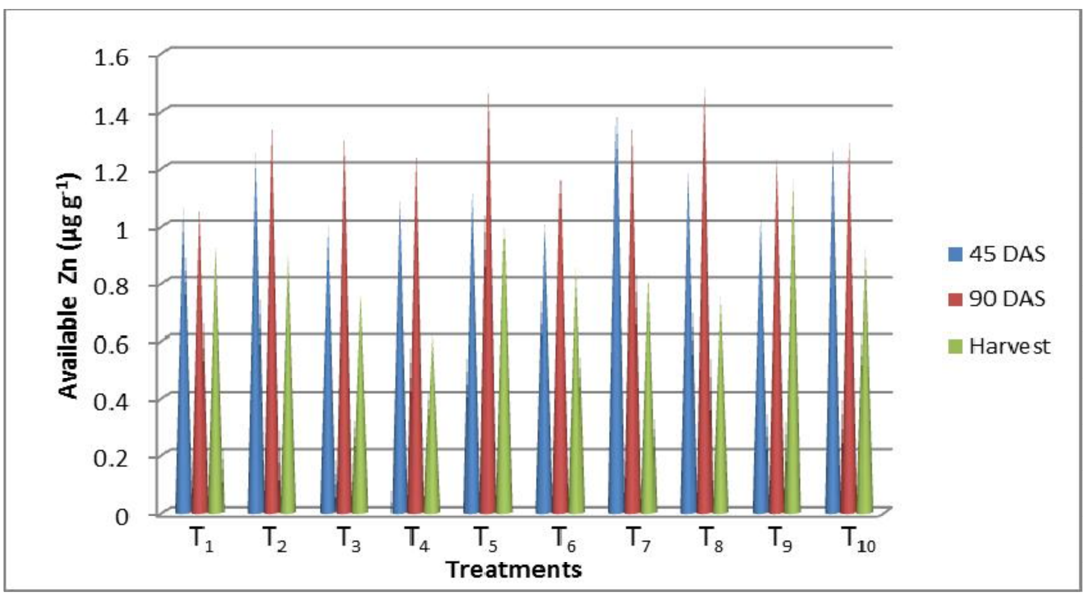

Fig. 4. Available zinc in soils

Table 2. Effect of Phosphorus levels, PSB and FYM on available micronutrients in soil

	Available zinc			Available copper			Available manganese			Available iron		
	(µg g^{-1})									(µg g^{-1})		
	45 DAS	**90 DAS**	**Harvest**	**45 DAS**	**90 DAS**	**Harvest**	**45 DAS**	**90 DAS**	**Harvest**	**45 DAS**	**90 DAS**	**Harvest**
T1	1.06	1.07	0.93	3.81	3.52	2.93	6.02	5.63	5.39	9.16	9.44	8.27
T2	1.25	1.36	0.90	3.93	3.32	2.88	6.35	6.22	6.42	9.42	9.55	8.36
T3	1.00	1.32	0.76	4.29	3.44	2.93	5.74	6.20	5.86	9.33	9.31	8.12
T4	1.09	1.26	0.62	3.41	3.11	2.52	5.49	5.26	6.38	8.92	8.94	8.11
T5	1.12	1.49	0.99	2.97	3.59	2.77	5.64	6.67	6.10	9.58	9.71	8.68
T6	1.01	1.18	0.85	3.01	2.95	2.97	6.65	5.67	6.95	9.91	8.94	8.42
T7	1.39	1.36	0.83	3.51	2.96	3.06	6.31	5.60	6.58	10.00	9.86	8.24
T8	1.19	1.49	0.75	3.20	3.63	2.77	6.62	6.62	6.13	10.06	9.15	8.73
T9	1.03	1.24	1.16	3.27	3.06	2.93	6.36	6.32	6.77	9.71	10.28	8.36
T10	1.28	1.30	0.92	3.05	3.41	3.01	6.25	5.87	6.38	9.65	8.20	8.14
SEM+	0.12	0.14	0.08	0.16	0.14	0.11	0.33	0.39	0.53	0.63	0.60	0.36
CD@0.05	NS	NS	0.23	0.46	0.40	NS	NS	0.82	NS	NS	NS	NS
CV	14.4	13.5	15.67	7.85	7.15	6.84	9.17	8.04	6.43	11.33	11.12	7.50

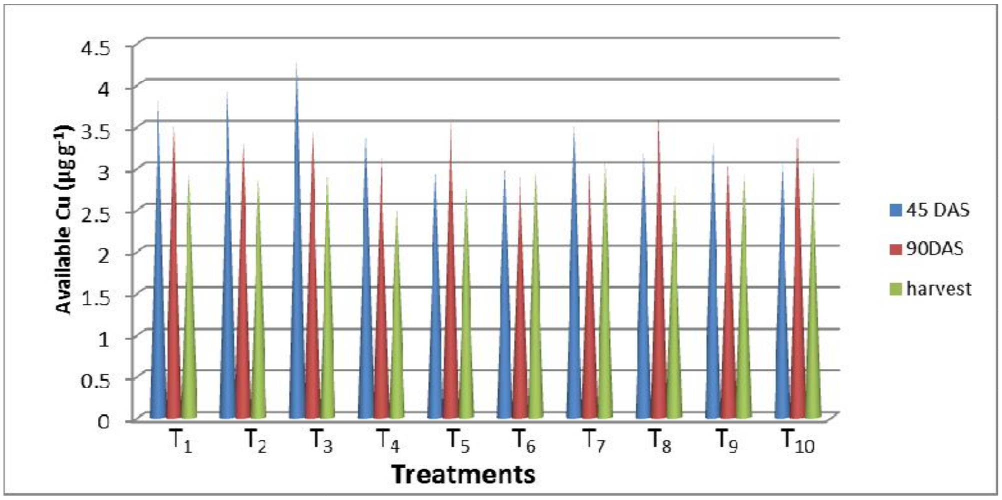

Fig. 5. Available copper in soils

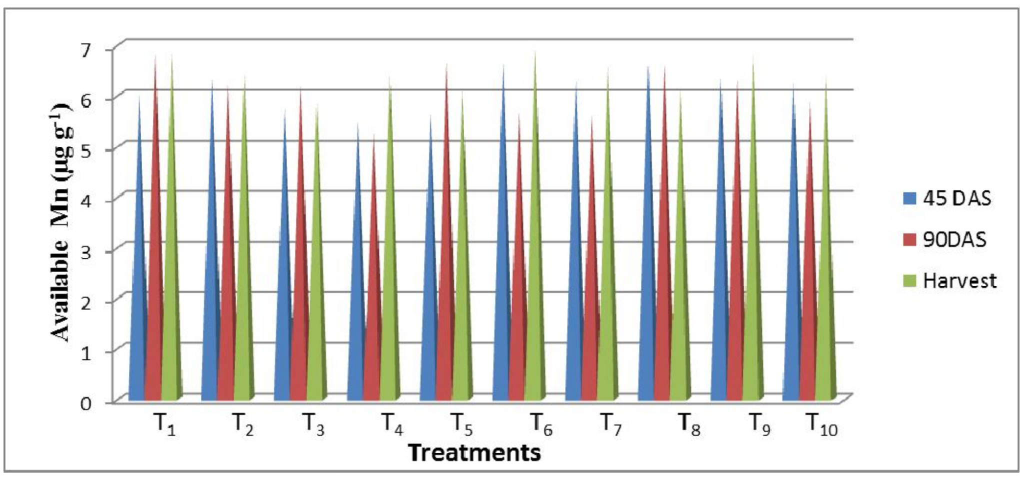

Fig. 6. Available manganese in soils

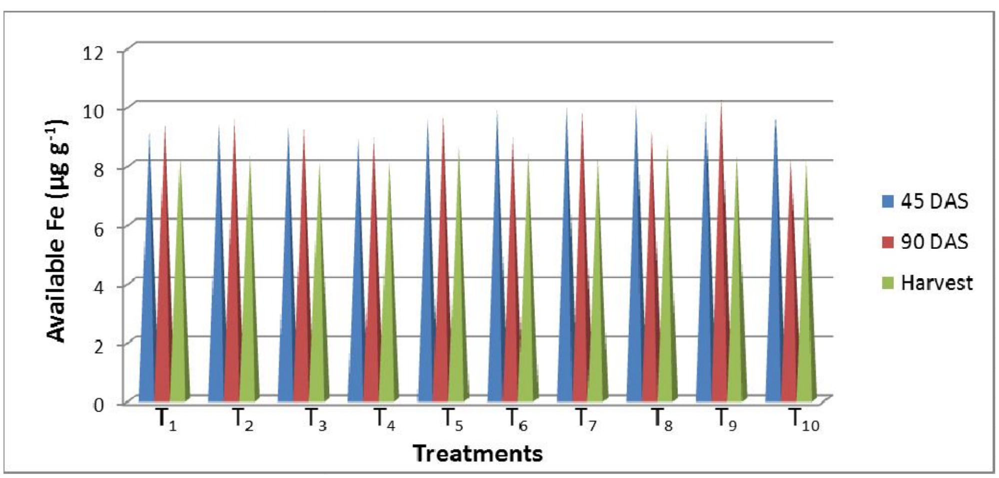

Fig. 7. Available iron in soils

4. CONCLUSION

It can be concluded that integration of inorganic phosphorus (60 kg ha^{-1} P_2O_5), PSB and FYM resulted in the higher values of soil nutrients indicating the contribution of different components of INM towards yield and soil health. The positive influence of PSB was more in the presence of inorganic phosphorus and FYM than its sole application. Increase in level of inorganic phosphorus increased the available phosphorus content in soil but nitrogen, potassium and micronutrients were not influenced significantly. Application of 30 kg P_2O_5 ha^{-1} + PSB + FYM was found to be on a par with addition of only 60 kg P_2O_5 ha^{-1}. Hence the fertilizer P dose can be reduced to half by integrating with PSB and FYM.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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